PADERBORN UNIVERSITY

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

MODULE HANDBOOK
MASTER'S PROGRAM COMPUTER ENGINEERING V3 (CEMA V3)

DATE: 6. MÄRZ 2024

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	* Pflichtmodul Informatik I * Pflichtmodul Informatik I * Pflichtmodul Elektrotechnik I * Pflichtmodul Elektrotechnik II * Projektgruppe * Wissenschaftliches Arbeiten
Catalogue advisor	
Credits ECTS	6
Learning objectives	

Pflichtmodul Informatik I

Computer Science I

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.079.01251	180	6	winter term
	Semester number:	**Duration (in sem.):**	**Teaching Language:**
	beliebig	1	en

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.079.05738 Networked Embedded Systems	L3 Ex2	75	105	CE	60/20

2 **Options within the module:**

none

3 Admission requirements:

Prerequisites of course Networked Embedded Systems:
Recommended Proficiencies
System software and system-level programming

4 Contents:

Contents of the course Networked Embedded Systems:
The objective of this course is gain insights into the operation and programming of embedded systems. A strong focus is on wireless sensor networks. We study the fundamentals of such sensor networks. In the scope of the exercises, we discuss selected topics in more detail.

- Design and architecture of embedded systems - Architecture of embedded systems, programming paradigms
- Sensor networks - Principles and applications
- Wireless communications - Concepts of modulation and encoding on the physical layer
- Wireless access - Typical medium access protocols for low-power sensor nodes
- Routing - Ad hoc routing and data centric communication
- Cooperation and clustering - Clustering algorithms, guaranteed connectivity

5 Learning outcomes and competences:

The learning objective is to unserstand the fundamental concepts of networded embedded systems. Students understand these concepts and are able to apply this knowledge.
Non-cognitive Skills

- Commitment
- Learning 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	90-120 minutes or 40 minutes	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 as 6 credits.
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v3 (CEMA v3)
12	**Module coordinator:** Dr. Florian Klingler
13	**Other Notes:** *Remarks of course Networked Embedded Systems:* **Implementation method** Lecture with practical exercises **Learning Material, Literature** Slides, textbooks, papers

Pflichtmodul Informatik II

Computer Science II

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.079.01252	180	6	winter term
	Semester number:	**Duration (in sem.):**	**Teaching Language:**
	beliebig	1	en

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.079.05724 Advanced Computer Architecture	L3 Ex2	75	105	CE	50/25

2 **Options within the module:**

none

3 **Admission requirements:**

Prerequisites of course Advanced Computer Architecture:
Recommended Proficiencies
Basic knowledge in computer architecture.

4 **Contents:**

Contents of the course Advanced Computer Architecture:
The course teaches concepts and methods used in modern processor architecture to exploit the available parallelism at the levels of instructions, data and threads.

- 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

5 **Learning outcomes and competences:**

After attending the course, the students

- are able to explain principles of modern memory hierarchies,
- to analyze different levels of parallelism,
- to assess the suitability of different architectural concepts and thus
- to evaluate modern developments in computer architecture.

Non-cognitive Skills

- Team work
- Learning 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	90-120 minutes or 40 minutes	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 as 6 credits.
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v3 (CEMA v3)
12	**Module coordinator:** Prof. Dr. Marco Platzner
13	**Other Notes:** *Remarks of course Advanced Computer Architecture:* **Implementation method** • Lecture with projector and board • Interactive exercises in the lecture room item Computer-based exercises with simulation tools • Analysis of 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 (5th edition or newer), Morgan Kauf- mann, 2012. • Information about alternative and additional literature as well as teaching material on the course's website and in the lecture slides

Pflichtmodul Elektrotechnik I			
Compulsory Module Electrical Engineering I			
Module number: M.048.45001	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
	Semester number: 1. Semester	**Duration (in sem.):** 1	**Teaching Language:** de / en

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
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:** -

<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</td><td>120-180 min or 30-45 min</td><td>100</td></tr>
<tr><td>b)</td><td>Written or Oral Examination</td><td>120-180 min or 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 :
Masterstudiengang Computer Engineering v3 (CEMA v3)</td></tr>
<tr><td>12</td><td>Module coordinator:
Prof. Dr. Reinhold Häb-Umbach</td></tr>
</table>

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.

Pflichtmodul Elektrotechnik II			
Compulsory Module Electrical Engineering II			
Module number: M.048.45002	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
	Semester number: 1. Semester	**Duration (in sem.):** 1	**Teaching Language:** en

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.90100 Circuit and Systems Design	2L 2Ex, WS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Circuit and Systems Design:
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 Circuit and Systems Design:
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	90-150 min or 20-30 min or 30-60 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)

12 **Module coordinator:**

Prof. Dr.-Ing. J. Christoph Scheytt

13	**Other Notes:** *Remarks of course Circuit and Systems Design:* **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.079.01254	**Workload (h):** 540	**Credits:** 18	**Regular Cycle:** summer term
	Semester number: 2-3	**Duration (in sem.):** 2	**Teaching Language:** en

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	Project Group	PG	240	360	C	15

2 **Options within the module:**

none

3 **Admission requirements:**

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.

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)	Partial Module Exam		100%

In the Project Group module, the successful completion of projects must be demonstrated by submitting software and documentation as a phase-related examination. A grade is awarded for the entirety of the projects worked on.
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)	Practical work		CA

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 as 9 credits.
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v3 (CEMA v3)
12	**Module coordinator:** Prof. Dr. Marco Platzner
13	**Other Notes:** *Remarks of course Projektgruppe:* **Implementation method** • The number of participants is limited to 16 people. • 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
	Semester number: 2. Semester	**Duration (in sem.):** 1	**Teaching Language:** de

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%

<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></td><td></td><td>QP</td></tr>
<tr><td>b)</td><td></td><td></td><td></td></tr>
</table>
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.</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 passing the module examination (MAP) and providing proof of the qualified participation.</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 v4 (CEMA v4)</td></tr>
<tr><td>12</td><td>Module coordinator:
Prof. Dr.-Ing. Katrin Temmen</td></tr>
</table>

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
	* Foundations of Cryptography
	* Integrierte Schaltungen für die drahtlose Kommunikation
	* Machine Learning I
	* Optical Communication A
	* Optical Communication B
	* Optical Communication C
	* Optimale und Adaptive Filter
	* Real World Crypto Engineering
	* Routing and Data Management in Networks
	* Schnelle integrierte Schaltungen für die leitungsgebundene Kommunikation
	* 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: M.079.01256	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
	Semester number: beliebig	**Duration (in sem.):** 1	**Teaching Language:** en

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.079.05700 Advanced Distributed Algorithms and Data Structures	L3 Ex2	75	105	C	30

2 **Options within the module:**

none

3 **Admission requirements:**

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:
The lecture will cover advanced topics in 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.

5 **Learning outcomes and competences:**

Students get to know advanced methods and algorithms for currently very relevant distributed systems. They are able to adapt algorithms to new situations and to determine their complexity. They can implement basic distributed algorithms.
Non-cognitive Skills

- Team work
- Learning competence
- 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)	Written or oral examination	90-120 minutes or 40 minutes	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 as 6 credits.

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

Masterstudiengang Computer Engineering v3 (CEMA v3)

12 **Module coordinator:**

Prof. Dr. Christian Scheideler

13 **Other Notes:**

Remarks of course Advanced Distributed Algorithms and Data Structures:
Implementation method
Lecture with tutorials and software project
Learning Material, Literature
Lectures notes

Foundations of Cryptography			
Foundations of Cryptography			
Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.079.01262	180	6	summer term

	Semester number:	**Duration (in sem.):**	**Teaching Language:**
	beliebig	1	en

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.079.05801 Foundations of Cryptography	L3 Ex2	75	105	C	25

2 **Options within the module:**

none

3 **Admission requirements:**

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:
The most important primitives of modern cryptography will be presented. These include encryption schemes, digital signatures, identification protocols, and multiparty computations. In each case we will define precise security notions. Starting from precisely stated assumptions, we develop constructions that provably satisfy these security definitions.

- Symmetric and asymmetric encryption schemes
- Pseudorandom generators, one-way functions, trapdoor permutations
- Hashfunctions and message authentication codes
- Digital signatures, one-time signatures, random oracles
- Identification protocols, Σ protocols
- Secure multiparty computation

5 **Learning outcomes and competences:**

Students understand fundamental concepts and methods of modern cryptography. They are able to choose appropriate cryptographic tools for various security problems. Students are able to combine and modify basic cryptographic primitives, they are able to define new security concepts, they are able to the the security of new constructions with respect to the security concepts.
Non-cognitive Skills

- Commitment
- Team work
- Learning 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)	Written or oral examination	90-120 minutes or 40 minutes	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 as 6 credits.

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

Masterstudiengang Computer Engineering v3 (CEMA v3)

12 **Module coordinator:**

Prof. Dr. Johannes Blömer

13 **Other Notes:**

Remarks of course Foundations of Cryptography:
Implementation method
Lectures, exercises, reading groups
Learning Material, Literature

- Oded Gorldreich, Foundations of Cryptography I,II,
- Jonathan Katz, Yehuda Lindell, Introduction to Modern Cryptogtraphy
- Slides from the lectures

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
	Semester number: 1.-3. Semester	**Duration (in sem.):** 1	**Teaching Language:** de / en

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 v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, NEU23 Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik
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

Machine Learning I			
Machine Learning I			
Module number: M.079.01274	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
	Semester number: beliebig	**Duration (in sem.):** 1	**Teaching Language:** en

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.079.05717 Machine Learning I	L3 Ex2	75	105	CE	60/20

2 **Options within the module:**

none

3 **Admission requirements:**

Prerequisites of course Machine Learning I:
Recommended Proficiencies
Basic knowledge in mathematics (linear algebra, statistics), programming and algorithms.

