UNIVERSITY OF PADERBORN

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

MODULE HANDBOOK
MASTER'S PROGRAM ELECTRICAL SYSTEMS ENGINEERING
(ESEMA V2)

DATE: 4. MÄRZ 2021

Inhaltsverzeichnis

1 Preambles and Indications

For technical reasons the preamble of the module catalogue was relocated. It can be found at Regulations and Module Handbook in the category “Module Catalogues” on the pages of the Department EIM-E. Please take account of this preamble. In case of questions relating to this preamble, please contact

- the Student Advisory Service of Electrical Systems Engineering or
- the Course Management of Electrical Engineering.

Please also note that

1. all modules are listed in this module catalogue as determined by the respective examination regulation even if they are not offered in the current semester.
2. this module catalogue contains the content of the database on the creation date. All information supplied is subject to correction.

2 Module Descriptions

2.1 Module Group: Introduction to Electrical Systems Engineering

The modules of this group are compulsory to all MS-ESE students.

Module Group	Introduction to Electrical Systems Engineering
Modules	* Advanced System Theory * Modeling and Simulation
Teaching objectives	The students in the Master's program ESE have a very heterogeneous educational background. These two modules should provide a common level for all other modul to come.

The first module will provide a theoretical and methodological understanding of electrical systems. Nowadays, the process of developing electrical systems is assisted by various modeling and simulation tools. Therefore, the second module will give an overview of the underlying principles of modeling and simulation techniques and discuss their advantages as well as their limits.|

2.1.1 Advanced System Theory

Advanced System Theory			
Advanced System Theory			
Module number: M.048.92001	**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.048.92001 Advanced System Theory	2L 2Ex, WS	60	120	C	50

2 **Options within the module:**

None

3 **Admission requirements:**

none

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%

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

7 **Study Achievement:**

none

8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses:** Masterstudiengang Computer Engineering v3 (CEMA v3)
12	**Module coordinator:** Dr.-Ing. Oliver Wallscheid
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 tutorial questions; literature references will be given in the first lecture

2.1.2 Modeling and Simulation

Modeling and Simulation			
Modeling and Simulation			
Module number: M.048.90102	**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.048.90102 Modeling and Simulation	2L 2Ex, WS	60	120	C	100

2 **Options within the module:**
None

3 **Admission requirements:**

Prerequisites of course Modeling and Simulation:

- Prior knowledge of programming in Matlab will be required
- Knowledge of mathematics and physics at the level of the university entrance qualification

Information: Unless otherwise specified, these are recommendations.

4 **Contents:**

Contents of the course Modeling and Simulation:
Short Description
In this lecture, techniques of constructing models and simulations of technical systems are introduced and implemented
Contents

- Introduction to the modeling process
- Number representation in digital computers
- Numerical schemes for ordinary and partial differential equations
- Discrete simulations

5 **Learning outcomes and competences:**

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

- categorize and analyze modelling schemes and numerical methods
- identify and apply numerical methods for technical-physical systems
- illustrate and physically evaluate the obtained results
- extend, develop and validate numerical 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%

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

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

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

10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses:** keine
12	**Module coordinator:** Prof. Dr. Jens Förstner
13	**Other Notes:** *Remarks of course Modeling and Simulation:* **Course Homepage** `http://tet.upb.de` **Implementation** The theoretical concepts are taught in lecture form. The exercises consist of simple questions to be discussed as well as classical mathematical problems which are to be solved by the students in self-contained manner. Further, the students will use self-written as well as commercial software for selected topics.

2.2 Module Group: Management and Application

Two compulsory modules for all MS-ESE students.

Module Group	Introduction to Electrical Systems Engineering
Modules	* Management of Technical Projects * Topics in System Engineering
Teaching objectives	In the first module students will acquire soft skills on how to manage technical projects (e.g. requirement analysis, specification, scheduling, planning & design-ing, monitoring & controlling, communication in teams, communication with customers). The second module is organized as a project seminar offered alternatingly by different research groups of the institute EIM-E. The students will be familiarized with on-going projects. The aim is to demonstrate project management in real world examples.

2.2.1 Management of Technical Projects

Management of Technical Projects
Management of Technical Projects

Module number: M.048.90103	**Workload (h):** 60	**Credits:** 3	**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.048.90103 Management of Technical Projects	2L, WS	30	30	C	100

2 **Options within the module:**

None

3 **Admission requirements:**

Prerequisites of course Management of Technical Projects:
None

4 **Contents:**

Contents of the course Management of Technical Projects:
Short Description
In this course students will acquire key skills how to manage technical projects (e.g., risk analysis, work package specification, activity scheduling, resource planning, monitoring & controlling, communication in teams, communication with customers).
Contents
Foundations - The Project and its Environment:

- Types of Projects
- Stakeholder Analysis
- Project Organization
- Project Success Factors

Operative Project Management (Hard Factors):

- Project Objectives
- Process Models (traditional, agile, hybrid)
- Project Structuring
- Task Scheduling
- Cost and Resource Planning
- Configuration and Change Management
- Quality Management
- Controlling
- Project Completion and Lessons Learned

Humans in Projects (Soft Factors)

- Team Building and Leadership
- Communication in Teams
- Problem and Conflict Resolution

5 **Learning outcomes and competences:**

Domain competence
The participants are able to describe and use the fundamentals of technical project management.
Key qualifications
The participants are able to describe the aspects of communication in teams and make use of techniques to solve problems and conflicts.

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%

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

7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** None
10	**Weighing for overall grade:** The credit points are awarded after the module examination (MAP) was passed.
11	**Reuse in degree courses:** keine
12	**Module coordinator:** Dr. Stephan Flake
13	**Other Notes:** *Remarks of course Management of Technical Projects:* **Implementation** The participants can use the theoretical and methodical foundations from the lecture for an own project work about a selected topic. In some of the later lectures and depending on the overall number of students taking the course, the participants can present the results of their project work in a short presentation, followed by a discussion with the other participants and a feedback round. **Teaching Material, Literature** Lecture notes and additional material for self-study will be provided. There are various good reference lists available online, e.g., `http://www.ipcert.com/new/index.php/certification-evaluation/recommended-literature` or `https://www.vzpm.ch/fileadmin/dokumente/downloads/Deutsch/VZPM_IPMA_Literaturliste.pdf` (last checked on 24 Aug 2020). Further hints will be given during the course.

2.2.2 Topics in System Engineering

Topics in Sytems Engineering			
Topics in Sytems Engineering			
Module number: M.048.90104	**Workload (h):** 90	**Credits:** 3	**Regular Cycle:** summer- / winter term
	Semester number: 3. Semester	**Duration (in sem.):** 1	**Teaching Language:** en

<table>
<tr><td>1</td><td>Module structure:
<table>
<tr><th></th><th>Course</th><th>form of teachin</th><th>contact-time (h)</th><th>self-study (h)</th><th>status (C/CE)</th><th>group size (TN)</th></tr>
<tr><td>a)</td><td>L.048.62xxx
Topics in Systems Engineering</td><td>2PS, WS+SS</td><td>60</td><td>30</td><td>C</td><td>25</td></tr>
</table></td></tr>
<tr><td>2</td><td>Options within the module:
1 of n</td></tr>
<tr><td>3</td><td>Admission requirements:
Prerequisites of course Topics in Systems Engineering:
None</td></tr>
<tr><td>4</td><td>Contents:
Contents of the course Topics in Systems Engineering:
Short Description
The project seminar is organized alternatingly by different research groups of the institute EIM-E. The students will be familiarized with on-going projects. The aim is to demonstrate project management in real world examples.
Contents
Varying</td></tr>
<tr><td>5</td><td>Learning outcomes and competences:
Domain competence:
The students are
• able to do scientific research and to present scientific findings,
• to accumulate findings and knowledge autonomously and to reflect them in a critical manner.
By intensifying the course contents of the master's program the students are confronted with research questions and methodology as well as project management of Electrical System Engineering.
Key qualifications:
The students
• are able to design technical presentation and
• are familiar with basic presentation techniques.</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)</td><td>Written or Oral Examination or Presentation</td><td>90-150 min or 20-30 min or 30-60 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:
keine</td></tr>
<tr><td>12</td><td>Module coordinator:
Dr.-Ing. Carsten Balewski</td></tr>
<tr><td>13</td><td>Other Notes:
Remarks of course Topics in Systems Engineering:
Changing Lecturers
Implementation
Talks by the students
Teaching Material, Literature
Will be announced in the course.</td></tr>
</table>

2.3 Module Group: Fundamentals of Electrical Systems Engineering

These compulsory elective modules are meant to close gaps in the knowledge of students. They choose two from a list of six modules

Module Group	Fundamentals of Electrical Systems Engineering
Modules	* Digital Speech Signal Processing * High Frequency Engineering

Module Group	Fundamentals of Electrical Systems Engineering
	* Introduction to Algorithms * Mechatronics and Electrical Drives * Software Engineering
Teaching objectives	As students with quite different backgrounds may enter this Master's program it is necessary to harmonize their knowledge background.

For a student with a Bachelor degree in Electrical Engineering it may be e.g. necessary to fill up knowledge gaps in the field of Software Engineering, while students with a Computer Engineering degree should perhaps attend a module in Mechatronics & Electrical Drives. Students will be advised on which two modules out of the following list to choose from. |

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, WS+SS	60	120	C	50

2 **Options within the module:**

None

3 **Admission requirements:**

Prerequisites of course Advanced Control :
Undergraduate-level systems theory and automatic control
Information: Unless otherwise specified, these are recommendations.

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
- Optimal linear quadratic estimation
- Optimal linear quadratic control
- Exact linearization for controlling nonlinear systems
- Actuator constraints and anti-windup mechanism

5 **Learning outcomes and competences:**

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

- study the dynamics of discrete-time 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%

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

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses:** Masterstudiengang Computer Engineering v3 (CEMA v3)
12	**Module coordinator:** Dr.-Ing. Oliver Wallscheid
13	**Other Notes:** *Remarks of course Advanced Control :* **Course Homepage** `https://en.ei.uni-paderborn.de/rat` **Implementation** • Lectures using blackboard and slides • Tutorials with pen/paper exercises and computer-based programming tasks • Panda course for communication and material distribution **Teaching Material, Literature** Book and general literature recommendations will be made during the active course time.

