

# **Modulbeschreibungen**

## **Description of the Courses in CIT/CMM Master Studies**

**CIT: Communication and Information Technology**  
**CMM: Control, Microsystems, Microelectronics**

**Version of October 29th, 2019**

## Table of Contents

Advanced Design of Mixed-Signal Systems.....	4
Advanced Digital Signal Processing .....	5
Advanced Digital System Design.....	6
Advanced Topics in Digital Communications .....	7
Analog to Digital Converters .....	8
Antennas.....	9
Architectures and Design Methodologies of Integrated Digital Systems .....	10
Channel Coding I.....	11
Channel Coding II .....	12
Communication Networks: Systems .....	13
Communication Networks: Theory .....	14
Communication Technologies.....	15
Computational Intelligence in Modeling, Prediction and Signal Processing.....	16
Control Theory I.....	17
Control Theory II.....	18
Control Theory III .....	19
Design Methodologies with Hardware Description Languages.....	20
Digital Signal Processing .....	21
Digital Technology.....	22
Discrete Systems .....	23
Electrodynamics .....	24
German language course .....	25
Information and Communication Technology Laboratory I.....	26
Information and Communication Technology Laboratory II.....	27
Integrated Circuits .....	29
Intellectual Property, Patents and Further Protective Rights .....	30
Internet of Things .....	31
Lab 1 CMM - Lab .....	32
Lab 2 CMM - Lab .....	33
Low Power Strategies in Wireless Sensor Networks .....	34
Master Seminar.....	35
Master's Thesis.....	36
Microfluidic Devices .....	37
Microsystems.....	38
Micro Technology .....	39
Modeling and Simulation of Sensors, Circuits and Systems in Automotive Electronics ....	40

Network Simulation (previous title: Stochastic Simulation of Communication Networks and their Protocols) .....	42
Next Generation Cellular Networks .....	43
Nonlinear Systems.....	44
Optimisation Theory.....	45
Presenting science .....	46
Process Automation.....	47
Project.....	48
RF Frontend Devices and Circuits .....	49
Robotics I .....	50
Robotics II.....	52
Selected Topics in Sustainable Communication Networks.....	54
Sensors and Measurement Systems.....	55
Sensor Science.....	56
Speech and Audio Signal Processing I.....	57
Speech and Audio Signal Processing II .....	58
Systems-on-Chip: Architectures and Design Methods .....	59
System Theory.....	60
Understanding Germany.....	61
Wireless Communications.....	62
Annex 1: Details of the Labs for CMM .....	63

# Advanced Design of Mixed-Signal Systems

## 01-15-03-DMSS-V

**Responsible:** Prof. Dr.-Ing. Steffen Paul  
**Lecturer:** Dr. Dmitry Osipov

**Aim:**

After this 1-semester course, the students will have gained:

- Knowledge in system-level simulation of mixed-signal systems.
- An in-depth understanding of process and mismatch on the systems parameters.

**Prerequisite:** no formal requirements. Knowledge in the basics of electronics and electrical engineering and in semiconductor devices is an asset.

**Content:**

Mixed-systems design overview based on the example of 8 bit SAR ADC in 45 nm CMOS

**Literature:**

van de Plassche, Rudi: "CMOS Integrated Analog-to-Digital converters", Kluwer Academic Publishers, 2<sup>nd</sup> Edition, 2003.

**Methods:** Lectures, exercises

**Efficiency Statement:** Oral examination

**ECTS Credits:** 4

**SWS:** 3

**Workload:** 120 hours  
Lectures and courses 35%  
Reading, homework and preparation of exam 65%

**Suggested for:** CMM 2<sup>nd</sup> term (elective course), M.Sc. ET/IT

# Advanced Digital Signal Processing

## 01-15-03-DSP-V

**Responsible:** Prof. Dr.-Ing. A. Dekorsy  
**Lecturer:** Prof. Dr.-Ing. A. Dekorsy

### Aim:

This is part two of the two semester course on digital signal processing. After the course, the students will be able to:

- Apply FFT for spectral analysis of deterministic signals.
- Develop small numeric routines.
- Explain the basics of the traditional methods of spectral analysis for stochastic processes.
- Apply existing routines for simulation (Matlab)
- Understand the theoretical basics of parametric estimation procedures.
- Analyse language signals using existing program libraries.

**Prerequisite:** Digital Signal Processing I

### Content:

- |   |  |
|---|--|
| 1. Spectrum Analysis of Deterministic Signals | 3. Parametric Spectrum Est.                |
| 1.1.DFT of Real Valued Sequences              | 3.1.ARMA-Models                            |
| 1.2.Transform of Real Valued Bandpass Signals | 3.2.Markov Process (1 <sup>st</sup> Order) |
| 1.3.Analysis of Periodic Signals              | 3.3.Yule-Walker Equation                   |
| 1.4.Window-Functions (Time Domain)            | 3.4.Linear Prediction (Survey)             |
| 2. Traditional Spectrum Estimation            | 3.5.Levinson-Durbin Recursion              |
| 2.1.Estimation of the Autocorrelation         | 3.6.Lattice Structure                      |
| 2.2.Calculation of the ACF based on FFT       | 3.7.Yule-Walker Equation                   |
| 2.3.Periodogram (Variance)                    | 3.8.Examples                               |
| 2.4.Consistent Spectrum Estimation (Survey)   |  |

### Literature:

Haykin: Adaptive Filter Theorie (Prentice Hall).  
Van Trees: Detection, Estimation and Modulation Theory (Wiley).

