PADERBORN UNIVERSITY

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

MODULE HANDBOOK
MASTER'S PROGRAM ELECTRICAL SYSTEMS ENGINEERING V3 (ESEMA V3)

DATE: 8. SEPTEMBER 2026

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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

2.1.1 Advanced System Theory

<table>
<tr><th colspan="8">Advanced System Theory</th></tr>
<tr><td colspan="8">Advanced System Theory</td></tr>
<tr><td colspan="2">Module number:
M.048.92001</td><td colspan="2">Workload (h):
180</td><td colspan="2">Credits:
6</td><td colspan="2">Regular Cycle:
module.frequency.en</td></tr>
<tr><td colspan="2">Language:
de / en</td><td colspan="2">Semester number:
1. Semester</td><td colspan="2">Duration (in sem.):
1</td><td colspan="2">Module status (P=C/WP=CE)
P</td></tr>
<tr><td>1</td><td colspan="7">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.048.92001
Advanced System Theory</td><td>2L
2Ex,
WS/SS</td><td>60</td><td>120</td><td>C</td><td>60/30</td></tr>
</table></td></tr>
<tr><td>2</td><td colspan="7">Options within the module:
None</td></tr>
<tr><td>3</td><td colspan="7">Admission requirements:
None
Prerequisites of course Advanced System Theory:
Recommended:
Prerequisites are a basic understanding of differential equations, linear algebra, and Laplace transforms, as they are covered in a typical undergraduate course on system theory.</td></tr>
</table>

<table>
<tr><td>4</td><td>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</td></tr>
<tr><td>5</td><td>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.</td></tr>
<tr><td>6</td><td>Assessments:

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

<table><tr><th>zu</th><th>Type of examination</th><th>Duration or scope</th><th>Weighting for the module grade</th></tr><tr><td>a)</td><td>Written or Oral Examination or Presentation</td><td>120-180 min or 30-45 min or 30 min</td><td>100%</td></tr></table></td></tr>
<tr><td>7</td><td>Study Achievement:

none</td></tr>
<tr><td>8</td><td>Prerequisites for participation in examinations:

None</td></tr>
<tr><td>9</td><td>Prerequisites for assigning credits:

The credit points are awarded after the module examination (MAP) was passed.</td></tr>
<tr><td>10</td><td>Weighing for overall grade:

The module is weighted according to the number of credits (factor 1).</td></tr>
</table>

11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Computer Engineering v4 (CEMA v4), englisch, Master's Program Electrical Systems Engineering v2 (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)
12	**Module coordinator:** Prof. Dr. Erdal Kayacan
13	**Other Notes:** *Remarks of course Advanced System Theory:* **Course Homepage** `https://en.ei.uni-paderborn.de/rat` **Implementation** Lectures and exercises (including some computer simulations) Panda course for communication and material distribution **Teaching Material, Literature** Handouts and exercise / tutorial questions; literature references will be given in the first lecture

2.1.2 Modeling and Simulation

<table>
<tr><th colspan="5">Modeling and Simulation</th></tr>
<tr><td colspan="5">Modeling and Simulation</td></tr>
<tr><td>Module number:
M.048.90102</td><td>Workload (h):
180</td><td>Credits:
6</td><td colspan="2">Regular Cycle:
module.frequency.en</td></tr>
<tr><td>Language:
en</td><td>Semester number:
1. Semester</td><td>Duration (in sem.):
1</td><td colspan="2">Module status (P=C/WP=CE)
P</td></tr>
<tr><td>1</td><td colspan="4">Module structure:
<table>
<tr><th></th><th>Course</th><th>form of teachin</th><th>contact-time (h)</th><th>self-study (h)</th><th>status (C/CE)</th><th>group size (TN)</th></tr>
<tr><td>a)</td><td>L.048.90102
Modeling and Simulation</td><td>2L
2Ex,
WS</td><td>60</td><td>120</td><td>C</td><td>60/30</td></tr>
</table></td></tr>
<tr><td>2</td><td colspan="4">Options within the module:
None</td></tr>
<tr><td>3</td><td colspan="4">Admission requirements:
None
Prerequisites of course Modeling and Simulation:
Recommended:
• Prior knowledge of programming in Matlab/Octave
• Knowledge of mathematics and physics at the level of the university entrance qualification</td></tr>
<tr><td>4</td><td colspan="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 differential equations
• Numerical methods for partial differential equations
• Discrete simulations</td></tr>
</table>

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

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

<table><tr><th>zu</th><th>Type of examination</th><th>Duration or scope</th><th>Weighting for the module grade</th></tr><tr><td>a)</td><td>Written or Oral Examination or Presentation</td><td>120-180 min or 30-45 min or 30 min</td><td>100%</td></tr></table></td></tr>
<tr><td>7</td><td>Study Achievement:

none</td></tr>
<tr><td>8</td><td>Prerequisites for participation in examinations:

None</td></tr>
<tr><td>9</td><td>Prerequisites for assigning credits:

The credit points are awarded after the module examination (MAP) was passed.</td></tr>
<tr><td>10</td><td>Weighing for overall grade:

The module is weighted according to the number of credits (factor 1).</td></tr>
<tr><td>11</td><td>Reuse in degree courses or degree course versions :

Master’s Program Electrical Systems Engineering v2 (ESEMA v2), Master’s Program Electrical Systems Engineering v3 (ESEMA v3)</td></tr>
<tr><td>12</td><td>Module coordinator:

Prof. Dr. Jens Förstner</td></tr>
<tr><td>13</td><td>Other Notes:

Remarks of course Modeling and Simulation:
Course Homepage
<tt>http://tet.upb.de</tt>
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.</td></tr>
</table>

2.2 Module Group: Management and Application

2.2.1 Management of Technical Projects

<table>
<tr><th colspan="5">Management of Technical Projects</th></tr>
<tr><td colspan="5">Management of Technical Projects</td></tr>
<tr><td>Module number:
M.048.90103</td><td>Workload (h):
90</td><td>Credits:
3</td><td colspan="2">Regular Cycle:
module.frequency.en</td></tr>
<tr><td>Language:
de / en</td><td>Semester number:
1. Semester</td><td>Duration (in sem.):
1</td><td colspan="2">Module status (P=C/WP=CE)
P</td></tr>
<tr><td>1</td><td colspan="4">Module structure:
<table>
<tr><th></th><th>Course</th><th>form of teachin</th><th>contact-time (h)</th><th>self-study (h)</th><th>status (C/CE)</th><th>group size (TN)</th></tr>
<tr><td>a)</td><td>L.048.90103 Management of Technical Projects</td><td>2L, WS</td><td>30</td><td>60</td><td>C</td><td>100</td></tr>
</table></td></tr>
<tr><td>2</td><td colspan="4">Options within the module:
None</td></tr>
<tr><td>3</td><td colspan="4">Admission requirements:
None
Prerequisites of course Management of Technical Projects:
None</td></tr>
</table>

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 min	100%

7 **Study Achievement:**

none

8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Elektrotechnik v5 (EMA v5), Master's Program Electrical Systems Engineering v2 (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)
12	**Module coordinator:** Dr.-Ing. Arno Kühn
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/certification-evaluation/recommended-literature` or `https://www.vzpm.ch/fileadmin/dokumente/downloads/English/VZPM_IPMA_Literaturliste.pdf` (last checked on 03 Aug 2022). Further hints will be given during the course.

2.2.2 Topics in System Engineering

<table>
<tr><th colspan="5">Topics in Sytems Engineering</th></tr>
<tr><td colspan="5">Topics in Sytems Engineering</td></tr>
<tr><td>Module number:
M.048.90104</td><td>Workload (h):
90</td><td>Credits:
3</td><td colspan="2">Regular Cycle:
module.frequency.en</td></tr>
<tr><td>Language:
en</td><td>Semester number:
3. Semester</td><td>Duration (in sem.):
1</td><td colspan="2">Module status (P=C/WP=CE)
P</td></tr>
<tr><td>1</td><td colspan="4">Module structure:
<table>
<tr><th></th><th>Course</th><th>form of teachin</th><th>contact-time (h)</th><th>self-study (h)</th><th>status (C/CE)</th><th>group size (TN)</th></tr>
<tr><td>a)</td><td>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 colspan="4">Options within the module:
1 seminar from offer</td></tr>
<tr><td>3</td><td colspan="4">Admission requirements:
None
Prerequisites of course Topics in Systems Engineering:
None</td></tr>
<tr><td>4</td><td colspan="4">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>
</table>

<table>
<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>
<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 min</td><td>100%</td></tr></table></td></tr>
<tr><td>7</td><td>Study Achievement:

none</td></tr>
<tr><td>8</td><td>Prerequisites for participation in examinations:

None</td></tr>
<tr><td>9</td><td>Prerequisites for assigning credits:

The credit points are awarded after the module examination (MAP) was passed.</td></tr>
<tr><td>10</td><td>Weighing for overall grade:

The module is weighted according to the number of credits (factor 1).</td></tr>
<tr><td>11</td><td>Reuse in degree courses or degree course versions :

Master's Program Electrical Systems Engineering v2 (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)</td></tr>
<tr><td>12</td><td>Module coordinator:

Dr.-Ing. Carsten Balewski</td></tr>
</table>

13	**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.

2.3 Module Group: Fundamentals of Electrical Systems Engineering

Module Group	Fundamentals of Electrical Systems Engineering
Modules	* Advanced Control * Data-Driven Engineering * Data-Driven Innovation * Model-Based Systems Engineering * Digital Speech Signal Processing * High Frequency Engineering * Introduction to Algorithms * Optimization-Based Control Methods
Module group advisor	Head of Examination Board ESE (PAV ESE)
Credits ECTS	6
Type of examination	Written or Oral Examination or Presentation
Duration or Scope	120-180 min or 30-45 min or 30 min
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 module out of the following list to choose from.

Data-Driven Engineering			
Data-Driven Engineering			
Module number: M.079.4204	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** module.frequency.en
Language: en	**Semester number:** 1-3	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.079.05722 Data-Driven Engineering	L2 Ex3	75	105	C	60/30

2 **Options within the module:**

none

3 **Admission requirements:**

none

4 **Contents:**

Contents of the course Data-Driven Engineering:
The goal of the lecture is to provide a comprehensive overview of the potentials and use cases in data-driven engineering. Important fundamentals and concepts from the fields of engineering and artificial intelligence are introduced and explained using meaningful practical examples. The acquired knowledge is deepened and implemented in exercises. As part of a group project, participants will develop their own functional engineering assistant.
Data is the oil of the 21st century. Data is also becoming increasingly important in product development. Both field data and development data can be processed using modern data analysis methods and AI processes to increase the efficiency and effectiveness of product development. The lecture provides an overview of the challenges and possible solutions of Data-driven Engineering. Theoretical principles and concepts are introduced and exemplary applications from practice are presented. The process is considered from data acquisition to possibilities for data evaluation and the development of innovative assistance systems. The acquired knowledge is deepened and implemented in the exercises.
Contents of the course are:

- Motivation and definition of terms
- Potentials of data-driven engineering
- Engineering IT and data management along the product life cycle
- Fundamentals of data analytics and AI (in particular generative AI)
- Data structures and formats in product development
- Application examples and assistance systems (co-pilots) along the product life cycle (from requirements engineering to production planning)
- Methods for planning and implementing Data-driven Engineering use cases
- Technical development of assistance systems (co-pilots) in Data-driven Engineering

5 **Learning outcomes and competences:**

Students will be able to

- recognize and evaluate the potential of Data-driven Engineering
- evaluate prerequisites for the application of Data-driven product development concepts
- analyze and design Engineering IT infrastructures
- plan and implement use cases for Data-driven product development
- design assistance systems (co-pilots) for Data-driven use cases

6 **Assessments:**

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

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

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

9 **Prerequisites for assigning credits:**

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

10 **Weighing for overall grade:**

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

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

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

12 **Module coordinator:**

Prof. Dr.-Ing. Roman Dumitrescu

13 **Other Notes:**

Remarks of course Data-Driven Engineering:
Implementation Method
The course consists of three components: In the lecture, basic concepts of data-driven engineering are introduced using slides and underlined with practical examples. In the accompanying exercise, the concepts are applied by the students. The project allows students to apply what they have learned in group work.
Learning Material, Literature

- Literature will be announced in the course.

<table>
<tr><th colspan="5">Data-Driven Innovation</th></tr>
<tr><td colspan="5">Data-Driven Innovation</td></tr>
<tr><td>Module number:
M.079.4076</td><td>Workload (h):
180</td><td>Credits:
6</td><td colspan="2">Regular Cycle:
module.frequency.en</td></tr>
<tr><td>Language:
en</td><td>Semester number:
1-3</td><td>Duration (in sem.):
1</td><td colspan="2">Module status (P=C/WP=CE)
P</td></tr>
<tr><td>1</td><td colspan="4">Module structure:
<table>
<tr><th></th><th>Course</th><th>form of teachin</th><th>contact-time (h)</th><th>self-study (h)</th><th>status (C/CE)</th><th>group size (TN)</th></tr>
<tr><td>a)</td><td>L.079.05822
Data-Driven Innovation</td><td>L2
Ex3</td><td>75</td><td>105</td><td>C</td><td>70/35</td></tr>
</table></td></tr>
<tr><td>2</td><td colspan="4">Options within the module:
none</td></tr>
<tr><td>3</td><td colspan="4">Admission requirements:
none</td></tr>
</table>

4	**Contents:** *Contents of the course Data-Driven Innovation:* Innovations arise when companies successfully launch new or improved products and services on the market. Innovations are the prerequisite for prosperity, economic growth and competitive advantages. The increasing digitalization of all aspects of our lives has given rise to numerous new approaches to innovation and how it is created. The Data-Driven Innovation lecture provides a basic overview of this: The basics of innovation and data management are discussed, new digitized market services and business models are discussed and the impact on the innovation process is examined and analyzed. Building on this, the course deals with how organizations can implement data-driven innovations. The module includes the following content: • Innovation and Data – Fundamentals of Innovation Management – Fundamentals of Data in Organizations • Data-Driven Offerings – Smart Products – Smart Services – Digital Platforms – Data Spaces & Digital Business Models • Innovation Processes – Innovation Management Methods and Tools – Data-infused Innovation Processes • Organizing the data-driven Transformation – Digital Transformation – Using data for Sustainability
5	**Learning outcomes and competences:** The students • become familiar with the basics of innovation and data management as well as key concepts and approaches • understand the influence of digitalization on the market performance of manufacturing companies in particular • be able to understand and reflect on innovation processes in practice • understand how the transformation to a data-driven company can take place • be able to apply various approaches to analyze problems and find solutions. • be able to systematically find, conceptualize, test and develop ideas towards a market approach.