Digital Speech Signal Processing

Digital Speech Signal Processing

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.92041	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.048.92041 Digital Speech Signal Processing	2L 2Ex, SS	60	120	CE	50

2 **Options within the module:**

None

3	**Admission requirements:** *Prerequisites of course Digital Speech Signal Processing:* Prior knowledge from the module Higher Mathematics. Information: Unless otherwise specified, these are recommendations.
4	**Contents:** *Contents of the course Digital Speech Signal Processing:* **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 o Generating voice: human vocal tract, source filter model, vocoder o Acoustic waves o Listen: human ear, psycho acoustics and physiology of listening, loudness, acoustic occlusion, frequency groups • Time-discrete signals and systems o Basics: Elementary signals, LTI systems o Transformations: Fourier transformation of time-discrete signals, DFT, FFT o Time-discrete filtering in frequency domain: Overlap-Add, overlap-Save • Statistical speech signal analysis o Basics in theory of probabilities o Short-run analysis of speech signals: Spectrogram, cepstrum • Estimation of speech signals o Optimal filters o LPC analysis o Spectral filtering for noise suppression: spectral subtraction, Wiener filter o Adaptive Filters: LMS adaptation algorithm, echo compensation • Speech coding o Time domain coding: signal shape coding, parametric coding, hybride coding tech-niques o Frequency domain coding o Amplitude quantization: uniform quantization, quantization with companders (ulaw, alaw)
5	**Learning outcomes and competences:** **Domain competence:** After attending the course, the students will be able to • analyze digital signals, e.g., audio signals, in the time or frequency domain, • represent audio signals efficiently and • implement widely-used algorithms for speech analysis and speech processing in the frequency or time domain. **Key qualifications:** The students • are able to explain effects in real signals based on the theoretical knowledge, • are able to investigate theoretical approaches by a systematic analysis and • are, due to the precise treatment of the contents, in a position to continue their learning themselves

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

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

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

7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses:** keine
12	**Module coordinator:** Dr.-Ing. Jörg Schmalenströer
13	**Other Notes:** *Remarks of course Digital Speech Signal Processing:* **Course Homepage** `http://nt.upb.de/index.php?id=dssv` **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

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	CE	50

2 **Options within the module:**

None

3 **Admission requirements:**

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 (4 SWS, 6 ECTS credit points) extends the content of the lecture Theoretische Elektrotechnik by further application-relevant knowledge. The aim is to qualify the students for development tasks for example in the radio frequency part of a mobile telephone. But considerations of high-frequency engineering are also needed in prevalent digital circuits. The emphases of the lecture are passive devices, high-frequency properties of fundamental transistor circuits, linear and nonlinear amplifiers, noisy multiports, mixers, oscillators, injection-locking and phase-locked loop.

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%

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

7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses:** Masterstudiengang Computer Engineering v3 (CEMA v3)
12	**Module coordinator:** Prof. Dr. Reinhold Noé
13	**Other Notes:** *Remarks of course High Frequency Engineering:* **Course Homepage** `http://ont.upb.de` **Implementation** Lecture and exercise **Teaching Material, Literature** Scripts, exercise sheets and advanced literature (excerpt): • Thiede, A.: Skriptum Hochfrequenzelektronik/High-Frequency Electronics, Universität Paderborn • Sze, S. M.: High Speed Semiconductor Devices, John Wiley & Sons, 1990 • Herbst, L. J.: Integrated Circuit Engineering, Oxford University Press, 1996 • Yip, P. C. L.: High-Frequency Circuit Design and Measurement, Chapman & Hall, 1996 • Gonzalez, G.: Microwave Transistor Amplifiers, Prentice Hall, 1997 • Hoffmann, M.: Hochfrequenztechnik, Springer, 1997

Introduction to Algorithms

Module number:	Workload (h):	Credits:	Regular Cycle:
M.048.90501	180	6	winter term
	Semester number:	**Duration (in sem.):**	**Teaching Language:**
	1.-2. Semester	1	en

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.90501 Introduction to Algorithms	2L 2Ex, WS	60	120	CE	50

2 **Options within the module:**

None

3 **Admission requirements:**

Prerequisites of course Introduction to Algorithms:
Mathematical basics (e.g. asymptotic behavior of functions, probabilities)
Information: Unless otherwise specified, these are recommendations.

4 **Contents:**

Contents of the course Introduction to Algorithms:
Short Description
The course gives an introduction into the design and analysis of algorithms.
Contents
Sorting algorithms, basic data structures, graphs and graph algorithms, design and analysis of algorithms (problem complexity, run time and storage complexity of algorithms, exact vs. heuristic solu-tions, probabilistic approaches)

5 **Learning outcomes and competences:**

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

- to describe and explain basic algorithms and data structures,
- to apply them to new problems,
- to analyze and evaluate the developed solutions with respect to run time,
- to implement the developed algorithms in a modern object oriented programming language.

Key qualifications:
The students

- are able to apply the practiced strategies for problem solving across varying disciplines,
- have experience in developing solutions and implementing them together in cooperation with their fellow students,
- 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	120-180 min or 30-45 min	100%

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

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

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

10 **Weighing for overall grade:**

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

11 **Reuse in degree courses:**

keine

12 **Module coordinator:**

Prof. Dr. Sybille Hellebrand

13 **Other Notes:**

Remarks of course Introduction to Algorithms:
Course Homepage
`http://www.date.uni-paderborn.de`
Implementation

- Lecture combined with lab course (partly with hands-on programming exercises)
- Programming project

Teaching Material, Literature

- T. Cormen, C. Leiserson, R. Rivest, C. Stein: Introduction to Algorithms. 2nd Edition, MIT Press, 2002.
- E. Horowitz, B. Sahni, B. Rajabkaran: Computer Algorithms – C++, 2nd Edition, Computer Science Press, 1998
- V. Aho, J. E. Hopcroft, and J. Ullman, Data Structures and Algorithms. 1st Edition Addison-Wesley, 1983
- R. Sedgewick: Algorithms in C++, Addison-Wesley, 2001.
- M. R. Garey and D. S. Johnson: Computers and Intractability: A Guide to the Theory of NP-Completeness, W. H. Freeman & Co Ltd., 1979
- Handouts of Lecture Slides

2.4 Specialization-Specific: Signal and Information Processing

2.4.1 Module Group: Introduction to Signal and Information Processing

The modules of this group are compulsory to all MS-ESE students choosing the specialization Signal and Information Processing (S&IP).

Module Group	Introduction to Signal and Information Processing
Modules	* Statistical Signal Processing * Statistical Learning and Pattern Recognitionm
Teaching objectives	The students will acquire fundamental knowledge on how to apply statistical methods to signals and under-stand the paradigms of learning paradigms and classification.

Statistical Learning and Pattern Recognition

Statistical Learning and Pattern Recognition

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.92005	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.048.92005 Statistical and Machine Learning	2L 2Ex, SS	60	120	CE	50

2 **Options within the module:**

None

3 **Admission requirements:**

Prerequisites of course Statistical and Machine Learning:
Elementary knowledge in Statistics, as is taught in the course Statistical Signal Processing. Programming skills are desirable
Information: Unless otherwise specified, these are recommendations.

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 course 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

<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:
keine</td></tr>
<tr><td>12</td><td>Module coordinator:
Prof. Dr. Reinhold Häb-Umbach</td></tr>
</table>

13	**Other Notes:** *Remarks of course Statistical and Machine Learning:* **Course Homepage** http://nt.uni-paderborn.de/en/teaching/statistical-methods-for-learning-and-pattern-recognitio **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 Signal Processing			
Statistical Signal Processing			
Module number: M.048.92004	**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.048.92004 Statistical Signal Processing	2L 2Ex, WS	60	120	C	100

2 **Options within the module:**

None

3 **Admission requirements:**

Prerequisites of course Statistical Signal Processing:
Undergraduate courses in signal processing and probability
Information: Unless otherwise specified, these are recommendations.

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

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

After attending this course, students will be familiar with the basic principles of statistical signal processing. They will understand how to apply statistical signal processing techniques to relevant fields in electrical engineering (such as communications). 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</td><td>120-180 min or 30-45 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:

keine</td></tr>
<tr><td>12</td><td>Module coordinator:

Prof. Dr. Peter Schreier</td></tr>
</table>

13	**Other Notes:** *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.

2.4.2 Module Group: Signal and Information Processing

The module group contains a wide selection of modules from which the students can choose two modules.

Module Group	Signal and Information Processing
Modules	* Advanced Control * Advanced Topics In Robotics * Algorithms and Tools for Test and Diagnosis of Systems on a Chip * Cognitive Systems Engineering * Digital Image Processing I * Digital Image Processing II * Numerical Simulations with the Discontinuous Galerkin Time Domain Method * Optical Waveguide Theory * Optimal and Adaptive Filters * Reinforcement Learning * Robotics * Topics in Audio, Speech, and Language Processing * Topics in Pattern Recognition and Machine Learning * Topics in Signal Processing * Wireless Coummunications
Teaching objectives	The students select two modules according to their interests in the chosen specialization to acquire expertise in certain topics.

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, WS+SS	60	120	C	50

2 **Options within the module:**

None

3 **Admission requirements:**

Prerequisites of course Advanced Control :
Undergraduate-level systems theory and automatic control
Information: Unless otherwise specified, these are recommendations.

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
- Optimal linear quadratic estimation
- Optimal linear quadratic control
- Exact linearization for controlling nonlinear systems
- Actuator constraints and anti-windup mechanism

5 **Learning outcomes and competences:**

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

- study the dynamics of discrete-time 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%

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

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

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

10 **Weighing for overall grade:**

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

11 **Reuse in degree courses:**

Masterstudiengang Computer Engineering v3 (CEMA v3)

12 **Module coordinator:**

Dr.-Ing. Oliver Wallscheid

13	**Other Notes:** *Remarks of course Advanced Control :* **Course Homepage** `https://en.ei.uni-paderborn.de/rat` **Implementation** • Lectures using blackboard and slides • Tutorials with pen/paper exercises and computer-based programming tasks • Panda course for communication and material distribution **Teaching Material, Literature** Book and general literature recommendations will be made during the active course time.

