UNIVERSITÄT DES SAARLANDES

Faculty of Mathematics and Computer Science

Module Descriptions

Embedded Systems MSc

17th December 2024

List of module categories and modules

Module Category 1

Stammvorlesungen

Audio-Visual Communication and Networks — AVCN

st. semester	std. st. sem.	cycle	duration	SWS	ECTS
1-3	**4**	**at least every two years**	**1 semester**	**6**	**9**

responsible Prof. Dr.-Ing. Thorsten Herfet

lecturers Prof. Dr.-Ing. Thorsten Herfet

entrance requirements Solid foundation of mathematics (differential and integral calculus) and probability theory. The course will build on the mathematical concepts and tools taught in TC I while trying to enable everyone to follow and to fill gaps by an accelerated study of the accompanying literature. *Signals and Systems* as well as *Digital Transmission and Signal Processing (TC I)* are strongly recommended but not required.

assessments / exams Regular attendance of classes and tutorials Passing the final exam
Oral exam directly succeeding the course. Eligibility: Weekly excersises / task sheets, grouped into two blocks corresponding to first and second half of the lecture. Students must provide min. 50% grade in each of the two blocks to be eligible for the exam.

course types / weekly hours
```
  4 h lectures
+ 2 h tutorial
= 6 h (weekly)
```

total workload
```
   90 h of classes
+ 180 h private study
= 270 h (= 9 ECTS)
```

grade Final Exam Mark

language English

aims / competences to be developed

AVCN will deepen the students' knowledge on modern communications systems and will focus on wireless systems.

Since from a telecommunications perspective the combination of audio/visual data – meaning inherently high data rate and putting high requirements on the realtime capabilities of the underlying network – and wireless transmission – that is unreliable and highly dynamic with respect to the channel characteristics and its capacity – is the most demanding application domain.

content

As the basic principle the course will study and introduce the building blocks of wireless communication systems. Multiple access schemes like TDMA, FDMA, CDMA and SDMA are introduced, antennas and propagation incl. link budget calculations are dealt with and more advanced channel models like MIMO are investigated. Modulation and error correction technologies presented in Telecommunications I will be expanded by e.g. turbo coding and receiver architectures like RAKE and BLAST will be introduced. A noticeable portion of the lecture will present existing and future wireless networks and their extensions for audio/visual data. Examples include 802.11n and the terrestrial DVB system (DVB-T2).

literature & reading

Will be announced before the start of the course on the course page on the Internet.

additional information

This module was formerly also known as *Telecommunications II*.

Aufbau- und Verbindungstechnik 1

st. semester	std. st. sem.	cycle	duration	SWS	ECTS
1-3	**4**	**jedes Wintersemester**	**1 Semester**	**3**	**4**

responsible Prof. Dr.-Ing. habil. Steffen Wiese

lecturers Prof. Dr.-Ing. habil. Steffen Wiese

entrance requirements none

assessments / exams Übungsbetrieb / mündliche oder schriftliche Abschlussprüfung

course types / weekly hours

```
  2 SWS Vorlesung
+ 1 SWS Übung
= 3 SWS
```

total workload

```
   30 h Präsenzzeit Vorlesung
+  15 h Präsenzzeit Übung
+  45 h Vor- und Nachbereitung
+  30 h Klausurvorbereitung
= 120 h (= 4 ECTS)
```

grade Note der Klausur bzw. der mündlichen Prüfung

language Deutsch

aims / competences to be developed

Das Ziel der Lehrveranstaltung besteht darin, die Studierenden in das Gebiet der Aufbau- und Verbindungstechnik der Elektronik einzuführen. Dabei sollen grundlegende Kenntnisse über Verfahren und technologische Abläufe zur Herstellung elektronischer Aufbauten vermittelt werden sowie die Spezifika der in der industriellen Fertigung eingesetzten Verbindungstechnologien diskutiert werden.

content

- Einführung in die Problematik der Herstellung elektronischer Aufbauten
- Architektur elektronischer Aufbauten (Hierarchischer Aufbau, Funktion der Verbindungsebenen)
- Erste Verbindungsebene (Die-Bonden, Drahtbonden, Flip-Chip- und Trägerfilmtechnik)
- Zweite Verbindungsebene (Bauelementeformen, Leiterplatten, Dickschichtsubstrate)
- Verbindungstechniken (Kaltpressschweißen, Löten, Kleben)

literature & reading

Bekanntgabe zu Beginn der Vorlesung

Automation Systems AS

st. semester	std. st. sem.	cycle	duration	SWS	ECTS
1-3	**4**	**jedes Sommersemester**	**1 Semester**	**3**	**4**

responsible	Prof. Dr.-Ing. Georg Frey
lecturers	Prof. Dr.-Ing. Georg Frey
entrance requirements	none
assessments / exams	Benotete mündliche oder schriftliche Prüfung
course types / weekly hours	2 SWS Vorlesung + 1 SWS Übung = 3 SWS
total workload	30 h Präsenzzeit Vorlesung + 15 h Präsenzzeit Übung + 45 h Vor- und Nachbereitung + 30 h Klausurvorbereitung = 120 h (= 4 ECTS)
grade	Prüfungsnote
language	English

aims / competences to be developed

Automation Systems is based on the fundamentals of discrete-event systems and networks. Students will acquire:

- detailed knowledge of describing and designing discrete-event systems for control applications;
- understanding of the specific challenges occurring in distributed (networked) automation systems as well as the knowledge of appropriate methods for the modeling and the analysis of automation networks.

content

- Signals and Communication in Automation Systems
- Introduction to Logic Control
- Design and realization of logic control systems
- Domain specific languages (IEC 61131)
- Formal specification using Petri Nets
- Verification and Validation (V&V)
- Software quality
- Communication in Automation: Real-time and Dependability
- Application: Industrial Ethernet Solutions and CAN-Bus
- Application: Automotive Networks (LIN, CAN, FlexRay, MOST)
- Analysis of Networked Automation Systems
- Design of Distributed Controllers (IEC 61499)

literature & reading

Literatur wird in der Vorlesung zur Verfügung gestellt bzw. bekannt gegeben.

Compiler Construction CC

st. semester	std. st. sem.	cycle	duration	SWS	ECTS
1-3	**4**	**at least every two years**	**1 semester**	**6**	**9**

responsible Prof. Dr. Sebastian Hack

lecturers Prof. Dr. Sebastian Hack

entrance requirements For graduate students: none

assessments / exams

- Regular attendance of classes and tutorials
- Written exam at the end of the course, theoretical exercises, and compiler-laboratory project.
- A re-exam takes place during the last two weeks before the start of lectures in the following semester.

course types / weekly hours

```
  4 h lectures
+ 2 h tutorial
= 6 h (weekly)
```

total workload

```
   90 h of classes
+ 180 h private study
= 270 h (= 9 ECTS)
```

grade Will be determined from performance in exams, exercises and practical tasks. The exact modalities will be announced at the beginning of the module.

language English

aims / competences to be developed

The students learn, how a source program is lexically, syntactically, and semantically analyzed, and how they are translated into semantically equivalent machine programs. They learn how to increase the efficiency by semantics-preserving transformations. They understand the automata-theoretic foundations of these tasks and learn, how to use the corresponding tools.

content

Lexical, syntactic, semantic analysis of source programs, code generation for abstract and real machines, efficiency-improving program transformations, foundations of program analysis.

literature & reading

Will be announced before the start of the course on the course page on the Internet.

Computational Electromagnetics 1 CEM1

st. semester	std. st. sem.	cycle	duration	SWS	ECTS
1-3	**4**	**every winter semester**	**1 semester**	**3**	**4**

responsible	Romanus Dyczij-Edlinger
lecturers	Romanus Dyczij-Edlinger
entrance requirements	a first course in Electromagnetics (e.g. *Theoretische Elektrotechnik*) is recommended
assessments / exams	Programming projects during the semester. Written or oral final exam.

course types / weekly hours	`2 h lectures`
	`+ 1 h tutorial`
	`= 3 h (weekly)`

total workload	`45 h of classes`
	`+ 75 h private study`
	`= 120 h (= 4 ECTS)`

grade	Programming projects: 50 % Final exam: 50 %
language	German or English

aims / competences to be developed

- To master selected topics in numerical linear algebra.
- To know how to pose linear (initial-) boundary value problems of classical electrodynamics.
- To understand the principles of differential and integral equation methods.

content

- Selected topics in numerical linear algebra
- Linear (initial-) boundary value problems of classical electrodynamics
- Numerical methods:
  - Finite difference method / finite integration technique
  - Finite element method
  - Boundary element method

literature & reading

See lecture notes.

additional information

Lecture notes (in English), project assignments, old exams, and selected solutions are available online. Students may choose between German or English.

Computational Electromagnetics 2 CEM2

st. semester	std. st. sem.	cycle	duration	SWS	ECTS
1-3	**4**	**every summer semester**	**1 semester**	**3**	**4**

responsible Romanus Dyczij-Edlinger

lecturers Romanus Dyczij-Edlinger

entrance requirements *Computational Electromagnetics 1* is recommended

assessments / exams Oral final exam: student presentations of selected topics from current research papers.

course types / weekly hours

```
  2 h lectures
+ 1 h tutorial
= 3 h (weekly)
```

total workload

```
   45 h of classes
+  75 h private study
= 120 h (= 4 ECTS)
```

grade Final exam: 100 %

language German or English

aims / competences to be developed

To gain a deep understanding of finite element techniques for time-harmonic electromagnetic fields. Students are familiar with essential theoretical and implementation aspects of modern finite element methods and able to study advanced research papers on their own.

content

- Functional analytical and geometric foundations
- Modal analysis of electromagnetic cavities
- Modal analysis of driven time-harmonic fields
- Analysis of driven time-harmonic fields
- Special modeling techniques
- Advanced numerical solution methods

literature & reading

Each section of lecture notes contains list of references.

additional information

Lecture notes are available online. Students may choose between German or English.