4 **Contents:**

Contents of the course Machine Learning I:
Due to the ever increasing amount of data that is routinely produced in our information society, the topic of machine learning has become increasingly important in the recent years, not only as a scientific discipline but also as a key technology of modern software and intelligent systems. This lecture provides an introduction to the topic of machine learning, with a specific focus on supervised learning for classification and regression. The lecture covers theoretical foundations of generalisation as well as practical topics and concrete learning algorithms.

- Introduction
- The Learning Problem
- Training versus Testing
- The Linear Model
- Non-Linear Methods
- Overfitting

5 **Learning outcomes and competences:**

The students understand the statistical foundations of generalisation, i.e., the induction of models from data, as well as practical tools for model validation. They are able to apply basic methods of supervised learning to problems of classification and regression.
Non-cognitive Skills

- Learning competence
- Learning motivation
- Literacy (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)	Written or oral examination	90-120 minutes or 40 minutes	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:** none
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 as 6 credits.
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v3 (CEMA v3)
12	**Module coordinator:** Prof. Dr. Eyke Hüllermeier
13	**Other Notes:** *Remarks of course Machine Learning I:* **Implementation method** Theoretical foundations and concepts of machine learning will be taught in the form of a lecture and deepened in practical exercise courses, group work as well as individual homework. **Learning Material, Literature** • Script • Y.S. Abu-Mostafa, M. Magdon-Ismail, H.T. Lin. Learning from Data, AMLBook, 2012. • P. Flach. Machine Learning, Cambridge Univ. Press, 2012. • E. Alpaydin. Machine Learning, Oldenbourg, 2008. • C.M. Bishop. Pattern Recognition and Machine Learning, Springer, 2006.

Optical Communication A			
Optical Communication A			
Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.92019	180	6	summer term

	Semester number:	**Duration (in sem.):**	**Teaching Language:**
	1.-3. Semester	1	en

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

<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 v4 (CEMA v4), Masterstudiengang Electrical Systems Engineering v3 (ESEMA v3) - Amtssprache, Master’s Program Electrical Systems Engineering (ESEMA v2)</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

Optical Communication B

Optical Communication B

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.92020	180	6	summer term
	Semester number:	**Duration (in sem.):**	**Teaching Language:**
	1.-3. Semester	1	en

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.
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 v4 (CEMA v4), Masterstudiengang Electrical Systems Engineering v3 (ESEMA v3) - Amtssprache, Master's Program Electrical Systems Engineering (ESEMA v2)
12	**Module coordinator:** Prof. Dr. Reinhold Noé
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:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.92021	180	6	winter term
	Semester number:	**Duration (in sem.):**	**Teaching Language:**
	1.-3. Semester	1	en

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 v4 (CEMA v4), Masterstudiengang Electrical Systems Engineering v3 (ESEMA v3) - Amtssprache, Master's Program Electrical Systems Engineering (ESEMA v2)
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
	Semester number: 1.-3. Semester	**Duration (in sem.):** 1	**Teaching Language:** de / en

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 v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, NEU23 Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik
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

Real World Crypto Engineering			
Real World Crypto Engineering			
Module number: M.079.01286	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
	Semester number: beliebig	**Duration (in sem.):** 1	**Teaching Language:** en

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.079.05819 Real World Crypto Engineering	L3 Ex2	75	105	C	40

2 **Options within the module:**

none

3 **Admission requirements:**

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.

5 **Learning outcomes and competences:**

Upon successful completion, students have a comprehensive understanding of the technical aspects of applied cryptographic algorithms. They have recognized that cryptography alone is not sufficient to solve security-related problems. They have an overview of current cryptographic attacks and know how to practically prevent them.

Non-cognitive Skills

- Team work
- Literacy (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)	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 as 6 credits.

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

Masterstudiengang Computer Engineering v3 (CEMA v3)

12 **Module coordinator:**

Prof. Dr.-Ing. Juraj Somorovsky

13	**Other Notes:** *Remarks of course Real World Crypto Engineering:* **Implementation method** Lectures, exercises **Learning Material, Literature** Lecture slides, scientific papers

Routing and Data Management in Networks			
Routing and Data Management in Networks			
Module number: M.079.01271	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
	Semester number: beliebig	**Duration (in sem.):** 1	**Teaching Language:** en

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.079.05806 Routing and Data Management in Networks	L3 Ex2	75	105	CE	40/20

2 **Options within the module:**

none

3 **Admission requirements:**

Prerequisites of course Routing and Data Management in Networks:
Recommended Proficiencies
Algorithm design, theoretical correctness and efficiency proofs, tools from combinatorics and probability theory.

4 **Contents:**

Contents of the course Routing and Data Management in Networks:
Routing and data management are fundamental tasks to be solved in order to ensure efficient use of large networks, e.g. the Internet, peer-to-peer systems, or wireless mobile ad-hoc networks. This lecture deals with algorithms and their analysis for routing and data management in such systems and describes, in particular, methods for dealing with their dynamics (movement of nodes, joining and exiting nodes). In particular, local, distributed algorithms, often as online algorithms, are considered.

- Offline and online routing strategies
- Scheduling strategies
- Data management strategies

<table>
<tr><td>5</td><td>Learning outcomes and competences:
The students get to know fundamental techniques in the area of routing and data management of large networks. They can decide in which situation which data management, scheduling, or routing algorithm is most appropriate. They can adapt algorithms to a new situation.
Non-cognitive Skills
• Attitude
• Self-monitoring</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</td><td>90-120 minutes or 40 minutes</td><td>100%</td></tr>
</table>
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.</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>Written exercises</td><td></td><td>CA</td></tr>
</table>
Within the first three weeks of the lecture period each respective lecturer will specify the manner in which the course achievement will be conducted.</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 as 6 credits.</td></tr>
<tr><td>11</td><td>Reuse in degree courses or degree course versions :
Masterstudiengang Computer Engineering v3 (CEMA v3)</td></tr>
<tr><td>12</td><td>Module coordinator:
Prof. Dr. Friedhelm Meyer auf der Heide</td></tr>
</table>

13	**Other Notes:** *Remarks of course Routing and Data Management in Networks:* **Implementation method** • Lecture with beamer and blackboard • Practice in small groups • Expected activities of the students: Solving homework exercises, contributing to the tutorials **Learning Material, Literature** • Introduction to Parallel Algorithms and Architectures: Arrays, Trees, Hypercubes, Frank Thomson Leighton, M. Kaufmann Publishers, 1992. • Research papers, script, slide set of the lecture, exercise sheets

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
	Semester number: 1.-3. Semester	**Duration (in sem.):** 1	**Teaching Language:** de / en

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 v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, NEU23 Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik
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).

Topics in Signal Processing
Topics in Signal Processing

Module number:	Workload (h):	Credits:	Regular Cycle:
M.048.92014	180	6	winter term
	Semester number:	**Duration (in sem.):**	**Teaching Language:**
	1.-3. Semester	1	en

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 v4 (CEMA v4), Masterstudiengang Electrical Systems Engineering v3 (ESEMA v3) - Amtssprache, Master's Program Electrical Systems Engineering (ESEMA v2)
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.

Web Security			
Web Security			
Module number: M.079.01284	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
	Semester number: beliebig	**Duration (in sem.):** 1	**Teaching Language:** de

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.079.05820 Web Security	L3 Ex2	75	105	C	40

2 **Options within the module:**
none

3	**Admission requirements:** *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.
5	**Learning outcomes and competences:** After successful completion, students have a comprehensive understanding of the technical aspects of web applications, web services, and various authentication mechanisms. They have learned that the web technologies used today are complex and that their complexity poses many security problems. Students have an overview of current web attacks and know how to prevent them practically. **Non-cognitive Skills** • Team work • Literacy (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)	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 as 6 credits.
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v3 (CEMA v3)
12	**Module coordinator:** Prof. Dr.-Ing. Juraj Somorovsky
13	**Other Notes:** *Remarks of course Web Security:* **Implementation method** Lecture with exercises **Learning Material, Literature** • Lecture slides • Scientific papers

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

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 v4 (CEMA v4), Masterstudiengang Electrical Systems Engineering v3 (ESEMA v3) - Amtssprache, Master's Program Electrical Systems Engineering (ESEMA v2)
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 * Databases and Information Systems * Introduction to Quantum Computation * Machine Learning I * Reconfigurable Computing * Usable Security and Privacy * 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:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.92007	180	6	summer- / winter term
	Semester number:	**Duration (in sem.):**	**Teaching Language:**
	1.-3. Semester	1	en

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 v4 (CEMA v4), Masterstudiengang Electrical Systems Engineering v3 (ESEMA v3) - Amtssprache, Master’s Program Electrical Systems Engineering (ESEMA v2)</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:* **ATTENTION - IMPORTANT NOTICE** The course doesn't take place in summer term 2024. Please see the notice boards of the group. **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.)

Databases and Information Systems			
Databases and Information Systems			
Module number: M.079.01260	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
	Semester number: beliebig	**Duration (in sem.):** 1	**Teaching Language:** en

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.079.05532 Databases and Information Systems	L3 Ex2	75	105	CE	120/30

2 **Options within the module:**

none

3 **Admission requirements:**

Prerequisites of course Databases and Information Systems:
Recommended Proficiencies
Students are required to have previous knowledge of relational database systems and SQL comparable to the course “Datanbanksysteme” and programming knowledge and skills comparable to the courses “Programming” and “Grundlagen der Programmiersprachen”.