Advanced Topics in Robotics			
Advanced Topics in Robotics			
Module number: M.048.92006	**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.048.92006 Advanced Topics in Robotics	2L 2Ex, WS	60	120	CE	50

2 **Options within the module:**

None

3 **Admission requirements:**

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	120-180 min or 30-45 min	100%

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

7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.

10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses:** Masterstudiengang Computer Engineering v3 (CEMA v3)
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

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	CE	50

2	**Options within the module:** None
3	**Admission requirements:** *Prerequisites of course Algorithms and Tools for Test and Diagnosis of Systems on a Chip:* Introduction to Computer Engineering Information: Unless otherwise specified, these are recommendations.
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.

<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>
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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:
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<tr><td>11</td><td>Reuse in degree courses:
Masterstudiengang Computer Engineering v3 (CEMA v3)</td></tr>
<tr><td>12</td><td>Module coordinator:
Prof. Dr. Sybille Hellebrand</td></tr>
</table>

13	**Other Notes:** *Remarks of course Algorithms and Tools for Test and Diagnosis of Systems on a Chip:* **Module Homepage** `http://www.date.upb.de/pages/en/teaching/homepage.php` **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 koala • 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.)

Cognitive Systems Engineering			
Cognitive Systems Engineering			
Module number: M.048.9070X	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer- / 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.048.90701 Cognitive Systems Engineering A - Visual Attention	2L, WS	30	60	CE	50
b)	L.048.90702 Cognitive Systems Engineering B - Sensation and Perception in Biological Systems	2L, SS	30	60	CE	50
c)	L.048.62008 Cognitive Systems Engineering C - GET Research Seminar	2L, WS+SS	30	60	CE	50

2 **Options within the module:**

2 of 3

3 **Admission requirements:**

None - but interest in the subject-matter and interdisciplinary work Information: Unless otherwise specified, these are recommendations.

Prerequisites of course Cognitive Systems Engineering A - Visual Attention:
None - but interest in the subject-matter and interdisciplinary work
Information: Unless otherwise specified, these are recommendations

Prerequisites of course Cognitive Systems Engineering B - Sensation and Perception in Biological Systems:
None - but interest in the subject-matter and interdisciplinary work
Information: Unless otherwise specified, these are recommendations

Prerequisites of course Cognitive Systems Engineering C - GET Research Seminar:
None - but interest in cutting-edge topics in the field of cognitive systems engineering
Information: Unless otherwise specified, these are recommendations

4	**Contents:** This module is **offered in two parts**. Students have to choose **two out of three**. Each part covers two hours per week and yields three credits. *Contents of the course Cognitive Systems Engineering A - Visual Attention:* **Part A** focuses on the phenomenon of visual attention in animals and humans and its use in technical systems. Initially, it is shown how visual attention enables living beings to selectively process visual information through the prioritization of regions in the visual field. This ability allows a faster and more accurate reaction to a target. In presentations and discussions among the participants, the students are introduced to modeling and experimental research of visual attention. Subsequently, the development of technical models for visual attention is studied. The participants implement their own models. It is also intended to demonstrate the possibility of joint research across boundaries of different disciplines. *Contents of the course Cognitive Systems Engineering B - Sensation and Perception in Biological Systems:* The input about the physical world obtained by sensory receptors is called *sensation*, while the process by which the brain selects, organizes, and interprets these sensations is labeled *perception*. **Part B** of the course CSE offers a broad overview of the fundamentals of sensation and perception in animals and humans and the associated intriguing phenomena. Moreover, the implementation of bio-inspired mechanisms in technical systems is considered. The students provide presentations about different topics from the fields of vision, hearing, vestibular sensation, touch, olfaction, and taste. Each presentation includes hands-on experiments and is followed by a discussion among the participants. *Contents of the course Cognitive Systems Engineering C - GET Research Seminar:* Each semester various presentations take place in the context of cognitive systems. In **part C** current interim reports and results of seminar papers, bachelor's and master's theses, research projects, and third-party funded projects are presented. Furthermore, there are lectures by guests of GET Lab. Students who opt for this part have to give a presentation on their own.
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.

<table>
<tr><td>6</td><td>Assessments:
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<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:
keine</td></tr>
<tr><td>12</td><td>Module coordinator:
Prof. Dr. Bärbel Mertsching</td></tr>
</table>

13	**Other Notes:** **Module Homepage** [http://getwww.uni-paderborn.de/teaching/cse] *Remarks of course Cognitive Systems Engineering A - Visual Attention:* **References (except)** • Backer, G. (2003) Modellierung visueller Aufmerksamkeit im Computer Sehen: Ein zweistufiges Selektionsmodell für ein Aktives Sehsystem. Dissertation U Hamburg [http://ediss.sub.uni-hamburg.de/volltexte/2004/2226/]. (Last access: March 3, 2021). • Itti, L., Rees, G. & Tsotsos (2005): Neurobiology of Attention (sections Foundations and Systems). Amsterdam (Elsevier) 3-196 resp. 547-676. *Remarks of course Cognitive Systems Engineering B - Sensation and Perception in Biological Systems:* **References (excerpt)** • Foley, H., & Matlin, M. Sensation and Perception. Psychology Press, 2015 • O'Regan, J. K. Why Red Doesn't Sound Like a Bell. Oxford University Press, Inc, 2011 • Wolfe, J. M. et al. Sensation & Perception, Fifth Edition. Oxford University Press, Inc, 2019 *Remarks of course Cognitive Systems Engineering C - GET Research Seminar:* None

Digital Image Processing I

Digital Image Processing I

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.92008	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.048.92008 Digital Image Processing I	2L 2Ex, WS	60	120	CE	50

2 **Options within the module:**

None

3 **Admission requirements:**

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%

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

7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** none
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.

10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses:** Masterstudiengang Computer Engineering v3 (CEMA v3)
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	CE	50

2	**Options within the module:** None
3	**Admission requirements:** *Prerequisites of course Digital Image Processing II:* • Basic knowledge of image processing, (e. g. from the course Digital Image Processing I (L.048.23002 / L.048.92008) Information: Unless otherwise specified, these are recommendations
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.

<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:
Masterstudiengang Computer Engineering v3 (CEMA v3), Master’s Program Electrical Systems Engineering (ESEMA v2)</td></tr>
<tr><td>12</td><td>Module coordinator:
Prof. Dr. Bärbel Mertsching</td></tr>
<tr><td>13</td><td>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</td></tr>
</table>

Numerical Simulations with the Discontinuous Galerkin Time Domain Method
Numerical Simulations with the Discontinuous Galerkin Time Domain Method

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.92036	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.048.92036 Numerical Simulations with the Discontinuous Galerkin Time Domain Method	2L 2Ex, SS	60	120	CE	50

2 **Options within the module:**

None

3 **Admission requirements:**

Prerequisites of course Numerical Simulations with the Discontinuous Galerkin Time Domain Method:
Detailed knowledge of the Maxwell Equations, their properities and solutions as taught in the course Fields&Waves. Mathematical basis knowledge on differential equations and vector analysis.
Information: Unless otherwise specified, these are recommendations.

4 **Contents:**

Contents of the course Numerical Simulations with the Discontinuous Galerkin Time Domain Method:
Short Description
This course provides an introduction tot he sophisticated and powerful Discontinuous Galerkin method in time domain. With this numerical technique it is possible to describe spatiotermporal effects like electromagnetic field propagation and other physical models which can be described by partial differential equations.
Contents
Contents

- Introduction, Motivation, History
- Basic elements of the Discontinuous Galerkin Method
- Linear systems * Theory foundation and discrete stability
- Nonlinear problems and properties
- Higher order, global problems
- Application to electromagnetic field simulation

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

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

• mathematically model complex electromagnetic field problems
• transfer, apply, validate the Discontinuous Galerkin method on physical problems
• to physically interpret and visualise the obtained results

Key qualifications:
The students

• learn to transfer the acquired skills also to other disciplines
• extend their cooperation and team capabilities as well as the presentation skills in the context of solving the exercises
• learn strategies to acquire knowledge from literature and internet
• acquire a specialised foreign language competence</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>
<tr><td>11</td><td>Reuse in degree courses:

keine</td></tr>
<tr><td>12</td><td>Module coordinator:

Dr. Yevgen Grynko</td></tr>
</table>

13	**Other Notes:** *Remarks of course Numerical Simulations with the Discontinuous Galerkin Time Domain Method:* **Implementation** The theoretical concepts are presented in form of a lecture. In the corresponding exercises simulation techniques are practised by writing or adapting small programs.

Optical Waveguide Theory			
Optical Waveguide Theory			
Module number: M.048.92038	**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.048.92038 Optical Waveguide Theory	2L 2Ex, SS	60	120	CE	50

2 **Options within the module:**

None

3 **Admission requirements:**

Prerequisites of course Optical Waveguide Theory:
Bachelor-level knowledge in electrodynamics and mathematics as taught in the course Fields&Waves.
Information: Unless otherwise specified, these are recommendations.