<table>
<tr><td>6</td><td>Assessments:
☒Final module exam (MAP) □Module exam (MP) □Partial module exams (MTP)
<table>
<tr><th>zu</th><th>Type of examination</th><th>Duration or scope</th><th>Weighting for the module grade</th></tr>
<tr><td>a)</td><td>Written or oral examination or report</td><td>120-180 min or 30-45 min or 30 min</td><td>100%</td></tr>
</table></td></tr>
<tr><td>7</td><td>Study Achievement:
none</td></tr>
<tr><td>8</td><td>Prerequisites for participation in examinations:</td></tr>
<tr><td>9</td><td>Prerequisites for assigning credits:
The credit points are awarded after the module examination was passed.</td></tr>
<tr><td>10</td><td>Weighing for overall grade:
The module is weighted according to the number of credits (factor 1).</td></tr>
<tr><td>11</td><td>Reuse in degree courses or degree course versions :
Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Computer Engineering v4 (CEMA v4), englisch, Masterstudiengang Informatik v4, Master’s Program Electrical Systems Engineering v2 (ESEMA v2), Master’s Program Electrical Systems Engineering v3 (ESEMA v3)</td></tr>
<tr><td>12</td><td>Module coordinator:
Dr. Christian Koldewey, Prof. Dr.-Ing. Roman Dumitrescu</td></tr>
<tr><td>13</td><td>Other Notes:
Remarks of course Data-Driven Innovation:
Implementation method
The module consists of two parts 1. lecture with slides: basics and concepts are explained in the lecture and illustrated with examples. 2. exercises (tutorial): In the exercises, knowledge is transferred and the concepts are applied. The exercises have to be prepared by the students themselves.
Learning Material, Literature
• Gausemeier, Jürgen & Dumitrescu, Roman & Echterfeld, Julian & Pfänder, Tomas & Steffen, Daniel & Thielemann, Frank. (2018). Innovationen für die Märkte von morgen: Strategische Planung von Produkten, Dienstleistungen und Geschäftsmodellen. 10.3139/9783446429727. (https://www.hanser-fachbuch.de/fachbuch/artikel/9783446428249#content–desc)
• Beverungen, Daniel & Dumitrescu, Roman & Kühn, Arno & Plass, Christoph. (2024). Digitale Plattformen im industriellen Mittelstand Strategien, Methoden, Umsetzungsbeispiele.
• https://ki-marktplatz.com/wp-content/uploads/2021/02/KI-MP_Whitepaper.pdf
• https://www.advanced-systems-engineering.de/#studie</td></tr>
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<table>
<tr><th colspan="5">Digital Speech Signal Processing</th></tr>
<tr><td colspan="5">Digital Speech Signal Processing</td></tr>
<tr><td>Module number:
M.048.92041</td><td>Workload (h):
180</td><td>Credits:
6</td><td colspan="2">Regular Cycle:
module.frequency.en</td></tr>
<tr><td>Language:
en</td><td>Semester number:
1.-3. Semester</td><td>Duration (in sem.):
1</td><td colspan="2">Module status (P=C/WP=CE)
WP</td></tr>
<tr><td>1</td><td colspan="4">Module structure:
<table>
<tr><th></th><th>Course</th><th>form of teachin</th><th>contact-time (h)</th><th>self-study (h)</th><th>status (C/CE)</th><th>group size (TN)</th></tr>
<tr><td>a)</td><td>L.048.92041
Digital Speech Signal Processing</td><td>2L
2Ex,
SS</td><td>60</td><td>120</td><td>C</td><td>30/30</td></tr>
</table></td></tr>
<tr><td>2</td><td colspan="4">Options within the module:
None</td></tr>
<tr><td>3</td><td colspan="4">Admission requirements:
None
Prerequisites of course Digital Speech Signal Processing:
Recommended: Prior knowledge from the module Higher Mathematics.</td></tr>
</table>

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

<table>
<tr><td>6</td><td>Assessments:
☒Final module exam (MAP) □Module exam (MP) □Partial module exams (MTP)
<table>
<tr><th>zu</th><th>Type of examination</th><th>Duration or scope</th><th>Weighting for the module grade</th></tr>
<tr><td>a)</td><td>Written or Oral Examination or Presentation</td><td>120-180 min or 30-45 min or 30 min</td><td>100%</td></tr>
</table></td></tr>
<tr><td>7</td><td>Study Achievement:
none</td></tr>
<tr><td>8</td><td>Prerequisites for participation in examinations:
None</td></tr>
<tr><td>9</td><td>Prerequisites for assigning credits:
The credit points are awarded after the module examination (MAP) was passed.</td></tr>
<tr><td>10</td><td>Weighing for overall grade:
The module is weighted according to the number of credits (factor 1).</td></tr>
<tr><td>11</td><td>Reuse in degree courses or degree course versions :
Master’s Program Electrical Systems Engineering v2 (ESEMA v2), Master’s Program Electrical Systems Engineering v3 (ESEMA v3)</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 Digital Speech Signal Processing:
Course Homepage
<code>https://ei.uni-paderborn.de/en/nt/teaching/veranstaltungen/digital-speech-signal-processing</code>
Implementation
• Lectures using the blackboard and presentations,
• Alternating theoretical and practical exercise classes with exercise sheets and computer and
• Demonstration of real technical systems in the lecture hall.

Teaching Material, Literature
Allocation of a script; information on textbooks ; matlab scripts</td></tr>
</table>

High Frequency Engineering			
High Frequency Engineering			
Module number: M.048.92002	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** module.frequency.en
Language: en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

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

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course High Frequency Engineering:
None

4 **Contents:**

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

5 **Learning outcomes and competences:**

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

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

6 **Assessments:**

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

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

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

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

10 **Weighing for overall grade:**

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

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

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

12 **Module coordinator:**

Prof. Dr. Reinhold Noé

13	**Other Notes:** *Remarks of course High Frequency Engineering:* --- **ATTENTION - IMPORTANT NOTICE** The course doesn't take place in winter term 2026/27 summer term 2026. Please see the notice boards of the group. --- **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			
Introduction to Algorithms			
Module number: M.048.90501	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** module.frequency.en
Language: en	**Semester number:** 1.-2. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.90501 Introduction to Algorithms	2L 2Ex, WS	60	120	C	50/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Introduction to Algorithms:
Recommended: Mathematical basics (e.g. asymptotic behavior of functions, probabilities)

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 or Presentation	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

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

10 **Weighing for overall grade:**

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

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

Master's Program Electrical Systems Engineering v2 (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)

12 **Module coordinator:**

Prof. Dr.-Ing. Lennart Bamberg

13	**Other Notes:** *Remarks of course Introduction to Algorithms:* **Course Homepage** `https://ei.uni-paderborn.de/en/electrical-engineering/date/teaching/electrical-engineering/overview` **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

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

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.079.05810 Model-Based Systems Engineering	L3 Ex2	75	105	C	70/35

2 **Options within the module:**

none

3 **Admission requirements:**

none

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

4 **Contents:**

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

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

5	**Learning outcomes and competences:** The students • acquire a solid understanding of Model-Based System Engineering • know different methods, languages, and tools • are able to apply the knowledge they have gained • are able to work out solutions independently and communicate them to the lecturers.
6	**Assessments:** ☒Final module exam (MAP) □Module exam (MP) □Partial module exams (MTP)

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

7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:**
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Computer Engineering v4 (CEMA v4), englisch, Masterstudiengang Informatik v4, Master's Program Electrical Systems Engineering v2 (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)
12	**Module coordinator:** Prof. Dr.-Ing. Roman Dumitrescu

13	**Other Notes:** *Remarks of course Model-Based Systems Engineering:* **Implementation Method** The module consists of two parts 1. lecture with slides: basics and concepts are explained in the lecture and illustrated with examples. 2. exercises (tutorial): In the exercises, knowledge is transferred and the concepts are applied. The exercises have to be prepared by the students themselves. **Learning Material, Literature** • Gausemeier, J.; Dumitrescu, R.; Steffen, D.; Czaja, A.; Wiederkehr, O.; Tschirner, C.: Systems Engineering in industrial practice. Heinz Nixdorf Institute, University Paderborn, 2013, Under: https://www.hni.uni-paderborn.de/en/spe/systemsengineering/ • Dumitrescu, R.; Albers, A.; Riedel, O.; Stark, R.;Gausemeier, J. (Eds): Engineering in Germany – Status quo in Business and Science. Federal Ministry of Education and Research, 2021 Under: https://www.advanced-systems-engineering.de/#studie • Additional literature will be announced in the course.

Optimization-Based Control Methods

Optimization-Based Control Methods

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.92051	180	6	module.frequency.en
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
en	1.-3. Semester	1	WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.92051 Optimization-Based Control Methods	2L 2Ex, WS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Optimization-Based Control Methods:
None

4 **Contents:**

Contents of the course Optimization-Based Control Methods:
The course begins with Bellman's Principle of Optimality and introduces the foundations of Dynamic Programming (DP) techniques for solving optimization problems in finite and infinite time horizons. Based on this framework, students will study Finite and Infinite Horizon Optimal Control Problems, learning how to apply DP to real-world control problems over different time scales. A significant portion of the course is then devoted to linear quadratic regulator (LQR) and linear quadratic estimator (LQE) problems, focusing on designing Optimal State Feedback controllers and estimators for linear systems. The linear quadratic Gaussian (LQG) framework then combines LQR and LQE into a robust framework for Gaussian state and measurement noise. To address optimization problems with state and input constraints, students will be introduced to Quadratic Programming (QP) and the fundamentals of Convex Optimization, which are essential for handling real-world control applications that impose limits on system inputs and states. A section on Model Predictive Control (MPC) will then focus on designing optimal control strategies for constrained linear systems by solving a series of optimization problems in real-time, offering a bridge between theory and industrial applications. The course then covers Approximate Dynamic Programming (ADP) and its connection to MPC, exploring methods to approximate optimal solutions for computationally intractable problems using traditional DP techniques. Lastly, students will use modern methods for designing Convex Optimization Control Policies, learning to create efficient and scalable control solutions using convexity and optimization frameworks. Finally, if time permits, the course will close with a short introduction to Proximal Policy Optimization methods.

<table>
<tr><td>5</td><td>Learning outcomes and 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>a)</td><td>Written or Oral Examination or Presentation</td><td>120-180 min or 30-45 min or 30 min</td><td>100%</td></tr>
</table></td></tr>
<tr><td>7</td><td>Study Achievement:
none</td></tr>
<tr><td>8</td><td>Prerequisites for participation in examinations:
None</td></tr>
<tr><td>9</td><td>Prerequisites for assigning credits:
The credit points are awarded after the module examination (MAP) was passed.</td></tr>
<tr><td>10</td><td>Weighing for overall grade:
The module is weighted according to the number of credits (factor 1).</td></tr>
<tr><td>11</td><td>Reuse in degree courses or degree course versions :
Master’s Program Electrical Systems Engineering v2 (ESEMA v2), Master’s Program Electrical Systems Engineering v3 (ESEMA v3)</td></tr>
<tr><td>12</td><td>Module coordinator:
Dr. Adrian Redder</td></tr>
<tr><td>13</td><td>Other Notes:
Module Homepage
http://sst.upb.de/teaching
Implementation
Lectures and exercises (including some computer simulations)
Teaching Material, Literature
Handouts and tutorial questions; literature references will be given in the first lecture</td></tr>
</table>

2.4 Specialization-Specific: Signal and Information Processing

2.4.1 Module Group: Introduction to Signal and Information Processing

Statistical and Machine Learning

Statistical and Machine Learning

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.92046	270	9	module.frequency.en
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
en	2. Semester	1	P

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.92005 Statistical and Machine Learning	2L 2Ex, SS	60	120	C	30/30
b)	L.048.92046 Statistical and Machine Learning - Practical Exercise	2Ex, SS	30	60	C	30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Statistical and Machine Learning:
Recommended: Elementary knowledge in Statistics, as is taught in the course Statistical Signal Processing. Programming skills are desirable

Prerequisites of course Statistical and Machine Learning - Practical Exercise:
None

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, Percepton, Support Vector Machines • Deep neural networks (deep learning) • Dimensionality reduction (PCA, LDA) • Unsupervised learning (mixture densities, clustering techniques) *Contents of the course Statistical and Machine Learning - Practical Exercise:* Application of the concepts taught in the course on a concrete classification or regression task and discussion and evaluation of the achieved results.
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, both an appropriate choice of the feature vectors and their size and of the classifier and its size in terms of learnable parameters **Key qualifications:** The students • Can assess the importance of the principle of parsimony and are able to transfer it to other areas • Are able to analyse a given classification or regression problem, synthesize a solution, and evaluate the performance on test data • Are able to apply the knowledge and skills learnt in this course to a wide range of disciplines • Can work cooperatively in a team and subdivide an overall task into manageable subtasks and work packages • Acquired a general understanding of the power and limitations of machine learning algorithms

6 **Assessments:**

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

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a) - b)	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:**

zu	**Type of achievement**	**Duration or Scope**	**SL / QT**
a)			
b)	Programming excercise	Several pages of code; 3-6 weeks to complete assignment	QP

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

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

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

10 **Weighing for overall grade:**

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

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

Master's Program Electrical Systems Engineering v3 (ESEMA v3)

12 **Module coordinator:**

Dr.-Ing. Mohammad Soleymani

13	**Other Notes:** *Remarks of course Statistical and Machine Learning:* **Course Homepage** `https://ei.uni-paderborn.de/en/statistical-and-machine-learning` **Implementation** • Lectures predominantly using the blackboard or overhead projector, occasional presentations of (powerpoint) slides , • Exercise classes with exercise sheets and demonstrations on computer • Implementation of learning and classification algorithms on a computer by the students themselves; use of algorithms on real-world data or data generated on the computer, evaluation of the simulation results **Teaching Material, Literature** Course script and summary slides are provided to the students. Exercises and solutions to exercises, as well as sample implementations of algorithms are provided to the students • R.O. Duda, P.E. Hart, D.G.~ Stork, Pattern Classification, Wiley, 2001 • I. Goodfellow, Y. Bengio, A. Courville: Deep Learning, MIT Press, 2016 • S. Theodoridis: Machine Learning, Academic Press, 2015 • K. Fukunaga, Introduction to Statistical Pattern Recognition, Academic Press, 1990

Statistical Signal Processing			
Statistical Signal Processing			
Module number: M.048.92004	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** module.frequency.en
Language: en	**Semester number:** 1. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** P

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.92004 Statistical Signal Processing	2L 2Ex, WS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

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

4 **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.