**Methods:** Lectures, PC exercises using Matlab

**Efficiency Statement:** Written examination

### Information,

**Downloads:** <http://www.ant.uni-bremen.de/en/courses/dsp2>

**ECTS Credits:** 4

**SWS:** 3

**Workload:** 120 hours  
Lectures and courses 38%  
Reading, homework and preparation of exam 62%

**Suggested for:** CIT 2<sup>nd</sup> term, (compulsory course), CMM 2<sup>nd</sup> (elective course), Master ET/IT

# Advanced Digital System Design

## 01-15-03-ADS-V

**Responsible:** Prof. Dr.-Ing. Alberto García-Ortiz  
**Lecturer:** Prof. Dr.-Ing. Alberto García-Ortiz

### **Aim:**

The students will learn the relevant skills for the realization of function-specific digital systems, including high-performance processors; they will master the systematic construction and the design of a digital system; and they will be able to design and analyse digital systems with multiple processors.

**Prerequisite:** Knowledge about fundamental digital modules: its use, operation principles, and design methodologies (e.g. Digital Technology).

### **Content:**

High-performance processors

    Pipelining

    Dynamic scheduling and out-of-order execution

Multiprocessors

    Taxonomy

    SIMD architectures

    Shared memory vs message passing multiprocessors

Data coherency in multiprocessor systems

    Cache architectures

    Snooping-protocols

Interconnect architectures

    Metrics and topologies

    On-chip buses

    Networks-on-Chip

### **Literature:**

- Lecture script and lecture slides.
- Patterson, David A.; Hennessy, John L.; Hower, Walter; Computer Organization and Design, Elsevier Inc., ISBN 9780123744937
- J.M. Rabaey, A. Chandrakasan, B. Nikolic, Digital Integrated Circuits – A Design Perspective, ISBN-10\_9788120322578

**Methods:** 2h lecture, 1h exercises  
Use of CAD tools for selected exercises

**Efficiency Statement:** written or oral examination

### **Information,**

**Downloads:** <https://elearning.uni-bremen.de/>

**ECTS Credits:** 4

**SWS:** 3

**Workload:** 120 hours (lectures and courses 42h, homework 28h and preparation of exam 50h)

**Suggested for:** CMM 3rd term (compulsory course), can also be done in 1st term, CIT 3rd term (elective course), can also be done in 1st term

# Advanced Topics in Digital Communications

## 01-15-03-ATDC-V

Responsible: Dr. Carsten Bockelmann  
Lecturer: Dr. Carsten Bockelmann

### Aim:

Advanced Topics in Digital Communications is a one semester elective course for master students. The aim of this course is to close the gap between topics taught in basic courses and the requirements for master theses in the area of digital communications. Therefore, the course covers selected current research topics that are presented in an illustrative form. Supervised exercises with Matlab programming should enable students to get familiar with the simulation of digital communication systems, the application of certain algorithms, etc. After this course, you should be able to:

- build a simulation model of a digital communication system
- implementation of multi-user detection techniques in CDMA or SDMA systems
- analyze the performance of communication systems by simulations

**Prerequisite:** Communications Technology I+II, Channel Coding I+II

### Content:

- Contents, Organisation
- Structure of digital communication system
  - Mobile radio channel
  - Systems with multiple inputs and outputs
- Information Theory
  - Single-input single-output fading channels
- Multiple-input multiple-output channels
- Multiuser detection in CDMA
- Multiple antenna systems
- Diversity concepts
- Space division multiple access

### Literature:

V. Kühn: Wireless communications over MIMO Channels: Applications to CDMA and Multiple Antenna Systems.  
D. Tse, P. Viswanath: Fundamentals of Wireless Communication  
A. Paulraj, R. Nabar, D. Gore: Introduction to Space-Time Wireless Communications  
E. Biglieri, R. Calderbank, A. Constantinides, A. Goldsmith: MIMO Wireless Communications

**Methods:** Lectures, exercises with Matlab

**Efficiency Statement:** Oral examination

**Information, Downloads:** <http://www.ant.uni-bremen.de/en/courses/atdc>

**ECTS Credits:** 4

**SWS:** 3

**Workload:** 120 hours  
Lectures and courses 38%  
Reading, homework and preparation of exam 62%

**Suggested for:** CIT and CMM 2<sup>nd</sup> or 3<sup>rd</sup> term, (elective course), Studienabschnitt, Master ET/IT

# Analog to Digital Converters

01-15-03-AtD-V

Responsible: Prof. Dr.-Ing. Steffen Paul

Lecturer: Dr. Dmitry Osipov

Aim:

- After this course, the students
- know the basic modules of ADCs
- understand errors in ADCs
- know how to select the appropriate structure for a given specification

**Prerequisite:** Basic knowledge of integrated circuits

**Content:**

- Theory of analog digital conversion
- Static and dynamic errors
- Sample and hold circuits
- Realisations of ADCs, parallel structures, multistage converters, SAR ADCs, delta sigma ADCs

**Literature:**

**Methods:**

**Efficiency Statement:** Oral examination

**Information, Downloads:**

**ECTS Credits:** 4

**SWS:** 3

**Workload:** 120 hours

Lectures and courses 38%

Reading, homework and preparation of exam 62%

**Suggested for:** CIT and CMM 2<sup>nd</sup> or 3<sup>rd</sup> term, (elective course), Master ET/IT



# Antennas

## 01-15-03-Ant-V

**Responsible:** Prof. Dr.-Ing. Martin Schneider  
**Lecturer:** Prof. Dr.-Ing. Martin Schneider

### Aim:

The students will learn the fundamentals of antennas and their calculation. Basic theoretical part is the introduction of electrodynamic vector potentials that give the electromagnetic fields generated by rapidly varying electric currents. First, fundamental insight in antennas will be given by the analysis of the Hertzian dipole and the small loop antenna. Main terms and definitions are introduced: directivity, gain, efficiency, half power beamwidth, path loss, and equivalently radiated isotropic power (EIRP). Then different antennas are calculated: linear antennas like the half-wave dipole, array antennas, and aperture antennas like horn antennas, slot antennas and reflector antennas. Also lens antennas and microstrip patch antennas are discussed.