4	**Contents:** *Contents of the course Optical Waveguide Theory:* **Short Description** Dielectric optical waveguides constitute key-elements of present-day integrated optical / photonic circuits. This course provides an introduction to their theoretical background, and, as such, a sound basis for further, more specific, modelling, simulation, and design work, as well as for experimental activities in the field. **Contents** * Photonics / integrated optics, dielectric waveguides: introductory examples, motivation. * Brush up on mathematical tools. * Maxwell equations, survey of different formulations; classes of simulation tasks. * Normal modes of dielectric optical waveguides, orthogonality, completeness, scattering matrices, reciprocal circuits. * Examples for dielectric optical waveguides (multilayer slabs, integrated optical channels, fibers), bent waveguides, whispering gallery resonances. * Coupled mode theory, conventional codirectional, and hybrid analytical / numerical variant, perturbations of optical waveguides. * Optional, brief remarks on: boundary conditions, initial value problems (beam propagation method), waveguide discontinuities (BEP/QUEP simulations), photonic crystal waveguides & fibers, plasmonic waveguides.
5	**Learning outcomes and competences:** **Domain competence:** After attending the course, the student will be able to • to mathematically model electromagnetic field problems of systems in integrated optics and photonics • to identify, apply and verify appropriate analytical methods and approximation techniques • to physically interpret and visualise the obtained results • to extend, develop and validate theoretical models for integrated optics and photonics **Key qualifications:** The students • learn to transfer the acquired skills also to other disciplines • extend their cooperation and team capabilities as well as the presentation skills in the context of solving the exercises • learn strategies to acquire knowledge from literature and internet • acquire a specialised foreign language competence
6	**Assessments:** ☒Final module exam (MAP) □Module exam (MP) □Partial module exams (MTP)

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

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

7	**Study Achievement:** none

8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses:** keine
12	**Module coordinator:** Dr. Manfred Hammer
13	**Other Notes:** *Remarks of course Optical Waveguide Theory:* **Course Homepage** `http://ei.uni-paderborn.de/tet/` **Implementation** The theoretical concepts will be presented as a lecture. The methods presented will be practiced in exercises classes and by means of homework assignments.

Optimal and Adaptive Filters

Optimal and Adaptive Filters

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.92011	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.048.92011 Optimal and Adaptive Filters	2L 2Ex, WS	60	120	CE	50

2 **Options within the module:**
None

3 **Admission requirements:**
Prerequisites of course Optimal and Adaptive Filters:
Prior knowledge from the modules Higher Mathematics and Digital Signal Processing
Information: Unless otherwise specified, these are recommendations.

4	**Contents:** *Contents of the course Optimal and Adaptive Filters:* **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 o Estimators o MMSE-Estimation o Linear estimators o Orthogonality principle o Evaluation of estimators • Wiener filter o Wiener-Hopf equation o AR- and MA processes o Linear prediction • Iterative optimization methods o Gradient ascent/descent o Newton method • Linear adaptive filters o LMS algorithm o Least-Squares method o Blockwise and recursive adaptiv filters o Realization aspects • Statemodel based filters o Kalman filter • Applications o System identification o Channel estimation and equalization o Multi-channel speech signal processing o 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

<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:
keine</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 Optimal and Adaptive Filters:
*Course Homepage**
http://nt.uni-paderborn.de/index.php?id=oaf&L=2
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</td></tr>
</table>

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	CE	50

2 **Options within the module:**

None

3 **Admission requirements:**

Prerequisites of course Reinforcement Learning:
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.
Information: Unless otherwise specified, these are recommendations.

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
- Integration of expert knowledge

<table>
<tr><td>5</td><td>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.</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 min120</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:

Masterstudiengang Computer Engineering v3 (CEMA v3)</td></tr>
<tr><td>12</td><td>Module coordinator:

Dr.-Ing. Oliver Wallscheid</td></tr>
</table>

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	CE	50

2 **Options within the module:**

None

3 **Admission requirements:**

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%

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

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

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

10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses:** Masterstudiengang Computer Engineering v3 (CEMA v3)
12	**Module coordinator:** Prof. Dr. Bärbel Mertsching
13	**Other Notes:** *Remarks of course Robotics:* **Course Homepage** [http://getwww.uni-paderborn.de/teaching/robotik] **Course Documents** see PANDA ([https://panda.uni-paderborn.de]) **References (excerpt)** • Mertsching, Bärbel: Robotics (lecture notes) • McKerrow, Phillip J.: Introduction to Robotics. Addison-Wesley, 1991 • Lynch, Kevin M. and Park, Frank C.: Modern Robotics: Mechanics, Planning, and Control. Cambridge University Press, 2017. ISBN-13 : 978-1107156302

Topics in Audio, Speech and Language Processing

Topics in Audio, Speech and Language Processing

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.92044	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.048.92044 Topics in Audio, Speech, and Language Processing	2L 2Ex, SS	60	120	CE	50

2 **Options within the module:**

None

3 **Admission requirements:**

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:**

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%

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

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses:** keine
12	**Module coordinator:** Prof. Dr. Reinhold Häb-Umbach
13	**Other Notes:** *Remarks of course Topics in Audio, Speech, and Language Processing:* --- **ATTENTION - IMPORTANT NOTICE** The course doesn't take place in summer term 2020. Please see the notice boards of the group. ---

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	CE	50

2 **Options within the module:**

None

3	**Admission requirements:** *Prerequisites of course Topics in Pattern Recognition and Machine Learning:* 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 Information: Unless otherwise specified, these are recommendations
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	120-180 min or 30-45 min	100%

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

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

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

10 **Weighing for overall grade:**

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

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

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	12	CE	50

2 **Options within the module:**

None

3	**Admission requirements:** *Prerequisites of course Topics in Signal Processing:* Signal and system theory, at least a basic understanding of probability and linear algebra Information: Unless otherwise specified, these are recommendations.
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%

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

7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses:** Masterstudiengang Computer Engineering v3 (CEMA v3)
12	**Module coordinator:** Prof. Dr. Peter Schreier

13	**Other Notes:** **Module Homepage** `http://sst.upb.de` **Implementation** Lectures and tutorials with active student participation, student presentations **Teaching Material, Literature** References will be given in the first lecture. *Remarks of course Topics in Signal Processing:* **Course Homepage** `http://sst.upb.de` **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: 2.-4. 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.048.92035 Wireless Communications	2L 2Ex, SS	60	120	CE	

2 **Options within the module:**

None

3 **Admission requirements:**

Prerequisites of course Wireless Communications:
Some basic knowledge in digital communication systems.
These requirements are not mandatory but desirable

4	**Contents:** *Contents of the course Wireless Communications:* Wireless Communications presents an introduction into the fundamentals and practical systems in the field of wireless communications. Based on a thorough description of the characteristics of a wireless communication channel the principle approaches to reliable communication over frequency-nonselective and frequency selective channels are presented, such as time diversity, space diversity (including MIMO) and frequency diversity. Practical cellular systems will also be described. 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

<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:
Masterstudiengang Computer Engineering v3 (CEMA v3)</td></tr>
<tr><td>12</td><td>Module coordinator:
Prof. Dr. Reinhold Häb-Umbach</td></tr>
<tr><td>13</td><td>Other Notes:
Remarks of course Wireless Communications:
Website: <code>https://ei.uni-paderborn.de/en/nt/teaching/veranstaltungen/wireless-communications</code>
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
</td></tr>
</table>

2.5 Specialization-Specific: Electronics and Devices

2.5.1 Module Group: Introduction to Electronics and Devices

The modules of this group are compulsory to all MS-ESE students choosing the specialization Electronics and Devices (E&D).

Module Group	Introduction to Signal and Information Processing
Modules	* Circuit and Systems Design * Fields & Waves
Teaching objectives	The students will acquire fundamental knowledge in theoretical electrical engineering and the design of electrical systems including their components.

Fields & Waves

Fields & Waves

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.90101	180	6	summer term
	Semester number:	**Duration (in sem.):**	**Teaching Language:**
	2. Semester	1	

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.90101 Fields & Waves	2L 2Ex, SS	60	120	C	50

2 **Options within the module:**

None

3 **Admission requirements:**

Prerequisites of course Fields & Waves:
None

4 **Contents:**

Contents of the course Fields & Waves:
Contents
Recapitulation of Basics (Maxwell's equations, constitutive relations, continuity conditions, energy), the wave equation and its solutions , Snell's law and Fresnel formulas, dispersion, waveguides, radiation of waves

5 **Learning outcomes and competences:**

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

- to mathematically model time harmonic electromagnetic field problems
- to identify and apply appropriate analytical methods
- to physically interpret and visualise the obtained results
- to extend, develop and validate theoretical models for electromagnetic field problems

Key qualifications:
The students

- learn to transfer the acquired skills also to other disciplines
- extend their cooperation and team capabilities as well as the presentation skills in the context of solving the exercises
- learn strategies to acquire knowledge from literature and internet
- acquire a specialised foreign language competence

6 **Assessments:**

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

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

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

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

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

10 **Weighing for overall grade:**

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

11	**Reuse in degree courses:** keine
12	**Module coordinator:** Prof. Dr. Jens Förstner
13	**Other Notes:** *Remarks of course Fields & Waves:* **Course Homepage** `http://tet.upb.de` **Implementation** The theoretical concepts are taught in lecture form. The exercises consist of simple questions to be discussed as well as classical field problems with mathematical solutions which are to be solved by the students in self-contained manner. **Teaching Material, Literature** Slides and lecture notes, additional recommendations for textbooks will be given in the course.

Circuit and Systems Design			
Circuit and Systems Design			
Module number: M.048.90100	**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	50

2 **Options within the module:**

None

3 **Admission requirements:**

Prerequisites of course Circuit and Systems Design:
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)
Information: Unless otherwise specified, these are recommendations.

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”.
Contents

- Analysis methods for analog systems
- Analysis methods for digital systems
- Elementary analog and digital circuits
- Modeling and numerical simulation of analog and digital circuits and systems
- Typical components and subsystems
- 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 technical 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 Examination	150 min	100%

Within the first three weeks of the lecture period each respective lecturer will specify the manner in which the academic achievement and/or qualified participation will be conducted.

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

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

9	**Prerequisites for assigning credits:** The credit points are awarded after all module examinations (MTP) were passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses:** keine
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. 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

2.5.2 Module Group: Electronics and Devices

The module group contains a wide selection of modules from which the students can choose two modules.