5 **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.

<table>
<tr><td>6</td><td>Assessments:
☒Final module exam (MAP) □Module exam (MP) □Partial module exams (MTP)
<table>
<tr><th>zu</th><th>Type of examination</th><th>Duration or scope</th><th>Weighting for the module grade</th></tr>
<tr><td>a)</td><td>Written or Oral Examination or Presentation</td><td>120-180 min or 30-45 min or 30 min</td><td>100%</td></tr>
</table></td></tr>
<tr><td>7</td><td>Study Achievement:
none</td></tr>
<tr><td>8</td><td>Prerequisites for participation in examinations:
None</td></tr>
<tr><td>9</td><td>Prerequisites for assigning credits:
The credit points are awarded after the module examination (MAP) was passed.</td></tr>
<tr><td>10</td><td>Weighing for overall grade:
The module is weighted according to the number of credits (factor 1).</td></tr>
<tr><td>11</td><td>Reuse in degree courses or degree course versions :
Masterstudiengang Informatik v3, Master’s Program Electrical Systems Engineering v2 (ESEMA v2), Master’s Program Electrical Systems Engineering v3 (ESEMA v3)</td></tr>
<tr><td>12</td><td>Module coordinator:
Prof. Dr. Peter Schreier</td></tr>
<tr><td>13</td><td>Other Notes:
Remarks of course Statistical Signal Processing:
Course Homepage
<code>http://sst.upb.de/teaching</code>
Implementation
Lectures and tutorials
Teaching Material, Literature
Literature references are given in the first lecture.</td></tr>
</table>

2.4.2 Module Group: Signal and Information Processing

Module Group	Signal and Information Processing
Modules	* Advanced Topics In Robotics * Cognitive Systems Engineering * Design of Integrated Energy Systems * Digital Image Processing I * Digital Image Processing II * Information Theory * Nonlinear control of autonomous and robotic systems * Optical Waveguide Theory * Optimal and Adaptive Filters * Optimization-Based Control Methods * Resource-Efficient AI: Architectures and Methodologies * Robotics * Theory and Design of Integrated Photonic Devices * Topics in Advanced Control * Topics in Signal Processing * Wireless Coummunications
Module group advisor	Head of Examination Board ESE (PAV ESE)
Credits ECTS	6
Type of examination	Written or Oral Examination or Presentation
Duration or Scope	120-180 min or 30-45 min or 30 min
Teaching objectives	The students select two modules according to their interests in the chosen specialization to acquire expertise in certain topics.

Advanced Topics in Robotics			
Advanced Topics in Robotics			
Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.92006	180	6	module.frequency.en

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

1 **Module structure:**

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

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Advanced Topics in Robotics:
None

4 **Contents:**

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

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

5 **Learning outcomes and competences:**

Domain competence:
The students

- are able to name and analyze the basic robot architectures for mobile robots,
- have a good command of the methods for the navigation and control of mobile robots and
- are able to implement, test and apply them.

Key qualifications:
The students have a good command of programming in the C language

<table>
<tr><td>6</td><td>Assessments:
☒Final module exam (MAP) □Module exam (MP) □Partial module exams (MTP)
<table>
<tr><th>zu</th><th>Type of examination</th><th>Duration or scope</th><th>Weighting for the module grade</th></tr>
<tr><td>a)</td><td>Written or Oral Examination or Presentation</td><td>120-180 min or 30-45 min or 30 min</td><td>100%</td></tr>
</table></td></tr>
<tr><td>7</td><td>Study Achievement:
none</td></tr>
<tr><td>8</td><td>Prerequisites for participation in examinations:
None</td></tr>
<tr><td>9</td><td>Prerequisites for assigning credits:
The credit points are awarded after the module examination (MAP) was passed.</td></tr>
<tr><td>10</td><td>Weighing for overall grade:
The module is weighted according to the number of credits (factor 1).</td></tr>
<tr><td>11</td><td>Reuse in degree courses or degree course versions :
Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Computer Engineering v4 (CEMA v4), englisch, Master’s Program Electrical Systems Engineering v2 (ESEMA v2), Master’s Program Electrical Systems Engineering v3 (ESEMA v3)</td></tr>
<tr><td>12</td><td>Module coordinator:
Prof. Dr. Bärbel Mertsching</td></tr>
</table>

13 **Other Notes:**

Remarks of course Advanced Topics in Robotics:

ATTENTION - IMPORTANT NOTICE
The course doesn't take place in winter term 2026/27 summer term 2026. Please see the notice boards of the group.

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

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

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

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

Cognitive Systems Engineering			
Cognitive Systems Engineering			
Module number: M.048.9070X	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** module.frequency.en
Language: en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.90701 Cognitive Systems Engineering A - Visual Attention	2L, WS	30	60	C	30
b)	L.048.90702 Cognitive Systems Engineering B - Sensation and Perception in Biological Systems	2L, SS	30	60	C	30
c)	L.048.62008 Cognitive Systems Engineering C - GET Research Seminar	2L, WS+SS	30	60	CE	50

2 **Options within the module:**

Choosing 2 course of a)-c)

3 **Admission requirements:**

None

Prerequisites of course Cognitive Systems Engineering A - Visual Attention:
Recommended: None - but interest in the subject-matter and interdisciplinary work

Prerequisites of course Cognitive Systems Engineering B - Sensation and Perception in Biological Systems:
Recommended: None - but interest in the subject-matter and interdisciplinary work

Prerequisites of course Cognitive Systems Engineering C - GET Research Seminar:
Recommended: None - but interest in the subject-matter and interdisciplinary work

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

<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) - c)</td><td>Written or Oral Examination or Presentation</td><td>120-180 min or 30-45 min or 30 min</td><td>100%</td></tr></table></td></tr>
<tr><td>7</td><td>Study Achievement:
none</td></tr>
<tr><td>8</td><td>Prerequisites for participation in examinations:
None</td></tr>
<tr><td>9</td><td>Prerequisites for assigning credits:
The credit points are awarded after the module examination (MAP) was passed.</td></tr>
<tr><td>10</td><td>Weighing for overall grade:
The module is weighted according to the number of credits (factor 1).</td></tr>
<tr><td>11</td><td>Reuse in degree courses or degree course versions :
Master’s Program Electrical Systems Engineering v2 (ESEMA v2), Master’s Program Electrical Systems Engineering v3 (ESEMA v3)</td></tr>
<tr><td>12</td><td>Module coordinator:
Prof. Dr. Bärbel Mertsching</td></tr>
</table>

13	**Other Notes:** **Module Homepage** `http://getwww.uni-paderborn.de/teaching/cse` **Teaching Material, Literature** Literature references will be given at the first dates of the seminar. *Remarks of course Cognitive Systems Engineering A - Visual Attention:* --- **ATTENTION - IMPORTANT NOTICE** The course doesn't take place in winter term 2026/27 summer term 2026. Please see the notice boards of the group. --- *Remarks of course Cognitive Systems Engineering C - GET Research Seminar:* --- **ATTENTION - IMPORTANT NOTICE** The course doesn't take place in winter term 2026/27 summer term 2026. Please see the notice boards of the group. ---

Design of Integrated Energy Systems			
Design of Integrated Energy Systems			
Module number: M.048.92059	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** module.frequency.en
Language: en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.92059 Design of Integrated Energy Systems	2L 2Ex, WS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Design of Integrated Energy Systems:
None

4 **Contents:**

Contents of the course Design of Integrated Energy Systems:
An integrated energy system involves a holistic approach to thermal, electrical and chemical energy systems, as well as the associated provision of useful energy, energy distribution and an understanding of energy demand. This course covers the fundamentals of integrated energy systems. Building on descriptions of the key individual components, the course analyses in particular how they interact to meet energy demand. Accordingly, aspects of sector coupling as well as storage technologies are introduced as components of energy systems. In addition to the technical description and design of energy systems, ecological and economic aspects are also presented for the holistic assessment of energy systems. Using these fundamentals, integrated energy systems are then calculated and designed in increasingly complex examples.

5 **Learning outcomes and competences:**

The module provides the technical background of integrated, sustainable energy systems. Students know the structure and functions of individual energy systems (electricity grid, gas grid, heating grids, mobility, etc.) as well as the principles of sector coupling. Furthermore, the participants are able to evaluate energy systems with methods of economic and ecological balancing. In addition to the technical content, the focus of this course is on encouraging critical discussion of scientific texts and studies. The module requires the active participation of students.

<table>
<tr><td>6</td><td>Assessments:
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<table>
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</table></td></tr>
<tr><td>7</td><td>Study Achievement:
none</td></tr>
<tr><td>8</td><td>Prerequisites for participation in examinations:
None</td></tr>
<tr><td>9</td><td>Prerequisites for assigning credits:
The credit points are awarded after the module examination (MAP) was passed.</td></tr>
<tr><td>10</td><td>Weighing for overall grade:
The module is weighted according to the number of credits (factor 1).</td></tr>
<tr><td>11</td><td>Reuse in degree courses or degree course versions :
Master’s Program Electrical Systems Engineering v2 (ESEMA v2), Master’s Program Electrical Systems Engineering v3 (ESEMA v3)</td></tr>
<tr><td>12</td><td>Module coordinator:
Prof. Dr. Henning Meschede</td></tr>
<tr><td>13</td><td>Other Notes:
Module Homepage
https://ei.uni-paderborn.de/en/est/course-offerings
Implementation
Lectures and exercises (including some computer simulations)
Teaching Material, Literature
Handouts and tutorial questions; literature references will be given in the first lecture</td></tr>
</table>

<table>
<tr><th colspan="5">Digital Image Processing I</th></tr>
<tr><td colspan="5">Digital Image Processing I</td></tr>
<tr><td>Module number:
M.048.92008</td><td>Workload (h):
180</td><td>Credits:
6</td><td colspan="2">Regular Cycle:
module.frequency.en</td></tr>
<tr><td>Language:
en</td><td>Semester number:
1.-3. Semester</td><td>Duration (in sem.):
1</td><td colspan="2">Module status (P=C/WP=CE)
WP</td></tr>
<tr><td>1</td><td colspan="4">Module structure:
<table>
<tr><th></th><th>Course</th><th>form of teachin</th><th>contact-time (h)</th><th>self-study (h)</th><th>status (C/CE)</th><th>group size (TN)</th></tr>
<tr><td>a)</td><td>L.048.92008
Digital Image Processing I</td><td>2L
2Ex,
SS</td><td>60</td><td>120</td><td>C</td><td>30/30</td></tr>
</table></td></tr>
<tr><td>2</td><td colspan="4">Options within the module:
None</td></tr>
<tr><td>3</td><td colspan="4">Admission requirements:
None
Prerequisites of course Digital Image Processing I:
None. Basic programming knowledge is an advantage.</td></tr>
</table>

4	**Contents:** *Contents of the course Digital Image Processing I:* **Short Description** This course provides a fundamental introduction to digital image processing. Upon successful completion, students will be able to thoroughly describe the basic concepts of image generation and representation. Additionally, they will acquire the skills to apply methods for enhancing and segmenting grayscale and color images in both the spatial and frequency domains, as well as techniques for image compression. Students will be capable of independently selecting, implementing, testing, and applying these techniques to complex image processing tasks. A typical application area is automation technology. **Contents** 1. Introduction (Graphics File Formats, Application Examples, Human Vision) 2.Image Formation and Image Models (Camera Models, Image Formation, Image Sampling and Quantization) 2. Image Enhancement in the Spatial Domain (Gray-Level Transformation Functions, Histogram Processing, Spatial Filtering) 3. Image Enhancement in the Frequency Domain (2D Fourier Transform, Smoothing and Sharpening Filters, Implementation Details) 4. Color Image Processing (Color Spaces, Color and Pseudo-Color Image Processing, Spatial Filtering) 5. Image Compression and Reduction (Types of Redundancy, Compression Models, Lossless and Lossy Compression)
5	**Learning outcomes and competences:** **Domain competence** The students • are able to describe the basics of image generation and image digitization and • are able to select, implement, test and apply methods for the enhancement of images in the spatial and frequency domain, image segmentation and data reduction independently for complex image processing tasks. **Key qualifications** The students have a good command of programming in Python.
6	**Assessments:** ☒Final module exam (MAP) □Module exam (MP) □Partial module exams (MTP)

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

7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:**

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

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

1 **Module structure:**

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

2 **Options within the module:**

None

3 **Admission requirements:**

None

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

4 **Contents:**

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

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

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

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

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

<table><tr><th>zu</th><th>Type of examination</th><th>Duration or scope</th><th>Weighting for the module grade</th></tr><tr><td>a)</td><td>Written or Oral Examination or Presentation</td><td>120-180 min or 30-45 min or 30 min</td><td>100%</td></tr></table></td></tr>
<tr><td>7</td><td>Study Achievement:

none</td></tr>
<tr><td>8</td><td>Prerequisites for participation in examinations:

None</td></tr>
<tr><td>9</td><td>Prerequisites for assigning credits:

The credit points are awarded after the module examination (MAP) was passed.</td></tr>
<tr><td>10</td><td>Weighing for overall grade:

The module is weighted according to the number of credits (factor 1).</td></tr>
<tr><td>11</td><td>Reuse in degree courses or degree course versions :

Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Computer Engineering v4 (CEMA v4), englisch, Master’s Program Electrical Systems Engineering v2 (ESEMA v2), Master’s Program Electrical Systems Engineering v3 (ESEMA v3)</td></tr>
<tr><td>12</td><td>Module coordinator:

Dr.-Ing. Markus Hennig</td></tr>
</table>

13	**Other Notes:** *Remarks of course Digital Image Processing II:* --- **ATTENTION - IMPORTANT NOTICE** The course doesn't take place in winter term 2026/27 summer term 2026. Please see the notice boards of the group. --- **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

<table>
<tr><th colspan="5">Information Theory</th></tr>
<tr><td colspan="5">Information Theory</td></tr>
<tr><td>Module number:
M.048.24021</td><td>Workload (h):
180</td><td>Credits:
6</td><td colspan="2">Regular Cycle:
module.frequency.en</td></tr>
<tr><td>Language:
en</td><td>Semester number:
2.-4. Semester</td><td>Duration (in sem.):
1</td><td colspan="2">Module status (P=C/WP=CE)
WP</td></tr>
<tr><td>1</td><td colspan="4">Module structure:
<table>
<tr><th></th><th>Course</th><th>form of teachin</th><th>contact-time (h)</th><th>self-study (h)</th><th>status (C/CE)</th><th>group size (TN)</th></tr>
<tr><td>a)</td><td>L.048.24021
Information Theory</td><td>2L
2Ex,
SS</td><td>60</td><td>120</td><td>CE</td><td>30/30</td></tr>
</table></td></tr>
<tr><td>2</td><td colspan="4">Options within the module:
None</td></tr>
<tr><td>3</td><td colspan="4">Admission requirements:
None

Prerequisites of course Information Theory:
**Recommended:*
Prior knowledge from the modules Signal and Information Transmission, and Probability for Engineers.</td></tr>
<tr><td>4</td><td colspan="4">Contents:

Contents of the course Information Theory:
Information theory is the mathematical foundation of modern communication, data compression, and statistical inference. Originally developed by Claude Shannon, information theory quantifies information, uncertainty, and the fundamental limits of data transmission and storage.
This course provides a first rigorous introduction to information theory. Students will learn the core concepts of entropy, mutual information, relative entropy, and typicality, and understand their operational meaning in compression and communication systems. The course covers lossless and lossy source coding, channel capacity, and the fundamental limits of reliable communication over noisy channels. Classical results such as Shannon’s source coding theorem and channel coding theorem are derived from first principles. Strong emphasis will be placed on an intuitive understanding of mathematical concepts and the practical interpretation of these results in the context of real-world systems.
Beyond communication systems, the course highlights connections to machine learning, statistics, signal processing, and networked systems.</td></tr>
</table>

5 **Learning outcomes and competences:**

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

- explain fundamental questions, models, tools, and results of Shannon's information theory;
- apply information-theoretic measures to assess the quality processing blocks of communication systems and explain the operational meaning;
- explain the relationship between abstract communication-theoretic models and realistic physical systems and apply them purposefully in system design;
- understand scientific documents in information theory.