Computer Architecture

CAr

st. semester	std. st. sem.	cycle	duration	SWS	ECTS
1-3	**4**	**at least every two years**	**1 semester**	**6**	**9**

responsible Prof. Dr. W.-J. Paul

lecturers Prof. Dr. W.-J. Paul

entrance requirements For graduate students: none

assessments / exams **Studying:** Students should listen to the lectures, read the lecture notes afterwards and understand them. They should solve the exercises alone or in groups. Students must present and explain their solutions during the tutorials.

Exams: Students who have solved 50 % of all exercises are allowed to participate in an oral exam at the end of the semester.

course types / weekly hours

```
  4 h lectures
+ 2 h tutorial
= 6 h (weekly)
```

total workload

```
   90 h of classes
+ 180 h private study
= 270 h (= 9 ECTS)
```

grade Will be determined from performance in exams, exercises and practical tasks. The exact modalities will be announced at the beginning of the module.

language English

aims / competences to be developed

After attending this lecture students know how to design pipelined processors with interrupt mechanisms, caches and MMUs. Given a benchmark they know how to analyse, whether a change makes the processor more or less cost effective.

content

General comment: constructions are usually presented together with correctness proofs

- Complexity of Architectures
  - Hardware cost and cycle time
  - Compilers and benchmarks
- Circuits
  - Elementary computer arithmetic
  - Fast adders
  - Fast multipliers
- Sequential processor design
  - DLX instruction set
  - Processor design
- Pipelining
  - Elementary pipelining
  - Forwarding
  - Hardware-Interlock
- Interrupt mechanisms
  - Extension of the instruction set
  - Interrupt service routines

    - hardware construction
- Caches
    - Specification including consistency between instruction and data cache
    - Cache policies
    - Bus protocol
    - Hardware construction (k-way set associative cache, LRU replacement, realisation of bus protocols by automat)
- Operating System Support
    - Virtual and Physical machines
    - Address translation
    - Memory management unit (MMU) construction
    - Virtual memory simulation

literature & reading

Will be announced before the start of the course on the course page on the Internet.

Cyber-Physical Systems

st. semester	std. st. sem.	cycle	duration	SWS	ECTS
1-3	**4**	**at least every two years**	**1 semester**	**6**	**9**

responsible Prof. Dr. Martina Maggio

lecturers Prof. Dr. Martina Maggio

entrance requirements none

assessments / exams
- Written exam at the end of the course.
- A re-exam takes place before the start of the following semester.

course types / weekly hours

```
  4 h lectures
+ 2 h tutorials
= 6 h (weekly)
```

total workload

```
   75 h lectures
+  15 h mandatory assignments
+ 180 h individual study
= 270 h (= 9 ECTS)
```

grade Will be determined from performance in exams and assignments. The exact modalities will be announced at the beginning of the module.

language English

aims / competences to be developed

By completing the Cyber-Physical Systems course, students will acquire the ability to model, analyze, control, and implement embedded systems that interact with the physical world, equipping them to design reliable and efficient systems for a variety of applications in modern technology.

content

Cyber-Physical Systems are embedded systems that integrate computation with physical processes. These systems are ubiquitous in our daily lives, powering technologies such as smart watches, household appliances, mobile phones, and automotive control systems. In fact, the majority of modern computing devices are embedded systems, with an estimated 98% of new CPUs being embedded in larger systems.

This course provides a comprehensive foundation for understanding, designing, and programming cyber-physical systems, emphasizing their theoretical and practical aspects. It is structured into three interconnected parts:

1. *Models:* Students will learn how to represent the physical systems that embedded systems interact with, exploring dynamical systems in both continuous and discrete time. Additionally, the course will briefly introduce more advanced models, which combine discrete state systems with dynamical systems.
2. *Control:* This module focuses on principles for modifying the behavior of physical systems through computation. Students will study and apply control techniques such as state feedback and PID control, learning how these methods influence the interaction between embedded systems and their environments.
3. *Implementation:* The final course part addresses practical challenges in embedded systems programming. Topics include scheduling, communication, and fault tolerance. This ensures that students are equipped to implement robust and efficient embedded systems in real-world scenarios.

By the end of this course, students will possess the skills needed to design and implement cyber-physical systems that meet specific functional and performance requirements, preparing them for roles in cutting-edge industries where embedded systems play a critical role, such as the automotive industry and for research in the cyber-physical systems domain.

literature & reading

Will be announced before the start of the course on the course page on the Internet.

additional information

This module was formerly also known as *Embedded Systems*.

Data Networks DN

st. semester	std. st. sem.	cycle	duration	SWS	ECTS
1-3	**4**	**at least every two years**	**1 semester**	**6**	**9**

responsible Prof. Dr.-Ing. Holger Hermanns

lecturers Prof. Dr.-Ing. Holger Hermanns
Prof. Dr. Anja Feldmann

entrance requirements For graduate students: none

assessments / exams

- Regular attendance of classes and tutorials
- Qualification for final exam through mini quizzes during classes
- Possibility to get bonus points through excellent homework
- Final exam
- A re-exam takes place during the last two weeks before the start of lectures in the following semester.

course types / weekly hours

```
  4 h lectures
+ 2 h tutorial
= 6 h (weekly)
```

total workload

```
   90 h of classes
+ 180 h private study
= 270 h (= 9 ECTS)
```

grade Will be determined from performance in exams, exercises and practical tasks. The exact modalities will be announced at the beginning of the module.

language English

aims / competences to be developed

After taking the course students have

- a thorough knowledge regarding the basic principles of communication networks,
- the fundamentals of protocols and concepts of protocol,
- Insights into fundamental motivations of different pragmatics of current network solutions,
- Introduction to practical aspects of data networks focusing on internet protocol hierarchies

content

Introduction and overview

Cross section:

- Stochastic Processes, Markov models,
- Fundamentals of data network performance assessment
- Principles of reliable data transfer
- Protokols and their elementary parts
- Graphs and Graphalgorithms (maximal flow, spanning tree)
- Application layer:
- Services and protocols
- FTP, Telnet
- Electronic Mail (Basics and Principles, SMTP, POP3, ..)
- World Wide Web (History, HTTP, HTML)

- Transport Layer:
- Services and protocols
- Addressing
- Connections and ports
- Flow control
- QoS
- Transport Protocols (UDP, TCP, SCTP, Ports)
- Network layer:
- Services and protocols
- Routing algorithms
- Congestion Control
- Addressing
- Internet protocol (IP)
- Data link layer:
- Services and protocols
- Medium access protocols: Aloha, CSMA (-CD/CA), Token passing
- Error correcting codes
- Flow control
- Applications: LAN, Ethernet, Token Architectures, WLAN, ATM
- Physical layer
- Peer-to-Peer and Ad-hoc Networking Principles

literature & reading

Will be announced before the start of the course on the course page on the Internet.

Digital Signal Processing

st. semester	std. st. sem.	cycle	duration	SWS	ECTS
1-3	**4**	**every summer semester**	**1 semester**	**4**	**6**

responsible Prof. Dr. Dietrich Klakow

lecturers Prof. Dr. Dietrich Klakow

entrance requirements Sound knowledge of mathematics as taught in engineering, computer science or physics is recommended.

assessments / exams Final exam

course types / weekly hours

```
  2 h lecture
+ 2 h tutorial
= 4 h (weekly)
```

total workload

```
   60 h of classes
+ 120 h private study
= 180 h (= 6 ECTS)
```

grade The grade is determined by result of the final exam. A re-exam takes place half a year after the first exam.

language English

aims / competences to be developed

The students will get familiar with advanced signal processing techniques in particular those that are relevant to speech processing. There will be practical and theoretical exercises.

content

1. Introduction
2. Signal Representations
3. Filtering and Smoothing
4. Linear Predictive Coding
5. Microphone Arrays
6. Object Tracking and the Kalman-Filter
7. Wiener Filter
8. Feature Extraction from Audio Signals
9. KL-Transform and Linear Discriminant Analysis
10. Basics of Classification
11. Speaker Recognition
12. Musical Genre Classification

literature & reading

- Dietrich W. R. Paulus, Joachim Hornegger “Applied Pattern Recognition”, Vieweg
- Peter Vary, Ulrich Heute, Wolfgang Hess “Digitale Sprachsignalverarbeitung”, Teubner Verlag
- Xuedong Huang, Hsiao-Wuen Hon “Spoken Language Processing”, Prentice Hall
- C. Bishop „Pattern Recognition and Machine Learning“, Springer

Further reading will be announced in the lecture.