Module Group	Electronics and Devices
Modules	* Advanced VLSI Design
	* Analog CMOS Ics
	* Controlled AC Drives
	* Energy Transition
	* Fast Integrated Circuits for Wireline Communications

Module Group	Electronics and Devices
	* High-Frequency Electronics
	* Integrated Circuits for Wireless Communications
	* Micro-Electromechanical Systems
	* Numerical Simulations with the Discontinuous Galerkin Time Domain Method
	* Optical Communication A
	* Optical Communication B
	* Optical Communication C
	* Optical Communication D
	* Optical Waveguide Theory
	* Power Electronics
	* Processing of Semiconductor Devices
	* Radio Frequency Power Amplifiers
	* Sensor Technologie
	* Solar Electric Energy Systems
	* VLSI Testing
Teaching objectives	The students select two modules according to their interests in the chosen specialization to acquire expertise in certain topics.

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	CE	50

2 **Options within the module:**

None

3 **Admission requirements:**

Prerequisites of course Advanced VLSI Design:
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.

<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:
Masterstudiengang Computer Engineering v3 (CEMA v3)</td></tr>
<tr><td>12</td><td>Module coordinator:
Dr. Wolfgang Mueller</td></tr>
<tr><td>13</td><td>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</td></tr>
</table>

Analog CMOS ICs
Analog CMOS ICs

Module number:	Workload (h):	Credits:	Regular Cycle:
M.048.92015	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.048.92015 Analog CMOS ICs	2L 2Ex, SS	60	120	CE	50

2 **Options within the module:**

None

3 **Admission requirements:**

Prerequisites of course Analog CMOS ICs:
Prior knowledge from the modules Higher Mathematics, Physics, and the Foundations of Electrical Engineering, Materials of Electrical Engineering, Semiconductor Devices, Signal Theory, System Theory.
Information: Unless otherwise specified, these are recommendations

4 **Contents:**

Contents of the course Analog CMOS ICs:
Short Description
The course provides basic knowledge on analogue circuit technology with particular regard to complementary MOS transistors.
Contents
Based on simplified as well as advanced current-voltage characteristics of MOS transistors, analogue amplifier circuits are introduced and analyzed with respect of its DC behavior. Next, frequency performance, noise, effects of feed-backs, stability, non-linearity, and impacts of fabrication related asymmetries are considered. Further circuits such as oscillators, reference voltage sources, and switched capacitors are discussed. The course concludes with remarks on modeling and layout issues of basic devices.

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

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

• analyse the characteristics of analogue circuits using scientific methods
• and can make creative use of the acquired knowledge in the circuit design process.

Key qualifications:
The students

• make use of methodic knowledge for systematic problem analysis,
• consolidate their basic knowledge by practical training,
• enhance their creative abilities,
• and gain foreign language competences related to the field.</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>
<tr><td>11</td><td>Reuse in degree courses:

keine</td></tr>
<tr><td>12</td><td>Module coordinator:

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

13	**Other Notes:** *Remarks of course Analog CMOS ICs:* **Course Homepage** `http://groups.upb.de/hfe/teaching/acc.html` **Implementation** • Lectures with black board presentation, supported by animated graphics and transparencies, • Presence exercises with task sheets to be solved by the students together, supported by the teacher. **Teaching Material, Literature** A. Thiede, Analog CMOS Integrated Circuits, Lecture Script University Paderborn • Razavi, B.: Design of Analog CMOS Integrated Circuits. McGraw Hill. 2001

Controlled AC Drives			
Controlled AC Drives			
Module number: M.048.92016	**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.048.92016 Controlled AC Drives	2L 2Ex, SS	60	120	CE	50

2 **Options within the module:**

None

3 **Admission requirements:**

Prerequisites of course Controlled AC Drives:
It is strongly recommended that the students should have already finished a Bachelor course on the basics of electrical drives
Information: Unless otherwise specified, these are recommendations.

4 **Contents:**

Contents of the course Controlled AC Drives:
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%

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

7 **Study Achievement:**

none

8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses:** keine
12	**Module coordinator:** Prof. Dr.-Ing. Joachim Böcker
13	**Other Notes:** *Remarks of course Controlled AC Drives:* **Course Homepage** `http://ei.uni-paderborn.de/lea/` **Implementation** Parts of the course are organized as computer-based exercises. **Teaching Material, Literature** Lecture notes, slides. Other literature will be given in the lecture

Energy Transition

Energy Transition

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.92034	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.048.92034 Energy Transition	2L 2Ex, WS	60	120	CE	50

2 **Options within the module:**
None

3 **Admission requirements:**
Prerequisites of course Energy Transition:
None

4 **Contents:**

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

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

5 **Learning outcomes and competences:**

Domain competence:
After completing the course the students should in a position to: understand the implications, necessities and properties of an energy supply system (energy system 2.0) based on the combination of different renewable energy sources, distribution, storage, demand side management and be familiarized with the components, its specific characteristics and parameters.
** Key qualifications:**
The students are enabled to apply the knowledge and skills across disciplines are enabled to use method-oriented approaches for the implementation of sustainable energy supply are enabled to educate themselves in the future

6 **Assessments:**

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

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

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

7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses:** keine
12	**Module coordinator:** Prof. Dr.-Ing. Stefan Krauter
13	**Other Notes:** *Remarks of course Energy Transition:* **Course Homepage** `http://www.nek.upb.de/lehre` **Implementation** Lecture combined with practical examples & simulations; Excursion to see applications in practice. **Teaching Material, Literature** All presentations and exercises plus additional resources are available on PAUL. Stephen W. Fardo, Dale R. Patrick: Electrical Power Systems Technology. The Fairmont Press, Inc., 2009. Michel Crappe: Electric Power Systems. John Wiley & Sons, 2008. Magdi S. Mahmoud: Decentralized Systems with Design Constraints. Springer: Berlin Heidelberg, New York, 2011. Hermann Scheer, The Energy Imperative, 100 Percent Renewable Now. Routledge, 2011. Hermann Scheer: Energy Autonomy. Earthscan/James & James, 2006. Geert Verbong, Derk Loorbach: Governing the Energy Transition - Reality, Illusion or Necessity?, Routledge, 2012 Journals: Renewable Energy, Elsevier; IEEE Transactions on Power Systems **Comments** Excursion to a practical project (e.g., pumped hydro storage (PHS))

High-Frequency Electronics			
High-Frequency Electronics			
Module number: M.048.92017	**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.048.92017 High-Frequency Electronics	2L 2Ex, WS	60	120	CE	50

2 **Options within the module:**

None

3 **Admission requirements:**

Prerequisites of course High-Frequency Electronics:
Prior knowledge from the modules Higher Mathematics, Physics, and the Foundations of Electrical Engineering, Materials of Electrical Engineering, Semiconductor Devices, Signal Theory, System Theory, Introduction to High-Frequency Engineering.
Information: Unless otherwise specified, these are recommendations.

4 **Contents:**

Contents of the course High-Frequency Electronics:
Short Description
The course High-Frequency Electronics provides necessary knowledge for the design of integrated high-frequency circuits ranging from device physics, semiconductor technology, high-frequency engineering, and packaging technology. Besides conveying new specialized knowledge, skills developed by various other courses are integrated, and thus students are directly prepared for a professional life in the field.
** Contents**
Starting from physically founded properties of different semiconductor systems, knowledge about the function, modeling, and fabrication of special high-frequency transistors is conveyed. Subsequently, all necessary steps of a high-frequency amplifier design are explained with respect to theoretical concepts and practical implementation. After that, further circuits such as broad-band amplifiers, oscillators, mixers and digital gates are presented. As currently most interesting applications, optoelectronic data transmission systems, mixed-signal systems such as ADC, DAC, digital synthesizers and PLL's, as well as millimeter wave transceivers are discussed. The course closes with an overview of high-frequency assembling and packaging technologies.

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

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

• select the most suitable semiconductor technology for a given problem,
• run the complete design process of a high-frequency integrated circuit,
• and to characterize fabricated samples.

Key qualifications:
The students

• can use of methodic knowledge for systematic problem analysis,
• include aspects of fabrication technology and economy into complex optimization problems,
• get familiar with the CAD system ADS, which is commonly used in industry
• and gain foreign language competences related to the field.</td></tr>
<tr><td>6</td><td>Assessments:

☒Final module exam (MAP) □Module exam (MP) □Partial module exams (MTP)
<table><tr><th>zu</th><th>Type of examination</th><th>Duration or scope</th><th>Weighting for the module grade</th></tr><tr><td>a)</td><td>Written or Oral Examination or Presentation</td><td>120-180 min or 30-45 min or 30 min</td><td>100%</td></tr></table>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:

keine</td></tr>
<tr><td>12</td><td>Module coordinator:

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

13	**Other Notes:** *Remarks of course High-Frequency Electronics:* **Course Homepage** `http://groups.upb.de/hfe/teaching/hfe.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, High-Frequency Electronics, Lecture Script University Paderborn References to continuative and deepening literature can be found in the respective sections of the script.

Integrated Circuits for Wireless Communication

Integrated Circuits for Wireless Communication

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.92028	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.048.92028 Integrated Circuits for Wireless Communication	2L 2Ex, SS	60	120	CE	50

2 **Options within the module:**

None

3 **Admission requirements:**

Prerequisites of course Integrated Circuits for Wireless Communication:
Lecture Schaltungstechnik rsp. Circuit and System Design. Helpful supplement: Lecture “Wireless Communications” by Prof. Hab-Umbach.
Information: Unless otherwise specified, these are recommendations.

4 **Contents:**

Contents of the course Integrated Circuits for Wireless Communication:
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%

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

7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses:** Masterstudiengang Computer Engineering v3 (CEMA v3)
12	**Module coordinator:** Prof. Dr.-Ing. J. Christoph Scheytt
13	**Other Notes:** *Remarks of course Integrated Circuits for Wireless Communication:* **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 modern 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

Micro-Electromechanical Systems			
Micro-Electromechanical Systems			
Module number: M.048.92018	**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.048.92018 Micro-Electromechanical Systems	2L 2Ex, WS	60	120	CE	50

2 **Options within the module:**

None

3 **Admission requirements:**

Prerequisites of course Micro-Electromechanical Systems:
A basic knowledge of semiconductor technology is necessary.
Information: Unless otherwise specified, these are recommendations.