Key qualifications:
The students

- can abstract complex problems and decompose them into solvable subproblems;
- are able to understand and apply mathematics as a universal language for describing the physical world;
- can transfer information-theoretic concepts and results to problems beyond the field of communications engineering.

6 **Assessments:**

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

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

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

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

10 **Weighing for overall grade:**

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

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

BF Informationstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Computer Engineering v4 (CEMA v4), englisch, Masterstudiengang Elektrotechnik v4/v4b (EMA v4/v4b), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4, Master's Program Electrical Systems Engineering v3 (ESEMA v3)

12	**Module coordinator:** Prof. Dr. Bho Matthiesen
13	**Other Notes:** **Module Homepage** `https://www.hni.uni-paderborn.de/en/nt` **Implementation** Lectures and exercises (including some computer simulations) **Teaching Material, Literature** Handouts and tutorial questions; literature references will be given in the first lecture

Nonlinear control of autonomous and robotic systems

Nonlinear control of autonomous and robotic systems

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.92052	180	6	module.frequency.en
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
en	1.-3. Semester	1	WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.92052 Nonlinear control of autonomous and robotic systems	2L 2Ex, SS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Nonlinear control of autonomous and robotic systems:
Recommended:
Prerequisites are a basic understanding of linear algebra, linear system theory, and control theory as they are covered in a typical undergraduate course on control theory.

4 **Contents:**

Contents of the course Nonlinear control of autonomous and robotic systems:
Building on an undergraduate control theory course, this course introduces the analysis and control of nonlinear dynamical systems. The course focuses on fundamental nonlinear control concepts and methods, with particular emphasis on their application to autonomous and robotic systems. It is primarily intended for engineering students but may also be useful to students in physics and other natural sciences.
Contents

- Nonlinear system modeling and state-space representations
- Phase-plane analysis and nonlinear system behavior
- Equilibrium points and local stability analysis
- Lyapunov stability theory
- Feedback linearization and nonlinear controller design
- Nonlinear control applications in autonomous and robotic systems

5 **Learning outcomes and competences:**

-

<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 or degree course versions :
Master’s Program Electrical Systems Engineering v2 (ESEMA v2), Master’s Program Electrical Systems Engineering v3 (ESEMA v3)</td></tr>
<tr><td>12</td><td>Module coordinator:
Prof. Dr. Erdal Kayacan</td></tr>
<tr><td>13</td><td>Other Notes:
Module Homepage
http://sst.upb.de/teaching
Implementation
Lectures and exercises (including some computer simulations)
Teaching Material, Literature
Handouts and tutorial questions; literature references will be given in the first lecture</td></tr>
</table>

Optical Waveguide Theory

Optical Waveguide Theory

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.92038	180	6	module.frequency.en
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
en	1.-3. Semester	1	WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.92038 Optical Waveguide Theory	2L 2Ex, SS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Optical Waveguide Theory:
Recommended: Bachelor-level knowledge in electrodynamics and mathematics as taught in the course Fields&Waves.

4 **Contents:**

Contents of the course Optical Waveguide Theory:
Short Description
Dielectric optical waveguides constitute key-elements of present-day integrated optical / photonic circuits. This course provides an introduction to their theoretical background, and, as such, a sound basis for further, more specific, modelling, simulation, and design work, as well as for experimental activities in the field.
Contents * Photonics / integrated optics, dielectric waveguides: introductory examples, motivation. * Brush up on mathematical tools. * Maxwell equations, survey of different formulations; classes of simulation tasks. * Normal modes of dielectric optical waveguides, orthogonality, completeness, scattering matrices, reciprocal circuits. * Examples for dielectric optical waveguides (multilayer slabs, integrated optical channels, fibers), bent waveguides, whispering gallery resonances. * Coupled mode theory, conventional codirectional, and hybrid analytical / numerical variant, perturbations of optical waveguides. * Optional, brief remarks on: boundary conditions, initial value problems (beam propagation method), waveguide discontinuities (BEP/QUEP simulations), photonic crystal waveguides & fibers, plasmonic waveguides.

5 **Learning outcomes and competences:**

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

- to mathematically model electromagnetic field problems of systems in integrated optics and photonics
- to identify, apply and verify appropriate analytical methods and approximation techniques
- to physically interpret and visualise the obtained results
- to extend, develop and validate theoretical models for integrated optics and photonics

Key qualifications:
The students

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

6 **Assessments:**

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

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

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

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

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

10 **Weighing for overall grade:**

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

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

Master's Program Electrical Systems Engineering v2 (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)

12 **Module coordinator:**

PD 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: M.048.92011	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** module.frequency.en
Language: en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.92011 Optimal and Adaptive Filters	2L 2Ex, WS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Optimal and Adaptive Filters:
Recommended: Prior knowledge from the modules Higher Mathematics and Digital Signal Processing

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

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

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

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

Key qualifications:
The students

• are able to check theoretical results using practical realizations,
• are able to undertake theoretical approaches a systematic analysis using methodical procedures and
• are, due to the precise treatment of the contents, in a position to continue their learning themselves</td></tr>
<tr><td>6</td><td>Assessments:

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

<table><tr><th>zu</th><th>Type of examination</th><th>Duration or scope</th><th>Weighting for the module grade</th></tr><tr><td>a)</td><td>Written or Oral Examination or Presentation</td><td>120-180 min or 30-45 min or 30 min</td><td>100%</td></tr></table>
Within the first three weeks of the lecture period each respective lecturer will specify the manner in which the examination will be conducted.</td></tr>
<tr><td>7</td><td>Study Achievement:

none</td></tr>
<tr><td>8</td><td>Prerequisites for participation in examinations:

None</td></tr>
<tr><td>9</td><td>Prerequisites for assigning credits:

The credit points are awarded after the module examination (MAP) was passed.</td></tr>
<tr><td>10</td><td>Weighing for overall grade:

The module is weighted according to the number of credits (factor 1).</td></tr>
<tr><td>11</td><td>Reuse in degree courses or degree course versions :

Master’s Program Electrical Systems Engineering v2 (ESEMA v2), Master’s Program Electrical Systems Engineering v3 (ESEMA v3)</td></tr>
<tr><td>12</td><td>Module coordinator:

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

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

Optimization-Based Control Methods

Optimization-Based Control Methods

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.92051	180	6	module.frequency.en
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
en	1.-3. Semester	1	WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.92051 Optimization-Based Control Methods	2L 2Ex, WS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Optimization-Based Control Methods:
None

4 **Contents:**

Contents of the course Optimization-Based Control Methods:
The course begins with Bellman's Principle of Optimality and introduces the foundations of Dynamic Programming (DP) techniques for solving optimization problems in finite and infinite time horizons. Based on this framework, students will study Finite and Infinite Horizon Optimal Control Problems, learning how to apply DP to real-world control problems over different time scales. A significant portion of the course is then devoted to linear quadratic regulator (LQR) and linear quadratic estimator (LQE) problems, focusing on designing Optimal State Feedback controllers and estimators for linear systems. The linear quadratic Gaussian (LQG) framework then combines LQR and LQE into a robust framework for Gaussian state and measurement noise. To address optimization problems with state and input constraints, students will be introduced to Quadratic Programming (QP) and the fundamentals of Convex Optimization, which are essential for handling real-world control applications that impose limits on system inputs and states. A section on Model Predictive Control (MPC) will then focus on designing optimal control strategies for constrained linear systems by solving a series of optimization problems in real-time, offering a bridge between theory and industrial applications. The course then covers Approximate Dynamic Programming (ADP) and its connection to MPC, exploring methods to approximate optimal solutions for computationally intractable problems using traditional DP techniques. Lastly, students will use modern methods for designing Convex Optimization Control Policies, learning to create efficient and scalable control solutions using convexity and optimization frameworks. Finally, if time permits, the course will close with a short introduction to Proximal Policy Optimization methods.

<table>
<tr><td>5</td><td>Learning outcomes and 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>a)</td><td>Written or Oral Examination or Presentation</td><td>120-180 min or 30-45 min or 30 min</td><td>100%</td></tr>
</table></td></tr>
<tr><td>7</td><td>Study Achievement:
none</td></tr>
<tr><td>8</td><td>Prerequisites for participation in examinations:
None</td></tr>
<tr><td>9</td><td>Prerequisites for assigning credits:
The credit points are awarded after the module examination (MAP) was passed.</td></tr>
<tr><td>10</td><td>Weighing for overall grade:
The module is weighted according to the number of credits (factor 1).</td></tr>
<tr><td>11</td><td>Reuse in degree courses or degree course versions :
Master’s Program Electrical Systems Engineering v2 (ESEMA v2), Master’s Program Electrical Systems Engineering v3 (ESEMA v3)</td></tr>
<tr><td>12</td><td>Module coordinator:
Dr. Adrian Redder</td></tr>
<tr><td>13</td><td>Other Notes:
Module Homepage
http://sst.upb.de/teaching
Implementation
Lectures and exercises (including some computer simulations)
Teaching Material, Literature
Handouts and tutorial questions; literature references will be given in the first lecture</td></tr>
</table>

Resource-Efficient AI: Architectures and Methodologies			
Resource-Efficient AI: Architectures and Methodologies			
Module number: M.048.92061	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** module.frequency.en
Language: en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.92061 Resource-Efficient AI: Architectures and Methodologies	2L 2Ex, WS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Resource-Efficient AI: Architectures and Methodologies:
None

4 **Contents:**

Contents of the course Resource-Efficient AI: Architectures and Methodologies:
The course introduces methods and architectures for resource-efficient execution of modern artificial intelligence applications under performance, energy, and memory constraints. Topics include:

- Fundamentals of deep learning and training methodologies
- Characteristics of modern AI workloads (e.g., CNNs and transformers)
- Computational, memory, and energy bottlenecks during AI inference
- Techniques for efficient model design and optimization:
  - Quantization
  - Pruning and sparsity
  - Knowledge distillation
  - Efficient neural network architectures (e.g., MobileNet)
- Mapping AI workloads onto hardware platforms
- Architectures for AI acceleration:
  - SIMD and vector architectures
  - GPU architectures
  - Dataflow architectures and systolic arrays
  - Neural Processing Units (NPUs) and domain-specific accelerators
- Hardware-software co-design for efficient AI systems

5 **Learning outcomes and competences:**

After successful completion of the module, students are able to:

- explain fundamental principles of deep learning from a systems perspective,
- analyze AI workloads with respect to computational, memory, and communication requirements,
- identify performance, energy, and memory bottlenecks,
- apply model optimization techniques to improve efficiency,
- map AI workloads onto different hardware platforms and evaluate their suitability,
- compare different architectures for AI acceleration,
- analyze trade-offs between accuracy, latency, throughput, and energy efficiency,
- apply hardware-software co-design methodologies for resource-efficient AI 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)	120-180 min oder 30-45 min oder 30 min	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

none

8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Master's Program Electrical Systems Engineering v2 (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)
12	**Module coordinator:** Prof. Dr.-Ing. Lennart Bamberg
13	**Other Notes:** **Module Homepage** PANDA (more information will be provided in the first lecture) **Implementation** Lectures and exercises (including some computer simulations) **Teaching Material, Literature** Handouts and tutorial questions; literature references will be given in the first lecture

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

1 **Module structure:**

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

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Robotics:
None

4 **Contents:**

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

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

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

5	**Learning outcomes and competences:** **Domain competence:** The students • know how to transfer basic methods from control and system theory to robotics and • are able to apply adequate methods to model as well as plan and control the movements of robot arms. **Key qualifications:** The students are able to identify and evaluate the function and behavior of robots and their integration into the social and economic environment while also considering ethical aspects.
6	**Assessments:** ☒Final module exam (MAP) □Module exam (MP) □Partial module exams (MTP)

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

7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Computer Engineering v4 (CEMA v4), englisch, Master's Program Electrical Systems Engineering v2 (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)
12	**Module coordinator:** Prof. Dr. Bärbel Mertsching

13	**Other Notes:** *Remarks of course Robotics:* --- **ATTENTION - IMPORTANT NOTICE** The course doesn't take place in winter term 2026/27 summer term 2026. Please see the notice boards of the group. --- **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

Theory and Design of Integrated Photonic Devices			
Theory and Design of Integrated Photonic Devices			
Module number: M.048.92062	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** module.frequency.en
Language: en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.92062 Theory and Design of Integrated Photonic Devices	2L 2Ex, WS	60	12	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Theory and Design of Integrated Photonic Devices:
Recommended:
Knowledge on electromagnetic fields and waves Experience with MATLAB/Python scripting would be beneficial

4 **Contents:**

Contents of the course Theory and Design of Integrated Photonic Devices:

- Introduction
  - Historical evolution of integrated photonics and relevance in today's world
  - Brief overview on the required background theory
    - Electromagnetic waves and Maxwell's equations
    - EM waves propagation in different media
- Theory of optical waveguides: Device #0
  - 1-D waveguide analysis
    - Ray optics model
    - Vector wave equation and boundary conditions
  - 2-D waveguide analysis
    - Overview of waveguide platforms and effective index method
    - Overview of the full vectorial method
    - Dispersion, polarization and orthogonality of guided modes
- Coupled-mode theory: analytical formulation
- Passive integrated photonic devices
  - Directional coupler (DC): Device #1
  - Multi-mode interferometers (MMI) : Device #2
  - Distributed Bragg reflector (DBR): Device #3
- Tunable/active integrated photonic devices
  - Mach-Zehnder interferometer (MZI) / modulator (MZM): Device #4
  - Microring resonators (MRR) / modulator (MRM): Device #5
  - Overview of phase shifters: thermal, electro-optic and MEMS-based
- Fabrication variability and tolerances of the integrated photonic devices
- Overview of photonic integrated circuit (PIC) analysis, introduction to compact-modeling and electronic-photonic design automation (EPDA)

5 **Learning outcomes and competences:**

Understanding the working and fundamental theory of integrated photonic devices, constraints involved in the device designs and overcoming strategies.