After this course, the students should be able

- to explain the working principle of antennas
- to decide which kind of antennas suits a certain application at a certain frequency
- to apply the method of electrodynamic potentials for solving antenna problems
- to explain and to apply the method of equivalent sources for calculating aperture antennas

**Prerequisite:** Electrodynamics

### Content:

- Fundamentals of antennas
- Electrodynamic Potentials
- Method of equivalent sources and Huygens' principle
- Calculation of linear antennas
- Calculation of array antennas
- Calculation of aperture antennas
- Calculation of microstrip patch antennas

### Literature:

Lecture script and lecture slides.

Balanis, C. A., "Antenna Theory," John Wiley & Sons, 3rd Edition, 2005.

Kraus, J. D., "Antennas For All Applications," McGraw-Hill, 3rd Edition, 2002.

**Methods:** 2h lecture, 1h exercises and tutorial

**Efficiency Statement:** written examination

**Information, Downloads:** <http://www.hf.uni-bremen.de>

**ECTS Credits:** 4

**SWS:** 3

**Workload:** 120 hours  
Lectures and courses 38%  
Reading, homework and preparation of exam 62%

**Suggested for:** CIT 2<sup>nd</sup> term (compulsory course), Master ET/IT

# Architectures and Design Methodologies of Integrated Digital Systems

## 01-15-03-DIDS-V

**Responsible:** Prof. Dr.-Ing. Alberto García-Ortiz

**Lecturer:** Prof. Dr.-Ing. Alberto García-Ortiz

### **Aim:**

The students will learn the design methodologies, theoretical algorithms, and tools used for the development of microelectronic integrated systems, as well as the strategies regarding their practical implementation with industrial CAD tools. The students will be able to implement a complex microelectronic integrated digital guarantying its correctness and testability.

**Prerequisite:** None

### **Content:**

- Design tools and abstractions levels
- Physical design
  - Floorplanning and placement
  - Routing and wire estimation
  - DRC and LVS
- Design-for-Test
  - Scan-based design, Boundary scan
  - BIST
- Test-architectures for SoCs
- Test-generation and error diagnosis
  - ATPG
  - Fault simulation

### **Literature:**

- J.M. Rabaey, A. Chandrakasan, B. Nikolic, Digital Integrated Circuits – A Design Perspective, ISBN-10\_9788120322578
- Michael John Sebastian Smith, Application-Specific Integrated Circuits, Addison-Wesley Publishing Company ISBN 0-201-50022-1
- Charles Stroud, Nur Touba und Laung-Terng Wang, System-On-Chip Test Architectures: Nanometer Design for Testability, ISBN-10: 012373973X
- Laung-Terng Wang, Cheng-Wen Wu, Xiaoqing Wen, VLSI Test Principles and Architectures: Design for Testability, ISBN: 978-0-12-370597-6

**Methods:** 2h lecture, 1h exercises  
Possibility of complementing the lecture with a laboratory

**Efficiency Statement:** written or oral examination

**Information, Downloads:** <https://elearning.uni-bremen.de/>

**ECTS Credits:** 4

**SWS:** 3

**Workload:** 120 hours (lectures and courses 42h, homework 28h and preparation of exam 50h)

**Suggested for:** CMM 1<sup>st</sup> term (compulsory course), can also be done in 3<sup>rd</sup> term  
CIT 1<sup>st</sup> term (elective course), can also be done in 3<sup>rd</sup> term

# Channel Coding I

## 01-15-03-CCod1-V

**Responsible:** Dr. Dirk Wübben  
**Lecturer:** Dr. Dirk Wübben

### Aim:

Channel Coding I is a one semester elective course. The aim is to provide a basic understanding how channel coding works and to present the most important code families. Moreover, results obtained from information theory show the ultimate limits theoretically achievable with optimal codes.

After this course, you should be able to:

- Explain the principle of channel coding
- Explain the ultimate limits from information theory
- Perform encoding and decoding for linear block and convolutional codes
- Grade the performance of different codes

**Prerequisite:** Basics of communication technology and digital signal processing

### Content:

- Contents, Organisation
- System model for digital communications
- One lesson of information theory
- Linear block codes
  - Generator and parity check matrix
  - Standard array and syndrome decoding
- Examples (SPC, Hamming, Simplex)
- Cyclic Codes (description by polynomials)
- Examples (CRC, BCH, Reed-Solomon)
- Convolutional codes
- Encoder, graphical representations
- Viterbi decoding

### Literature:

Neubauer, A., J. Freudenberger, V. Kühn: Coding Theory: Algorithms, Architectures and Applications.

Lin, S., D. J. Costello, Jr.: Error Control Coding: Fundamentals and Applications.

Moreira, J. C., P.G. Farr: Essentials of Error-Control.