4 **Contents:**

Contents of the course Databases and Information Systems:
Data storage and data management play a central role in enterprises since a large part of the companies’ knowledge is stored as data. Furthermore, data collections are rapidly growing, and an efficient processing of these big data collections requires know how beyond that of SQL and traditional database systems. Examples for these big data collections are genome databases, text document collections, sensor data, satellite data, data from cameras, microphones, and RFID tags, telecommunication data, weather data, finance data, news readers, data from messengers, etc.. To develop applications or information systems that lead to acceptable response times on these big data collections requires knowledge about non-standard data models, main-memory databases, compression, indexing of big data, and efficient search in these data collections.
This module focusses on algorithms for compression and for efficient processing of complex structured massive data, including text data, genome data, tree structured data, and graph data. The content of this module covers:

- Overview of search engines and information systems
- Main memory databases and succinct encoding techniques
- String compression algorithms
- Genome databases
- Processing of huge tree data collections (XML and JSON) and tree compression
- Graph databases and graph compression
- Search Algorithms for Big Data and for data streams

5 **Learning outcomes and competences:**

After completing the module students can comprehend, design, implement and assess (with respect to time and space complexity) XML processing in software systems. They known pivotal search and query techniques to acquire information in uncompressed and compressed XML data. They can appropriately process infinite data streams. They can acquire new research results from scientific publications.
Non-cognitive Skills:

- Team work
- Learning competence
- Learning motivation

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 minutes or 40 minutes	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 as 6 credits.

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

Masterstudiengang Computer Engineering v3 (CEMA v3)

12 **Module coordinator:**

Prof. Dr. Stefan Böttcher

13	**Other Notes:** *Remarks of course Databases and Information Systems:* **Implementation method** The fundamental concepts are presented in a lecture. Additioanlly, theoretical concepts are deepened in small groups during class-based tutorials. This method is used in particular for core concepts of databases (searching in and querying Big Data, distributed databases, and mobile data and manangement). Additionally, practical skills are acquired through computer-based exercises, where the students have to develop their own information systems, search or compression algorithms, based on the introduction given in the lecture. **Learning Material, Literature** Links to material will be provided during the lecture.

Introduction to Quantum Computation

Introduction to Quantum Computation

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.079.01279	180	6	winter term
	Semester number:	**Duration (in sem.):**	**Teaching Language:**
	beliebig	1	en

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.079.05807 Introduction to Quantum Computation	L3 Ex2	75	105	C	40

2 **Options within the module:**

none

3 **Admission requirements:**

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

Non-cognitive Skills

- Learning competence
- 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 minutes or 40 minutes	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 as 6 credits.
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v3 (CEMA v3)
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 I

Machine Learning I

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.079.01274	180	6	winter term
	Semester number:	**Duration (in sem.):**	**Teaching Language:**
	beliebig	1	en

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.079.05717 Machine Learning I	L3 Ex2	75	105	CE	60/20

2 **Options within the module:**

none

3 **Admission requirements:**

Prerequisites of course Machine Learning I:
Recommended Proficiencies
Basic knowledge in mathematics (linear algebra, statistics), programming and algorithms.

4	**Contents:** *Contents of the course Machine Learning I:* Due to the ever increasing amount of data that is routinely produced in our information society, the topic of machine learning has become increasingly important in the recent years, not only as a scientific discipline but also as a key technology of modern software and intelligent systems. This lecture provides an introduction to the topic of machine learning, with a specific focus on supervised learning for classification and regression. The lecture covers theoretical foundations of generalisation as well as practical topics and concrete learning algorithms. • Introduction • The Learning Problem • Training versus Testing • The Linear Model • Non-Linear Methods • Overfitting
5	**Learning outcomes and competences:** The students understand the statistical foundations of generalisation, i.e., the induction of models from data, as well as practical tools for model validation. They are able to apply basic methods of supervised learning to problems of classification and regression. **Non-cognitive Skills** • Learning competence • Learning motivation • Literacy (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)	Written or oral examination	90-120 minutes or 40 minutes	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:** none
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 as 6 credits.

11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v3 (CEMA v3)
12	**Module coordinator:** Prof. Dr. Eyke Hüllermeier
13	**Other Notes:** *Remarks of course Machine Learning I:* **Implementation method** Theoretical foundations and concepts of machine learning will be taught in the form of a lecture and deepened in practical exercise courses, group work as well as individual homework. **Learning Material, Literature** • Script • Y.S. Abu-Mostafa, M. Magdon-Ismail, H.T. Lin. Learning from Data, AMLBook, 2012. • P. Flach. Machine Learning, Cambridge Univ. Press, 2012. • E. Alpaydin. Machine Learning, Oldenbourg, 2008. • C.M. Bishop. Pattern Recognition and Machine Learning, Springer, 2006.

Reconfigurable Computing

Reconfigurable Computing

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.079.01270	180	6	winter term
	Semester number:	**Duration (in sem.):**	**Teaching Language:**
	beliebig	1	en

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.079.05703 Reconfigurable Computing	L2 Ex3	75	105	CE	50/20

2 **Options within the module:**

none

3 **Admission requirements:**

Prerequisites of course Reconfigurable Computing:
Recommended Proficiencies
Knowledge of “Digital Design” and “Computer Architecture” is beneficial.

4 **Contents:**

Contents of the course Reconfigurable Computing:
This lecture provides an understanding of architectures and design methods for reconfigurable hardware systems and presents applications in the areas of high performance computing and embedded systems.

- Introduction: evolution of programmable logic devices, market economics
- Architectures: FPGA architectures, reconfigurable devices, reconfigurable systems
- Design methods: CAD for FPGAs, high-level languages and compilers, system-level design
- Applications: custom computing machines, embedded systems

5 **Learning outcomes and competences:**

After attending the course, the students are able to

- explain the architectures of reconfigurable hardware devices,
- name and analyze the main design methods and
- judge the suitability of reconfigurable hardware for different application domains.

Non-cognitive Skills

- Team work
- Learning 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	90-120 minutes or 40 minutes	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 as 6 credits.
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v3 (CEMA v3)
12	**Module coordinator:** Prof. Dr. Marco Platzner
13	**Other Notes:** *Remarks of course Reconfigurable Computing:* **Implementation method** • Lecture with projector and board • Interactive exercises in the lecture room • Computer-based exercises with reconfigurable systems **Learning Material, Literature** • Lecture slides and exercise sheets • Exercise sheets and technical documentation for the for the computer-based exercises • S. Hauck and A. DeHon (editors): Reconfigurable Computing, Volume 1: The Theory and Practice of FPGA-Based Computation, Morgan Kaufmann, 2008 • Information about alternative and additional literature as well as teaching material on the course's website and in the lecture slides

Usable Security and Privacy

Usable Security and Privacy

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.079.01285	180	6	summer term
	Semester number:	**Duration (in sem.):**	**Teaching Language:**
	beliebig	1	en

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.079.05804 Usable Security and Privacy	L2 Ex3	75	105	CE	40

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:** Participants of the course • 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 **Non-cognitive Skills** • Literacy (scientific) • Self-monitoring • Team work

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)	Practical work with written report and discussion		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 as 6 credits.

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

Masterstudiengang Computer Engineering v3 (CEMA v3)

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.

VLSI-Testing

VLSI-Testing

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.92027	180	6	winter term
	Semester number:	**Duration (in sem.):**	**Teaching Language:**
	1.-3. Semester	1	en

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 micro-electronic 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 v4 (CEMA v4), Masterstudiengang Electrical Systems Engineering v3 (ESEMA v3) - Amtssprache, Master's Program Electrical Systems Engineering (ESEMA v2)
12	**Module coordinator:** Prof. Dr. Sybille Hellebrand

13	**Other Notes:** *Remarks of course VLSI Testing:* **ATTENTION - IMPORTANT NOTICE** The course doesn't take place in summer term 2024. Please see the notice boards of the group. **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
	* Data Science for Dynamical Systems
	* Gekoppelte Felder
	* Geregelte Drehstromantriebe
	* Machine Learning I
	* Reinforcement Learning

Specialisation Area	Control and Automation
	* Robotics
	* Systemidentifikation
	* Ultraschallmesstechnik
	* Umweltmesstechnik
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:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.92037	180	6	summer term
	Semester number:	**Duration (in sem.):**	**Teaching Language:**
	1.-3. Semester	1	en

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 v4 (CEMA v4), Masterstudiengang Electrical Systems Engineering v3 (ESEMA v3) - Amtssprache, Master's Program Electrical Systems Engineering (ESEMA v2)
12	**Module coordinator:** Dr.-Ing. Oliver Wallscheid
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:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.92001	180	6	winter term
	Semester number:	**Duration (in sem.):**	**Teaching Language:**
	1. Semester	1	en

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

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
	Semester number:	**Duration (in sem.):**	**Teaching Language:**
	1.-3. Semester	1	en

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 v4 (CEMA v4), Masterstudiengang Electrical Systems Engineering v3 (ESEMA v3) - Amtssprache, Master's Program Electrical Systems Engineering (ESEMA v2)
12	**Module coordinator:** Prof. Dr. Bärbel Mertsching
13	**Other Notes:** *Remarks of course Advanced Topics in Robotics:* **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

Data Science for Dynamical Systems			
Data Science for Dynamical Systems			
Module number: M.048.27029	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
	Semester number: 1.-3.Semester	**Duration (in sem.):** 1	**Teaching Language:** en

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.27029 Data Science for Dynamical Systems	2L 2Ex, WS	60	120	C	70/35

2	**Options within the module:** None
3	**Admission requirements:** None *Prerequisites of course Data Science for Dynamical Systems:* None
4	**Contents:** *Contents of the course Data Science for Dynamical Systems:* This course has a modular structure and is offered in an interdisciplinary way for different degree programs and faculties. Depending on the available prior knowledge of the participants, the content will be tailored to the specific degree program. Overarching core topics include • Basics of modelling dynamic systems using differential and difference equation models • Data-driven identification methods for linear models on the basis of the least squares approach • Data-driven identification methods for non-linear models (e.g., artificial neural networks) • Learning of data-driven models utilizing a priori system knowledge • Identification of underlying model structure equations (topology selection), e.g., by means of regularization or hypothesis tests with regard to competing objectives • (Data-driven) model reduction • Manipulation of the available model input data (dimensionality reduction and augmentation methods), e.g., autoencoders, principal component analysis and kernel methods • Statistical evaluation of the available input and output data of dynamic systems as well as corresponding procedures for system excitation • Statistical evaluation of the achieved model quality (over-fitting vs. under-fitting) by means of cross-validation In addition to obtain new methodological knowledge, extensive programming and simulation exercises are developed using modern software programs (especially in the programming language Julia). Diverse application examples from the practice of various domains (e.g., engineering, natural sciences and economics) round off the course.
5	**Learning outcomes and competences:** After completing the course, the participants are able to • describe and apply methods for the identification of dynamic systems, • critically evaluate identification results, • to understand and analyze complex data-driven modelling tasks in interdisciplinary teams, to derive target-oriented solution methods and to evaluate independently developed results.