6 **Assessments:**

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

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

7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Master's Program Electrical Systems Engineering v2 (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)
12	**Module coordinator:** Dr. Ashitosh Velamuri
13	**Other Notes:** **Module Homepage** **Implementation** Lectures and exercises (including some computer simulations) **Teaching Material, Literature** Handouts and tutorial questions; literature references will be given in the first lecture

Theory and Design of Phase-locked Loops

Theory and Design of Phase-locked Loops

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.92056	180	1	module.frequency.en
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
en	1.-3. Semester	1	WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.92056 Theory and Design of Phase-locked Loops	2L 2Ex, WS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Theory and Design of Phase-locked Loops:
Recommended:

- Advanced Signal Theory
- Statistical Signal Processing (or another course with comparable syllabus in their bachelor)
- Circuit and system design (or another course with comparable syllabus in their bachelor)

4 **Contents:**

Contents of the course Theory and Design of Phase-locked Loops:
Chapter 1: Motivation

- Time and frequency definition – definition in SI units – static frequency error
- random fluctuations – Amplitude/Phase (AM/PM) noise

Chapter 2: Mathematical formalism of signals

- baseband and bandpass signals
- time and frequency domain

Chapter 3: introduction to random processes

- baseband random processes and noise – correlation functions in time and frequency domain – some basedband random processes (thermal noise, shot noise, flicker noise . . .)
- bandpass random processes – correlation functions – relation to baseband processes – phase noise and amplitude noise

Chapter 4: PLL building blocks

- Phase detector – Phase detector model – phase noise of phase detector
- VCO – VCO model – phase noise of VCO
- Frequency translators – frequency divider – frequency multiplier – phase noise of frequency translators
- transistor level design of PLL blocks

Chapter 5: Integer N PLLs: – Time domain – frequency domain – phase noise – spurious frequencies
Chapter 6: Fractional PLLs – Time domain – frequency domain – phase noise – spurious frequencies

5 **Learning outcomes and competences:**

Understanding of static/dynamic error in frequency standards. Mathematical modeling of amplitude/phase noise. Modeling random processes in time and frequency domain. Basic and modern PLL architecture and its building blocks. Systematic design of PLLs. Design and Modeling of Integer/Fractional N PLL.

6 **Assessments:**

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

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

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Master's Program Electrical Systems Engineering v2 (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)
12	**Module coordinator:** Dr. Meysam Bahmanian
13	**Other Notes:** **Module Homepage** `https://www.hni.uni-paderborn.de/en/sct/teaching/theory-and-design-of-plls` **Implementation** Lectures and exercises (including some computer simulations) **Teaching Material, Literature** Handouts and tutorial questions; literature references will be given in the first lecture

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

1 **Module structure:**

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

2 **Options within the module:**

None

3 **Admission requirements:**

None

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

4 **Contents:**

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

5 **Learning outcomes and competences:**

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

<table>
<tr><td>6</td><td>Assessments:
☒Final module exam (MAP) □Module exam (MP) □Partial module exams (MTP)
<table>
<tr><th>zu</th><th>Type of examination</th><th>Duration or scope</th><th>Weighting for the module grade</th></tr>
<tr><td>a)</td><td>Written or Oral Examination or Presentation</td><td>120-180 min or 30-45 min or 30 min</td><td>100%</td></tr>
</table></td></tr>
<tr><td>7</td><td>Study Achievement:
none</td></tr>
<tr><td>8</td><td>Prerequisites for participation in examinations:
None</td></tr>
<tr><td>9</td><td>Prerequisites for assigning credits:
The credit points are awarded after the module examination (MAP) was passed.</td></tr>
<tr><td>10</td><td>Weighing for overall grade:
The module is weighted according to the number of credits (factor 1).</td></tr>
<tr><td>11</td><td>Reuse in degree courses or degree course versions :
Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Computer Engineering v4 (CEMA v4), englisch, Masterstudiengang Informatik v3, Masterstudiengang Informatik v4, Master's Program Electrical Systems Engineering v2 (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)</td></tr>
<tr><td>12</td><td>Module coordinator:
Prof. Dr. Peter Schreier</td></tr>
<tr><td>13</td><td>Other Notes:
Remarks of course Topics in Signal Processing:
Course Homepage
http://sst.uni-paderborn.de/teaching/courses/
Implementation
Lectures and tutorials with active student participation, student presentations
Teaching Material, Literature
References will be given in the first lecture.</td></tr>
</table>

Wireless Communications

Wireless Communications

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.92058	180	6	module.frequency.en
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
en	2.-4. Semester	1	WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.92058 Wireless Communications	2L 2Ex, SS	60	120	CE	40

2 **Options within the module:**

None

3 **Admission requirements:**

Prerequisites of course Wireless Communications:
Recommended:
Prior knowledge from the modules Signal and Information Transmission, Signal Theory, and Probability for Engineers.

4 **Contents:**

Contents of the course Wireless Communications:
The course provides students with important basic knowledge necessary for understanding the transmission concepts of modern mobile communication systems. Starting with a physical understanding of the mobile communications channel, in particular the phenomena of multipath propagation and the Doppler effect, the physical and statistical modeling of time-varying communication systems is presented. Subsequently, important diversity techniques for channel-adaptive transmission and multiple access techniques are introduced.

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

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

• understand the fundamental propagation mechanisms in mobile radio channels;
• describe and apply physical and statistical modeling principles to time-varying communication channels;
• analyze fading processes and asses their impact on transmission reliability;
• explain diversity techniques, apply them to design physical layer signal processing algorithms, and assess their impact on transmission reliability;
• explain, compare, and evaluate common multiple access schemes;
• assess transmission concepts employed in contemporary mobile communication systems;
• connect theoretical channel models with practical system design considerations.

Key qualifications:
The students

• have strong analytical and mathematical reasoning skills;
• have the ability to abstract complex physical phenomena into engineering models;
• can interpret analytical results at the system level;
• have experience in clear and precise technical communication (oral and written)
• can learn independently and engage critically with technical literature.</td></tr>
<tr><td>6</td><td>Assessments:

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

<table><tr><th>zu</th><th>Type of examination</th><th>Duration or scope</th><th>Weighting for the module grade</th></tr><tr><td>a)</td><td>Written or Oral Examination or Presentation</td><td>120-180 min or 30-45 min or 30 min</td><td>100%</td></tr></table></td></tr>
<tr><td>7</td><td>Study Achievement:

none</td></tr>
<tr><td>8</td><td>Prerequisites for participation in examinations:

None</td></tr>
<tr><td>9</td><td>Prerequisites for assigning credits:

The credit points are awarded after the module examination (MAP) was passed.</td></tr>
<tr><td>10</td><td>Weighing for overall grade:

The module is weighted according to the number of credits (factor 1).</td></tr>
<tr><td>11</td><td>Reuse in degree courses or degree course versions :

Master’s Program Electrical Systems Engineering v2 (ESEMA v2), Master’s Program Electrical Systems Engineering v3 (ESEMA v3)</td></tr>
<tr><td>12</td><td>Module coordinator:

Prof. Dr. Bho Matthiesen</td></tr>
</table>

13	**Other Notes:** **Module Homepage** `https://www.hni.uni-paderborn.de/en/nt` **Implementation** Lectures and exercises **Teaching Material, Literature** Lecture slides and reading assignments for each lecture; additional reading suggestions.

2.5 Specialization-Specific: Electronics and Devices

2.5.1 Module Group: Introduction to Electronics and Devices

Electromagnetic Waves and Waveguides

Electromagnetic Waves and Waveguides

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.90105	270	9	module.frequency.en
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
en	2. Semester	1	P

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.90105 Electromagnetic Waves and Waveguides	2L 2Ex, SS	60	120	C	100/30
b)	L.048.90106 Electromagnetic Waves and Waveguides - Practical Exercise	2Ex, SS	30	60	C	100/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Electromagnetic Waves and Waveguides:
None

Prerequisites of course Electromagnetic Waves and Waveguides - Practical Exercise:
None

4 **Contents:**

Contents of the course Electromagnetic Waves and Waveguides:
Contents

- Recapitulation of Basics: Maxwell's equations, constitutive relations, continuity conditions,
- Fundamentals: frequency domain, linear material models, Kramers-Kronig relation, Poynting theorem
- the wave equation and its solutions: plane waves, optical polarization, attenuation, standing waves,
- dispersion: phase and group velocity, group velocity dispersion,
- interfaces: Fresnel formulas for normal and oblique incidence, Snell's law, transfer matrix method,
- waveguides: Mode classification, hollow waveguides (rectangular and axialsymmetric), dielectric planar dielectric waveguides and optical fibers, attenuation in waveguides, transmission line theory, S-parameters,
- resonators: hollow core resonators, losses in resonators, dielectric resonators
- radiation of waves: far-field approximation, dipole and linear antennas, antenna characteristics, phased antenna arrays

Contents of the course Electromagnetic Waves and Waveguides - Practical Exercise:
Application of the concepts taught in the course on a concrete classification or regression task and discussion and evaluation of the achieved results.

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) - b)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

<table>
<tr><td>7</td><td>Study Achievement:
<table>
<tr><th>zu</th><th>Type of achievement</th><th>Duration or Scope</th><th>SL / QT</th></tr>
<tr><td>a)</td><td></td><td></td><td></td></tr>
<tr><td>b)</td><td>Short Written Examination</td><td>two each</td><td>QP</td></tr>
</table></td></tr>
<tr><td>8</td><td>Prerequisites for participation in examinations:
None</td></tr>
<tr><td>9</td><td>Prerequisites for assigning credits:
The credit points are awarded after the module examination (MAP) was passed and the qualified participation of Ëlectromagnetic Waves and Waveguides - Practical Excercise"was determined.</td></tr>
<tr><td>10</td><td>Weighing for overall grade:
The module is weighted according to the number of credits (factor 1).</td></tr>
<tr><td>11</td><td>Reuse in degree courses or degree course versions :
Master’s Program Electrical Systems Engineering v3 (ESEMA v3)</td></tr>
<tr><td>12</td><td>Module coordinator:
Prof. Dr. Jens Förstner</td></tr>
<tr><td>13</td><td>Other Notes:
Remarks of course Electromagnetic Waves and Waveguides:
Course Homepage
<tt>http://tet.upb.de</tt>
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.</td></tr>
</table>

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

1 **Module structure:**

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

2 **Options within the module:**

None

3 **Admission requirements:**

None

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

4 **Contents:**

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

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

5 **Learning outcomes and competences:**

Domain competence:
The students will be able to

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

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

6 **Assessments:**

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

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

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

2.5.2 Module Group: Electronics and Devices

Module Group	Electronics and Devices
Modules	* Advanced Quantum Optics
	* Advanced VLSI Design
	* Analog CMOS ICs
	* Controlled AC Drives
	* Design of Energy Transition Scenarios
	* Design of Integrated Energy Systems
	* Energy Transition
	* Fast Integrated Circuits for Wireline Communications
	* Fundamentals of Optics
	* Integrated Circuits for Wireless Communications
	* Modern Semiconductor Lasers
	* Nonlinear control of autonomous and robotic systems
	* Optical Communication A
	* Optical Communication B
	* Optical Communication C
	* Optical Communication D
	* Optical Waveguide Theory
	* Optimization-Based Control Methods
	* Optoelectronics
	* Power Electronics
	* Solar Electric Energy Systems
	* Theory and Design of Integrated Photonic Devices
	* VLSI Testing
Module group advisor	Head of Examination Board ESE (PAV ESE)
Credits ECTS	6
Type of examination	Written or Oral Examination or Presentation
Duration or Scope	120-180 min or 30-45 min or 30 min

Teaching objectives	The students select two modules according to their interests in the chosen specialization to acquire expertise in certain topics.

Advanced Quantum Optics

Advanced Quantum Optics

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.92054	180	6	module.frequency.en
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
en	1.-3. Semester	1	WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.92054 Advanced Quantum Optics	2L 2Ex, WS/SS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Advanced Quantum Optics:
Recommended:
It is strongly advised that the participants should have already passed a more introductory lecture such as “Theoretical Quantum Optics”, “Quantum Optics”, or any similar lectures on basic concepts in quantum optics. Hence, participants should already be generally familiar with concepts such as field quantization, properties of nonclassical states of light such as Fock states and coherent states, quantum theory of light-matter interaction and Jaynes-Cummings model.

4 **Contents:**

- Introducing density operators and quantum operations (Krauss maps)
- Derivation of Lindblad master equation from both a phenomenological approach and a derivation from first principles. Introducing Jump operators.
- Addressing various examples of an open quantum system involving a 2-level system and/or a lossy optical cavity.
- Introducing the physics and the mathematical methods for phase-space treatments in quantum optics, such as operator spaces and expansions in operator basis.
- Introducing various quasi-probability distributions (including the Wigner function) and investigating the fundamental relations between them, including specific examples for some basic states.
- Introducing general measurements.

Contents of the course Advanced Quantum Optics:

- Introducing density operators and quantum operations (Krauss maps)
- Derivation of Lindblad master equation from both a phenomenological approach and a derivation from first principles. Introducing Jump operators.
- Addressing various examples of an open quantum system involving a 2-level system and/or a lossy optical cavity.
- Introducing the physics and the mathematical methods for phase-space treatments in quantum optics, such as operator spaces and expansions in operator basis.
- Introducing various quasi-probability distributions (including the Wigner function) and investigating the fundamental relations between them, including specific examples for some basic states.
- Introducing general measurements.