Digital Transmission & Signal Processing — DTSP

st. semester	std. st. sem.	cycle	duration	SWS	ECTS
1-3	**4**	**at least every two years**	**1 semester**	**6**	**9**

responsible Prof. Dr.-Ing. Thorsten Herfet

lecturers Prof. Dr.-Ing. Thorsten Herfet

entrance requirements The lecture requires a solid foundation of mathematics (differential and integral calculus) and probability theory. The course will, however, refresh those areas indispensably necessary for telecommunications and potential intensification courses and by this open this potential field of intensification to everyone of you.

assessments / exams Regular attendance of classes and tutorials
Passing the final exam in the 2nd week after the end of courses.
Eligibility: Weekly exercises / task sheets, grouped into two blocks corresponding to first and second half of the lecture. Students must provide min. 50% grade in each of the two blocks to be eligible for the exam.

course types / weekly hours

```
  4 h lectures
+ 2 h tutorial
= 6 h (weekly)
```

total workload

```
   90 h of classes
+ 180 h private study
= 270 h (= 9 ECTS)
```

grade Final exam mark

language English

aims / competences to be developed

Digital Signal Transmission and Signal Processing refreshes the foundation laid in "Signals and Systems" [Modulkennung]. Including, however, the respective basics so that the various facets of the introductory study period (Bachelor in Computer Science, Vordiplom Computer- und Kommunikationstechnik, Elektrotechnik or Mechatronik) and the potential main study period (Master in Computer Science, Diplom-Ingenieur Computer- und Kommunikationstechnik or Mechatronik) will be paid respect to.

content

As the basic principle, the course will give an introduction into the various building blocks that modern telecommunication systems do incorporate. Sources, sinks, source and channel coding, modulation and multiplexing are the major keywords, but we will also deal with dedicated pieces like A/D- and D/A-converters and quantizers in a little bit more depth.

The course will refresh the basic transformations (Fourier, Laplace) that give access to system analysis in the frequency domain, it will introduce derived transformations (z, Hilbert) for the analysis of discrete systems and modulation schemes and it will briefly introduce algebra on finite fields to systematically deal with error correction schemes that play an important role in modern communication systems.

literature & reading

Will be announced before the start of the course on the course page on the Internet.

additional information

This module was formerly also known as *Telecommunications I*.

Distributed Systems DS

st. semester	std. st. sem.	cycle	duration	SWS	ECTS
1-3	**4**	**at least every two years**	**1 semester**	**6**	**9**

responsible Prof. Peter Druschel, Ph.D.

lecturers Prof. Peter Druschel, Ph.D.
Allen Clement, Ph.D

entrance requirements *Operating Systems* or *Concurrent Programming*

assessments / exams

- Regular attendance at classes and tutorials.
- Successful completion of a course project in teams of 2 students. (Project assignments due approximately every 2 weeks.)
- Passing grade on 2 out of 3 written exams: midterm, final exam, and a re-exam that takes place during the last two weeks before the start of lectures in the following semester.
- Final course grade: 50% project, 50% best 2 out of 3 exams.

course types / weekly hours

```
  4 h lectures
+ 2 h tutorial
= 6 h (weekly)
```

total workload

```
   90 h of classes
+ 180 h private study
= 270 h (= 9 ECTS)
```

grade Will be determined from performance in exams, exercises and practical tasks. The exact modalities will be announced at the beginning of the module.

language English

aims / competences to be developed

Introduction to the principles, design, and implementation of distributed systems.

content

- Communication: Remote procedure call, distributed objects, event notification, Inhalt dissemination, group communication, epidemic protocols.
- Distributed storage systems: Caching, logging, recovery, leases.
- Naming. Scalable name resolution.
- Synchronization: Clock synchronization, logical clocks, vector clocks, distributed snapshots.
- Fault tolerance: Replication protocols, consistency models, consistency versus availability trade-offs, state machine replication, consensus, Paxos, PBFT.
- Peer-to-peer systems: consistent hashing, self-organization, incentives, distributed hash tables, Inhalt distribution networks.
- Data centers. Architecture and infrastructure, distributed programming, energy efficiency.

literature & reading

Will be announced before the start of the course on the course page on the Internet.

Einführung in die elektromagnetische Feldsimulation EMSim

st. semester	std. st. sem.	cycle	duration	SWS	ECTS
1-3	4	jährlich	1 Semester	3	4

responsible Romanus Dyczij-Edlinger

lecturers Romanus Dyczij-Edlinger

entrance requirements none

assessments / exams Computerimplementierungen,
mündliche Prüfung

course types / weekly hours
```
  2 SWS Vorlesung
+ 1 SWS Übung
= 3 SWS
```

total workload
```
   45 h Präsenzzeit Vorlesung und Übung
+  45 h Vor- und Nachbereitung
+  30 h Klausurvorbereitung
= 120 h (= 4 ECTS)
```

grade Computerimplementierungen 40 %
Mündliche Prüfung 60 %

language Deutsch

aims / competences to be developed

Studierende sind in der Lage, wichtige Klassen von Feldproblemen zu klassifizieren und kennen typische Fallbeispiele aus Wärmelehre, Akustik und Elektrodynamik. Sie sind mit den Gemeinsamkeiten und besonderen Eigenheiten der resultierenden Typen von (Anfangs-)RandwertProblemen vertraut, und verstehen die Grundlagen von Differenzial- und Integralgleichungsverfahren zur numerischen Lösung von Problemstellungen der klassischen Maxwellschen Theorie.

content

Numerische lineare Algebra (Eigenwert-, Singulärwert-, QR- und LR-Zerlegungen, schwach besetzte Matrizen, Krylov-Unterraum-Verfahren); ausgesuchte lineare Randwert- und Anfangsrandwertprobleme (sachgemäß und unsachgemäß gestellte Probleme, elliptische, parabolische, hyperbolische und unklassifizierte Gleichungen); Separationsansätze; Konsistenz, Stabilität und Konvergenz numerischer Verfahren; Finite-Differenzen-Methoden (Diskretisierung, Anfangs- und Randbedingungen, explizite und implizite Zeitintegrationsverfahren, Stabilitätsanalyse); Variationsmethoden (Euler-LagrangeGleichungen, essentielle und natürliche Randbedingungen, Ritzsches Verfahren); Methode der gewichteten Residuen (Kollokation, Galerkin, Galerkin-Bubnow); Finite-Elemente-Methoden (Diskretisierung, Formfunktionen, Elementmatrizen, Einbringen von Randbedingungen und Quellen); Integralgleichungsmethoden (Greensche Funktionen, Klassifizierung); Randelemente-Methoden (Diskretisierung, Singularitäten)

literature & reading

Treffethen, Bau: Numerical Linear Algebra;
Demmel: Applied Numerical Linear Algebra;
Farlow: Partial Differential Equations for Scientists and Engineers;
Courant, Hilbert: Methoden der mathematischen Physik;
Stakgold: Green's Functions and Boundary Value Problems;

Strang, Fix: An Analysis of the Finite Element Method;
Grossmann, Roos: Numerik partieller Differentialgleichungen;
Bossavit, Alain: Computational Electromagnetism

additional information

Vorlesungsskripten erhältlich, Übungsbeispiele und alte Prüfungen vom Internet abrufbar.

Elektrische Antriebe **EA**

st. semester	std. st. sem.	cycle	duration	SWS	ECTS
1-3	**4**	**jedes Wintersemester**	**1 Semester**	**3**	**4**

responsible Prof. Dr.-Ing. Matthias Nienhaus

lecturers Prof. Dr.-Ing. Matthias Nienhaus

entrance requirements none

assessments / exams Benotete Prüfung (Klausur)

course types / weekly hours

```
  2 SWS Vorlesung
+ 1 SWS Übung
= 3 SWS
```

total workload

```
   30 h Präsenzzeit Vorlesung
+  15 h Präsenzzeit Übung
+  45 h Vor- und Nachbereitung
+  30 h Klausurvorbereitung
= 120 h (= 4 ECTS)
```

grade Klausurnote

language Deutsch

aims / competences to be developed

Es werden die Grundlagen zu Aufbau, Wirkungsweise und Betriebsverhaltens von Gleichstrom-, Synchron- und Asynchronmaschinen sowie deren elektrische Ansteuerung vermittelt. Studierende erwerben Basiswissen für eine anforderungsgerechte Spezifikation und Auswahl elektrischer Antriebe.

content

- Physikalische Grundlagen
- Gleichstrommaschinen
- Asynchronmaschinen
- Synchronmaschinen
- Ansteuerungen

literature & reading

Merz, H., Lipphardt, G.: Elektrische Maschinen und Antriebe, VDE, 2009
Fischer, R.: Elektrische Maschinen, Hanser, München, 2009
Riefenstahl, U.: Elektrische Antriebssysteme, Vieweg+Teubner, 2010

Elektronik / Bauelemente   ENK

st. semester	std. st. sem.	cycle	duration	SWS	ECTS
1-3	**4**	**jährlich**	**1 Semester**	**2**	**3**

responsible Prof. Dr.-Ing. Michael Möller

lecturers Prof. Dr.-Ing. Michael Möller
Prof. Dr.-Ing. habil. Steffen Wiese

entrance requirements none

assessments / exams Benotete Prüfungen Modulelementprüfungen

course types / weekly hours

```
 2 SWS Vorlesung und Übung
```

total workload

```
   30 h Präsenzzeit Vorlesung und Übung
+  30 h Vor- und Nachbereitung
+  30 h Klausurvorbereitung
= 90 h (= 3 ECTS)
```

grade Gewichteter Mittelwert der Einzelnoten nach Studienordnung

language Deutsch

aims / competences to be developed

Vorstellung von Konzepten und Aufbau aktiver und passiver elektronischer Bauelemente, Erlernung des Zusammenhangs zwischen physikalischem Grundprinzip, Kennlinie und schaltungstechnischer Funktion. Darstellung ausgewählter physikalischer Eigenschaften von charakteristischen BauelementFunktionswerkstoffen. Erlernen erster Bauelementanwendungen in einfachen Grundschaltungen. Vorstellung von Sonderbauelementen zur Energieversorgung und für die Leistungselektronik

content

- Einführung (Gegenstand der LV „Bauelemente“, Physikalische Funktionsbeschreibung von Bauelementen, Verarbeitung von Bauelementen, Zuverlässigkeit von Bauelementen)
- Diskrete aktive Bauelemente (Diode, Bipolartransistor, Feldeffekttransistor)
- Diskrete passive Bauelemente (Widerstände, Kapazitäten, Induktivitäten)
- Integrierte Schaltungen als Bauelemente (Analoge integrierte Schaltungen, Digitale integrierte Schaltungen)
- Bauelemente der Energieversorgung (Netzteil- und Spannungswandler-Komponenten, Elektrochemische Generatoren, Batterien, Akkumulatoren, Brennstoffzellen, Photovoltaische Generatoren, Thermoelektrische Generatoren, Elektromechanische Generatoren)
- Leistungsbauelemente (Der Logik- und der Leistungsteil in Schaltungen, Leistungstransistoren und –dioden, Thyristor, IGBT, Relais, Kühlkörper)

literature & reading

Beuth, Klaus: Bauelemente (Elektronik 2), Würzburg: Vogel 2010, 19. Aufl.
Möschwitzer, Albrecht: Mikroelektronik, Berlin: Verlag Technik 1987, 1. Aufl.
Möschwitzer, Albrecht: Einführung in die Elektronik, Berlin: Verlag Technik 1988, 6. Aufl.