<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>Within the first three weeks of the lecture period each respective lecturer will specify the manner in which the examination will be conducted.</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 v3 (CEMA v3), Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Informatik v4, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, NEU23 Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik</td></tr>
<tr><td>12</td><td>Module coordinator:
Dr.-Ing. Oliver Wallscheid, Dr. Sebastian Peitz</td></tr>
</table>

13	**Other Notes:** **Implementation** Modular flipped classroom course based on digital self-learning materials (especially learning videos) in conjunction with weekly contact appointments on campus for the discussion of questions, application examples, small group work as well as discussion of homework. Interdisciplinary course for study programs of different faculties with individual curricula as well as joint, interdisciplinary project phase. The latter takes place at the end of the course in small groups incl. final presentation of the results. **Teaching Material, Literature** • Learning videos, exercise tasks, programming examples • Brunton, Steven L., and J. Nathan Kutz. Data-driven science and engineering: Machine learning, dynamical systems, and control. Cambridge University Press, 2022. • Goodfellow, Ian, Yoshua Bengio, and Aaron Courville. Deep learning. MIT press, 2016. • Isermann, Rolf, and Marco Münchhof. Identification of dynamic systems: an introduction with applications. Vol. 85. Heidelberg: Springer, 2011. • Nelles, Oliver. Nonlinear dynamic system identification. Springer Berlin Heidelberg, 2001.

Gekoppelte Felder

Coupled Fields

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.27028	180	6	summer term
	Semester number:	**Duration (in sem.):**	**Teaching Language:**
	1.-3. Semester	1	de

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”.

<table>
<tr><td>4</td><td>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.</td></tr>
<tr><td>5</td><td>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.</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>
Within the first three weeks of the lecture period each respective lecturer will specify the manner in which the examination will be conducted.</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>
</table>

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 v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, NEU23 Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik
12	**Module coordinator:** 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
	Semester number: 1.-3. Semester	**Duration (in sem.):** 1	**Teaching Language:** en

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 v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, NEU23 Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik
12	**Module coordinator:** Prof. Dr.-Ing. Joachim Böcker
13	**Other Notes:** --- **ATTENTION - IMPORTANT NOTICE** The course doesn't take place in summer term 2024. --- *Remarks of course Geregelte Drehstromantriebe:* **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 --- **ATTENTION - IMPORTANT NOTICE** The course doesn't take place in summer term 2024. ---

Machine Learning I			
Machine Learning I			
Module number: M.079.01274	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
	Semester number: beliebig	**Duration (in sem.):** 1	**Teaching Language:** en

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.079.05717 Machine Learning I	L3 Ex2	75	105	CE	60/20

2 **Options within the module:**

none

3 **Admission requirements:**

Prerequisites of course Machine Learning I:
Recommended Proficiencies
Basic knowledge in mathematics (linear algebra, statistics), programming and algorithms.

4 **Contents:**

Contents of the course Machine Learning I:
Due to the ever increasing amount of data that is routinely produced in our information society, the topic of machine learning has become increasingly important in the recent years, not only as a scientific discipline but also as a key technology of modern software and intelligent systems. This lecture provides an introduction to the topic of machine learning, with a specific focus on supervised learning for classification and regression. The lecture covers theoretical foundations of generalisation as well as practical topics and concrete learning algorithms.

- Introduction
- The Learning Problem
- Training versus Testing
- The Linear Model
- Non-Linear Methods
- Overfitting

5 **Learning outcomes and competences:**

The students understand the statistical foundations of generalisation, i.e., the induction of models from data, as well as practical tools for model validation. They are able to apply basic methods of supervised learning to problems of classification and regression.
Non-cognitive Skills

- Learning competence
- Learning motivation
- Literacy (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)	Written or oral examination	90-120 minutes or 40 minutes	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:** none
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 as 6 credits.
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v3 (CEMA v3)
12	**Module coordinator:** Prof. Dr. Eyke Hüllermeier
13	**Other Notes:** *Remarks of course Machine Learning I:* **Implementation method** Theoretical foundations and concepts of machine learning will be taught in the form of a lecture and deepened in practical exercise courses, group work as well as individual homework. **Learning Material, Literature** • Script • Y.S. Abu-Mostafa, M. Magdon-Ismail, H.T. Lin. Learning from Data, AMLBook, 2012. • P. Flach. Machine Learning, Cambridge Univ. Press, 2012. • E. Alpaydin. Machine Learning, Oldenbourg, 2008. • C.M. Bishop. Pattern Recognition and Machine Learning, Springer, 2006.

Reinforcement Learning			
Reinforcement Learning			
Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.92045	180	6	summer term

	Semester number:	Duration (in sem.):	Teaching Language:
	1.-3. Semester	1	en

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 v4 (CEMA v4), Masterstudiengang Electrical Systems Engineering v3 (ESEMA v3) - Amtssprache, Master's Program Electrical Systems Engineering (ESEMA v2)
12	**Module coordinator:** Dr.-Ing. Oliver Wallscheid

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: M.048.92012	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
	Semester number: 1.-3. Semester	**Duration (in sem.):** 1	**Teaching Language:** en

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

Systemidentifikation

System identification

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.27026	180	6	winter term
	Semester number:	**Duration (in sem.):**	**Teaching Language:**
	1.-3. Semester	1	de

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.27026 System Identification	2L 2Ex, WS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Systemidentifikation:
Recommended: Signal and system theory, Control theory

4 **Contents:**

Contents of the course Systemidentifikation:
Short Description
The course deals with the experimental identification of quantitative models describing the behavior of a given system. This includes both the selection of the model class, the determination of the parameters of the model and, if necessary, the state estimation. Depending on the field of application, a variety of model properties and, as a result, identification techniques can be distinguished: static vs. dynamic, deterministic vs. stochastic, discrete-time vs. continuous-time etc. The course gives an introduction to the most important methods of system identification, whereby the application-oriented realization (also with the use of software tools) is focused.
Contents

- Introduction: Application fields of system identification and basic terms
- Repetition of basics: Dynamic models in state space, time discretization, stochastic processes
- Identification of deterministic, static processes (function fitting)
- Systematic evaluation of the identification results (accuracy analysis)
- Numerical optimization methods for (non-)linear problems
- Identification of dynamic processes in the state space by means of iterative optimization
- State and parameter estimation using Kalman filtering
- Practical aspects of implementation (e.g. optimal system excitation)

5 **Learning outcomes and competences:**

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

- Explain system theoretic model classes / properties and distinguish them from each other.
- Independently select, apply and, if necessary, adapt problem-specific solution methods for system identification.
- Evaluate identification results and deduce whether the chosen solution has been effective or may need to be modified.

Key qualifications:
The students

- are able to apply system identification methods to (interdisciplinary) problems from different science domains (e.g. within electrical engineering, mechanical engineering or economics).
- can empirically determine and interpret mathematical models of complex systems (abstraction ability).
- can apply and develop software-based engineering tools.
- are able to familiarize themselves with adjacent and further topics.

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 v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, NEU23 Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik
12	**Module coordinator:** Dr.-Ing. Oliver Wallscheid
13	**Other Notes:** *Remarks of course Systemidentifikation:* **Course Homepage** `http://ei.uni-paderborn.de/lea/` **Implementation** Lecture with script, slide set and blackboard Exercises on the blackboard and in the PC pool room (Matlab / Simulink) Homework exercises and short term paper (both voluntary) **Teaching Material, Literature** Isermann, R.: Identification of Dynamic Systems, Springer-Verlag, Berlin Heidelberg, 2011 Ljung, L: System Identifiation - Theory for the User (2nd ed.), Prentice Hall, Upper Saddle River, NJ, 1999 Schröder, D.: Intelligente Verfahren: Identifikation und Regelung nichtlinearer Systeme, Springer-Verlag, Berlin Heidelberg, 2010 Walter, E.: Identification of Parametric Models, Springer-Verlag, Berlin Heidelberg, 1997 Isermann, R.: Identification of Dynamic Systems, Springer-Verlag, Berlin Heidelberg, 2011 Ljung, L: System Identifiation - Theory for the User (2nd ed.), Prentice Hall, Upper Saddle River, NJ, 1999 Schröder, D.: Intelligente Verfahren: Identifikation und Regelung nichtlinearer Systeme, Springer-Verlag, Berlin Heidelberg, 2010 Walter, E.: Identification of Parametric Models, Springer-Verlag, Berlin Heidelberg, 1997

Ultraschallmesstechnik			
Ultrasonic measurement technology			
Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.27015	180	6	summer term
	Semester number:	**Duration (in sem.):**	**Teaching Language:**
	1.-3. Semester	1	de

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 v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, NEU23 Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik
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.