5 **Learning outcomes and competences:**

After attending the lectures and the associated exercise sessions, the students will:

- Be able to mathematically model quantum optics problems in open quantum systems
- Gain a basic yet fundamental understanding of phase-space methods in quantum optics
- Be able to identify the appropriate methods and approximations to solve quantum optics problems in open quantum systems

6 **Assessments:**

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

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

7 **Study Achievement:**

none

8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Master's Program Electrical Systems Engineering v2 (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)
12	**Module coordinator:** Prof. Dr. Sina Saravi
13	**Other Notes:** **Module Homepage** Not yet available **Implementation** The theoretical concepts will be taught in a lecture format. The exercises consist of theoretical problems related to the concepts from the lecture, to be solved mathematically by the students, and later on the solutions will be presented in the exercise sessions. **Teaching Material, Literature** Lecture notes will be handed out; literature recommendations will be given in the first lecture.

Advanced VLSI Design

Advanced VLSI Design

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

1 **Module structure:**

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

2 **Options within the module:**

None

3 **Admission requirements:**

None

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

4 **Contents:**

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

5 **Learning outcomes and competences:**

Domain competence:
After the course students are able

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

Key qualifications:
After the course students are able

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

6 **Assessments:**

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

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

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

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

10 **Weighing for overall grade:**

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

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

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

12 **Module coordinator:**

apl. Prof. Dr. Wolfgang Mueller

13	**Other Notes:** *Remarks of course Advanced VLSI Design:* **Course Homepage** `www.hni.uni-paderborn.de/en/system-and-circuit-technology/teaching/advanced-vlsi-design` **Implementation** * Vorlesung mit Beamer und White-Board * Übungen mit Übungsblättern am Computer * Lecture with LCD projector and white board * Exercises with assignments and hands-on labs **Teaching Material, Literature** • Lecture notes and exercise sheets will be provided via PAUL • IEEE standard reference manuals: IEEE Std 1800/1685/1666/1364/1076/1801/1497 • Specific references for individual teaching units

Analog CMOS ICs			
Analog CMOS ICs			
Module number: M.048.92015	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** module.frequency.en
Language: en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.92015 Analog CMOS ICs	2L 2Ex, SS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Analog CMOS ICs:
Recommended: Prior knowledge from the modules Higher Mathematics, Physics, and the Foundations of Electrical Engineering, Materials of Electrical Engineering, Semiconductor Devices, Signal Theory, System Theory.

4 **Contents:**

Contents of the course 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.

5 **Learning outcomes and competences:**

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

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

Key qualifications:
The students

- make use of methodic knowledge for systematic problem analysis,
- consolidate their basic knowledge by practical training,
- enhance their creative abilities,
- and gain foreign language competences related to the field.

6 **Assessments:**

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

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

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

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

10 **Weighing for overall grade:**

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

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

Master's Program Electrical Systems Engineering v2 (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)

12 **Module coordinator:**

Prof. Dr. Andreas Thiede

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

Control of Electric Drives			
Control of Electric Drives			
Module number: M.048.92016	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** module.frequency.en
Language: en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** P

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.92016 Control of Electric Drives	2L 2Ex, SS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Control of Electric Drives:
Recommended:

- basics of control theory
- basics of electrical machines
- basics of power electronics

4 **Contents:**

Contents of the course Control of Electric Drives:
Short Description
The course teaches the closed-loop control for electrical machines (DC machines, synchronous machines, and induction machines). The presented content is tested in simulations within the exercises.
Contents

- machine models (dc machines, synchronous machines, and induction machines)
- coordinate transformations
- field-oriented control for particular machines
- observers
- advanced control techniques (direct torque control, model-predictive control)

<table>
<tr><td>5</td><td>Learning outcomes and competences:
After successfully completing the module, students will be able to
• explain the functionality of electric drives (based on dc machines, synchronous machines, and induction machines)
• set up a simulation model for the target application
• design a suitable control system for the particular electric machines and implement it as a simulation model</td></tr>
<tr><td>6</td><td>Assessments:
☒Final module exam (MAP) □Module exam (MP) □Partial module exams (MTP)
<table>
<tr><th>zu</th><th>Type of examination</th><th>Duration or scope</th><th>Weighting for the module grade</th></tr>
<tr><td>a)</td><td>Written or Oral Examination or Presentation</td><td>120-180 min or 30-45 min or 30 min</td><td>100%</td></tr>
</table></td></tr>
<tr><td>7</td><td>Study Achievement:
none</td></tr>
<tr><td>8</td><td>Prerequisites for participation in examinations:
None</td></tr>
<tr><td>9</td><td>Prerequisites for assigning credits:
The credit points are awarded after the module examination (MAP) was passed.</td></tr>
<tr><td>10</td><td>Weighing for overall grade:
The module is weighted according to the number of credits (factor 1).</td></tr>
<tr><td>11</td><td>Reuse in degree courses or degree course versions :
Master’s Program Electrical Systems Engineering v2 (ESEMA v2), Master’s Program Electrical Systems Engineering v3 (ESEMA v3)</td></tr>
<tr><td>12</td><td>Module coordinator:
Prof. Dr.-Ing. Jakub Kucka</td></tr>
<tr><td>13</td><td>Other Notes:
Remarks of course Control of Electric Drives:
Implementation
Parts of the course are organized as computer-based simulation exercises.
Teaching Material
Lecture slides.</td></tr>
</table>

Design of Integrated Energy Systems			
Design of Integrated Energy Systems			
Module number: M.048.92059	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** module.frequency.en
Language: en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.92059 Design of Integrated Energy Systems	2L 2Ex, WS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Design of Integrated Energy Systems:
None

4 **Contents:**

Contents of the course Design of Integrated Energy Systems:
An integrated energy system involves a holistic approach to thermal, electrical and chemical energy systems, as well as the associated provision of useful energy, energy distribution and an understanding of energy demand. This course covers the fundamentals of integrated energy systems. Building on descriptions of the key individual components, the course analyses in particular how they interact to meet energy demand. Accordingly, aspects of sector coupling as well as storage technologies are introduced as components of energy systems. In addition to the technical description and design of energy systems, ecological and economic aspects are also presented for the holistic assessment of energy systems. Using these fundamentals, integrated energy systems are then calculated and designed in increasingly complex examples.

5 **Learning outcomes and competences:**

The module provides the technical background of integrated, sustainable energy systems. Students know the structure and functions of individual energy systems (electricity grid, gas grid, heating grids, mobility, etc.) as well as the principles of sector coupling. Furthermore, the participants are able to evaluate energy systems with methods of economic and ecological balancing. In addition to the technical content, the focus of this course is on encouraging critical discussion of scientific texts and studies. The module requires the active participation of students.

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

Energy Transition			
Energy Transition			
Module number: M.048.92034	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** module.frequency.en
Language: en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.92034 Energy Transition	2L 2Ex, WS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Energy Transition:
None

4 **Contents:**

Contents of the course Energy Transition:
Short Description
With 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 or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Master's Program Electrical Systems Engineering v2 (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)
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))

Fast Integrated Circuits for Wireline Communications

Fast Integrated Circuits for Wireline Communications

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.90704	180	6	module.frequency.en
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
en	1.-3. Semester	1	WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.90704 Fast Integrated Circuits for Wireline Communications	2L 2Ex, WS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Fast Integrated Circuits for Wireline Communications:
Recommended: Module “Schaltungstechnik” of the Bachelor Electrical Engineering or module “Circuit and System Design” of the Master “Electrical Systems Engineering” or comparable modules / lectures

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

<table>
<tr><td>6</td><td>Assessments:
☒Final module exam (MAP) □Module exam (MP) □Partial module exams (MTP)
<table>
<tr><th>zu</th><th>Type of examination</th><th>Duration or scope</th><th>Weighting for the module grade</th></tr>
<tr><td>a)</td><td>Written or Oral Examination or Presentation</td><td>120-180 min or 30-45 min or 30 min</td><td>100%</td></tr>
</table></td></tr>
<tr><td>7</td><td>Study Achievement:
none</td></tr>
<tr><td>8</td><td>Prerequisites for participation in examinations:
None</td></tr>
<tr><td>9</td><td>Prerequisites for assigning credits:
The credit points are awarded after the module examination (MAP) was passed.</td></tr>
<tr><td>10</td><td>Weighing for overall grade:
The module is weighted according to the number of credits (factor 1).</td></tr>
<tr><td>11</td><td>Reuse in degree courses or degree course versions :
Master’s Program Electrical Systems Engineering v2 (ESEMA v2), Master’s Program Electrical Systems Engineering v3 (ESEMA v3)</td></tr>
<tr><td>12</td><td>Module coordinator:
Prof. Dr.-Ing. J. Christoph Scheytt</td></tr>
<tr><td>13</td><td>Other Notes:
Remarks of course Fast Integrated Circuits for Wireline Communications:
Course Homepage
https://www.hni.uni-paderborn.de/en/system-and-circuit-technology/teaching/fast-integrated-circuits-for-wireline-communications/
Implementation
Lecture with Exercises (including computer-aided design using electronic design software)
Teaching Material, Literature
Handouts and literature references will be given in the lecture.
• E. Säckinger, “Broadband Circuits for Optical Fiber Communication”, Wiley, 2005
• B. Razavi, “Design of Integrated Circuits for Optical Communications”, McGraw-Hill, 2003
Comments
As part of the lecture a 2-day excursion to IHP Leibnizinstitute for High-Performance Microelectronics in Frankfurt (Oder) is offered which includes the visit of a modern chip fabrication facility (participation in the excursion is voluntary).</td></tr>
</table>

Fundamentals of Optics			
Fundamentals of Optics			
Module number: M.048.92053	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** module.frequency.en
Language: en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.92053 Fundamentals of Optics	2L 2Ex, WS/SS	60	120	CP	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Fundamentals of Optics:
Recommended:
It is strongly advised that the participants should have already passed a more introductory lecture such as “Fields and Waves”, “Electromagnetic Waves and Waveguides”, or any similar lectures on basic concepts in electromagnetic field propagation. Hence, participants should already be generally familiar with concepts such as Maxwell’s equations, constitutive relations, wave equation and plane-wave solutions to it, and Poynting vector.

4 **Contents:**

Contents of the course Fundamentals of Optics:

- Diffraction theory (describing beam propagation in homogenous media, considering different approximation regimes, e.g. Fresnel regime and Fraunhofer regime).
- Gaussian beams (including propagation of Gaussian beams and Gaussian beams in a resonator).
- Pulse propagation in dispersive homogenous media (considering effects like chirp and also specific case of a Gaussian pulse).
- Fourier optics (studying the transfer function of a thin lens, 2f setups and 4f setups for optical filtering).
- Optics in anisotropic media (studying the index ellipsoid and the normal modes of anisotropic crystals).

5	**Learning outcomes and competences:** After attending the lectures and the associated exercise sessions, the students will: • Be able to mathematically model problems in spatial and temporal propagation of electromagnetic/optical field in homogenous media • Gain physical intuition about the electromagnetic/optical beam and pulse propagation • Be able to identify the appropriate methods and approximations to solve field propagation problems
6	**Assessments:** ☒Final module exam (MAP) □Module exam (MP) □Partial module exams (MTP)

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

7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Master's Program Electrical Systems Engineering v2 (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)
12	**Module coordinator:** Prof. Dr. Sina Saravi
13	**Other Notes:** **Module Homepage** Not yet available **Implementation** The theoretical concepts will be taught in a lecture format. The exercises consist of theoretical problems related to the concepts from the lecture, to be solved mathematically by the students, and later on the solutions will be presented in the exercise sessions. **Teaching Material, Literature** Lecture notes will be handed out; literature recommendations will be given in the first lecture.

Integrated Circuits for Wireless Communication			
Integrated Circuits for Wireless Communication			
Module number: M.048.92028	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** module.frequency.en
Language: de / en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.92028 Integrated Circuits for Wireless Communication	2L 2Ex, SS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Integrated Circuits for Wireless Communication:
Recommended: Lecture Schaltungstechnik rsp. Circuit and System Design. Helpful supplement: Lecture “Wireless Communications” by Prof. Hab-Umbach.

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)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Master's Program Electrical Systems Engineering v2 (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA 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

Modern Semiconductor Lasers			
Modern Semiconductor Lasers			
Module number: M.048.92060	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** module.frequency.en
Language: en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.92060 Modern Semiconductor Lasers	2L 2Ex, WS	60	120	C	40/40

2 **Options within the module:**

Nein

3 **Admission requirements:**

Nein

Prerequisites of course Modern Semiconductor Lasers:
Recommended:
The familiarity with basic concepts from optics, quantum mechanics and semiconductor physics is highly recommended.

4 **Contents:**

Contents of the course Modern Semiconductor Lasers:
Semiconductor lasers are the key light sources of modern photonics, enabling applications ranging from optical communications and sensing to quantum technologies. While reviewing the fundamental principles of semiconductor laser operation, this course focuses on recent advances and emerging directions that are reshaping the field. Participants will explore novel laser concepts based on photonic crystals, nanophotonics, spintronics, topology, and non-Hermitian physics, as well as the theoretical frameworks required to describe these devices beyond conventional laser theory.
Topics covered include:

- Fundamentals of semiconductor laser operation: gain media, laser dynamics, modulation response, and linewidth
- State-of-the-art semiconductor laser technologies and their performance limits
- Photonic-crystal surface-emitting lasers (PCSELs) and scalable single-mode high-power emission
- Nanolasers, cavity quantum electrodynamics, and thresholdless lasing
- Spin lasers and new approaches to ultrafast information encoding
- Bound-state-in-continuum (BIC) lasers and topological lasers
- Emerging concepts including supersymmetric, PT-symmetric, Dirac, polaritonic, and plasmonic lasers
- Advanced theoretical topics: non-Hermitian effects, quantum noise, complex gain media, and modern computational approaches for large-scale laser systems

5 **Learning outcomes and competences:**

Upon successful completion of this course, participants will be able to explain the physical principles governing semiconductor laser operation, including optical gain, laser dynamics, modulation response, and origin of linewidth. They will be able to analyze and compare established semiconductor laser technologies and evaluate their performance limitations. Furthermore, participants will develop a critical understanding of emerging laser concepts, including photonic-crystal, nano-, spin-, BIC, and topological lasers, and will be able to relate their operation to contemporary concepts in photonics such as cavity quantum electrodynamics, non-Hermitian physics, and topology. Finally, participants will gain familiarity with advanced theoretical and computational approaches used to describe modern semiconductor lasers and will be able to assess current research literature in this rapidly evolving field.