High Speed Electronics

st. semester	std. st. sem.	cycle	duration	SWS	ECTS
1-3	**4**	**every winter semester**	**1 semester**	**3**	**4**

responsible	Prof. Dr.-Ing. Michael Möller
lecturers	Prof. Dr.-Ing. Michael Möller
entrance requirements	For graduate students: none Bachelor level in Electronics and Circuits
assessments / exams	Theoretical and practical (CAD examples) exercises • Regular attendance of lecture and tutorial • Final oral exam • A re-exam takes place during the last two weeks before the start of lectures in the following semester.
course types / weekly hours	2 h lectures + 1 h tutorial = 3 h (weekly)
total workload	45 h of classes + 75 h private study = 120 h (= 4 ECTS)
grade	Final exam mark
language	English

aims / competences to be developed

To know and understand limitations on maximum speed and performance of integrated circuits. To know and to be able to apply design methods and concepts to enhance speed and performance of a circuit. To be familiar with basic circuit stages and methods for combining them to gain a specific functionality and performance. To understand basic circuit concepts for high-speed data- and signaltransmission and –processing with special regard to the transmitter- and receiver-electronics. To be able to design such circuits. To acquire the fundamentals of circuit design as a preparation for the related hands-on training on "High-speed analogue circuit design".

content

- Bipolar transistor model and properties at technological speed limit.
- Concept of negative supply voltage and differential signalling.
- Method of symbolic calculation and modelling of transistor stages.
- Basic electrical properties of transistor stages with special regard to high-frequency considerations.
- Concept of conjugate impedance mismatch.
- Functional stages for broadband operation up to 160 Gbit/s (e.g. photodiode–amplifier, modulator driver, linear and limiting gain stages and amplifier, circuits for gain control, equalizing and analogue signal processing, Multiplexer, Demultiplexer, logic gates(e.g. exor), phase detector, Oscillator (VCO), phase-locked-loop (PLL)).

literature & reading

- Lecture notes
- High Speed Integrated Circuit Technology Towards 100 GHz Logic, M. Rodwell, World Scientific
- Intuitive Analog Circuit Design, Marc T. Thompson, Elsevier 2006
- Related articles from journals and conferences.

additional information

Used Media: Beamer, blackboard, lecture notes, Computer (CAD examples)

High-Frequency Engineering

st. semester	std. st. sem.	cycle	duration	SWS	ECTS
1-3	**4**	**every winter semester**	**1 semester**	**3**	**4**

responsible Prof. Dr.-Ing. Michael Möller

lecturers Prof. Dr.-Ing. Michael Möller

entrance requirements For graduate students: none
Bachelor level in Electronics and Circuits

assessments / exams Theoretical and practical (CAD examples) exercises

- Regular attendance of lecture and tutorial
- Final oral exam
- A re-exam takes place during the last two weeks before the start of lectures in the following semester.

course types / weekly hours

```
  2 h lectures
+ 1 h tutorial
= 3 h (weekly)
```

total workload

```
   45 h of classes
+  75 h private study
= 120 h (= 4 ECTS)
```

grade Final exam mark

language English

aims / competences to be developed

Acquiring basic knowledge on fundamental high-frequency and network-theory methods to characterize and model distributed and lumped element networks. Applying these methods to modelling, design and measurement of high-speed circuits. Introduction to general optimization criteria and optimization strategy. To prepare for hands-on training on "RF-circuits and measurement techniques".

content

- *Introduction:*
  Retardation, Skin-, Proximity-Effect, Signal path lengths, lumped and distributed properties, Interconnect and Transmission Line modelling
- *Waves and S-parameters:*
  Generalised waves, power, reflection, Smith diagram, matching, S-parameters, ABCD-parameters, Signal flow graph methods.
- *Network properties:*
  Tellegen theorem, linearity, reciprocity, symmetry, unitarity, modal network description (differential operation),
- *Network measurement methods and components:*
  time domain reflectometry (TDR), line-coupler, power splitter/divider, Vector Network Analyzer (VNA)
- *Electrical Noise:*
  Noise processes, characterization and properties, network models
- *Optimization criteria*
  (e.g. noise, phase- and frequency response, linearity, stability, matching CMRR, PSRR, pulse fidelity, eye-diagram)
- *Optimization strategy:*
  Trade-off, degees of freedom (DOF), Introducing DOFs by decoupling, optimization example

literature & reading

- Lecture notes
- Hochfrequenztechnik 2, Zinke, Brunswig, 5. Auflage, Springer
- Microwave Engineering, David M. Pozar, 3rd ed., Wiley
- Grundlagen der Hochfrequenzmesstechnik, B. Schiek, Springer
- Rauschen, R. Müller, Springer
- Related articles from journals and conferences.

additional information

Used Media: Beamer, blackboard, lecture notes, Computer (CAD examples)

Image Processing and Computer Vision — IPCV

st. semester	std. st. sem.	cycle	duration	SWS	ECTS
1-3	**4**	**at least every two years**	**1 semester**	**6**	**9**

responsible Prof. Dr. Joachim Weickert

lecturers Prof. Dr. Joachim Weickert

entrance requirements Undergraduate mathematics (e.g. Mathematik für Informatiker I-III) and elementary programming knowledge in C

assessments / exams

- For the homework assignments one can obtain up to 24 points per week. Actively participating in the classroom assignments gives 12 more points per week, regardless of the correctness of the solutions. To qualify for both exams one needs 2/3 of all possible points.
- Passing the final exam or the re-exam.
- A re-exam takes place during the last two weeks before the start of lectures in the following semester.

course types / weekly hours

```
  4 h lectures
+ 2 h tutorial
= 6 h (weekly)
```

total workload

```
   90 h of classes
+ 180 h private study
= 270 h (= 9 ECTS)
```

grade Will be determined from the performance in the exam or the re-exam. The better grade counts.

language English

aims / competences to be developed

Broad introduction to mathematical methods in image processing and computer vision. The lecture qualifies students for a bachelor thesis in this field. Together with the completion of advanced or specialised lectures (9 credits at least) it is the basis for a master thesis in this field.

content

```
Inhalt

1. Basics
   1.1 Image Types and Discretisation
   1.2 Degradations in Digital Images
2. Colour Perception and Colour Spaces
3. Image Transformations
   3.1 Continuous Fourier Transform
   3.2 Discrete Fourier Transform
   3.3 Image Pyramids
   3.4 Wavelet Transform
4. Image Compression
5. Image Interpolation
6. Image Enhancement
   6.1 Point Operations
```

```
   6.2 Linear Filtering and Feature Detection
   6.3 Morphology and Median Filters
   6.3 Wavelet Shrinkage, Bilateral Filters, NL Means
   6.5 Diffusion Filtering
   6.6 Variational Methods
   6.7 Deconvolution Methods
7. Texture Analysis
8. Segmentation
   8.1 Classical Methods
   8.2 Variational Methods
9. Image Sequence Analysis
   9.1 Local Methods
   9.2 Variational Methods
10. 3-D Reconstruction
   10.1 Camera Geometry
   10.2 Stereo
   10.3 Shape-from-Shading
11. Object Recognition
   11.1 Hough Transform
   11.2 Invariants
   11.3 Eigenspace Methods
```

literature & reading

Will be announced before the start of the course on the course page on the Internet.

Internet Transport

st. semester	std. st. sem.	cycle	duration	SWS	ECTS
1-3	**4**	**at least every two years**	**1 semester**	**6**	**9**

responsible Prof. Dr.-Ing. Thorsten Herfet

lecturers Prof. Dr.-Ing. Thorsten Herfet

entrance requirements

- Motivation for networks and communication
- Practical experience (e.g. through *Hands on Networking*) is recommended
- Knowledge of the fundamentals of communication (e.g. through *Digital Transmission & Signal Processing*) is recommended

assessments / exams

- Regular attendance of classes and tutorials
- Eligibility for exam through quizzes and assignments
- Final Exam
- A re-exam typically takes place during the last two weeks before the start of lectures in the following semester

course types / weekly hours

```
  4 h lectures
+ 2 h tutorial
= 6 h (weekly)
```

total workload

```
   90 h of classes
+ 180 h private study
= 270 h (= 9 ECTS)
```

grade Will be determined from performance in exams, quizzes and assigments. The exact modalities will be announced at the beginning of the module.

language English

aims / competences to be developed

Today the majority of all services is available via Internet-connections. Other than in the past this comprises not only data- but also media-services (like Voice Over IP or Video Streaming) and even Cyber-Physical Systems with their networked control loops.