**Methods:** Lecture, exercises using Matlab

**Efficiency Statement:** Written Exam

**Information, Downloads:** <http://www.ant.uni-bremen.de/en/courses/cc1>

**ECTS Credits:** 4

**SWS:** 3

**Workload:** 120 hours  
Lectures and courses 38%  
Reading, homework and preparation of exam 62%

**Suggested for:** CIT and CMM 2<sup>nd</sup> or 3<sup>rd</sup> term, (elective course)

## Channel Coding II

### 01-15-03-CCod2-V

**Responsible:** Dr. Dirk Wübben  
**Lecturer:** Dr. Dirk Wübben

#### **Aim:**

Channel Coding II is a one semester elective course that requires the basics taught in Channel Coding I. The focus of this course is on sophisticated channel coding approaches for specific applications, i.e. transmitting high data rates over bandlimited channels. Moreover, the course covers topics like concatenated codes that are part of actual research work and thus important for subsequent master theses.

After this course, you should be able to:

- Explain the principle of coded modulation and possible realizations
- Explain the concept of code concatenation and iterative turbo decoding
- Explain the principle of adaptive error control schemes and the difference to forward error correction

**Prerequisite:** Communications Technologies, Wireless Communications , Channel Coding I

#### **Content:**

- |                                     |   |
|-------------------------------------|---|
| - Contents, Organisation            | - L-Algebra                             |
| - Coded Modulation                  | - Soft-output decoding                  |
| - Ungerböck's approach              | - Examples (Product Codes, Turbo Codes) |
| - Pragmatic approach by Viterbi     | - Adaptive Error Control                |
| - Multilevel Codes                  | - Basic ARQ strategies                  |
| - Concatenated codes                | - Hybrid schemes (ARQ + FEC)            |
| - Serial and parallel concatenation |   |
| - Analysis of distance properties   |   |

#### **Literature:**

Neubauer, A., J. Freudenberger, V. Kühn: Coding Theory: Algorithms, Architectures and Applications.

Lin, S., D. J. Costello, Jr.: Error Control Coding: Fundamentals and Applications.

Moreira, J. C., P.G. Farr: Essentials of Error-Control.

**Methods:** Lecture, exercises

**Efficiency Statement:** Written examination

**Information, Downloads:** <http://www.ant.uni-bremen.de/en/courses/cc2>

**ECTS Credits:** 4

**SWS:** 3

**Workload:** 120 hours  
Lectures and courses 38%  
Reading, homework and preparation of exam 62%

**Suggested for:** CIT and CMM 2<sup>nd</sup> or 3<sup>rd</sup> term, (elective course)

# Communication Networks: Systems

## 01-15-03-CNS-V

**Responsible:** Prof. Dr. A. Förster  
**Lecturer:** Prof. Dr. A. Förster / Dr. Andreas Könsgen

### Aim:

This course gives a survey of methods and systems related to communication networks. After this course, you should be able to:

- describe exemplary systems of communication networks;
- name and explain the layers of a communication network;
- know the basic technologies used for communication protocols;
- know basic error handling mechanisms for communication protocols.

**Prerequisite:** None

### Content:

The main topics of this course are:

- Distributed Systems
- ISO/OSI 7 Layer Reference Model for Open Communication
- Formal Specification Methods for Protocols
- Services and Protocols of the Data Link, Network and Transport Layer
- Local Area Networks
- Wide Area Networks
- Network Control: (Virtual) Connections, Routing, Addressing, Flow Control
- System Examples:
  - TCP/IP
  - Wireless Networks
- Performance Analysis
- Network Security

### Literature:

- Tanenbaum, A.S.: Computer Networks, 5<sup>th</sup> ed., Pearson new internat. ed., 2014
- Ross/Kurose, Computer Networking: A Top Down Approach, 6th ed., internat. ed., Pearson 2013
- Walrand, J.: Communication Networks, A first course, WCB/McGraw-Hill 1998

**Methods:** Lectures and exercises

**Efficiency Statement:** Homework and electronic examination

### Information,

**Downloads:** Literature is given in the lectures,  
Please also refer to [www.comnets.uni-bremen.de](http://www.comnets.uni-bremen.de)

**ECTS Credits:** 4  
**SWS:** 3

**Workload:** 120 hours  
Lectures and courses 38%  
Reading, homework and preparation of exam 62%

**Suggested for:** CIT 2<sup>nd</sup> term, (compulsory course), CMM 2<sup>nd</sup> or 3<sup>rd</sup> term, (elective course); M. Sc. ET/IT

# Communication Networks: Theory

## 01-15-03-CNT-V

**Responsible:** Prof. Dr. Anna Förster  
**Lecturer:** Prof. Dr. Anna Förster

### Aim:

This course gives a survey of methods used for the performance analysis of communication networks. After this course, you should be able to analyse simple communication protocols and networks.

**Prerequisite:** None

### Content:

The main topics are:

- Fundamentals of probability theory
- Graphs, random graphs and network flows
- Finite state (Markovian) processes
- Simple queues and queuing networks
- Petri Nets
- Statistical model fitting and evaluation of performance data
- Traffic modelling and random number generators
- Discrete event simulation

### Literature:

- David Easley and Jon Kleinberg: “Networks, Crowds and Markets”, Cambridge University Press, 2010 (available online)
- Jean-Yves Le Boudec: “Performance Evaluation of Computer and Communication Systems”, EPFL Press, 2010 (available online)
- G.R. Dattatreya: “Performance Analysis of Queuing and Computer Networks”, CRC Press, 2008
- Jain, R.K. : The Art of Computer Systems Performance Analysis: Techniques for Experimental Design, Measurement, Simulation, and Modeling, John Wiley & Sons, 1991.
- Kleinrock L.: Queueing Systems. Vol I: Theory. John Wiley & Sons, 1975

**Methods:** Lectures and exercises

**Efficiency Statement:** Homework and electronic examination

### Information,

**Downloads:** Literature is given in the lectures,  
Please also refer to [www.comnets.uni-bremen.de](http://www.comnets.uni-bremen.de)

**ECTS Credits:** 4

**SWS:** 3

**Workload:** 120 hours  
Lectures and courses 38%  
Reading, homework and preparation of exam 62%

**Suggested for:** CIT 1<sup>st</sup> term, (compulsory course), CMM 2<sup>nd</sup> or 3<sup>rd</sup> term, (elective course), M. Sc. ET/IT

# Communication Technologies

01-15-03-ComT-V

**Responsible:** Prof. Dr.-Ing. A. Dekorsy

**Lecturer:** Prof. Dr.-Ing. A. Dekorsy

## Aim:

Communications Technology I is the first part of a two semester course. It covers the basics of digital signal transfer.