Umweltmesstechnik

Environmental monitoring and measuring technologies

Module number:	Workload (h):	Credits:	Regular Cycle:
M.048.22010	180	6	winter term
	Semester number:	**Duration (in sem.):**	**Teaching Language:**
	1.-3. Semester	1	de

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 v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, NEU23 Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, 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
	* Hardware/Software Codesign (EIM-I)
	* Integrierte Schaltungen für die drahtlose Kommunikation
	* Machine Learning I

Specialisation Area	Embedded Systems
	* Model-Based Systems Engineering * Reconfigurable Computing * Schnelle integrierte Schaltungen für die leitungsgebundene Kommunikation * 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:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.92043	180	6	summer term
	Semester number:	**Duration (in sem.):**	**Teaching Language:**
	1.-3. Semester	1	en

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 v4 (CEMA v4), Masterstudiengang Electrical Systems Engineering v3 (ESEMA v3) - Amtssprache, Master's Program Electrical Systems Engineering (ESEMA v2)
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
	Semester number:	**Duration (in sem.):**	**Teaching Language:**
	1.-3. Semester	1	en

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 v4 (CEMA v4), Masterstudiengang Electrical Systems Engineering v3 (ESEMA v3) - Amtssprache, Master's Program Electrical Systems Engineering (ESEMA v2)
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:* **ATTENTION - IMPORTANT NOTICE** The course doesn't take place in summer term 2024. Please see the notice boards of the group. **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.)

Architektur paralleler Rechnersysteme

Architectures of Parallel Computer Systems

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.079.01258	180	1	summer term
	Semester number:	**Duration (in sem.):**	**Teaching Language:**
	beliebig	1	de

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.079.05806 Architecture of Parallel Computer Systems	L3 Ex2	75	105	CE	20

2 **Options within the module:**

none

3 **Admission requirements:**

Prerequisites of course Architektur paralleler Rechnersysteme:
Recommended Proficiencies
Principles of computer architectures

4 **Contents:**

Contents of the course Architektur paralleler Rechnersysteme:
The lecture considers computer architectures of actual parallel computer systems and the usage of this systems. The focus of the lecture is on high-performance computers (supercomputers).

- Users‘ view on Parallel Computers
- Programming of Parallel Computers
- Principles of Computer Architecture
- Overview of actual Parallel Computer Systems
- Shared Memory Systems
- Cache Coherency of Scalabel Computer Systems
- High Performance Interconnects
- Datacenter Architectures
- Energy Efficiency

5 **Learning outcomes and competences:**

- Students name and explain programming paradigms of parallel programming languages. They master basic constructions of the languages and library functions of the most important parallel programming languages and environments (e.g. OpenMP, POSIX-Threads, MPI, PGAS) and name the areas of applications.
- Students are able to describe the features of actual HPC systems and processors. They describe major underlying trends (power wall, Memory wall, ILP wall) of the systems.
- Students name and describe General used classifications of parallel systems. They describe the important structure elements of Operation principles of parallel computer systems. They master the theoretical behavior of scaling (Amdahl, Gustafson) and quantitative Evaluations of parallel computers.
- Students name and describe architectural characteristics of scalable shared memory systems. They master different techniques to maintain memory consistency and coherency in bus based systems (Invalidation protocols, update protocols). They describe technics to increase the Performance of These systems (Multi Level caches, transient states, split Transaction busses).
- Students describe mechanisms to establish synchronizations (locks, barriers) in parallel systems.
- Students demonstrate knowledge and understanding of in maintaining cache coherency within scalable computer systems (hierarchical snooping, directories). They master techniques to increase the performance of these systems (e.g. latency, throughput).
- Students describe techniques based on token coherency.
- Students name and describe fundamental features of the architectures of cluster systems. They are able to describe the topology of communication systems and metrics for evaluation (e.g. degree, diameter, bisection). They master communication techniques of high performance interconnect networks (e.g. wormhole Routing, virtual cut-through). They master techniques to proof are deadlock are avoided.
- Students describe features of existing interconnects (InfiniBand, OmniPath).

Non-cognitive Skills

- Commitment
- Learning 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	90-120 minutes or 40 minutes	100%

The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

<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>Written exercises</td><td></td><td>CA</td></tr>
</table>
Within the first three weeks of the lecture period each respective lecturer will specify the manner in which the course achievement will be conducted.</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 as 6 credits.</td></tr>
<tr><td>11</td><td>Reuse in degree courses or degree course versions :
Masterstudiengang Computer Engineering v3 (CEMA v3)</td></tr>
<tr><td>12</td><td>Module coordinator:
Dr. Jens Simon</td></tr>
<tr><td>13</td><td>Other Notes:
Remarks of course Architektur paralleler Rechnersysteme:
Implementation method
Presentation of slides. Exercises on available high performance computers to practise the usage of the systems and deepen the knowledge of the lecture.
Learning Material, Literature
Slides</td></tr>
</table>

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

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 v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, NEU23 Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik
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

Machine Learning I			
Machine Learning I			
Module number: M.079.01274	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
	Semester number: beliebig	**Duration (in sem.):** 1	**Teaching Language:** en

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.079.05717 Machine Learning I	L3 Ex2	75	105	CE	60/20

2 **Options within the module:**

none

3 **Admission requirements:**

Prerequisites of course Machine Learning I:
Recommended Proficiencies
Basic knowledge in mathematics (linear algebra, statistics), programming and algorithms.

<table>
<tr><td>4</td><td>Contents:

Contents of the course Machine Learning I:
Due to the ever increasing amount of data that is routinely produced in our information society, the topic of machine learning has become increasingly important in the recent years, not only as a scientific discipline but also as a key technology of modern software and intelligent systems. This lecture provides an introduction to the topic of machine learning, with a specific focus on supervised learning for classification and regression. The lecture covers theoretical foundations of generalisation as well as practical topics and concrete learning algorithms.

• Introduction
• The Learning Problem
• Training versus Testing
• The Linear Model
• Non-Linear Methods
• Overfitting</td></tr>
<tr><td>5</td><td>Learning outcomes and competences:

The students understand the statistical foundations of generalisation, i.e., the induction of models from data, as well as practical tools for model validation. They are able to apply basic methods of supervised learning to problems of classification and regression.
Non-cognitive Skills

• Learning competence
• Learning motivation
• Literacy (scientific)</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</td><td>90-120 minutes or 40 minutes</td><td>100%</td></tr></table>The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.</td></tr>
<tr><td>7</td><td>Study Achievement:

none</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 as 6 credits.</td></tr>
</table>

11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v3 (CEMA v3)
12	**Module coordinator:** Prof. Dr. Eyke Hüllermeier
13	**Other Notes:** *Remarks of course Machine Learning I:* **Implementation method** Theoretical foundations and concepts of machine learning will be taught in the form of a lecture and deepened in practical exercise courses, group work as well as individual homework. **Learning Material, Literature** • Script • Y.S. Abu-Mostafa, M. Magdon-Ismail, H.T. Lin. Learning from Data, AMLBook, 2012. • P. Flach. Machine Learning, Cambridge Univ. Press, 2012. • E. Alpaydin. Machine Learning, Oldenbourg, 2008. • C.M. Bishop. Pattern Recognition and Machine Learning, Springer, 2006.

Model-Based Systems Engineering			
Model-Based Systems Engineering			
Module number: M.079.01277	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
	Semester number: beliebig	**Duration (in sem.):** 1	**Teaching Language:** en

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.079.05815 Model-Based Systems Engineering	L3 Ex2	75	105	CE	??

2 **Options within the module:**

none

3 **Admission requirements:**

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

4 **Contents:**

Contents of the course Model-Based Systems Engineering:
The goal of the lecture is a comprehensive understanding of Model-Based Systems Engineering (MBSE) and its components. The students are taught the essential topics of MBSE. This includes fundamentals including languages, methods and IT tools, which are also tested in practice. The benefits of MBSE (an understanding of the system by all involved actors, a basis for communication and cooperation between different disciplines but also functional areas, . . .) will be conveyed to the students. Furthermore, essential analysis methods for testing system designs are covered. The focus is on multidisciplinary, software-intensive systems from the mechanical and plant engineering and automotive industries.

- Basics of MBSE
- SysML for multidisciplinary systems
- CONSENS
- further MBSE approaches
- design patterns
- MBSE Tools
- analysis methods based on the system model

5 **Learning outcomes and competences:**

Learning Outcomes
Students will be able to,

- Work in a model-based manner
- Apply systems thinking
- Create system architectures & derive requirements.

Non-Cognitive Competencies

- Self-monitoring
- Literacy (scientific)
- Learning competence
- Learning motivation

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 minutes or 40 minutes	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:**

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 as 6 credits.
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v3 (CEMA 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 three 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. 3. practical course (labs): In the practical course, the application of what has been learned takes place in group work. **Learning Material, Literature** • Friedenthal, S.; Moore, A.; Steiner, R.: A Practical Guide to SysML. The Systems Modeling Language. Morgan Kaufmann, Waltham, 2. Auflage, 2012 • Gausemeier, J.; Rammig, J.; Schäfer, W. (Eds.): Design Methodology for Intelligent Technical Systems. Develop Intelligent Technical Systems of the Future. Springer-Verlag, 2014 • Gausemeier, J.; Dumitrescu, R.; Steffen, D.; Czaja, A.; Wiederkehr, O.; Tschirner, C.: Systems Engineering in industrial practice. Heinz Nixdorf Institute, University • Haberfellner, R., L., D. W. O., Fricke, E., & Voössnersiegfried. (2019). Systems engineering: fundamentals and applications. Cham: Springer International Publishing • Incose Systemsengineeringhandbook: A Guide for System Life Cycle Processes and Activities(2015) • Weilkiens, Tim: Systems Engineering with SysML/UML: Modeling, Analysis, Design (The MK/OMG Press) (English Edition) • Dumitrescu, R.; Albers, A.; Riedel, O.; Stark, R.; Gausemeier, J. (Hrsg.): Engineering in Deutschland – Status quo in Wirtschaft und Wissenschaft, Ein Beitrag zum Advanced Systems Engineering, Paderborn, 2021 – English Version: www.advanced-systems-engineering.de

Reconfigurable Computing			
Reconfigurable Computing			
Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.079.01270	180	6	winter term

	Semester number:	Duration (in sem.):	Teaching Language:
	beliebig	1	en

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.079.05703 Reconfigurable Computing	L2 Ex3	75	105	CE	50/20

2 **Options within the module:**

none

3 **Admission requirements:**

Prerequisites of course Reconfigurable Computing:
Recommended Proficiencies
Knowledge of “Digital Design” and “Computer Architecture” is beneficial.