The course introduces the basic characteristics of Internet-based communication (packetization on different layers, packet error detection and correction). It shows how existing protocols like HTTP, TCP and UDP can be shaped and evolved to fulfill the service requirements and how new protocols should be designed to serve the large variety of services.

content

- Introcudion of *EverythingoverIP* and *IPoverEverything*
- Theory of erasure channels (i.i.d, Gilbert-Elliott, channel capacity, minimum redundancy information)
- Wireless link layers (WiFi, PHY-bursts, Logical Link Control with DCF & EDCA, aggregation and ACK-techniques)
- Frame Check Sums, Cyclic Redundancy Checks
- Time Sensitive Networking
- Transport Layer services (flow control, congestion control, error control, segmentation and reassembly)
- QUIC media transport
- Error Coding under predictable reliability and latency (MDS-codes, binary codes)
- Upper layer protocols (HTTP, RTP/RTSP, DASH)

literature & reading

The course will come with a self-contained interactive manuscript. Complementary material will be announced before the start of the course on the course page on the Internet.

additional information

This module was formerly also known as *Future Media Internet* and *Multimedia Transport*.

Messtechnik und Sensorik MTS

st. semester	std. st. sem.	cycle	duration	SWS	ECTS
1-3	**4**	**jährlich**	**1 Semester**	**4**	**6**

responsible Prof. Dr. rer. nat. Andreas Schütze

lecturers Mitarbeiter des Lehrstuhls
Prof. Dr. rer. nat. Andreas Schütze

entrance requirements none

assessments / exams benotete Klausur, zusätzlich benotete Hausaufgaben zum Erwerb von Bonuspunkten für die Klausur

course types / weekly hours
```
  3 SWS Vorlesung
+ 1 SWS Übung
= 4 SWS
```

total workload
```
   60 h Präsenzzeit Vorlesung und Übung
+  60 h Vor- und Nachbereitung
+  60 h Klausurvorbereitung
= 180 h (= 4 ECTS)
```

grade Klausurnote

language Deutsch

aims / competences to be developed

Erlangung von Grundkenntnissen über den Messvorgang an sich (Größen, Einheiten, Messunsicherheit) sowie über die wesentlichen Komponenten vor allem digitaler elektrischer Messsysteme. Kennen lernen verschiedener Methoden und Prinzipien für die Messung nichtelektrischer Größen; Bewertung unterschiedlicher Methoden für applikationsgerechte Lösungen. Vergleich unterschiedlicher Messprinzipien für gleiche Messgrößen inkl. Bewertung der prinzipbedingten Messunsicherheiten und störender Quereinflüsse sowie ihrer Kompensationsmöglichkeiten durch konstruktive und schaltungstechnische Lösungen.

content

Messtechnik:

- Einführung: Was heißt Messen?; Größen und Einheiten (MKSA- und SI-System);
- Fehler, Fehlerquellen, Fehlerfortpflanzung, Messunsicherheit nach GUM;
- Messen von Konstantstrom, -spannung und Widerstand;
- Gleich- und Wechselstrombrücken;
- Mess- und Rechenverstärker (Basis: idealer Operationsverstärker);
- Grundlagen der Digitaltechnik (Logik, Gatter, Zähler);
- AD-Wandler (Flashwandler, sukzessive Approximation, Dual-Slope-Wandler);
- Digitalspeicheroszilloskop;

Sensorik:

- Temperaturmessung;
- Strahlungsmessung (berührungslose Temperaturmessung);
- magnetische Messtechnik: Hall- und MR-Sensoren;
- Messen physikalischer (mechanischer) Größen:
  - Weg & Winkel

- Kraft & Druck (piezoresistiver Effekt in Metallen und Halbleitern)
- Beschleunigung &Drehrate (piezoelektrischer Effekt, Corioliseffekt)
- Durchfluss (Vergleich von 6 Prinzipien)

literature & reading

E. Schrüfer: „Elektrische Messtechnik“, Hanser Verlag, München, 2004
H.-R. Tränkler: „Taschenbuch der Messtechnik“, Verlag Oldenbourg München, 1996
W. Pfeiffer: „Elektrische Messtechnik“, VDE-Verlag Berlin, 1999
R. Lerch, Elektrische Messtechnik, Springer Verlag, neue Auflage 2006
J. Fraden: „Handbook of Modern Sensors“, Springer Verlag, New York, 1996
T. Elbel: „Mikrosensorik“, Vieweg Verlag, 1996
H. Schaumburg; „Sensoren“ und „Sensoranwendungen“, Teubner Verlag Stuttgart, 1992 und 1995
J.W. Gardner: „Microsensors – PrinciplesandApplications“, John Wiley&Sons, Chichester, UK, 1994

additional information

Vorlesungsfolien, Übungsaufgaben und Musterlösungen zum Kopieren und Downloaden

Übungen in Kleingruppen (14-täglich) mit korrigierten Hausaufgaben

Ein besonderer Schwerpunkt in der Sensorik liegt auf der Betrachtung miniaturisierter Sensoren und Sensortechnologien.

Mikroelektronik 2 ME2

st. semester	std. st. sem.	cycle	duration	SWS	ECTS
1-3	4	jedes Sommersemester	1 Semester	3	4

responsible Prof. Dr.-Ing. Chihao Xu

lecturers Prof. Dr.-Ing. Chihao Xu

entrance requirements none

assessments / exams Klausur am Semesterende

course types / weekly hours

```
  2 SWS Vorlesung
+ 1 SWS Übung
= 3 SWS
```

total workload

```
   30 h Präsenzzeit Vorlesung
+  15 h Präsenzzeit Übung
+  45 h Vor- und Nachbereitung
+  30 h Klausurvorbereitung
= 120 h (= 4 ECTS)
```

grade Aus Klausurnote

language Deutsch

aims / competences to be developed

Verständnis der Abläufe bei Herstellungs- und Entwicklungsprozessen von integrierten Digitalschaltungen – CAD in der Mikroelektronik

content

- Wertschöpfungskette der Fertigung (Waferprozess, Montage, Testen)
- Einzelprozess-Schritte, Gehäuse, analoges Testen, Abgleich
- Abstraktionsebene in der ME (physikalisch, Symbol, Funktion), Y-Baum
- Entwurfsablauf, Entwurfsstile
- Tools für den Entwurf integrierter Schaltungen, Integration der Tools
- Schaltungssimulation (Prinzip, Numerik, Analysen incl. Sensitivity-, WC-, Monte-Carlo- und Stabilitätsanalyse)
- Logiksimulation (höhere Sprache, ereignisgesteuert, Verzögerung)
- Hardware Beschreibungssprache VHDL
- Logikoptimierung (Karnaugh Diagram, Technology Mapping) Test digitaler Schaltungen, design for testibility, Testmuster, Autotest
- Layout: Floorplanning, Polygone, Pcell/Cells, Generators, Design Rules, Constraints
- Parasitics, Backannotation, Matching, Platzierung und Verdrahtung, OPC

literature & reading

Skriptum des Lehrstuhls zur Vorlesung, Vorlesungsfolien

Mikroelektronik 3 ME3

st. semester	std. st. sem.	cycle	duration	SWS	ECTS
1-3	**4**	**jedes Wintersemester**	**1 Semester**	**3**	**4**

responsible Prof. Dr.-Ing. Chihao Xu

lecturers Prof. Dr.-Ing. Chihao Xu

entrance requirements none

assessments / exams benotete mündliche Abschlussprüfung

course types / weekly hours

```
  2 SWS Vorlesung
+ 1 SWS Übung
= 3 SWS
```

total workload

```
   30 h Präsenzzeit Vorlesung
+  15 h Präsenzzeit Übung
+  45 h Vor- und Nachbereitung
+  30 h Klausurvorbereitung
= 120 h (= 4 ECTS)
```

grade Abschlussprüfungsnote

language Deutsch

aims / competences to be developed

Verständnisse und Kenntnisse im Verhalten, in der Beschreibung und im Entwurf integrierter analoger und mixed-signal CMOS-Schaltungen.

content

- Einführung in die Analogtechnik
- MOS-Technologie (Eigenschaften, Bauelemente Funktionale Sicht)
- MOS-Transitoren in Schaltungen (CMOS-Schaltungskomponenten)
- Frequenzgang der Verstärker (allgemein, Kapazität und Pol, Common Source, Kaskode, Rückkopplung)
- OP-Verstärker (Einstufiger- und Zweistufiger Verstärker, Ausgangsstufe, Kenngrößen)
- Referenzschaltungen (einfache Referenzschaltungen, Bandgap-Rferenz, Spannungsregler, IReferenz, gm-Referenz)
- Switched Capacitor Schaltungen (Swiched Capacitor (SC) Grundlagen, SC Integrator und Verstärker, SC Filter, Sample und Hold Schaltungen)
- AD-Wandler (Einführung, Komparator, paralleler AD-Wandler, sukzessive Approximation ADWandler, Integrierter Dual Slop AD-Wandler)
- DA-Wandler (Einführung, paralleler AD-Wandler, serieller DA-Wandler)

literature & reading

Skriptum des Lehrstuhls zur Vorlesung, Vorlesungsfolien, weiterführende Literatur wird zu Beginn der ersten Vorlesung bekannt gegeben

additional information

Methoden: Information durch Vorlesung, Vertiefung durch Eigentätigkeit (Nacharbeiten, aktive Teilnahme an den Übungen)