After this first part, the students should be able to:

- Explain the important prerequisites for digital signal transfer
- Layout simple transfer systems
- Solve simple layout problems for signal shaping and filtering
- Develop simulation models using Matlab

**Prerequisite:** System theory, stochastic systems, basics of communication theory

## Content:

0. Introduction: Stochastic Processes	3. Principles of Time Multiplex
1. Digital Baseband Transmission	3.1.Example: PCM-Hierachy
1.1.Spectra of Data Signals	3.2.Synchronisation (symbol rate)
1.2.Nyquist Criterion	4. Digital Modulation
1.3.Partial Response Transmission	4.1.Linear Modulation Methods
1.4.Matched Filter	4.2.Nonlinear Modulation Methods
1.5.Bit Error Probability	4.3.Spectral Characteristics
2. Equalization	4.3.Coherent Demodulation
2.1.Linear Equalization	4.4.Carrier Synchronisation
2.2.Decision Feedback	4.5.Noncoherent Demodulation
2.3.Adaptive Equalization	

## Literature:

David Tse, Pramond Viswanath: Fundamentals of Wireless Communications.

Proakis, J.: Digital Communications.

**Methods:** Lecture, exercises with presentation by the students

**Efficiency Statement:** Written examination

## Information,

**Downloads:** <http://www.ant.uni-bremen.de/en/courses/ct1>

**ECTS Credits:** 4

**SWS:** 3

**Workload:** 120 hours  
Lectures and courses 38%  
Reading, homework and preparation of exam 62%

**Suggested for:** CIT 2<sup>nd</sup> term, (compulsory course), CMM 2<sup>nd</sup> term, (elective course),  
Master ET/IT

# Computational Intelligence in Modeling, Prediction and Signal Processing

## 01-15-03-CIMP-V

**Responsible:** PD. Dr.-Ing. habil. Ajoy K. Palit

**Lecturer:** PD. Dr.-Ing. habil. Ajoy K. Palit

### Aim:

Computational Intelligence (CI) in modeling, prediction and signal processing is an independent one semester course which will give you a basic understanding of intelligent computing technologies primarily based on fuzzy logic, neural networks, evolutionary computations/genetic algorithms and hybrid intelligent systems such as neuro-fuzzy networks etc. that can be applied for system modeling, data prediction, and signal processing purposes.

After this course, you should be able to:

- Understand the importance of computationally intelligent techniques based on fuzzy logic, neural networks, genetic algorithms and fuzzy-neural networks in engineering applications.
- Understand the difference between the classical set and fuzzy set, fuzzy set as generalization of crisp set and terms like fuzzy arithmetic, fuzzy logic systems, fuzzification, fuzzy relation, fuzzy-rules, defuzzification, and inferencing mechanism, tuning membership functions etc.
- Generate fuzzy rules through learning from examples and clustering method
- Implement and fine tune the fuzzy logic system using neural networks based technology
- Analyze the transparency, interpretability and accuracy of the fuzzy/ fuzzy-neural model
- Apply fuzzy logic / fuzzy-neural systems in (white box) system modeling, data prediction and linearization of nonlinear sensor characteristic, adaptive filtering purposes etc.

**Prerequisite:** Mathematics, C++ / MATLAB programming

### Content:

- |  |   |
|--|---|
| - Introduction to CI & their Applications                        | - Neuro implementation of fuzzy system                                      |
| - Principal constituents of CI                                   | - Introduction to ANFIS / neuro-fuzzy network                               |
| - Fuzzy sets and properties, Fuzzy relation                      | - Backpropagation, Marquardt training algorithm for neuro-fuzzy network     |
| - Fuzzy logic systems (Mamdani, TS, singleton, relational model) | - Problems in automatic data driven rule generation                         |
| - Fuzzy inferencing mechanism                                    | - CI Applications in modeling, prediction and intelligent signal processing |
| - Generation of fuzzy rule (Wang's method)                       |   |
| - Clustering and LSE based rule generation                       |   |

### Literature/Reference Book:

Computational Intelligence in Time Series Forecasting, Theory and Engg. Applications, Authors: A.K. Palit & D. Popovic, Springer-Verlag, London, 2005, ISBN: 1852339489.