6 **Assessments:**

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

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

7 **Study Achievement:**

none

8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Master's Program Electrical Systems Engineering v2 (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)
12	**Module coordinator:** Dr. Mariusz Drong
13	**Other Notes:** **Module Homepage** `https://panda.uni-paderborn.de/` **Implementation** Lectures and exercises **Teaching Material, Literature** Handouts and tutorial questions; literature references will be given in the first lecture

Nonlinear control of autonomous and robotic systems			
Nonlinear control of autonomous and robotic systems			
Module number: M.048.92052	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** module.frequency.en
Language: en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.92052 Nonlinear control of autonomous and robotic systems	2L 2Ex, SS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Nonlinear control of autonomous and robotic systems:
Recommended:
Prerequisites are a basic understanding of linear algebra, linear system theory, and control theory as they are covered in a typical undergraduate course on control theory.

4 **Contents:**

Contents of the course Nonlinear control of autonomous and robotic systems:
Building on an undergraduate control theory course, this course introduces the analysis and control of nonlinear dynamical systems. The course focuses on fundamental nonlinear control concepts and methods, with particular emphasis on their application to autonomous and robotic systems. It is primarily intended for engineering students but may also be useful to students in physics and other natural sciences.
Contents

- Nonlinear system modeling and state-space representations
- Phase-plane analysis and nonlinear system behavior
- Equilibrium points and local stability analysis
- Lyapunov stability theory
- Feedback linearization and nonlinear controller design
- Nonlinear control applications in autonomous and robotic systems

5 **Learning outcomes and competences:**

-

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

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

1 **Module structure:**

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

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Optical Communication A:
None

4 **Contents:**

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

5	**Learning outcomes and competences:** **Professional Competence** After attending the course, the students will be able, in the taught subjects, to • describe, model and apply the function of components, systems and effects of optical communications and • apply knowledge of optoelectronics **(Soft) Skills** The students • are able to apply the knowledge and skills to a wide range of disciplines, • are able to make use of a methodical procedure when undertaking systematic analysis and • are, due to the abstract and precise treatment of the contents, in a position to continue and develop their learning themselves
6	**Assessments:** ☒Final module exam (MAP) □Module exam (MP) □Partial module exams (MTP)

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

7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Computer Engineering v4 (CEMA v4), englisch, Master's Program Electrical Systems Engineering v2 (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)
12	**Module coordinator:** Prof. Dr. Reinhold Noé

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

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

1 **Module structure:**

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

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Optical Communication B:
None

4 **Contents:**

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

5	**Learning outcomes and competences:** **Professional Competence** After attending the course, the students will be able, in the taught subjects, to • describe, model and apply the function of components, systems and effects of optical communications and • apply knowledge of optoelectronics **(Soft) Skills** The students • are able to apply the knowledge and skills to a wide range of disciplines, • are able to make use of a methodical procedure when undertaking systematic analysis and • are, due to the abstract and precise treatment of the contents, in a position to continue and develop their learning themselves
6	**Assessments:** ☒Final module exam (MAP) □Module exam (MP) □Partial module exams (MTP)

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

7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Computer Engineering v4 (CEMA v4), englisch, Master's Program Electrical Systems Engineering v2 (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)
12	**Module coordinator:** Prof. Dr. Reinhold Noé

13	**Other Notes:** *Remarks of course Optical Communication B:* --- **ATTENTION - IMPORTANT NOTICE** The course doesn't take place in winter term 2026/27 summer term 2026. Please see the notice boards of the group. --- **Course Homepage** `http://ont.upb.de` **Teaching Material, Literature** Scripts, exercise sheets and advanced literature (excerpt): • Noe, Essentials of Modern Optical Fiber Communication, Springer, 2. Auflage / 2nd Edition, 2016, ISBN 978-3-662-49621-3, ISBN ISBN 978-3-662-49623-7 • Petermann/Voges, Optische Kommunikationstechnik, Springer-Verlag (modernes Nachschlagewerk) 2002 • D. As, Univ. Paderborn, Vorlesung Optoelektronik • W. Sohler, Univ. Paderborn, Vorlesung Integrierte Optik • G. Grau, W. Freude, Optische Nachrichtentechnik, Springer-Verlag, Heidelberg, 1991, (umfassend, viele Zwischenschritte fehlen) • K.J. Ebeling, Integrierte Optoelektronik, Springer-Verlag, Heidelberg, 1992 • H.-G. Unger, Optische Nachrichtentechnik, Teile I und II, Hüthig-Verlag Heidelberg, 1984 und 1985, (Schwerpunkt optische Wellenleiter) • Yariv, Optical Electronics, Holt, 1984 (und weitere Werke, sehr physikalisch, kaum Nachrichtentechnik) • R. Th. Kersten, Einführung in die Optische Nachrichtentechnik, Springer-Verlag

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

1 **Module structure:**

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

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Optical Communication C:
None

4 **Contents:**

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

5	**Learning outcomes and competences:** **Professional Competence** After attending the course, the students will be able, in the taught subjects, to • describe, model and apply the function of components, systems and effects of optical communications and • apply knowledge of optoelectronics **(Soft) Skills** The students • are able to apply the knowledge and skills to a wide range of disciplines, • are able to make use of a methodical procedure when undertaking systematic analysis and • are, due to the abstract and precise treatment of the contents, in a position to continue and develop their learning themselves
6	**Assessments:** ☒Final module exam (MAP) □Module exam (MP) □Partial module exams (MTP)

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

7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Computer Engineering v4 (CEMA v4), englisch, Master's Program Electrical Systems Engineering v2 (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)
12	**Module coordinator:** Prof. Dr. Reinhold Noé

13	**Other Notes:** *Remarks of course Optical Communication C:* **ATTENTION - IMPORTANT NOTICE** The course doesn't take place in winter term 2026/27 summer term 2026. Please see the notice boards of the group. **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:** module.frequency.en
Language: en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.92022 Optical Communication D	2L 2Ex, SS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Optical Communication D:
None

4 **Contents:**

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

5	**Learning outcomes and competences:** **Professional Competence** After attending the course, the students will be able, in the taught subjects, to • describe, model and apply the function of components, systems and effects of optical communications and • apply knowledge of optoelectronics **(Soft) Skills** The students • are able to apply the knowledge and skills to a wide range of disciplines, • are able to make use of a methodical procedure when undertaking systematic analysis and • are, due to the abstract and precise treatment of the contents, in a position to continue and develop their learning themselves
6	**Assessments:** ☒Final module exam (MAP) □Module exam (MP) □Partial module exams (MTP)

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

7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Computer Engineering v4 (CEMA v4), englisch, Master's Program Electrical Systems Engineering v2 (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)
12	**Module coordinator:** Prof. Dr. Reinhold Noé

13	**Other Notes:** *Remarks of course Optical Communication 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: M.048.92038	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** module.frequency.en
Language: en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.92038 Optical Waveguide Theory	2L 2Ex, SS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Optical Waveguide Theory:
Recommended: Bachelor-level knowledge in electrodynamics and mathematics as taught in the course Fields&Waves.

4 **Contents:**

Contents of the course Optical Waveguide Theory:
Short Description
Dielectric optical waveguides constitute key-elements of present-day integrated optical / photonic circuits. This course provides an introduction to their theoretical background, and, as such, a sound basis for further, more specific, modelling, simulation, and design work, as well as for experimental activities in the field.
Contents * Photonics / integrated optics, dielectric waveguides: introductory examples, motivation. * Brush up on mathematical tools. * Maxwell equations, survey of different formulations; classes of simulation tasks. * Normal modes of dielectric optical waveguides, orthogonality, completeness, scattering matrices, reciprocal circuits. * Examples for dielectric optical waveguides (multilayer slabs, integrated optical channels, fibers), bent waveguides, whispering gallery resonances. * Coupled mode theory, conventional codirectional, and hybrid analytical / numerical variant, perturbations of optical waveguides. * Optional, brief remarks on: boundary conditions, initial value problems (beam propagation method), waveguide discontinuities (BEP/QUEP simulations), photonic crystal waveguides & fibers, plasmonic waveguides.

5 **Learning outcomes and competences:**

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

- to mathematically model electromagnetic field problems of systems in integrated optics and photonics
- to identify, apply and verify appropriate analytical methods and approximation techniques
- to physically interpret and visualise the obtained results
- to extend, develop and validate theoretical models for integrated optics and photonics

Key qualifications:
The students

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

6 **Assessments:**

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

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

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

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

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

10 **Weighing for overall grade:**

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

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

Master's Program Electrical Systems Engineering v2 (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)

12 **Module coordinator:**

PD 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.

Optimization-Based Control Methods

Optimization-Based Control Methods

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.92051	180	6	module.frequency.en
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
en	1.-3. Semester	1	WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.92051 Optimization-Based Control Methods	2L 2Ex, WS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Optimization-Based Control Methods:
None

4 **Contents:**

Contents of the course Optimization-Based Control Methods:
The course begins with Bellman's Principle of Optimality and introduces the foundations of Dynamic Programming (DP) techniques for solving optimization problems in finite and infinite time horizons. Based on this framework, students will study Finite and Infinite Horizon Optimal Control Problems, learning how to apply DP to real-world control problems over different time scales. A significant portion of the course is then devoted to linear quadratic regulator (LQR) and linear quadratic estimator (LQE) problems, focusing on designing Optimal State Feedback controllers and estimators for linear systems. The linear quadratic Gaussian (LQG) framework then combines LQR and LQE into a robust framework for Gaussian state and measurement noise. To address optimization problems with state and input constraints, students will be introduced to Quadratic Programming (QP) and the fundamentals of Convex Optimization, which are essential for handling real-world control applications that impose limits on system inputs and states. A section on Model Predictive Control (MPC) will then focus on designing optimal control strategies for constrained linear systems by solving a series of optimization problems in real-time, offering a bridge between theory and industrial applications. The course then covers Approximate Dynamic Programming (ADP) and its connection to MPC, exploring methods to approximate optimal solutions for computationally intractable problems using traditional DP techniques. Lastly, students will use modern methods for designing Convex Optimization Control Policies, learning to create efficient and scalable control solutions using convexity and optimization frameworks. Finally, if time permits, the course will close with a short introduction to Proximal Policy Optimization methods.

<table>
<tr><td>5</td><td>Learning outcomes and 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>a)</td><td>Written or Oral Examination or Presentation</td><td>120-180 min or 30-45 min or 30 min</td><td>100%</td></tr>
</table></td></tr>
<tr><td>7</td><td>Study Achievement:
none</td></tr>
<tr><td>8</td><td>Prerequisites for participation in examinations:
None</td></tr>
<tr><td>9</td><td>Prerequisites for assigning credits:
The credit points are awarded after the module examination (MAP) was passed.</td></tr>
<tr><td>10</td><td>Weighing for overall grade:
The module is weighted according to the number of credits (factor 1).</td></tr>
<tr><td>11</td><td>Reuse in degree courses or degree course versions :
Master’s Program Electrical Systems Engineering v2 (ESEMA v2), Master’s Program Electrical Systems Engineering v3 (ESEMA v3)</td></tr>
<tr><td>12</td><td>Module coordinator:
Dr. Adrian Redder</td></tr>
<tr><td>13</td><td>Other Notes:
Module Homepage
http://sst.upb.de/teaching
Implementation
Lectures and exercises (including some computer simulations)
Teaching Material, Literature
Handouts and tutorial questions; literature references will be given in the first lecture</td></tr>
</table>

Optoelectronics			
Optoelectronics			
Module number: M.048.92055	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** module.frequency.en
Language: en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.92055 Optoelectronics	2L 2Ex, SS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Optoelectronics:
None

4 **Contents:**

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

5 **Learning outcomes and competences:**

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

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

** Key qualifications:**
The students

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

6 **Assessments:**

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

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

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

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

10 **Weighing for overall grade:**

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

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

Master's Program Electrical Systems Engineering v2 (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)

12 **Module coordinator:**

Prof. Dr.-Ing. Nils Christopher Gerhardt

13	**Other Notes:** **Course Homepage** [https://ei.uni-paderborn.de/hob/lehre] **Module Homepage** to be announced at the start of the lecture **Implementation** Lectures and exercises (including some computer simulations) **Teaching Material, Literature** Lecture notes and handouts for the tutorial; literature references will be given in the first lecture

Power Electronics			
Power Electronics			
Module number: M.048.92023	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** module.frequency.en
Language: en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.92023 Power Electronics	2L 2Ex, WS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Power Electronics:
None

4 **Contents:**

Contents of the course Power Electronics:
Short Description
This course introduces the topic of power electronics. It explains different converter topologies, their building blocks, functionality, and modulation techniques to operate these converters.
Contents

- ideal switches and non-ideal semiconductor switches
- dc-dc converters
- dc-ac converters
- pulse-width modulation and other modulation techniques
- rectifiers

5 **Learning outcomes and competences:**

After successfully completing the module, students will be able to

- explain the base principles of power electronics
- explain the functionality of different converter topologies
- draw the typical waveforms of currents and voltages for the different converters, and do basic sizing calculations
- create a simple simulation model to test the converter

<table>
<tr><td>6</td><td>Assessments:
☒Final module exam (MAP) □Module exam (MP) □Partial module exams (MTP)<table><tr><th>zu</th><th>Type of examination</th><th>Duration or scope</th><th>Weighting for the module grade</th></tr><tr><td>a)</td><td>Written or Oral Examination or Presentation</td><td>120-180 min or 30-45 min or 30 min</td><td>100%</td></tr></table>Within the first three weeks of the lecture period each respective lecturer will specify the manner in which the examination will be conducted.</td></tr>
<tr><td>7</td><td>Study Achievement:
none</td></tr>
<tr><td>8</td><td>Prerequisites for participation in examinations:
None</td></tr>
<tr><td>9</td><td>Prerequisites for assigning credits:
The credit points are awarded after the module examination (MAP) was passed.</td></tr>
<tr><td>10</td><td>Weighing for overall grade:
The module is weighted according to the number of credits (factor 1).</td></tr>
<tr><td>11</td><td>Reuse in degree courses or degree course versions :
Master’s Program Electrical Systems Engineering v2 (ESEMA v2), Master’s Program Electrical Systems Engineering v3 (ESEMA v3)</td></tr>
<tr><td>12</td><td>Module coordinator:
Prof. Dr.-Ing. Jakub Kucka</td></tr>
<tr><td>13</td><td>Other Notes:
Remarks of course Power Electronics:
The course is organized via PANDA.
Implementation
Lecture with presentation slides and blackboard notes
Exercises with the group
Exercises in the computer room</td></tr>
</table>

Solar Electric Energy Systems			
Solar Electric Energy Systems			
Module number: M.048.92033	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** module.frequency.en
Language: en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.92033 Solar Electric Energy Systems	2L 2Ex, SS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

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

6 **Assessments:**

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

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

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

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

10 **Weighing for overall grade:**

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

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

Master's Program Electrical Systems Engineering v2 (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)

12 **Module coordinator:**

Prof. Dr.-Ing. Stefan Krauter

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
All lecture notes are available on the PANDA system: https://panda.uni-paderborn.de/course/view.php?id=34927
Playlist with the videos of the lectures: https://youtube.com/playlist?list=PLpgi7D_IhqlpHDSgyMep6oMviCimzup2
Literature:
World Meteorological Organization: Guide to Meteorological Instruments and Methods of Observation, WMO-No. 8, CIMO-Guide, 2018-20. ISBN: 978-92-63-10008-5. Update für 2023: https://community.wmo.int/activity-areas/imop/wmo-no.8/preliminary-2023-edition-wmo-no-8 Duffie, John; Beckmann, William: Solar Engineering of Thermal Processes, 4th Edition, Wiley & Sons, 2013. ISBN: 978-0470873663 *Green, Martin: Solar cells: operating principles, technology, and system applications, Prentice-Hall, 1986, ISBN: 978-0858235809* 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. Stephen W. Fardo, Dale R. Patrick: Electrical Power Systems Technology. The Fairmont Press, Inc., 2009.