Mikroelektronik 4 ME4

st. semester	std. st. sem.	cycle	duration	SWS	ECTS
1-3	4	jedes Sommersemester	1 Semester	3	4

responsible Prof. Dr.-Ing. Chihao Xu

lecturers Prof. Dr.-Ing. Chihao Xu

entrance requirements none

assessments / exams Präsentation einer Arbeit und mündliche Befragung am Semesterende

course types / weekly hours

```
  2 SWS Vorlesung
+ 1 SWS Übung
= 3 SWS
```

total workload

```
   30 h Präsenzzeit Vorlesung
+  15 h Präsenzzeit Übung
+  45 h Vor- und Nachbereitung
+  30 h Klausurvorbereitung
= 120 h (= 4 ECTS)
```

grade Abschlußprüfung

language Deutsch

aims / competences to be developed

Wie Mikroelektronik in Systemen, insbesondere zur Ansteuerung reeller Anwendungen wie Displays eingesetzt wird. Es schließt Systempartitionierung, Design und Algorithmen ein.

content

- HV circuit (charge pump, level shifter, hv driver)
- Automotiver Lampentreiber
- Power Management (LDO, Schaltnetzteile)
- Low Power Design
- Licht, Farbe und Visuelle Effekte
- PM-LCD Display Steuerung
- AM-LCD Display (TFT) Steuerung
- PM-OLED Display Steuerung
- AM-OLED Display Steuerung
- Weitere Themen je nach Auswahl der Studierenden

literature & reading

Vorlesungsfolien, Veröffentlichungen

Mikromechanische Bauelemente MM

st. semester	std. st. sem.	cycle	duration	SWS	ECTS
1-3	**4**	**jährlich**	**1 Semester**	**3**	**4**

responsible	Prof. Dr. Helmut Seidel
lecturers	Prof. Dr. Helmut Seidel
entrance requirements	none
assessments / exams	Schriftlich oder mündlich
course types / weekly hours	2 SWS Vorlesung + 1 SWS Übung = 3 SWS
total workload	45 h Präsenzzeit Vorlesung und Übung + 45 h Vor- und Nachbereitung + 30 h Klausurvorbereitung = 120 h (= 4 ECTS)
grade	Prüfungsnote
language	Deutsch

aims / competences to be developed

Erlangen von Grundkenntnissen im Bereich Bauelemente der Mikrosystemtechnik mit Schwerpunkt in der Mikroaktorik; Einführung in die Mikrofluidik.

content

- Einführung, Marktübersicht
- Skalierungsgesetze
- Passive mechanische Bauelemente
- Prinzipien der Mikroaktorik (Elektrostatik, Magnetik, Piezoelektrik, Formgedächtnislegierungen)
- Aktive mechanische Bauelemente (Schalter, Relais, etc.)
- Passive fluidische Bauelemente
- Fluidische Aktoren (Ventile, Pumpen)
- Sensoren in der Fluidik

literature & reading

Mescheder, Ulrich: ”Mikrosystemtechnik - Konzepte und Anwendungen”
Büttgenbach, Stephanus: ”Mikromechanik - Einführung in Technologie und Anwendungen”
Gerlach, G.; Dötzel, W.: ”Grundlagen der Mikrosystemtechnik”
Menz, Wolfgang; Mohr, Jürgen: ”Mikrosystemtechnik für Ingenieure”
M. Madou: Fundamentals of Microfabrication

Mikrotechnologie

st. semester	std. st. sem.	cycle	duration	SWS	ECTS
1-3	**4**	**jedes Wintersemester**	**1 Semester**	**3**	**4**

responsible	Prof. Dr. Helmut Seidel
lecturers	Prof. Dr. Helmut Seidel
entrance requirements	none
assessments / exams	Mündliche oder schriftliche Prüfung
course types / weekly hours	2 SWS Vorlesung + 1 SWS Übung = 3 SWS
total workload	45 h Präsenzzeit Vorlesung und Übung + 45 h Vor- und Nachbereitung + 30 h Klausurvorbereitung = 120 h (= 4 ECTS)
grade	Prüfungsnote
language	Deutsch

aims / competences to be developed

Erlangen von vertieften Grundkenntnissen in der Herstellungstechnologie von Mikrosystemen und mikroelektronischen Schaltkreisen mit Schwerpunkt in der Halbleitertechnologie

content

- Einführung, Technologieüberblick, Reinraumtechnik
- Materialien der Mikrosystemtechnik, Kristallografie
- Herstellung von kristallinem Silizium (Czochralski, Float-Zone)
- Thermische Oxidation und Epitaxie
- Schichtabscheidung: CVD (Chemical Vapor Deposition)
- Physikalische Schichtabscheidung: PVD (Physical Vapor Deposition)
- Dotiertechniken: Diffusion, Ionenimplantation, Annealing
- Lithografie: Kontakt- und Proximity-Belichtung, Waferstepper, Lacktechnik
- Nassätzen, Reinigen (isotrop, anisotrop, elektrochemisch)
- Trockenätzen: Ionenstrahlätzen, Reaktives Ionenätzen, Plasmaätzen
- Bulk-/Oberflächen-Mikromechanik,
- LIGA-Verfahren, Abformtechniken
- Waferbonden, Planarisierungstechniken (Chemisch-mechanisches Polieren)

literature & reading

Mescheder, Ulrich: ”Mikrosystemtechnik - Konzepte und Anwendungen”
Büttgenbach, Stephanus: ”Mikromechanik - Einführung in Technologie und Anwendungen”
Gerlach, G.; Dötzel, W.: ”Grundlagen der Mikrosystemtechnik”
Menz, Wolfgang; Mohr, Jürgen: ”Mikrosystemtechnik für Ingenieure”

Neural Networks: Theory and Implementation — NNTI

st. semester	std. st. sem.	cycle	duration	SWS	ECTS
1-3	**4**	**every winter semester**	**1 semester**	**6**	**9**

responsible Prof. Dr. Dietrich Klakow

lecturers Prof. Dr. Dietrich Klakow

entrance requirements *Mathemathik für Informatiker I - III* or comparable; good programming skills.

assessments / exams Written Exam

course types / weekly hours

```
  2 h lectures
+ 2 h tutorial
+ 2 h project work
= 6 h (weekly)
```

total workload

```
   90 h of classes
+ 180 h private study
= 270 h (= 9 ECTS)
```

grade Written exam and graded projects. Exact details will be announced in the first lecture.

language English

aims / competences to be developed

The participants will be introduced to the key ideas of basic classification algorithms and in particular neural networks. A focus is also the implementation and applications to relevant problems. To achieve this, there will be theoretical exercises as well as project work.

content

- Classification
- Regression
- Linear Classifiers
- Perceptron
- Support Vector Machines
- Multy-Layer Perceptrons
- Deep Learning Software
- Autoencoders
- LSTMs
- Recurrent Neural Networks
- Sequence-to-sequence learning

literature & reading

Ian Goodfellow and Yoshua Bengio and Aaron Courville
Deep Learning
MIT Press, 2016
http://www.deeplearningbook.org

Operating Systems OS

st. semester	std. st. sem.	cycle	duration	SWS	ECTS
1-3	**4**	**at least every two years**	**1 semester**	**6**	**9**

responsible Prof. Peter Druschel, Ph.D.

lecturers Prof. Peter Druschel, Ph.D.
Björn Brandenburg, Ph.D

entrance requirements For graduate students: none

assessments / exams Regular attendance at classes and tutorials
Successful completion of a course project in teams of 2 students
Passing 2 written exams (midterm and final exam)
A re-exam takes place during the last two weeks before the start of lectures in the following semester.

course types / weekly hours
```
  4 h lectures
+ 2 h tutorial
= 6 h (weekly)
```

total workload
```
   90 h of classes
+ 180 h private study
= 270 h (= 9 ECTS)
```

grade Will be determined from performance in exams, exercises and practical tasks. The exact modalities will be announced at the beginning of the module.

language English

aims / competences to be developed

Introduction to the principles, design, and implementation of operating systems

content

Process management:

- Threads and processes, synchronization
- Multiprogramming, CPU Scheduling
- Deadlock

Memory management:

- Dynamic storage allocation
- Sharing main memory
- Virtual memory

I/O management:

- File storage management
- Naming
- Concurrency, Robustness, Performance

Virtual machines

literature & reading

Will be announced before the start of the course on the course page on the Internet.