**Methods:** Lecture, exercises

**Efficiency Statement:** Written examination, Programming Exercise

**Information, Course Materials:** E-mail: [palit \(at\) uni-bremen.de](mailto:palit(at)uni-bremen.de) & see the Ref. Book

**ECTS Credits:** 4

**SWS:** 3

**Workload:** 120 hours

Lectures and courses 40%

Reading, homework and preparation of exam 60%

**Suggested for:** CIT and CMM, 2<sup>nd</sup> or 3<sup>rd</sup> term. (elective course)



# Control Theory I

## 01-15-03-CTh1-V

**Responsible:** Prof. Dr.-Ing. Kai Michels  
**Lecturer:** Prof. Dr.-Ing. Kai Michels

### Aim:

- Understanding and Handling of state space methodology
- Design of state space controllers with different methods
- Observer design

### Prerequisite:

Lecture „Grundlagen der Regelungstechnik“ or equivalent knowledge about basics of control (bode diagrams, nyquist plots, nyquist stability criterion, PID controller design)

### Content:

- |   |  |
|---|--|
| - Definition and features of state variables        | - Controllability and observability                |
| - State space description of linear systems         | - Concept of state space control                   |
| - Normal forms                                      | - Steady-state accuracy of state space controllers |
| - Coordinate transformation                         | - Observer   |
| - General solution of a linear state space equation | - Controller design by pole placement              |
| - Lyapunov stability                                | - Riccati controller design                        |
|   | - Falb-Wolovitch controller design                 |

### Literature:

- K. Michels: Control Engineering (Script in German and English)

### German:

- J. Lunze: Regelungstechnik 2
- O. Föllinger: Regelungstechnik
- H. Unbehauen: Regelungstechnik II

### English:

- Norman S. Nise: Control Systems Engineering

**Methods:** Lectures, tutorial, demonstration of numerical and symbolical calculation with Matlab

**Efficiency Statement:** Written or oral examination, depending on number of participants.

**ECTS Credits:** 4

**SWS:** 3

**Workload:** 120 hours  
Lectures and courses 35%  
Homework and preparation of exam 65%

**Suggested for:** CMM 2<sup>nd</sup> term (compulsory course)  
CIT 2<sup>nd</sup> term (elective course)

## Control Theory II

### 01-15-03-CTh2-V

**Responsible:** Prof. Dr.-Ing. Kai Michels

**Lecturer:** Prof. Dr.-Ing. Kai Michels

#### **Aim:**

- Increasing the understanding of linear state space analysis and controller design
- Understanding the idea and the design of norm-optimal controllers

**Prerequisite:** Lecture „Control Theory I“

#### **Content:**

- Zeros of Multi-Input-Multi-Output systems
- Robustness
- Norms
- Design of norm-optimal controllers

#### **Literature:**

- K. Michels: Control Engineering (Script in German and English)
- K. Müller: Entwurf robuster Regelungen (German)
- J. Ackermann: Robust Control (English)

**Methods:** Lectures, tutorial, demonstration of numerical and symbolical calculation with Matlab

**Efficiency Statement:** Written or oral, depending on the number of participants

#### **Information, Downloads:**

**ECTS Credits:** 4

**SWS:** 3

**Workload:** 120 hours  
Lectures and courses 35%  
Homework and preparation of exam 65%

**Suggested for:** CMM and CIT 3<sup>rd</sup> term (elective course)

## **Control Theory III**

### **01-15-03-CTh3-V**

**Responsible:** Prof. Dr.-Ing. Kai Michels  
**Lecturer:** Dr.-Ing. Jochen Schüttler

#### **Aim:**

Getting familiar with the „State of the Art“ in the field of linear and non-linear control

**Prerequisite:** Lecture „Control Theory II“

#### **Content:**

- $\mu$ -synthesis as next stage of norm-optimal control, which was introduced in Control Theory II
- Exact Linearization

#### **Literature:**

- Isidori: Nonlinear Control Systems
- Ackermann et al.: Robust Control
- Adamy: Nichtlineare Regelungen
- Slotine: Applied Nonlinear Control
- Doyle et al.: Feedback Control Theory

**Methods:** Lectures, demonstration of numerical and symbolical calculation with Matlab

**Efficiency Statement:** Written or oral, depending on the number of participants

#### **Information, Downloads:**

**ECTS Credits:** 4

**SWS:** 3

**Workload:** 120 hours  
Lectures and courses 31%  
Homework and preparation of exam 69%

**Suggested for:** CMM and CIT 4<sup>th</sup> term (elective course)

# Design Methodologies with Hardware Description Languages

## 01-15-04-DHDL-V

**Responsible:** Prof. Dr.-Ing. A. Garcia Ortiz  
**Lecturer:** Prof. Dr.-Ing. A. Garcia-Ortiz

### Aim:

The students gain in-depth knowledge of the theoretical basics of methods and tools in hardware design with hardware description languages and strategies for their practical application. Students can describe, simulate and optimize and digital modules in a hardware description language as well as synthesize them for ASICs or FPGAs.

### Prerequisite:

#### Content:

- Introduction
  - IC technologies, design flow and abstraction levels
  - Introduction to hardware description languages
- Hardware modeling
  - Main concept of VHDL
  - Discrete event model
  - Data types and operators in VHDL
- Code structures and structural descriptions
  - Structural elements in VHDL
  - Hardware partitioning and hierarchies
  - Design-for-reuse: generics and generates
- RTL level modeling and synthesizable code
  - Standard libraries
  - Code quality recommendations
  - Synthesis and synthesis constraints
- Gate level modeling and back-annotation
  - VITAL
- Behavioral level
  - Advanced concepts: files, access types and assertions
  - Test benches
- EDA Design Flow

**Literature:** A list of references will be provided at the start of the semester.

### Methods:

**Efficiency Statement:** Written or oral examination

**ECTS Credits:** 4  
**SWS:** 3

**Workload:** 120 hours  
Lectures and courses 35%  
Reading, homework and preparation of exam 65%

**Suggested for:** CIT 1<sup>st</sup> or 3<sup>rd</sup> term (elective), Bachelor ET/IT

# Digital Signal Processing

## 01-15-04-DSI-V

**Responsible:** Prof. Dr.-Ing. A. Dekorsy  
**Lecturer:** Prof. Dr.-Ing. A. Dekorsy

### Aim:

This is the first part of the two semester course on digital signal processing. After this course, the students will be able to:

- Analyse recursive and non-recursive digital filters.
- Layout basic structures for practical realisation.
- Perform layouts using existing layout software.
- Simulate digital filters using Matlab.
- Apply the basics of FFT.