Theory and Design of Integrated Photonic Devices			
Theory and Design of Integrated Photonic Devices			
Module number: M.048.92062	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** module.frequency.en
Language: en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.92062 Theory and Design of Integrated Photonic Devices	2L 2Ex, WS	60	12	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Theory and Design of Integrated Photonic Devices:
Recommended:
Knowledge on electromagnetic fields and waves Experience with MATLAB/Python scripting would be beneficial

4 **Contents:**

Contents of the course Theory and Design of Integrated Photonic Devices:

- Introduction
  - Historical evolution of integrated photonics and relevance in today's world
  - Brief overview on the required background theory
    - Electromagnetic waves and Maxwell's equations
    - EM waves propagation in different media
- Theory of optical waveguides: Device #0
  - 1-D waveguide analysis
    - Ray optics model
    - Vector wave equation and boundary conditions
  - 2-D waveguide analysis
    - Overview of waveguide platforms and effective index method
    - Overview of the full vectorial method
    - Dispersion, polarization and orthogonality of guided modes
- Coupled-mode theory: analytical formulation
- Passive integrated photonic devices
  - Directional coupler (DC): Device #1
  - Multi-mode interferometers (MMI) : Device #2
  - Distributed Bragg reflector (DBR): Device #3
- Tunable/active integrated photonic devices
  - Mach-Zehnder interferometer (MZI) / modulator (MZM): Device #4
  - Microring resonators (MRR) / modulator (MRM): Device #5
  - Overview of phase shifters: thermal, electro-optic and MEMS-based
- Fabrication variability and tolerances of the integrated photonic devices
- Overview of photonic integrated circuit (PIC) analysis, introduction to compact-modeling and electronic-photonic design automation (EPDA)

5 **Learning outcomes and competences:**

Understanding the working and fundamental theory of integrated photonic devices, constraints involved in the device designs and overcoming strategies.

6 **Assessments:**

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

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

7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Master's Program Electrical Systems Engineering v2 (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)
12	**Module coordinator:** Dr. Ashitosh Velamuri
13	**Other Notes:** **Module Homepage** **Implementation** Lectures and exercises (including some computer simulations) **Teaching Material, Literature** Handouts and tutorial questions; literature references will be given in the first lecture

Theory and Design of Phase-locked Loops			
Theory and Design of Phase-locked Loops			
Module number: M.048.92056	**Workload (h):** 180	**Credits:** 1	**Regular Cycle:** module.frequency.en
Language: en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.92056 Theory and Design of Phase-locked Loops	2L 2Ex, WS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Theory and Design of Phase-locked Loops:
Recommended:

- Advanced Signal Theory
- Statistical Signal Processing (or another course with comparable syllabus in their bachelor)
- Circuit and system design (or another course with comparable syllabus in their bachelor)

4 **Contents:**

Contents of the course Theory and Design of Phase-locked Loops:
Chapter 1: Motivation

- Time and frequency definition – definition in SI units – static frequency error
- random fluctuations – Amplitude/Phase (AM/PM) noise

Chapter 2: Mathematical formalism of signals

- baseband and bandpass signals
- time and frequency domain

Chapter 3: introduction to random processes

- baseband random processes and noise – correlation functions in time and frequency domain – some basedband random processes (thermal noise, shot noise, flicker noise . . .)
- bandpass random processes – correlation functions – relation to baseband processes – phase noise and amplitude noise

Chapter 4: PLL building blocks

- Phase detector – Phase detector model – phase noise of phase detector
- VCO – VCO model – phase noise of VCO
- Frequency translators – frequency divider – frequency multiplier – phase noise of frequency translators
- transistor level design of PLL blocks

Chapter 5: Integer N PLLs: – Time domain – frequency domain – phase noise – spurious frequencies
Chapter 6: Fractional PLLs – Time domain – frequency domain – phase noise – spurious frequencies

5 **Learning outcomes and competences:**

Understanding of static/dynamic error in frequency standards. Mathematical modeling of amplitude/phase noise. Modeling random processes in time and frequency domain. Basic and modern PLL architecture and its building blocks. Systematic design of PLLs. Design and Modeling of Integer/Fractional N PLL.

6 **Assessments:**

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

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

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Master's Program Electrical Systems Engineering v2 (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)
12	**Module coordinator:** Dr. Meysam Bahmanian
13	**Other Notes:** **Module Homepage** `https://www.hni.uni-paderborn.de/en/sct/teaching/theory-and-design-of-plls` **Implementation** Lectures and exercises (including some computer simulations) **Teaching Material, Literature** Handouts and tutorial questions; literature references will be given in the first lecture

VLSI-Testing

VLSI-Testing

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

1 **Module structure:**

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

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course VLSI Testing:
Recommended: Digital Design

4 **Contents:**

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

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

5 **Learning outcomes and competences:**

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

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

Key qualifications:
The students

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

6 **Assessments:**

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

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

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

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

10 **Weighing for overall grade:**

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

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

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

12 **Module coordinator:**

Prof. Dr. Sybille Hellebrand

13 **Other Notes:**

Remarks of course VLSI Testing:

ATTENTION - IMPORTANT NOTICE
The course doesn't take place in winter term 2026/27 summer term 2026. Please see the notice boards of the group.

Course Homepage
`https://ei.uni-paderborn.de/en/electrical-engineering/date/teaching/electrical-engineering/overview`
Implementation

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

Teaching Material, Literature
Additional material can be found in panda

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

2.6 Module Group: Electrical Systems Engineering

Module Group	Electrical Systems Engineering
Modules	Students may choose any two modules from the following module groups * Signal & Information Processing * Electronics & Devices
Module group advisor	Head of Examination Board ESE (PAV ESE)
Credits ECTS	6
Type of examination	Written or Oral Examination or Presentation
Duration or Scope	120-180 min or 30-45 min or 30 min

2.6.1 Dummy

2.7 Projects

Module Group	Project
Modules	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 projects are offered by the different research groups from the institute EIM-E. * Signal & Information Processing * Electronics & Devices
Module group advisor	Head of Examination Board ESE (PAV ESE)
Credits ECTS	6
Type of examination	Written or Oral Examination or Presentation
Duration or Scope	120-180 min or 30-45 min or 30 min
Acadamic Achievement	Presentation 10-20 min

Projects
Projects

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.98501-98599	540	18	module.frequency.en
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
en	2.-3. Semester	2	P

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)	12P, WS+SS	270	270	C	5

2 **Options within the module:**

1 out of the offered projects

3 **Admission requirements:**

None

Prerequisites of course Project name (Project):
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)	Project Work	30-45 min	100%

<table>
<tr><td>7</td><td>Study Achievement:
<table>
<tr><th>zu</th><th>Type of achievement</th><th>Duration or Scope</th><th>SL / QT</th></tr>
<tr><td>a)</td><td>Presentation</td><td>10-20 min</td><td>AA</td></tr>
</table></td></tr>
<tr><td>8</td><td>Prerequisites for participation in examinations:
Prerequisite for the participation in the module final examination is the passing of the academic achievement on the course “Project”.</td></tr>
<tr><td>9</td><td>Prerequisites for assigning credits:
The credit points are awarded after the module examination (MAP) was passed.</td></tr>
<tr><td>10</td><td>Weighing for overall grade:
The module is weighted according to the number of credits (factor 1).</td></tr>
<tr><td>11</td><td>Reuse in degree courses or degree course versions :
Master’s Program Electrical Systems Engineering v3 (ESEMA v3)</td></tr>
<tr><td>12</td><td>Module coordinator:
Dr.-Ing. Carsten Balewski</td></tr>
<tr><td>13</td><td>Other Notes:
Changing lecturers
Alternatively, two semester projects of 9LP each may be taken (L.048.98001-98499).</td></tr>
</table>

2.8 General Studies

General Studies - Master			
General Studies - Master			
Module number: null	**Workload (h):** 270	**Credits:** 9	**Regular Cycle:** module.frequency.en
Language: de	**Semester number:** 1.-2. Semester	**Duration (in sem.):** 2	**Module status (P=C/WP=CE)** P

1 Module structure:

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)

2 Options within the module:

Any courses outside of the degree course electrical engineering may be chosen.

3 Admission requirements:

None

4 Contents:

Depending on the modules / courses chosen.

5 Learning outcomes and competences:

Students expand their scientific horizons beyond the boundaries of computer science and their chosen minor. Depending on the chosen course, they have acquired competencies in communication skills, teamwork and presentation techniques.
Non-cognitive Skills

- Commitment
- Cooperation
- Media competence
- Literacy (scientific)
- Self-monitoring

6 Assessments:

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

zu	Type of examination	Duration or scope	Weighting for the module grade
			100%

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

7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** Depending on the modules / courses chosen.
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Electrical Systems Engineering v3 (ESEMA v3) - Amtssprache, Master's Program Electrical Systems Engineering v3 (ESEMA v3)
12	**Module coordinator:** Dr.-Ing. Carsten Balewski
13	**Other Notes:**

2.9 Master's Thesis

Abschlussmodul			
Final Degree Module			
Module number: A.048.90001	**Workload (h):** 900	**Credits:** 30	**Regular Cycle:** module.frequency.en
Language: en	**Semester number:** 4. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** P

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	Working Plan (ESE)		15	135	C	
b)	Master Thesis (ESE)		150	600	C	

2 **Options within the module:**

None

3 **Admission requirements:**

The prerequisites for the start of the master's thesis are detailed in § 10 section 3 of the examination regulations.

4 **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.

5 **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.

6 **Assessments:**

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

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a) - b)	Masters Thesis incl. final presentation	max. 120 DIN A4-Pages incl. 45-60 min	100%

7 **Study Achievement:**

zu	**Type of achievement**	**Duration or Scope**	**SL / QT**
a)	Workinplan	150h	QP
b)			

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

Credits are awarded when the bachelor's thesis has been passed and the work plan has been verified.

10 **Weighing for overall grade:**

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

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

Master's Program Electrical Systems Engineering v3 (ESEMA v3)

12 **Module coordinator:**

Dr.-Ing. Carsten Balewski

13 **Other Notes:**

Supervison by academic staff of the institute

3 Overview of the offered modules in winter term

- A.048.90001 Abschlussmodul 162
- M.048.90102 Modeling and Simulation 7
- M.048.90103 Management of Technical Projects 9
- M.048.90104 Topics in Sytems Engineering 12
- M.048.90107 Analysis and Design of Electronic Circuits 90
- M.048.90501 Introduction to Algorithms 27
- M.048.90704 Fast Integrated Circuits for Wireline Communications 110
- M.048.9070X Cognitive Systems Engineering 45
- M.048.92001 Advanced System Theory 4
- M.048.92002 High Frequency Engineering 24
- M.048.92004 Statistical Signal Processing 39
- M.048.92006 Advanced Topics in Robotics 41
- M.048.92011 Optimal and Adaptive Filters 65
- M.048.92014 Topics in Signal Processing 82
- M.048.92021 Optical Communication C 129
- M.048.92023 Power Electronics 143
- M.048.92027 VLSI-Testing 154
- M.048.92034 Energy Transition 107
- M.048.92051 Optimization-Based Control Methods 138
- M.048.92053 Fundamentals of Optics 113
- M.048.92054 Advanced Quantum Optics 94
- M.048.92056 Theory and Design of Phase-locked Loops 151
- M.048.92059 Design of Integrated Energy Systems 105
- M.048.92060 Modern Semiconductor Lasers 118
- M.048.92061 Resource-Efficient AI: Architectures and Methodologies 70
- M.048.92062 Theory and Design of Integrated Photonic Devices 148
- M.048.98501-98599 Projects 157
- M.079.4062 Model-Based Systems Engineering 30
- M.079.4204 Data-Driven Engineering 15
- General Studies - Master 160

4 Overview of the offered modules in summer term

- A.048.90001 Abschlussmodul 162
- M.048.24021 Information Theory 57
- M.048.90104 Topics in Sytems Engineering 12
- M.048.90105 Electromagnetic Waves and Waveguides 87
- M.048.9070X Cognitive Systems Engineering 45
- M.048.92001 Advanced System Theory 4
- M.048.92008 Digital Image Processing I 51
- M.048.92010 Digital Image Processing II 54
- M.048.92012 Robotics 73
- M.048.92015 Analog CMOS ICs 100
- M.048.92016 Control of Electric Drives 103
- M.048.92019 Optical Communication A 123
- M.048.92020 Optical Communication B 126
- M.048.92022 Optical Communication D 132
- M.048.92028 Integrated Circuits for Wireless Communication 115
- M.048.92033 Solar Electric Energy Systems 145
- M.048.92038 Optical Waveguide Theory 135
- M.048.92041 Digital Speech Signal Processing 21
- M.048.92043 Advanced VLSI Design 97
- M.048.92046 Statistical and Machine Learning 35
- M.048.92052 Nonlinear control of autonomous and robotic systems 121
- M.048.92053 Fundamentals of Optics 113
- M.048.92054 Advanced Quantum Optics 94
- M.048.92055 Optoelectronics 140
- M.048.92058 Wireless Communications 84
- M.048.98501-98599 Projects 157
- M.079.4076 Data-Driven Innovation 18
- General Studies - Master 160

Erzeugt am 8. September 2026 um 12:42.