Security Sec

st. semester	std. st. sem.	cycle	duration	SWS	ECTS
1-3	**4**	**at least every two years**	**1 semester**	**6**	**9**

responsible Prof. Dr. Michael Backes

lecturers Prof. Dr. Michael Backes
Prof. Dr. Cas Cremers

entrance requirements For graduate students: none

assessments / exams
- Regular attendance of classes and tutorials
- Passing the final exam
- A re-exam is normally provided (as written or oral examination).

course types / weekly hours
```
  4 h lectures
+ 2 h tutorial
= 6 h (weekly)
```

total workload
```
   90 h of classes
+ 180 h private study
= 270 h (= 9 ECTS)
```

grade Will be determined by the performance in exams, tutor groups, and practical tasks. Details will be announced by the lecturer at the beginning of the course.

language English

aims / competences to be developed

Description, assessment, development and application of security mechanisms, techniques and tools.

content

- Basic Cryptography,
- Specification and verification of security protocols,
- Security policies: access control, information flow analysis,
- Network security,
- Media security,
- Security engineering

literature & reading

Will be announced on the course website

Software Engineering SE

st. semester	std. st. sem.	cycle	duration	SWS	ECTS
1-3	**4**	**at least every two years**	**1 semester**	**6**	**9**

responsible Prof. Dr. Sven Apel

lecturers Prof. Dr. Sven Apel

entrance requirements

- Knowledge of programming concepts (as taught in the lectures *Programmierung 1* and *Programmierung 2*)
- Basic knowledge of software processes, design, and testing (as taught and applied in the lecture *Softwarepraktikum*)

assessments / exams Beside the lecture and weekly practical exercises, there will be a number of assignments in the form of mini-projects for each student to work on (every two to three weeks). The assignments will be assessed based on the principles covered in the lecture. Passing all assignments is a prerequisite for taking the final written exam. The final grade is determined only by the written exam. Further examination details will be announced by the lecturer at the beginning of the course. In short:

- Passing all assignments (prerequisite for the written exam)
- Passing the written exam

course types / weekly hours

```
  4 h lectures
+ 2 h exercises
= 6 h (weekly)
```

total workload

```
   90 h of classes and exercises
+ 180 h private study and assignments
= 270 h (= 9 ECTS)
```

grade The grade is determined by the written exam. Passing all assignments is a prerequisite for taking the written exam. The assignments do not contribute to the final grade. Further examination details will be announced by the lecturer at the beginning of the course.

language English

aims / competences to be developed

- The students know and apply modern software development techniques.
- They are aware of key factors contributing to the complexity of real-world software systems, in particular, software variability, configurability, feature interaction, crosscutting concerns, and how to address them.
- They know how to apply established design and implementation techniques to master software complexity.
- They are aware of advanced design and implementation techniques, including collaboration-based design, mixins/traits, aspects, pointcuts, advice.
- They are aware of advanced quality assurance techniques that take the complexity of real-world software systems into account: variability-aware analysis, sampling, feature-interaction detection, predictive performance modeling, etc.
- They appreciate the role of non-functional properties and know how to predict and optimize software systems regarding these properties.
- They are able to use formal methods to reason about key techniques and properties covered in the lecture.

content

- Domain analysis, feature modeling
- Automated reasoning about software configuration using SAT solvers
- Runtime parameters, design patterns, frameworks
- Version control, build systems, preprocessors
- Collaboration-based design
- Aspects, pointcuts, advice
- Expression problem, preplanning problem, code scattering & tangling, tyranny of the dominant decomposition, inheritance vs. delegation vs. mixin composition
- Feature interaction problem (structural, control- & data-flow, behavioral, non-functional feature interactions)
- Variability-aware analysis and variational program representation (with applications to type checking and static program analysis)
- Sampling (random, coverage)
- Machine learning for software performance prediction and optimization

literature & reading

- Feature-Oriented Software Product Lines: Concepts and Implementation. S. Apel, et al., Springer, 2013.
- Generative Programming: Methods, Tools, and Applications: Methods, Techniques and Applications. K. Czarnecki, et al., Addison-Wesley, 2000.
- Mastering Software Variability with FeatureIDE. J. Meinicke, et al., Springer, 2017.

Statistical Natural Language Processing SNLP

st. semester	std. st. sem.	cycle	duration	SWS	ECTS
1-3	**4**	**every summer semester**	**1 semester**	**4**	**6**

responsible	Prof. Dr. Dietrich Klakow
lecturers	Prof. Dr. Dietrich Klakow
entrance requirements	For graduate students: none
assessments / exams	Written Exam

course types / weekly hours	`2 h lectures`
	`+ 2 h tutorial`
	`= 4 h (weekly)`

total workload	`60 h of classes`
	`+ 120 h problem solving and private study`
	`= 180 h (= 6 ECTS)`

grade	Final Exam Mark
language	English

aims / competences to be developed

Acquire core competencies in the mathematical basics of language processing and practice the implementation of essential methods.

content

- language processing: basic terms
- mathematical foundations
- word sense disambiguation
- part-of-speech tagging
- named-entity recognition
- information retrieval
- text classification

literature & reading

Chris Manning and Hinrich Schütze
Foundations of Statistical Natural Language Processing

Systemtheorie und Regelungstechnik 1 SR1

st. semester	std. st. sem.	cycle	duration	SWS	ECTS
1-3	**4**	**jährlich**	**1 Semester**	**3**	**5**

responsible Prof. Dr.-Ing. habil. J. Rudolph

lecturers Prof. Dr.-Ing. habil. J. Rudolph

entrance requirements none

assessments / exams Schriftliche Prüfung

course types / weekly hours

```
  2 SWS Vorlesung
+ 1 SWS Übung
= 3 SWS
```

total workload

```
   45 h Präsenzzeit Vorlesung und Übung
+  60 h Vor- und Nachbereitung
+  45 h Klausurvorbereitung
= 150 h (= 5 ECTS)
```

grade Note der Prüfung

language Deutsch

aims / competences to be developed

Verständnis für die systemtheoretischen Grundlagen linearer Systeme sowie für den Entwurf linearer Steuerungen und Regler.

content

Es werden lineare zeitinvariante Systeme (endlicher Dimension) mit je einer Eingangs- und einer Ausgangsgröße betrachtet.

- *Einführung:* Systembegriff und regelungstechnische Aufgabenstellungen, Linearität und Linearisierung, Zeitinvarianz, Eingangs-Ausgangs-Darstellung
- *Systeme niedriger Ordnung:* Trajektorienplanung, Steuerung, allgemeine Lösung, P-, PI-, PD- und PID-Regler, parametrische Unbestimmtheiten, Frequenzgang (Ortskurven und Bode-Diagramme)
- *Systeme beliebiger Ordnung:* Eingangs-Ausgangs-Darstellung, Regelungsform, Zustandskonzept, Beobachtbarkeits- und Beobachterform, Diagonalisierung und JordanForm, Phasenportrait für Systeme 2. Ordnung, Beobachtbarkeit, Stabilität (Definition, Ljapunov-Funktion, Ljapunov-Gleichung)

Der Lehrstoff wird in Vorlesungen und Übungen anhand technologischer Beispiele diskutiert und vertieft.

literature & reading

[1] Föllinger, O., Regelungstechnik, Einführung in die Methoden und ihre Anwendung, Hüthig, Heidelberg (1994).
[2] Lunze, J., Regelungstechnik 1, Springer, Heidelberg (2007).
[3] Rugh, W. J., Linear System Theory, Prentice Hall, New Jersey (1993).
[4] Kailath, T., Linear Systems, Prentice-Hall, Englewood Cliffs (1980).

additional information

Neben einem ausgearbeiteten Skriptum werden umfangreiche Lösungen zu den Übungsaufgaben zur Verfügung gestellt. Außerdem besteht die Möglichkeit, das Erlernte an einem Versuchsstand praktisch anzuwenden und weiter zu vertiefen.

Systemtheorie und Regelungstechnik 2 SR2

st. semester	std. st. sem.	cycle	duration	SWS	ECTS
1-3	**4**	**jährlich**	**1 Semester**	**3**	**5**

responsible Prof. Dr.-Ing. habil. J. Rudolph

lecturers Prof. Dr.-Ing. habil. J. Rudolph

entrance requirements none

assessments / exams Schriftliche oder mündliche Prüfung

course types / weekly hours

```
  2 SWS Vorlesung
+ 1 SWS Übung
= 3 SWS
```

total workload

```
   45 h Präsenzzeit Vorlesung und Übung
+  60 h Vor- und Nachbereitung
+  45 h Klausurvorbereitung
= 150 h (= 5 ECTS)
```

grade Note der Prüfung

language Deutsch

aims / competences to be developed

Verständnis für die systemtheoretischen Grundlagen linearer Systeme sowie für den Entwurf linearer Steuerungen, Regler und Beobachter.

content

Es werden allgemeine lineare zeitinvariante Systeme (endlicher Dimension) behandelt.

- *Einführung:*
  Systemdarstellung und Linearisierung
- *Analyse der Systemstruktur, Trajektorienplanung und Steuerung:*
  Polynom-Matrix-Darstellung, Autonomie und Spalten-Hermite-Form, Reduktion, Transformation, Basisgrößen, Kriterien für (Nicht-)Steuerbarkeit, Trajektorienplanung
- *Eingang und Zustand:*
  Wahl eines Eingangs, Zustandskonzept, Steuerbarkeitskriterien für Systeme in Zustandsdarstellung (z.B. Hautus-Kriterium, Kalman-Kriterium), Kalmansche Zerlegung
- *Regelung durch Zustandsrückführung:*
  Stabile Folgeregelung mittels Zustandsrückführung, Folgeregelung bei Messung einer Basis, Beobachterentwurf (Beobachtbarkeit, vollständige und reduzierte Beobachter)

Der Lehrstoff wird in Vorlesungen und Übungen anhand technologischer Beispiele diskutiert und vertieft.

literature & reading

[1] Kailath, T., Linear Systems, Prentice-Hall, Englewood Cliffs (1980).
[2] Reinschke, K., Lineare Regelungs- und Steuerungstheorie, Springer, Berlin (2006).
[3] MacDuffee, C. C., The Theory of Matrices, Chelsea Publishing Company, New York (1946).
[4] Wolovich, W. A., Linear Multivariable Systems, Springer, New York (1974).

additional information

Neben einem ausgearbeiteten Skriptum werden umfangreiche Lösungen zu den Übungsaufgaben sowie Programme zur Simulation ausgewählter Systeme aus Vorlesung und Übung zur Verfügung