**Prerequisite:** System theory, basics of stochastic and random variables

### Content:

- |  |   |
|--|---|
| 1. Introduction                        | 3.3.Design of Filters with Linear Phase |
| 2. Recursive Filters                   | 3.4.Special Non-Recursive Filters       |
| 2.1.Canonical Structures               | 3.5.Complex Valued FIR-Filters          |
| 2.2.Design of Recursive Filters        | 4. Discrete Fourier Transform (DFT)     |
| 2.3.Special Types of Recursive Filters | 4.1.Definition of the DFT               |
| 2.4.Quantization Effects               | 4.2.Properties of the DFT               |
| 3. Non-Recursive Filters               | 4.3.Relation with other Transforms      |
| 3.1.FIR-Systems                        | 4.4.Fast Fourier Transform (FFT)        |
| 3.2.Systems with Linear Phase          | 4.5.Fast Convolution                    |

### Literature:

J.G. Proakis, D.G. Manolakis: Digital Signal Processing (Prentice Hall).

**Methods:** Lectures, PC exercises with Matlab

**Efficiency Statement:** Written examination

### Information,

**Downloads:** <http://www.ant.uni-bremen.de/en/courses/dsp1>

**ECTS Credits:** 4

**SWS:** 3

**Workload:** 120 hours  
Lectures and courses 38%  
Reading, homework and preparation of exam 62%

**Suggested for:** CIT 1<sup>st</sup> term, (elective), CMM 1<sup>st</sup> or 3<sup>rd</sup> term, (elective course), Bachelor ET/IT

## Digital Technology

01-15-03-DiTe-V

**Responsible:** Prof. Dr.-Ing. Garica-Ortiz

**Lecturer:** Prof. Dr.-Ing Garcia-Ortiz

### Aim:

The students

- can realize function specific digital, combinatorial and complex sequential circuits,
- can apply different strategies to realize digital modules (data path, control path, synchronous vs. asynchronous circuits, programmability ...),
- understand and can use analysis and design methods of digital circuits

### Prerequisite:

### Content:

- Timing-strategies
- Non-programmable hardware modules
- Programmable hardware modules
- Selected algebraic and Boolean operations
- Introduction to digital coding

### Literature:

### Methods:

**Efficiency Statement:** Written examination

### Information, Downloads:

**ECTS Credits:** 4

**SWS:** 3

**Workload:** 120 hours  
Lectures and courses 38%  
Reading, homework and preparation of exam 62%

**Suggested for:** CMM Elective

# Discrete Systems

01-15-03-DS-V

**Responsible/Lecturer:** Prof. Dr.-Ing. Kai Michels

## Aim:

This lecture will give insight into discrete control theory, adaptive control, and Fuzzy-Neuro systems

**Prerequisite:** Lecture "Control Theory I"

## Content:

- Discrete systems: basic considerations
- Sampling theorem
- Linear difference equations
- State space description of discrete linear systems
- Stability of discrete systems
- Transformation of a continuous model into a discrete model
- z-transformation
- Controller design for discrete systems
- Adaptive control
- Fuzzy control
- Neural networks

## Literature:

German and English: K. Michels: Control Engineering (Script)

German:

- K. Michels: Fuzzy-Regler
- J. Lunze: Regelungstechnik 2
- R. Isermann: Digitale Regelsysteme Band I
- H. Unbehauen: Regelungstechnik 2
- Böcker, Hartmann, Zwanzig: Nichtlineare und adaptive Regelungssysteme

English:

- K. Michels: Fuzzy Control
- Norman S. Nise: Control Systems Engineering
- Karl J. Astrom: Adaptive Control
- Ioan Dore Landau: Adaptive Control

**Methods:** Lectures and tutorial

**Efficiency Statement:** Written or oral examination, depending on the number of participants

**ECTS Credits:** 4

**SWS:** 3

**Workload:** 120 hours  
Lectures and courses 35%  
Reading, homework and preparation of exam 65%

**Suggested for:** CMM 3<sup>rd</sup> term (compulsory course), CIT 3<sup>rd</sup> term (elective course)

# Electrodynamics

01-15-04-ED-V

**Responsible:** Prof. Dr.-Ing. Martin Schneider

**Lecturer:** Prof. Dr.-Ing. Martin Schneider

## Aim:

Without Electrodynamics, without the theory of Maxwell, Faraday, Ampere, Oersted, et al. about electric, magnetic, and electromagnetic phenomena like conduction, induction, and electromagnetic fields and waves, our modern world with all its achievements in electricity, electronics and communications would not exist. This course gives the students an understanding about the theory in the field of electrodynamics. The focus is on the discussion of Maxwell's equations and electromagnetic wave phenomena.

After this course the students should be able

- to explain electromagnetic phenomena with the help of Maxwell's equations
- to derive the wave equation, to give their solutions and to interpret them
- to explain the basics of antennas

**Prerequisite:** Fundamentals of electric and magnetic fields taught in B.Sc. programs in Electrical Engineering. Vector analysis.

## Content:

- Mathematical background of electrodynamics (scalar and vector fields, vector operations grad, div, curl)
- Maxwell's equations
- Electromagnetic waves
- transmission line theory incl. reflection, wave impedance, matching

## Literature:

Lecture script and lecture slides.

Matthew Sadiku, "Elements of Electromagnetics", Oxford University Press, 2007.

John Jackson, "Classical Electrodynamics", John Wiley & Sons, third edition, 1998.