4 **Contents:**

Contents of the course Reconfigurable Computing:
This lecture provides an understanding of architectures and design methods for reconfigurable hardware systems and presents applications in the areas of high performance computing and embedded systems.

- Introduction: evolution of programmable logic devices, market economics
- Architectures: FPGA architectures, reconfigurable devices, reconfigurable systems
- Design methods: CAD for FPGAs, high-level languages and compilers, system-level design
- Applications: custom computing machines, embedded systems

5 **Learning outcomes and competences:**

After attending the course, the students are able to

- explain the architectures of reconfigurable hardware devices,
- name and analyze the main design methods and
- judge the suitability of reconfigurable hardware for different application domains.

Non-cognitive Skills

- Team work
- Learning competence

<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</td><td>90-120 minutes or 40 minutes</td><td>100%</td></tr>
</table>
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<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>Written exercises</td><td></td><td>CA</td></tr>
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Passing of course achievement</td></tr>
<tr><td>9</td><td>Prerequisites for assigning credits:
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<tr><td>10</td><td>Weighing for overall grade:
The module is weighted as 6 credits.</td></tr>
<tr><td>11</td><td>Reuse in degree courses or degree course versions :
Masterstudiengang Computer Engineering v3 (CEMA v3)</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** • Lecture with projector and board • Interactive exercises in the lecture room • Computer-based exercises with reconfigurable systems **Learning Material, Literature** • Lecture slides and exercise sheets • Exercise sheets and technical documentation for the for the computer-based exercises • S. Hauck and A. DeHon (editors): Reconfigurable Computing, Volume 1: The Theory and Practice of FPGA-Based Computation, Morgan Kaufmann, 2008 • Information about alternative and additional literature as well as teaching material on the course's website and in the lecture slides

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
	Semester number: 1.-3. Semester	**Duration (in sem.):** 1	**Teaching Language:** de / en

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 v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, NEU23 Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik</td></tr>
<tr><td>12</td><td>Module coordinator:
Prof. Dr.-Ing. J. Christoph Scheytt</td></tr>
<tr><td>13</td><td>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).</td></tr>
</table>

Software Quality Assurance
Software Quality Assurance

Module number: M.079.01272	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
	Semester number: beliebig	**Duration (in sem.):** 1	**Teaching Language:** en

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.079.05805 Software Quality Assurance	L3 Ex2	75	105	CE	90/30

2 **Options within the module:**

none

3 **Admission requirements:**

Prerequisites of course Software Quality Assurance:
Recommended Proficiencies
Programming, Modeling, Model-based software development

4	**Contents:** *Contents of the course Software Quality Assurance:* The aim of the lecture is to cover approaches, technologies and strategies related to quality assurance for software systems. These include on the one hand constructive approaches such as design patterns, anti-patterns, domain-specific languages, model driven development, model quality analysis, and architectural styles, and on the other hand analytic approaches such as static reviewing techniques and dynamic testing techniques.. Furthermore, approaches for the improvement of the software development process and international standards like ISO 9001, 9126, CMM etc. are covered. • Introduction to software quality assurance • Standards – Product-related Standards: ISO 9126 – Process-related Standards: ISO 9001, CMM • Constructive approaches – Patterns and styles: Design patterns, Anti-Patterns, Architectural styles – Model-driven development – Metamodeling – Domain Specific Languages – Design by contract – Research: Process constraints • Analytical approaches – Reviews, inspections – Testing: Fundamental Test Process, Black Box Testing, White Box Testing
5	**Learning outcomes and competences:** The students are able to explain quality characteristics of software development processes, software models as well as software systems. They have understood constructive and analytical techniques used to ensure quality properties, and they are able to apply them. They can describe standards for measuring process and product quality. They are able to understand new research approaches in the area of process and product quality. **Non-cognitive Skills** • Empathy • Learning competence • Learning motivation • Motivation

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 minutes or 40 minutes	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 as 6 credits.

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

Masterstudiengang Computer Engineering v3 (CEMA v3)

12 **Module coordinator:**

Prof. Dr. Gregor Engels

13 **Other Notes:**

Remarks of course Software Quality Assurance:
Implementation method
Partially slides and partially board writing. All essential concepts and techniques will be repeatedly applied in examples during the tutorial. In a lab part, the techniques will be employed using tools, particularly testing tools.
Learning Material, Literature

- Daniel Galin: Software Quality Assurance: From Theory to Implementation, Pearson / Addison Wesley, 2004
- Slides, Exercises

VLSI-Testing

VLSI-Testing			
Module number: M.048.92027	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
	Semester number: 1.-3. Semester	**Duration (in sem.):** 1	**Teaching Language:** en

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 micro-electronic 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 v4 (CEMA v4), Masterstudiengang Electrical Systems Engineering v3 (ESEMA v3) - Amtssprache, Master's Program Electrical Systems Engineering (ESEMA v2)
12	**Module coordinator:** Prof. Dr. Sybille Hellebrand

13	**Other Notes:** *Remarks of course VLSI Testing:* **ATTENTION - IMPORTANT NOTICE** The course doesn't take place in summer term 2024. Please see the notice boards of the group. **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 * Algorithms for Synthesis and Optimization of Integrated Circuits * Einführung in die Hochfrequenztechnik * Halbleiterprozesstechnik * High Frequency Engineering * Integrierte Schaltungen für die drahtlose Kommunikation

Specialisation Area	Nano/Microelectronics
	* Machine Learning I * Schnelle integrierte Schaltungen für die leitungsgebundene Kommunikation * Technologie hochintegrierter Schaltungen * 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:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.92043	180	6	summer term
	Semester number:	**Duration (in sem.):**	**Teaching Language:**
	1.-3. Semester	1	en

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 v4 (CEMA v4), Masterstudiengang Electrical Systems Engineering v3 (ESEMA v3) - Amtssprache, Master's Program Electrical Systems Engineering (ESEMA v2)
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
	Semester number:	**Duration (in sem.):**	**Teaching Language:**
	1.-3. Semester	1	en

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 v4 (CEMA v4), Masterstudiengang Electrical Systems Engineering v3 (ESEMA v3) - Amtssprache, Master's Program Electrical Systems Engineering (ESEMA v2)
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:* **ATTENTION - IMPORTANT NOTICE** The course doesn't take place in summer term 2024. Please see the notice boards of the group. **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:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.11004	180	6	winter term
	Semester number:	**Duration (in sem.):**	**Teaching Language:**
	5.-6. Semester	1	de

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:**

Mandatory for WGBAET: Successful completion of the modules required under the study plan in semester 1 and 2.
Other degree courses: 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.

<table>
<tr><td>5</td><td>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.</td></tr>
<tr><td>6</td><td>Assessments:

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

<table><tr><td>zu</td><td>Type of examination</td><td>Duration or scope</td><td>Weighting for the module grade</td></tr><tr><td>a)</td><td>Written or Oral Examination</td><td>120-180 min or 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 :

Bachelorstudiengang Computer Engineering v4 (CEBA v4), Bachelorstudiengang Elektrotechnik v6 (EBA v6), Bachelorstudiengang Elektrotechnik v7 (EBA v7), Bachelorstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Computer Engineering v3 (CEMA v3), NEU23 Bachelorstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik</td></tr>
<tr><td>12</td><td>Module coordinator:

Prof. Dr. Andreas Thiede</td></tr>
</table>

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 Viewег 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)

High Frequency Engineering

High Frequency Engineering

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.92002	180	6	winter term
	Semester number:	**Duration (in sem.):**	**Teaching Language:**
	1.-3. Semester	1	en

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 v4 (CEMA v4), Masterstudiengang Electrical Systems Engineering v3 (ESEMA v3) - Amtssprache, Master's Program Electrical Systems Engineering (ESEMA v2)
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
	Semester number: 1.-3. Semester	**Duration (in sem.):** 1	**Teaching Language:** de / en

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 v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, NEU23 Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik
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

Machine Learning I

Machine Learning I			
Module number: M.079.01274	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
	Semester number: beliebig	**Duration (in sem.):** 1	**Teaching Language:** en

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.079.05717 Machine Learning I	L3 Ex2	75	105	CE	60/20

2 **Options within the module:**

none

3 **Admission requirements:**

Prerequisites of course Machine Learning I:
Recommended Proficiencies
Basic knowledge in mathematics (linear algebra, statistics), programming and algorithms.

4 **Contents:**

Contents of the course Machine Learning I:
Due to the ever increasing amount of data that is routinely produced in our information society, the topic of machine learning has become increasingly important in the recent years, not only as a scientific discipline but also as a key technology of modern software and intelligent systems. This lecture provides an introduction to the topic of machine learning, with a specific focus on supervised learning for classification and regression. The lecture covers theoretical foundations of generalisation as well as practical topics and concrete learning algorithms.

- Introduction
- The Learning Problem
- Training versus Testing
- The Linear Model
- Non-Linear Methods
- Overfitting

5 **Learning outcomes and competences:**

The students understand the statistical foundations of generalisation, i.e., the induction of models from data, as well as practical tools for model validation. They are able to apply basic methods of supervised learning to problems of classification and regression.
Non-cognitive Skills

- Learning competence
- Learning motivation
- Literacy (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)	Written or oral examination	90-120 minutes or 40 minutes	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:** none
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 as 6 credits.
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v3 (CEMA v3)
12	**Module coordinator:** Prof. Dr. Eyke Hüllermeier
13	**Other Notes:** *Remarks of course Machine Learning I:* **Implementation method** Theoretical foundations and concepts of machine learning will be taught in the form of a lecture and deepened in practical exercise courses, group work as well as individual homework. **Learning Material, Literature** • Script • Y.S. Abu-Mostafa, M. Magdon-Ismail, H.T. Lin. Learning from Data, AMLBook, 2012. • P. Flach. Machine Learning, Cambridge Univ. Press, 2012. • E. Alpaydin. Machine Learning, Oldenbourg, 2008. • C.M. Bishop. Pattern Recognition and Machine Learning, Springer, 2006.