Theoretische Elektrotechnik 2 TET2

st. semester	std. st. sem.	cycle	duration	SWS	ECTS
1-3	**4**	**jährlich**	**1 Semester**	**4**	**5**

responsible Romanus Dyczij-Edlinger

lecturers Romanus Dyczij-Edlinger

entrance requirements none

assessments / exams Mündliche oder schriftliche Prüfung

course types / weekly hours
```
  2 SWS Vorlesung
+ 2 SWS Übung
= 4 SWS
```

total workload
```
   60 h Präsenzzeit Vorlesung und Übung
+  60 h Vor- und Nachbereitung
+  30 h Klausurvorbereitung
= 150 h (= 5 ECTS)
```

grade mündliche oder schriftliche Prüfung

language Deutsch

aims / competences to be developed

Dieser Kurs lehrt die mathematischen und physikalischen Grundlagen der klassischen Elektrodynamik und versetzt Studierende in die Lage, physikalische Beobachtungen in feldtheoretische Modelle umzusetzen. Der Modul vermittelt grundsätzliches Verständnis für Diffusions- und Wellenausbreitungseffekte und befähigt Studierende, einfache Wirbelstromprobleme und Übertragungsleitungen zu berechnen, die modalen Eigenschaften einfacher Wellenleiter und Resonatoren zu bestimmen und die Strahlungsfelder von Antennenstrukturen zu berechnen.

content

Elektromagnetische Felder im Frequenzbereich (Phasoren, Maxwell-Gleichungen, Poynting-Satz); Wirbelströme (Felddiffusion im Zeit- und Frequenzbereich, Relaxationszeit, Eindringtiefe, Beispiele); homogene Übertragungsleitungen (Wellengleichung, Telegraphengleichungen im Zeit- und Frequenzbereich, Ausbreitungseigenschaften, Phasen- und Gruppengeschwindigkeit, Dispersion, Smith-Diagramm, Beispiele); Wellenausbreitung in quellenfreien Gebieten (ebene Wellen im Zeit- und Frequenzbereich, Reflexion und Brechung, Brechungsindex, Totalreflexion, Brewster-Winkel); Anregung elektromagnetischer Wellen (retardierte Potenziale, Freiraum-Lösungen im Zeit- und Frequenzbereich, elektrischer und magnetischer Dipol, Dualität, vektorielles Huygensches Prinzip, Fernfeldnäherungen, Gruppenstrahler); verlustfreie homogene Wellenleiter (axiale Separation, Wellentypen, Ein-Komponenten-Vektorpotenziale, Modenorthogonalität, Dispersionsgleichung, Ausbreitungseigenschaften, Beispiele); verlustfreie homogene Resonatoren (Modenorthogonalität, Störungsrechnung, Beispiele);

literature & reading

Harrington R.F.: Time-Harmonic Electromagnetic Fields;
Ramo S., Whinnery J.R., Van Duzer T.: Fields and Waves in Communication Electronics;
Unger, H.G.: Elektromagnetische Theorie für die Hochfrequenztechnik Bd. 1 & 2;
Zhan, K., Li, D.: Electromagnetic Theory for Microwaves and Optoelectronics;
Balanis, C.A., Advanced Engineering Electromagnetics;
Collin, R.E.: Field Theory of Guided Waves;

Pozar, D.M.: Microwave Engineering;
Jackson, J.J.: Klassische Elektrodynamik;
Simonyi, K.: Theoretische Elektrotechnik;
Feynman, R.P. Leighton, R.B., Sands, M: Vorlesungen über Physik, Bd. 2.

additional information

Vorlesungsskripte erhältlich, Übungsbeispiele und alte Prüfungen im Internet abrufbar

Verification

Veri

st. semester	std. st. sem.	cycle	duration	SWS	ECTS
1-3	**4**	**at least every two years**	**1 semester**	**6**	**9**

responsible Prof. Dr.-Ing. Holger Hermanns

lecturers Prof. Dr.-Ing. Holger Hermanns
Prof. Bernd Finkbeiner, Ph.D

entrance requirements For graduate students: none

assessments / exams

- Regular attendance of classes and tutorials
- Passing the final exam
- A re-exam takes place during the last two weeks before the start of lectures in the following semester.

course types / weekly hours

```
  4 h lectures
+ 2 h tutorial
= 6 h (weekly)
```

total workload

```
   90 h of classes
+ 180 h private study
= 270 h (= 9 ECTS)
```

grade Will be determined from performance in exams, exercises and practical tasks. The exact modalities will be announced at the beginning of the module.

language English

aims / competences to be developed

The students become familiar with the standard methods in computer-aided verification. They understand the theoretical foundations and are able to assess the advantages and disadvantages of different methods for a specific verification project. The students gain first experience with manual correctness proofs and with the use of verification tools.

content

- models of computation and specification languages: temporal logics, automata over infinite objects, process algebra
- deductive verification: proof systems (e.g., Floyd, Hoare, Manna/Pnueli), relative completeness, compositionality
- model checking: complexity of model checking algorithms, symbolic model checking, abstraction case studies

literature & reading

Will be announced before the start of the course on the course page on the Internet.

Module Category 2

Seminare

Seminar

st. semester	std. st. sem.	cycle	duration	SWS	ECTS
1-3	**4**	**every semester**	**1 semester**	**2**	**7**

responsible Dean of Studies of the Faculty of Mathematics and Computer Science
Dean of Studies of the Department of Computer Science

lecturers Lecturers of the department

entrance requirements Basic knowledge of the relevant sub-field of the study program.

assessments / exams
- Thematic presentation with subsequent discussion
- Active participation in the discussion
- short written report and/or project possible

course types / weekly hours `2 h seminar (weekly)`

total workload
```
  30 h of lectures and exercises
+ 180 h project work
= 210 h (= 7 ECTS)
```

grade Will be determined from the performance in the presentation and the written report and/or the seminar project. The exact modalities will be announced by the respective instructor.

language English or German

aims / competences to be developed

At the end of the seminar, students have primarily gained a deep understanding of current or fundamental aspects of a specific subfield of computer science.

They have gained further competence in independent scientific research, classifying, summarizing, discussing, criticizing and presenting scientific findings.

content

Largely independent research of the seminar topic:

- Reading and understanding of scientific papers
- Analysis and evaluation of scientific papers
- Discussion of the scientific work in the group
- Analyzing, summarizing and reporting the specific topic
- Developing common standards for scientific work
- Presentation techniques

Specific in-depth study related to the individual topic of the seminar.

The typical procedure of a seminar is usually as follows:

- Preparatory discussions for topic selection
- Regular meetings with discussion of selected presentations
- if applicable, work on a project related to the topic
- Presentation and, if necessary, writing a report on one of the presentations

literature & reading

Material is selected according to the topic.

additional information

The seminars available will be announced prior to the beginning of the semester and will vary by study programme.

Module Category 3

Master-Seminar und -Arbeit

Master Seminar

st. semester	std. st. sem.	cycle	duration	SWS	ECTS
3	**4**	**every semester**	**1 semester**	**2**	**12**

responsible Dean of Studies of the Faculty of Mathematics and Computer Science
Study representative of computer science

lecturers Professors of the department

entrance requirements Acquisition of at least 30 CP

assessments / exams

- Preparation of the relevant scientific literature
- Written elaboration of the topic of the master thesis
- Presentation about the planned topic with subsequent discussion
- Active participation in the discussion

course types / weekly hours 2 h seminar (weekly)

total workload

```
   30 h seminar
+  40 h contact with supervisor
+ 290 h private study
= 360 h (= 12 ECTS)
```

grade graded

language English or German

aims / competences to be developed

The Master seminar sets the ground for carrying out independent research within the context of an appropriately demanding research area. This area provides sufficient room for developing own scientific ideas.

At the end of the Master seminar, the basics ingredients needed to embark on a successful Master thesis project have been explored and discussed with peers, and the main scientific solution techniques are established.

The Master seminar thus prepares the topic of the Master thesis. It does so while deepening the students' capabilities to perform a scientific discourse. These capabilities are practiced by active participation in a reading group. This reading group explores and discusses scientifically demanding topics of a coherent subject area.

content

The methods of computer science are systematically applied, on the basis of the "state-of-the-art".

literature & reading

Scientific articles corresponding to the topic area in close consultation with the lecturer.

Master Thesis

st. semester	std. st. sem.	cycle	duration	SWS	ECTS
4	**4**	**every semester**	**6 months**	**-**	**30**

responsible Dean of Studies of the Faculty of Mathematics and Computer Science
Study representative of computer science

lecturers Professors of the department

entrance requirements Successful completion of the *Master Seminar*

assessments / exams Written elaboration in form of a scientific paper. It describes the scientific findings as well as the way leading to these findings. It contains justifications for decisions regarding chosen methods for the thesis and discarded alternatives. The student's own substantial contribution to the achieved results has to be evident. In addition, the student presents his work in a colloquium, in which the scientific quality and the scientific independence of his achievements are evaluated.

course types / weekly hours none

total workload

```
   50 h contact with supervisor
+ 850 h private study
= 900 h (= 30 ECTS)
```

grade Grading of the Master Thesis

language English or German

aims / competences to be developed

In the master thesis the student demonstrates his ability to perform independent scientific work focusing on an adequately challenging topic prepared in the master seminar.

content

In the master thesis the student demonstrates his ability to perform independent scientific work focusing on an adequately challenging topic prepared in the master seminar.

literature & reading

According to the topic