4	**Contents:** *Contents of the course Micro-Electromechanical Systems:* **Short Description** The lecture Micro-Electromechanical Systems consists of a technology oriented and a sensor based part to describe the integration and operation of modern microsystems based on silicon. It includes basic processes like wet and dry etching, physical principles for sensor effects, and common setups for sensor systems and packages. **Contents** Processes • Integration processes for 3D-microstructures • Wafer bonding • Lithography Galvanic • Bulk micro machining • Surface micro mechanics Sensor Devices • Acceleration sensors • Pressure sensor devices • Rotation rate sensors • Special sensors Actuators • Principles of micro actuators • Examples for integrated actuators • Micro motors • Ink jets • Digital mirror arrays for image projection Packaging • Substrates and carriers • Wire bonding • Tape automated bonding • Flip chip • Chip size packages
5	**Learning outcomes and competences:** **Domain competence:** The students are able to describe the operational principle of microsystems and micro electromechanical systems. They can explain the transfer characteristics of the sensor devices and they are able to choose the right sensor for a given application. **Key qualifications:** The students • learn to transfer the acquired skills also to other disciplines • extend their cooperation and team capabilities as well as the presentation skills in the context of solving the exercises • learn strategies to acquire knowledge from literature and internet

<table>
<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>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:
keine</td></tr>
<tr><td>12</td><td>Module coordinator:
Prof. Dr. Ulrich Hilleringmann</td></tr>
<tr><td>13</td><td>Other Notes:
Remarks of course Micro-Electromechanical Systems:
Course Homepage
http://sensorik.uni-paderborn.de
Implementation
Projector presentation accompanied by board sketches and short films about the sensor function.
Teaching Material, Literature Skript in deutscher Sprache Buch Mikrosystemtechnik vom Dozenten
• M. Köhler: Etching in Microsystem Technology, Wiley-VCH, 1999
• W. Elwenspoek, R. Wiegerink: Mechanical Microsensors, Springer, 2000
• T.-R. Hsu: MEMS Packaging, INSPEC, 2004 U. Hilleringmann: Mikrosystemtechnik, Teubner, 2006
Comments</td></tr>
</table>

Numerical Simulations with the Discontinuous Galerkin Time Domain Method
Numerical Simulations with the Discontinuous Galerkin Time Domain Method

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.92036	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.048.92036 Numerical Simulations with the Discontinuous Galerkin Time Domain Method	2L 2Ex, SS	60	120	CE	50

2 **Options within the module:**

None

3 **Admission requirements:**

Prerequisites of course Numerical Simulations with the Discontinuous Galerkin Time Domain Method:
Detailed knowledge of the Maxwell Equations, their properities and solutions as taught in the course Fields&Waves. Mathematical basis knowledge on differential equations and vector analysis.
Information: Unless otherwise specified, these are recommendations.

4 **Contents:**

Contents of the course Numerical Simulations with the Discontinuous Galerkin Time Domain Method:
Short Description
This course provides an introduction tot he sophisticated and powerful Discontinuous Galerkin method in time domain. With this numerical technique it is possible to describe spatiotermporal effects like electromagnetic field propagation and other physical models which can be described by partial differential equations.
Contents
Contents

- Introduction, Motivation, History
- Basic elements of the Discontinuous Galerkin Method
- Linear systems * Theory foundation and discrete stability
- Nonlinear problems and properties
- Higher order, global problems
- Application to electromagnetic field simulation

5 **Learning outcomes and competences:**

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

- mathematically model complex electromagnetic field problems
- transfer, apply, validate the Discontinuous Galerkin method on physical problems
- to physically interpret and visualise the obtained results

Key qualifications:
The students

- learn to transfer the acquired skills also to other disciplines
- extend their cooperation and team capabilities as well as the presentation skills in the context of solving the exercises
- learn strategies to acquire knowledge from literature and internet
- acquire a specialised foreign language competence

6 **Assessments:**

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

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

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

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

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

10 **Weighing for overall grade:**

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

11 **Reuse in degree courses:**

keine

12 **Module coordinator:**

Dr. Yevgen Grynko

13	**Other Notes:** *Remarks of course Numerical Simulations with the Discontinuous Galerkin Time Domain Method:* **Implementation** The theoretical concepts are presented in form of a lecture. In the corresponding exercises simulation techniques are practised by writing or adapting small programs.

Optical Communication A			
Optical Communication A			
Module number: M.048.92019	**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.048.92019 Optical Communication A	2L 2Ex, SS	60	120	CE	50

2 **Options within the module:**

None

3 **Admission requirements:**

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
Fundamentals (4 SWS, 6 ECTS credit points): Maxwell's equations, wave propagation, polarization, dielectric slab and cylindrical waveguides, dispersion, laser, photodiodes, optical amplifiers, modulation, signal formats, optical receivers, noise, regenerators, wavelength division multiplex. Here the most important knowledge is taught.

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

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

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

(Soft) Skills
The students

• are able to apply the knowledge and skills to a wide range of disciplines,
• are able to make use of a methodical procedure when undertaking systematic analysis and
• are, due to the abstract and precise treatment of the contents, in a position to continue and develop their learning themselves</td></tr>
<tr><td>6</td><td>Assessments:

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

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

Masterstudiengang Computer Engineering v3 (CEMA v3)</td></tr>
<tr><td>12</td><td>Module coordinator:

Prof. Dr. Reinhold Noé</td></tr>
</table>

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

Optical Communication B			
Optical Communication B			
Module number: M.048.92020	**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.048.92020 Optical Communication B	2L 2Ex, SS	60	120	CE	50

2 **Options within the module:**

None

3 **Admission requirements:**

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 (4 SWS, 6 ECTS credit points): 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%

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

7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.

10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses:** Masterstudiengang Computer Engineering v3 (CEMA v3)
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	CE	50

2	**Options within the module:** None
3	**Admission requirements:** *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 (4 SWS, 6 ECTS credit points): 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%

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

7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses:** Masterstudiengang Computer Engineering v3 (CEMA v3)
12	**Module coordinator:** Prof. Dr. Reinhold Noé
13	**Other Notes:** *Remarks of course Optical Communication C:* **Teaching Material, Literature** Scripts, exercise sheets and advanced literature (excerpt): • Noe, Essentials of Modern Optical Fiber Communication, Springer, 2. Auflage / 2nd Edition, 2016, ISBN 978-3-662-49621-3, ISBN ISBN 978-3-662-49623-7 • Petermann/Voges, Optische Kommunikationstechnik, Springer-Verlag (modernes Nachschlagewerk) 2002 • D. As, Univ. Paderborn, Vorlesung Optoelektronik • W. Sohler, Univ. Paderborn, Vorlesung Integrierte Optik • G. Grau, W. Freude, Optische Nachrichtentechnik, Springer-Verlag, Heidelberg, 1991, (umfassend, viele Zwischenschritte fehlen) • K.J. Ebeling, Integrierte Optoelektronik, Springer-Verlag, Heidelberg, 1992 • H.-G. Unger, Optische Nachrichtentechnik, Teile I und II, Hüthig-Verlag Heidelberg, 1984 und 1985, (Schwerpunkt optische Wellenleiter) • Yariv, Optical Electronics, Holt, 1984 (und weitere Werke, sehr physikalisch, kaum Nachrichtentechnik) • R. Th. Kersten, Einführung in die Optische Nachrichtentechnik, Springer-Verlag

Optical Communication D			
Optical Communication D			
Module number: M.048.92022	**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.048.92022 Optical Communication D	2L 2Ex, SS	60	120	CE	50

2 **Options within the module:**

None

3 **Admission requirements:**

Prerequisites of course Optical Communication D:
None

4 **Contents:**

Contents of the course Optical Communication D:
Short Description
The lecture Optical Communication D gives knowledge about nonlinear optical effects in waveguides, their electronical detection, furthermore polarization scrambling.
Contents
Selected Topics (4 SWS, 6 ECTS credit points) in Optical Communication: Nonlinear distortions in glass fibers and their polarization dependence, electronic detection of linear optical distortions, polar-ization scrambling, ... Nonlinear distortions are important in practice and difficult to handle. The stu-dents should also prepare topics of their choice and present them to the others.

5 **Learning outcomes and competences:**

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

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

(Soft) Skills
The students

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

<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:
keine</td></tr>
<tr><td>12</td><td>Module coordinator:
Prof. Dr. Reinhold Noé</td></tr>
</table>

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

Optical Waveguide Theory

Optical Waveguide Theory

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.92038	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.048.92038 Optical Waveguide Theory	2L 2Ex, SS	60	120	CE	50

2 **Options within the module:**

None

3 **Admission requirements:**

Prerequisites of course Optical Waveguide Theory:
Bachelor-level knowledge in electrodynamics and mathematics as taught in the course Fields&Waves.
Information: Unless otherwise specified, these are recommendations.

4	**Contents:** *Contents of the course Optical Waveguide Theory:* **Short Description** Dielectric optical waveguides constitute key-elements of present-day integrated optical / photonic circuits. This course provides an introduction to their theoretical background, and, as such, a sound basis for further, more specific, modelling, simulation, and design work, as well as for experimental activities in the field. **Contents** * Photonics / integrated optics, dielectric waveguides: introductory examples, motivation. * Brush up on mathematical tools. * Maxwell equations, survey of different formulations; classes of simulation tasks. * Normal modes of dielectric optical waveguides, orthogonality, completeness, scattering matrices, reciprocal circuits. * Examples for dielectric optical waveguides (multilayer slabs, integrated optical channels, fibers), bent waveguides, whispering gallery resonances. * Coupled mode theory, conventional codirectional, and hybrid analytical / numerical variant, perturbations of optical waveguides. * Optional, brief remarks on: boundary conditions, initial value problems (beam propagation method), waveguide discontinuities (BEP/QUEP simulations), photonic crystal waveguides & fibers, plasmonic waveguides.
5	**Learning outcomes and competences:** **Domain competence:** After attending the course, the student will be able to • to mathematically model electromagnetic field problems of systems in integrated optics and photonics • to identify, apply and verify appropriate analytical methods and approximation techniques • to physically interpret and visualise the obtained results • to extend, develop and validate theoretical models for integrated optics and photonics **Key qualifications:** The students • learn to transfer the acquired skills also to other disciplines • extend their cooperation and team capabilities as well as the presentation skills in the context of solving the exercises • learn strategies to acquire knowledge from literature and internet • acquire a specialised foreign language competence
6	**Assessments:** ☒Final module exam (MAP) □Module exam (MP) □Partial module exams (MTP)

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

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

7	**Study Achievement:** none

8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses:** keine
12	**Module coordinator:** Dr. Manfred Hammer
13	**Other Notes:** *Remarks of course Optical Waveguide Theory:* **Course Homepage** `http://ei.uni-paderborn.de/tet/` **Implementation** The theoretical concepts will be presented as a lecture. The methods presented will be practiced in exercises classes and by means of homework assignments.