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

<table>
<tr><td colspan="2"></td><td>Semester number:
1.-3. Semester</td><td>Duration (in sem.):
1</td><td>Teaching Language:
de / en</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.048.25019
Fast Integrated Circuits for Wireline Communications</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:
None</td></tr>
<tr><td>3</td><td colspan="4">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</td></tr>
</table>

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 v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, NEU23 Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik
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).

VLSI-Testing
VLSI-Testing

Module number: M.048.92027	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
	Semester number: 1.-3. Semester	**Duration (in sem.):** 1	**Teaching Language:** en

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 micro-electronic 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><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 v4 (CEMA v4), Masterstudiengang Electrical Systems Engineering v3 (ESEMA v3) - Amtssprache, Master's Program Electrical Systems Engineering (ESEMA v2)</td></tr>
<tr><td>12</td><td>Module coordinator:

Prof. Dr. Sybille Hellebrand</td></tr>
</table>

13	**Other Notes:** *Remarks of course VLSI Testing:* **ATTENTION - IMPORTANT NOTICE** The course doesn't take place in summer term 2024. Please see the notice boards of the group. **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, Image, and Speech Processing"

Specialisation Area	Signal, Image, and Speech Processing
Modules	* Advanced System Theory)
	* Digital Image Processing I
	* Digital Image Processing II
	* Digitale Sprachsignalverarbeitung
	* Machine Learning I
	* Machine Learning II
	* Messstochastik
	* Optimale und Adaptive Filter

Specialisation Area	Signal, Image, and Speech Processing
	* Schnelle integrierte Schaltungen für die leitungsgebundene Kommunikation * Statistical and Machine Learning * Statistical Natural Language Processing * Technische kognitive Systeme * Topics in Audio, Speech, and Language Processing * 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:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.92001	180	6	winter term
	Semester number:	**Duration (in sem.):**	**Teaching Language:**
	1. Semester	1	en

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

Digital Image Processing I			
Digital Image Processing I			
Module number: M.048.92008	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
	Semester number: 1.-3. Semester	**Duration (in sem.):** 1	**Teaching Language:** en

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, WS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Digital Image Processing I:
None

4	**Contents:** *Contents of the course Digital Image Processing I:* **Short Description** The course “Digital Image Processing I” is a fundamental module in the catalog “Cognitive Systems” of the Electrical Engineering Master’s program and related courses of studies. The course provides a fundamental introduction to digital image processing. **Contents** • Basic principles (coordinates, types of image data, human perception, light and electromagnetic spectrum) • Image acquisition (sampling, quantization, aliasing, neighborhoods) • Image enhancement in the spatial domain (transformations, histograms, arithmetic and logarithmic operations, spatial filters in general, smoothing filters, edge filters) • Image enhancement in the frequency domain (Fourier Transform, smoothing filters, edge filters) • Compression and reduction of image data (basic principles, compression models, information theory, compression standards)
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 the C language and C++.
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 v4 (CEMA v4), Masterstudiengang Electrical Systems Engineering v3 (ESEMA v3) - Amtssprache, Master's Program Electrical Systems Engineering (ESEMA v2)
12	**Module coordinator:** Prof. Dr. Bärbel Mertsching
13	**Other Notes:** *Remarks of course Digital Image Processing I:* **Course Homepage** http://getwww.uni-paderborn.de/teaching/dip-I **Implementation** • The theoretical and methodic 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 image processing algorithms. • The necessary programming skills will be taught during the practical, this is explicitly not considered a programming course. **Teaching Material, Literature** Lecture notes, exercise sheets and advanced literature (excerpt): • Mertsching, Bärbel: Digital Image Processing I (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 ImageProcessing. Prentice Hall, 3rd ed., 2007. ISBN-13: 978-013168728 • Jähne, Bernd: Digitale Bildverarbeitung. Springer, 7.Aufl., 2012. ISBN-13: 978-3642049514

Digital Image Processing II

Digital Image Processing II

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.92010	180	6	summer term
	Semester number:	**Duration (in sem.):**	**Teaching Language:**
	1.-3. Semester	1	en

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 v4 (CEMA v4), Masterstudiengang Electrical Systems Engineering v3 (ESEMA v3) - Amtssprache, Master's Program Electrical Systems Engineering (ESEMA v2)
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
	Semester number: 1.-3. Semester	**Duration (in sem.):** 1	**Teaching Language:** de / en

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 v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, NEU23 Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik</td></tr>
<tr><td>12</td><td>Module coordinator:
Dr.-Ing. Jörg Schmalenströer</td></tr>
<tr><td>13</td><td>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</td></tr>
</table>

Machine Learning I
Machine Learning I

Module number:	Workload (h):	Credits:	Regular Cycle:
M.079.01274	180	6	winter term
	Semester number:	**Duration (in sem.):**	**Teaching Language:**
	beliebig	1	en

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.079.05717 Machine Learning I	L3 Ex2	75	105	CE	60/20

2 **Options within the module:**

none

3 **Admission requirements:**

Prerequisites of course Machine Learning I:
Recommended Proficiencies
Basic knowledge in mathematics (linear algebra, statistics), programming and algorithms.

4 **Contents:**

Contents of the course Machine Learning I:
Due to the ever increasing amount of data that is routinely produced in our information society, the topic of machine learning has become increasingly important in the recent years, not only as a scientific discipline but also as a key technology of modern software and intelligent systems. This lecture provides an introduction to the topic of machine learning, with a specific focus on supervised learning for classification and regression. The lecture covers theoretical foundations of generalisation as well as practical topics and concrete learning algorithms.

- Introduction
- The Learning Problem
- Training versus Testing
- The Linear Model
- Non-Linear Methods
- Overfitting

5 **Learning outcomes and competences:**

The students understand the statistical foundations of generalisation, i.e., the induction of models from data, as well as practical tools for model validation. They are able to apply basic methods of supervised learning to problems of classification and regression.
Non-cognitive Skills

- Learning competence
- Learning motivation
- Literacy (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) / Written or oral examination / 90-120 minutes or 40 minutes / 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:** none
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 as 6 credits.
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v3 (CEMA v3)
12	**Module coordinator:** Prof. Dr. Eyke Hüllermeier
13	**Other Notes:** *Remarks of course Machine Learning I:* **Implementation method** Theoretical foundations and concepts of machine learning will be taught in the form of a lecture and deepened in practical exercise courses, group work as well as individual homework. **Learning Material, Literature** • Script • Y.S. Abu-Mostafa, M. Magdon-Ismail, H.T. Lin. Learning from Data, AMLBook, 2012. • P. Flach. Machine Learning, Cambridge Univ. Press, 2012. • E. Alpaydin. Machine Learning, Oldenbourg, 2008. • C.M. Bishop. Pattern Recognition and Machine Learning, Springer, 2006.

Machine Learning II			
Machine Learning II			
Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.079.01275	180	6	summer term

	Semester number:	Duration (in sem.):	Teaching Language:
	beliebig	1	en

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.079.05810 Machine Learning II	L3 Ex2	75	105	CE	20

2 **Options within the module:**

none

3 **Admission requirements:**

Prerequisites of course Machine Learning II:
Recommended Proficiencies
Basic knowledge in machine learning (as conveyed, for example, by the Machine Learning I lecture).

4 **Contents:**

Contents of the course Machine Learning II:
This lecture, which is conceived as a continuation of the Machine Learning I, covers advanced topics in contemporary machine learning research, such as reinforcement learning, online learning and bandit algorithms, multi-task learning, multi-target and structured output prediction, preference learning, learning from weak supervision, and uncertainty in machine learning. The focus of the lecture will be on methods and algorithms, though theoretical issues and applications will be addressed, too.

- From binary to multi-class classification
- Ordinal and hierarchical classification
- Ensemble methods
- Nonlinear models and kernel machines
- Multi-target prediction
- Semi-supervised learning
- Active learning
- Online learning
- Multi-armed bandits
- Reinforcement learning
- Preference learning and ranking

<table>
<tr><td>5</td><td>Learning outcomes and competences:
The students have an overview of methods for multi-class classification, the learning of nonlinear models, and extensions of the simple setting of supervised learning. They understand algorithmic concepts of corresponding methods and are able to apply them to real problems.
Non-cognitive Skills
• Learning competence
• Learning motivation
• Literacy (scientific)</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</td><td>90-120 minutes or 40 minutes</td><td>100%</td></tr>
</table>
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.</td></tr>
<tr><td>7</td><td>Study Achievement:
none</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 as 6 credits.</td></tr>
<tr><td>11</td><td>Reuse in degree courses or degree course versions :
Masterstudiengang Computer Engineering v3 (CEMA v3)</td></tr>
<tr><td>12</td><td>Module coordinator:
Prof. Dr. Eyke Hüllermeier</td></tr>
</table>

13	**Other Notes:** *Remarks of course Machine Learning II:* **Implementation method** Theoretical foundations and concepts of machine learning will be taught in the form of a lecture and deepened in practical exercise courses, group work as well as individual homework. **Learning Material, Literature** • Script • Y.S. Abu-Mostafa, M. Magdon-Ismail, H.T. Lin. Learning from Data, AMLBook, 2012. • P. Flach. Machine Learning, Cambridge Univ. Press, 2012. • E. Alpaydin. Machine Learning, Oldenbourg, 2008. • C.M. Bishop. Pattern Recognition and Machine Learning, Springer, 2006.

Messstochastik

Statistics in measurement

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.22008	180	6	summer term
	Semester number:	**Duration (in sem.):**	**Teaching Language:**
	1.-3. Semester	1	de

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.22008 Measuring Stochastics	2L 2Ex, SS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Messstochastik:
Recommended:
Prior knowledge from the Measurement Technology module is expected.