Power Electronics			
Power Electronics			
Module number: M.048.92023	**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.048.92023 Power Electronics	2L 2Ex, WS	60	120	CE	50

2	**Options within the module:** None
3	**Admission requirements:** *Prerequisites of course Power Electronics:* None

4 **Contents:**

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

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

5 **Learning outcomes and competences:**

Domain competence:

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

Key qualifications:
The students

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

6 **Assessments:**

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

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

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

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses:** keine
12	**Module coordinator:** Prof. Dr.-Ing. Joachim Böcker
13	**Other Notes:** *Remarks of course Power Electronics:* **ATTENTION - IMPORTANT NOTICE** The course doesn't take place in winter term 2020/21. Please see the notice boards of the group. **Course Homepage** `http://wwwlea.upb.de` **Implementation** • Lecture using blackboard as well as prepared slides • Exercises within the group • Exercises in the computer room **Teaching Material, Literature Lecture notes, slides. Other literature will be given in the lecture • J. Böcker: Skript/lecture notes: Leistungselektronik • D. Schröder: Elektrische Antriebe, Band 4: Leistungselektronische Schaltungen, Springer, 1998 • N. Mohan, T. Undeland, W. Robbins: Power Electronics - Converters, Applications and Design, John Wiley & Sons, Inc., 2. Edition, 2001 • R. Erickson, D. Maksimovic: Fundamentals of Power Electronics, Kluver Academic Publishers, 2. Edition, 2001

Processing of Semiconductors			
Processing of Semiconductors			
Module number: M.048.92024	**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.048.92024 Processing of Semiconductors	2L 2Ex, SS	60	120	CE	50

2 **Options within the module:**

None

3 **Admission requirements:**

Prerequisites of course Processing of Semiconductors:
None

4 **Contents:**

Contents of the course Processing of Semiconductors:
Short Description
The lecture Processing of Semiconductors describes the technical steps to build integrated circuits on silicon wafers. Physical models of the process steps will be given and the technical equipment will be explained. The students are able to explain the integration process for integrated circuits in detail.
Contents

- Oxidation of Silicon
- Optical Lithography and Electron Beam Lithography
- Diffusion of Dopants
- Ion Implantation
- Epitaxy
- Chemical Vapour Deposition
- Physical Deposition Techniques
- MOS Processes
- CMOS Technology
- Packaging (in short)

5 **Learning outcomes and competences:**

Domain competence:
The students are able to explain the equipment and the processes ot the semiconductor technology. They are able to apply this knowledge for the integration of complex integrated circuits.
Key qualifications:
Systematic of solving problems, detection of spreading influences

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%

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

7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses:** keine
12	**Module coordinator:** Prof. Dr. Ulrich Hilleringmann
13	**Other Notes:** *Remarks of course Processing of Semiconductors:* **Course Homepage** `http://sensorik.uni-paderborn.de` **Implementation** Beamer presentation accompanied by board sketches and short films about the technical equipment. **Teaching Material, Literature** • S. M. Sze: VLSI technology

Radio Frequency Power Amplifiers			
Radio Frequency Power Amplifiers			
Module number: M.048.92025	**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.048.92025 Radio Frequency Power Amplifiers	2L 2Ex, WS	60	120	CE	50

2 **Options within the module:**

None

3 **Admission requirements:**

Prerequisites of course Radio Frequency Power Amplifiers:
Prior knowledge from the modules Higher Mathematics, Physics, and the Foundations of Electrical Engineering, Materials of Electrical Engineering, Semiconductor Devices, Signal Theory, System Theory, High-Frequency Electronics.
Information: Unless otherwise specified, these are recommendations.

4 **Contents:**

5 **Learning outcomes and competences:**

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

- describe and analyse the performance of non-linear amplifiers,
- distinguish, make dedicated use, and dimension power amplifiers of different classes,
- take effective measures for efficiency enhancement and linearization,
- and to select appropriate semiconductor fabricated technologies for given problems.

Key qualifications:
The students

- can make use of methodic knowledge for systematic problem analysis,
- include aspects of fabrication technology and economy into complex optimization problems,
- get familiar with the CAD system ADS, which is commonly used in industry
- and gain foreign language competences related to the field.

<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:
keine</td></tr>
<tr><td>12</td><td>Module coordinator:
Prof. Dr. Andreas Thiede</td></tr>
<tr><td>13</td><td>Other Notes:
Remarks of course Radio Frequency Power Amplifiers:
Course Homepage
http://groups.uni-paderborn.de/hfe/teaching/acc.html
Implementation
• Lectures with black board presentation, supported by animated graphics and transparencies
• Presence exercises with task sheets to be solved by the students together, supported by the teacher, and partially using CAD software.
Teaching Material, Literature
A. Thiede, RF Power Amplifiers, Lecture Script University Paderborn Steve C. Cripps, RF Power Amplifiers for Wireless Communications, Artech House, 1999 Stephen A. Maas, Nonlinear Microwave and RF Circuits, Artech House, 1997</td></tr>
</table>

Sensor Technology
Sensor Technology

Module number: M.048.92026	**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.048.92026 Sensor Technology	2L 2Ex, SS	60	120	CE	50

2 **Options within the module:**

None

3 **Admission requirements:**

Prerequisites of course Sensor Technology:
None

4 **Contents:**

Short Description
The lecture Sensor Technology describes the physical behaviour of typical sensors and their applications in industry. Ranges and limitations of the sensors are presented. The lecture includes thermal sensors, force and magnetic sensors, gas and humidity sensitive devices
Contents
Temperature Sensors:

- Metal Resistors
- NTC
- PTC
- Junction Sensor
- Spreading Resistance Temperature Sensor
- Thermoelectric Sensors

Optical Sensors:

- Resistances and Diodes
- Photo Transistors
- CCD
- Thermal Column

Magnet Field Sensors:

- Hall Sensor
- Gauss Sensor Plate
- Ferromagnetic Resistive Sensors
- Split Drain Transistor
- Magneto Diode
- Flux-Gate-Sensor

Acceleration Based Sensors:

- Force
- Acceleration
- Rotation Rate Sensors

Gas Sensors:

- Metal-Oxide Sensors
- Catalytic Sensors
- SAW Sensors

Contents of the course Sensor Technology:
Short Description
The lecture Sensor Technology describes the physical behaviour of typical sensors and their applications in industry. Ranges and limitations of the sensors are presented. The lecture includes thermal sensors, force and magnetic sensors, gas and humidity sensitive devices
Contents
Temperature Sensors:

- Metal Resistors
- NTC
- PTC
- Junction Sensor
- Spreading Resistance Temperature Sensor
- Thermoelectric Sensors

Optical Sensors:

- Resistances and Diodes
- Photo Transistors
- CCD

5 **Learning outcomes and competences:**

Domain competence:
The students are able to describe the operation principle of different kinds of sensor devices and can choose a suitable sensor for a given application. They can explain the setup or manufacturing processes for the sensor devices. They can write down the sensitivity of different kind of sensors.
Key qualifications:
The students learn:

- to transfer the knowledge of sensor devices to other applications
- to work in groups to solve problems
- thinking in systems, not on device level

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%

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

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

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

10 **Weighing for overall grade:**

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

11 **Reuse in degree courses:**

keine

12 **Module coordinator:**

Prof. Dr. Ulrich Hilleringmann

13 **Other Notes:**

Remarks of course Sensor Technology:
Course Homepage
`http://sensorik.uni-paderborn.de`
Implementation
Beamer presentation accompanied by board sketches.
Teaching Material, Literature
Elvensproek: Mechanical Microsensors Handbook of Sensor Devices

Solar Electric Energy Systems			
Solar Electric Energy Systems			
Module number: M.048.92033	**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.048.92033 Solar Electric Energy Systems	2L 2Ex, SS	60	120	CE	50

2 **Options within the module:**

None

3 **Admission requirements:**

Prerequisites of course Solar Electric Energy Systems:
None

4 **Contents:**

Contents of the course Solar Electric Energy Systems:
Short Description
Conversion of solar energy into electricity for power supply: Basics, properties of devices and materials, performance issues, energy yield, durability, standards, testing, systems, modeling, simulation.
Contents

1. Potentials, Irradiance, Concentration
2. Solar Electricity via solar thermal systems
3. Principle of photovoltaic energy conversion
4. Characteristics of photovoltaic conversion devices
5. Manufacturing of solar cells, solar modules
6. PV systems: components, set-up, performance
7. Performance: optical, thermal and electrical modeling, simulation, measurement
8. Durability of PV modules and systems: Standards, tests, degradation effects
9. PV for power supply: predictability of PV output, combination with other energy sources, storage, performance in large energy grids, individual power supply
10. Market development of PV: off-grid markets, markets triggered by feed-in tariffs (FiT), self-sustainable markets, cost and price development 11./12. Excursion to a PV power plant (visit, interview with the operator, documentation)

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

Domain competence:
After completing the course the students should be Students in a position to:

• be familiarized with the basics of solar electric power engineering.
• understand the specific characteristics of a power supply via solar-thermal and photovoltaic energy conversion. understand, analyze and evaluate solar electric power plants and to be enabled to plan a layout of a PV power plant

Key qualifications:
The students are enabled to apply the knowledge and skills across disciplines are enabled to use method-oriented approaches for the implementation of sustainable energy supply are enabled to educate themselves in the future</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>
<tr><td>11</td><td>Reuse in degree courses:

keine</td></tr>
<tr><td>12</td><td>Module coordinator:

Prof. Dr.-Ing. Stefan Krauter</td></tr>
</table>

13	**Other Notes:** *Remarks of course Solar Electric Energy Systems:* **Course Homepage** `http://www.nek.upb.de/lehre` **Implementation** Lecture combined with practical examples & simulations; Excursion to see applications in practice **Teaching Material, Literature** Martin A. Green: Solar Cells Solar Cells: Operating Principles, Technology, and System Applications, UNSW, Sydney, Publisher: Prentice Hall, 1981. Stuart R. Wenham, Martin A. Green, Muriel Watt, Richard Corkish, Alistair Sproul: Applied Photovoltaics, UNSW, Sydney, softcover version: Earthscan, 2012. Stefan Krauter: Solar Electric Power Generation. 1st Ed. Springer: Berlin, Heidelberg, New York, 2006. Stefan Krauter: Solar Electric Power Generation. 2nd Ed. Springer: Berlin, Heidelberg, New York, 2015 (under preparation, preprint available). Stephen W. Fardo, Dale R. Patrick: Electrical Power Systems Technology. The Fairmont Press, Inc., 2009.