4 **Contents:**

Contents of the course Messstochastik:
Short description
In many areas of technology, randomly fluctuating (stochastic) variables occur, the course of which cannot be specified by formula. Such random temperature, pressure or voltage fluctuations can be disturbances, but also useful signals. Their treatment requires statistical methods, such as spectral analysis or correlation methods. The errors occurring during their realization with respect to measurement time and amplitude quantization are dealt with. The practical use of statistical methods in the field of communication and automation technology is demonstrated. Lecture-accompanying Matlab® and laboratory practical exercises help to deepen the material.
Contents
The lecture Measurement Stochastics covers the following topics:

- Fundamentals of measurement stochastics.
- Stochastic processes in nonlinear systems
- Devices of measurement stochastics
- Problems of finite measurement time
- Applications: Signal detection in noise, word recognition by partial autocorrelation, system identification, flame monitoring, localization, leak detection in pipes, separation of stochastic sum processes, time-of-flight and velocity measurement in rigid and turbulent as well as stationary and unsteady motion processes, rehocence and cepstrum methods, sensors for correlative velocity measurement, FTIR spectrometer as optical correlator.

5 **Learning outcomes and competences:**

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

- analyze and evaluate complex measurement tasks with stochastically varying quantities and develop their own solutions,
- evaluate algorithms with respect to computational efficiency, effectiveness, error estimation, and limitations.

Cross-disciplinary competencies:
The students

- can apply the acquired knowledge across disciplines to complex problems,
- are able to develop targeted solutions based on a systematic problem analysis,
- are methodically able to familiarize themselves with comparable fields of work.

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 v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, NEU23 Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, UF Technik Lehramt GyGe Master v5, UF Technik Lehramt HRSGe Master v5
12	**Module coordinator:** Dr.-Ing. Fabian Bause
13	**Other Notes:** *Remarks of course Messstochastik:* **Course Homepage** `http://emt.upb.de` **Implementation** • Lecture on interactive presentation board with step-by-step development of extensive correlations. • Solution of exercise problems and laboratory practical treatment mess **Teaching Material, Literature** Supporting material will be provided to be completed in lecture. References to textbooks and to important publications will be given.

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

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

<table>
<tr><td>5</td><td>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.</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 v3 (CEMA v3), Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, NEU23 Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik</td></tr>
<tr><td>12</td><td>Module coordinator:

Dr.-Ing. Jörg Schmalenströer</td></tr>
</table>

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: M.048.25019	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
	Semester number: 1.-3. Semester	**Duration (in sem.):** 1	**Teaching Language:** de / en

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 v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, NEU23 Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik
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
	Semester number:	**Duration (in sem.):**	**Teaching Language:**
	1.-3. Semester	1	en

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 v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, NEU23 Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik
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

Statistical Natural Language Processing

Statistical Natural Language Processing

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.079.01281	180	6	winter term
	Semester number:	**Duration (in sem.):**	**Teaching Language:**
	beliebig	1	en

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.079.05702 Statistical Natural Language Processing	L2 Ex3	75	105	CE	30

2 **Options within the module:**

none

3	**Admission requirements:** *Prerequisites of course Statistical Natural Language Processing:* **Recommended Proficiencies** Vector spaces, grammar of natural languages, probability theory
4	**Contents:** *Contents of the course Statistical Natural Language Processing:* The goal of this lecture is to present students with the foundational tools and methods necessary to implement natural language processing pipelines. The course includes content pertaining to text preprocessing, parsing, distributional semantics, dedicated machine learning approaches and applications such as question answering. • Text normalization • Language modeling • Spelling correction • Machine Learning • POS Tagging • Parsing • Distributional semantics • Word senses • Knowledge Extraction • Question Answering
5	**Learning outcomes and competences:** Students can list relevant problems and identify solution requirements for the following areas: • Text preprocessing • Language modelling • Spelling correction • Text and document classification • Distributional Semantics • Question Answering They are aware of basic techniques in these areas, can identify limitations and shortcomings of these techniques when applied to concrete problem situations, and develop modifications of these techniques for specific areas. They can evaluate such modifications qualitatively and quantitatively. **Non-cognitive Skills** • Team work • Learning competence • Media competence • Literacy (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)	Written or oral examination	90-120 minutes or 40 minutes	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 as 6 credits.

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

Masterstudiengang Computer Engineering v3 (CEMA v3)

12 **Module coordinator:**

Prof. Dr. Axel-Cyrille Ngonga Ngomo

13 **Other Notes:**

Remarks of course Statistical Natural Language Processing:
Implementation method
The weekly lectures (2SWS) cover new content on a weekly basis. In addition to the formal considerations, we will cover applications and corresponding limitations of the methods presented throughout the course. The exercises (1SWS) are both theoretical and practical in nature. The learners are to show that they understood the concepts and can apply them to practical problems. The mini-project (2SWS) give the students a holistic view of how to solve complex problems using Semantic Web technologies.
Learning Material, Literature
Slides and homework assignments

Technische kognitive Systeme

Cognitive Systems Engineering			
Module number: M.048.43019	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
	Semester number: 1.-3. Semester	**Duration (in sem.):** 1	**Teaching Language:** en

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:**

None

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 and yields three credits. *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	90-150 min or 20-30 min or 30-60 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)
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.

Topics in Audio, Speech and Language Processing			
Topics in Audio, Speech and Language Processing			
Module number: M.048.23021	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
	Semester number: 1.-3. Semester	**Duration (in sem.):** 1	**Teaching Language:** en

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.23021 Topics in Audio, Speech and Language Processing	2L 2Ex, SS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Topics in Audio, Speech and Language Processing:
None

4 **Contents:**

Contents of the course Topics in Audio, Speech and Language Processing:
Short Description
The course „Topics in Audio, Speech, and Language Processing" highlights current research topics in audio, speech, and language processing. From the methodological side we will discuss signal processing and machine learning aspects, and in particular their interaction, which is typical for many real-world applications. The selection of topics may change from year to year.
Contents
Example topics are

- Multi-channel signal processing for microphone arrays
- Sampling rate synchronisation
- Machine learning for speech enhancement
- Blind source separation for speech and audio
- „Deep learning" for acoustic and language modeling in automatic speech recognition
- Neural architectues für speech recognition, speech synthesis, machine translation, etc.
- Natural language processing

5 **Learning outcomes and competences:**

Domain competence:
After completion of the course the students

- Can assess the challenges and realized solutions of modern speech and audio processing systems
- Know the specific properties of speech, audio and language and know how those are exploited in specific signal processing and machine learning algorithms
- Understand the interplay of algorithmic performance, complexity and latency and identify appropriate operating points
- Apply the learnt signal processing and machine learning algorithms to other tasks in speech and audio processing, and beyond
- Understand current scientific literature in the field of audio, speech, and language processing and assess their importance for 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 Automatisierungstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, NEU23 Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik

12 **Module coordinator:**

Prof. Dr. Reinhold Häb-Umbach

13 **Other Notes:**

none

Topics in Pattern Recognition and Machine Learning

Topics in Pattern Recognition and Machine Learning

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.92030	180	6	winter term
	Semester number:	**Duration (in sem.):**	**Teaching Language:**
	1.-3. Semester	1	en

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

Topics in Signal Processing

Topics in Signal Processing

Module number:	Workload (h):	Credits:	Regular Cycle:
M.048.92014	180	6	winter term
	Semester number:	**Duration (in sem.):**	**Teaching Language:**
	1.-3. Semester	1	en

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

<table>
<tr><td>3</td><td>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</td></tr>
<tr><td>4</td><td>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.</td></tr>
<tr><td>5</td><td>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.</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 v4 (CEMA v4), Masterstudiengang Electrical Systems Engineering v3 (ESEMA v3) - Amtssprache, Master's Program Electrical Systems Engineering (ESEMA v2)</td></tr>
<tr><td>12</td><td>Module coordinator:
Prof. Dr. Peter Schreier</td></tr>
</table>

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.

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

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 v4 (CEMA v4), Masterstudiengang Electrical Systems Engineering v3 (ESEMA v3) - Amtssprache, Master's Program Electrical Systems Engineering (ESEMA v2)
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 Master's Thesis

<table>
<tr><th colspan="5">Abschlussarbeit</th></tr>
<tr><td colspan="5">Master's Project</td></tr>
<tr><td colspan="2">Module number:
A.048.17001</td><td>Workload (h):
900</td><td>Credits:
30</td><td>Regular Cycle:
summer- / winter term</td></tr>
<tr><td colspan="2"></td><td>Semester number:
4. Semester</td><td>Duration (in sem.):
1</td><td>Teaching Language:
de / en</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>Working Plan (CEMA)</td><td></td><td>15</td><td>135</td><td>C</td><td></td></tr>
<tr><td>b)</td><td>Master Thesis (CE)</td><td></td><td>30</td><td>720</td><td>C</td><td></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:
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.</td></tr>
<tr><td>4</td><td colspan="4">Contents:</td></tr>
<tr><td>5</td><td colspan="4">Learning outcomes and competences:
-</td></tr>
</table>

<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) - b)</td><td></td><td></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>Working Plan</td><td>150h</td><td>QP</td></tr><tr><td>b)</td><td></td><td></td><td></td></tr></table></td></tr>
<tr><td>8</td><td>Prerequisites for participation in examinations:
None</td></tr>
<tr><td>9</td><td>Prerequisites for assigning credits:
none</td></tr>
<tr><td>10</td><td>Weighing for overall grade:</td></tr>
<tr><td>11</td><td>Reuse in degree courses or degree course versions :
Masterstudiengang Computer Engineering v3 (CEMA v3)</td></tr>
<tr><td>12</td><td>Module coordinator:
Dr.-Ing. Carsten Balewski</td></tr>
<tr><td>13</td><td>Other Notes:
none</td></tr>
</table>

5 Overview of the modules offered in the winter semester

6 Overview of the modules offered in the summer semester

7 Overview of module offerings in English

Erzeugt am 6. März 2024 um 14:37.