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	CE	50

2 **Options within the module:**

None

3 **Admission requirements:**

Prerequisites of course VLSI Testing:
Introduction to Computer Engineering (Digital Design)
Information: Unless otherwise specified, these are recommendations.

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%

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

7 **Study Achievement:**

none

8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses:** Masterstudiengang Computer Engineering v3 (CEMA v3)
12	**Module coordinator:** Prof. Dr. Sybille Hellebrand
13	**Other Notes:** *Remarks of course VLSI Testing:* **Course Homepage** `http://www.date.upb.de/pages/en/teaching.php?id=9` **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 koala • 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

2.6 Projects

Students have to carry out either two projects each lasting one semester with 9 CP each, or one project lasting two semesters with 18 CP. The topics analysis, design, realization and test will be covered in small groups (max. 10 students). The projects are offered by the different research groups from the institute EIM-E.

Projects
Projects

Module number:	Workload (h):	Credits:	Regular Cycle:
M.048.98501-98599	540	18	summer- / winter term
	Semester number:	**Duration (in sem.):**	**Teaching Language:**
	2. Semester	2	en

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.98501 - 98999 Project name (Project)	18P, WS+SS	270	270	C	25

2 **Options within the module:**

1 of n

3 **Admission requirements:**

None

4 **Contents:**

Project groups will be formed as teams to work on tasks where the relevant subjects are embedded in the scientific environment of the institute and its versatile, close cooperations with enterprises and industries. The intercommunication between the institute and renowned companies opens up numerous and attractive tasks for project works and serves to underline the relevance for the professional field and the employment market, and to support the acquisition of interdisciplinary competences.

5 **Learning outcomes and competences:**

In the course of the project work students should practice independent, scientific and engineering processing of clearly defined theoretical and practical tasks within the team. This should enable them to solve complex problems as a team, while at the same time acquiring the capability for independent working as well as organizational skills. The students should also learn to formulate the research task, document the methods and analysis and present the findings of their work in a structured manner. Having completed the project work, the students will command in-depth technical competences in a selected area and understand the application relevance of their course contents.

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 report and presentation	30 min	100%

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

7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses:** keine
12	**Module coordinator:** Dr.-Ing. Carsten Balewski
13	**Other Notes:** Changing lecturers

2.7 General Studies

Students may choose freely from all modules offered at the University. However, it is recommended that students with limited or no proficiency in German devote part of their studies to acquire German language skills.

Workload:

Time of attendance: 2x30h; individual study: 2x60 h; total workload: 180 h

2.7.1 C++ Programming

C++ Programming			
C++ Programming			
Module number: M.048.92999	**Workload (h):** 135	**Credits:** 0	**Regular Cycle:** summer term
	Semester number: 1.-4. Semester	**Duration (in sem.):** 1	**Teaching Language:** de

<table>
<tr><td>1</td><td>Module structure:
<table>
<tr><th></th><th>Course</th><th>form of teachin</th><th>contact-time (h)</th><th>self-study (h)</th><th>status (C/CE)</th><th>group size (TN)</th></tr>
<tr><td>a)</td><td>L.048.92999
C++ Programming</td><td>2L
1Ex,
SS</td><td>45</td><td>0</td><td>opt.</td><td></td></tr>
</table></td></tr>
<tr><td>2</td><td>Options within the module:
None</td></tr>
<tr><td>3</td><td>Admission requirements:
Prerequisites of course C++ Programming:
There are no prerequisites, the C++ programming language is taught from scratch, so students without any programming background are welcome!
Information: Unless otherwise specified, these are recommendations.</td></tr>
</table>

4	**Contents:** *Contents of the course C++ Programming:* **Short Description** This is an introductory course to the C++ programming language, which is intended for those ESE master students who have little programming background and are going to take the advanced courses, e.g. Introduction to Algorithms and/or Software Engineering. In principle, the course will be designed as: lecture (2 h/w) + programming practice (1 h/w). Note: this is a supplementary course with no credit. Students will gain a lot of useful knowledge and increase their value on the job market! We highly encourage students to make use of this offer. **Contents** This course should give an overview on the C++ language. During the winter semester, we are going to study the following concepts in C++ programming (depends on the teaching progress): Background and basic introduction: • history of C and C++ • programming enviroments • basic terms / concepts Basic C++ programming: • primitive variable types • expressions / statements • functions • memory management / pointers / arrays • structures / unions / enumerations • strings / vectors • classes • smart pointers / move semantics The C++ standard template library (STL): • IO library • containers • generic algorithms Advanced techniques: • operator overloading • template programming • object-oriented programming • embarrassing parallel: OpenMP Useful libraries for further projects: • common used C++ libraries • where to find the right material

5	**Learning outcomes and competences:** **Domain competence:** After having attended this course, students might obtain following benefits: • understand modern C++ • be confident to take advanced courses that require C++ programming • the ability to easily realize programming tasks / projects • promoted from a C programmer to a state-of-art C++ programmer • the ability to develop a real object-oriented program • gain additional understanding of how a computer works • better understanding of (computationally) problems • know where to find the desired information to realize a challenging task on your own
6	**Assessments:**
7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** Keine
9	**Prerequisites for assigning credits:** No Credits will be given.
10	**Weighing for overall grade:** None, because this lecture is without an exam
11	**Reuse in degree courses:** keine
12	**Module coordinator:** Philipp Schubert, Prof. Dr. Eric Bodden
13	**Other Notes:** *Remarks of course C++ Programming:* **Course Homepage** `https://www.hni.uni-paderborn.de/swt/lehre/c-programming-ws20162017/` **Teaching Material, Literature** Main References: 1. A Tour of C++, Stroustrup 2013 2. The C++ Programming Language (4th Edition), Stroustrup 2013 3. C++ Reference: http://en.cppreference.com/ 4. C++ Tutorial: http://www.cplusplus.com/doc/tutorial/ 5. Advanced topics: CppCon experts sharing their knowledge: https://www.youtube.com/watch?v=1OEu9C51K2A&list=PLHTh1InhhwT75gykhs7pqcR_uSiG601oh https://www.youtube.com/watch?v=1OEu9C51K2A&list=PLHTh1InhhwT75gykhs7pqcR_uSiG601oh Additional material will be handed out in the course.

2.8 Master's Thesis

Students have to carry out a Master's thesis of one semester duration, resulting in 30 CP.

Workload:

Full time for one semester – total workload: 900 h

<table>
<tr><th colspan="6">Master thesis</th></tr>
<tr><td colspan="6">Master thesis</td></tr>
<tr><td colspan="2">Module number:
A.048.90000</td><td>Workload (h):
900</td><td>Credits:
30</td><td colspan="2">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 colspan="2">Teaching Language:
en</td></tr>
<tr><td>1</td><td colspan="5">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>
</table></td></tr>
<tr><td>2</td><td colspan="5">Options within the module:
None</td></tr>
<tr><td>3</td><td colspan="5">Admission requirements:
The prerequisites for the start of the master's thesis are detailed in § 10 section 3 of the examination regulations.</td></tr>
<tr><td>4</td><td colspan="5">Contents:
Short Description
The master thesis is a written examination paper to be authored without external help, and completes the scientific training. A thesis written as group work is also admissible if the individual candidate's contribution to be assessed as an exam paper can be distinguished and evaluated on the basis of sections or pages specified and other objective criteria allowing a clear differentiation.
Contents
The concrete content of the master thesis depends on the task defined by the supporting group of the institute. The focus of the thesis can either be placed on the methods applied, or the thesis can be oriented towards the applications. In both cases, the thesis subject will be embedded in the scientific environment of the institute and its versatile, close cooperations with enterprises and industries. The intercommunication between the institute and renowned companies opens up numerous and attractive tasks for master papers and serves to underline the relevance for the professional field and the employment market, and to support the acquisition of interdisciplinary competences.</td></tr>
</table>

<table>
<tr><td>5</td><td>Learning outcomes and competences:
By completing the master thesis the graduates prove their capability to elaborate on a problem in electrical engineering within a defined period of time by applying scientific methods. The thesis will also serve to prove that the graduates are capable of applying competences acquired in the course of their studies, in particular technical-methodical competences and where applicable interdisciplinary competences.</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></td><td></td><td></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:
keine</td></tr>
<tr><td>12</td><td>Module coordinator:
Dr.-Ing. Carsten Balewski</td></tr>
<tr><td>13</td><td>Other Notes:
Supervison by academic staff of the institute</td></tr>
</table>

3 Overview of the offered modules in winter term

4 Overview of the offered modules in summer term

Erzeugt am 4. März 2021 um 16:12.