David Pozar, "Microwave Engineering," John Wiley & Sons, third or fourth edition.

**Methods:** 2h lecture, 1h exercises and tutorial

**Efficiency Statement:** Written examination

## Information,

**Downloads:** <http://www.hf.uni-bremen.de>

**ECTS Credits:** 4

**SWS:** 3

**Workload:** 120 hours

Lectures and courses 38%

Reading, homework and preparation of exam 62%

**Suggested for:** CIT 1<sup>st</sup> term (compulsory course)

CMM 1<sup>st</sup> term (elective course)



## German language course

**Responsible:** Teachers of the language school  
**Lecturer:** Teachers of the language school

### **Aim:**

The aim of the German language course is to achieve a basic understanding of German. After the courses, the students should be able to communicate in German for the needs of everyday life. They should also be able to understand scientific and management topics so that they can follow the discussions in a research institute.

**Prerequisite:** None

### **Content:**

The German language course is given by the Goethe Institute in Bremen using the methods of language teaching. The course is obligatory, but not graded. There is no grade for this course given in the master certificate. The course is planned for two semesters, the 1<sup>st</sup> and the 2<sup>nd</sup> semester with 2CP each. However, due to lack of teaching capacities and due to reduced financial resources for language courses, a different approach may optionally be used. For that reason, the course may also be done in the first semester with one 4 CP course program. The students will be informed in a transparent way about this situation by the master office.

### **Literature:**

Schritte international 1, Kursbuch + Arbeitsbuch mit Audio-CD zum Arbeitsbuch und interaktiven Übungen, Hueber Verlag, ISBN 978-3-19-001851-2.

**Methods:** Language teaching methods

**Efficiency Statement:** No exam, participation statement

### **Information,**

**Downloads:** Given by the language school

**ECTS Credits:** 4

**Workload:** 120 hours  
Presence 40%  
Study time 60%

**Suggested for:** CIT and CMM 1<sup>st</sup> term, (compulsory course).

## Information and Communication Technology Laboratory I 01-15-03-IKT1-P

**Responsible:** Prof. Dr.-Ing. A. Dekorsy, Prof. Dr. A. Förster,  
Prof. Dr.-Ing. M. Schneider  
**Lecturer:** Prof. Dr.-Ing. A. Dekorsy, Prof. Dr. A. Förster  
Prof. Dr.-Ing. M. Schneider

### **Aim:**

The laboratory course “Information and Communication Technology Laboratory I“ is meant to provide the hands-on experience for the topics of the lectures *offered by the Institute of Telecommunications and High Frequency Techniques*. The module allows students to acquire the knowledge concerning the practical application of communication technology methods.

**Prerequisite:** No formal preconditions. With regard to contents of the experiments the students are supposed to attend or have attended the following lectures:

- Electrodynamics
- Communication Technologies
- Wireless Communications
- Communication Networks
- RF Frontend Devices and Circuits

### **Content:**

6 laboratory experiments are offered. Up to four students can form a group and perform the laboratory experiments together. CIT students have to select three out of the six experiments for 3 credit points, and at least one from each of the three institute labs. For 6 credit points all 6 experiments have to be performed (only for Master ET/IT, not CIT).

**Literature:** J. Proakis: Digital Communications; D. Tse, P. Viswanath: Fundamentals of Wireless Communications; A. Paulraj, R. Nabar, D. Gore: Introduction to Space-Time Wireless Communications; A. Goldsmith: Wireless Communications; D. Pozar: Microwave Engineering; C.A. Balanis: Antenna Theory

**Methods:** Groups of up to 4 students. Manuscripts are provided in English.  
Short examination of the preparation before the experiment.

### **Efficiency Statement:**

The preparation questions to the experiment have to be answered in hand-written form, required for each member of the group and presented at the beginning of each individual lab experiment. Otherwise taking part in the lab experiment is not possible. Hand-written protocols of the lab experiments have to be done during the lab.

### **Information, Downloads:**

[www.ant.uni-bremen.de/en/courses/](http://www.ant.uni-bremen.de/en/courses/) ; [www.comnets.uni-bremen.de](http://www.comnets.uni-bremen.de) ; [www.hf.uni-bremen.de](http://www.hf.uni-bremen.de)

**ECTS Credits:** 3 (6)  
**SWS:** 2 (4)  
**Workload:** 90 (180) hours

**Suggested for:** CIT 2<sup>nd</sup> term (compulsory course),  
Master ET/IT

## Information and Communication Technology Laboratory II 01-15-03-IKT2-P

**Responsible:** Prof. Dr.-Ing. A. Dekorsy, Prof. Dr. A. Förster  
Prof. Dr.-Ing. M. Schneider  
**Lecturer:** Prof. Dr.-Ing. A. Dekorsy, Prof. Dr. A. Förster  
Prof. Dr.-Ing. M. Schneider

### **Aim:**

The laboratory course “Communications Technology Laboratory I” is meant to provide the hands-on experience for the topics of the lectures *offered by the Institute of Telecommunications and High Frequency Techniques*. The module allows students to acquire the knowledge concerning the practical application of communication technology methods.

**Prerequisite:** No formal preconditions. With regard to contents of the experiments the students are supposed to attend or have attended the following lectures:

- Electrodynamics
- Communication Technologies
- Wireless Communications
- Communication Networks
- RF Frontend Devices and Circuits

### **Content:**

6 laboratory experiments are offered. Up to four students can form a group and perform the laboratory experiment together. CIT students have to select three out of the six experiments for 3 credit points, and at least one from each of the three institute labs. For 6 credit points all 6 experiments have to be performed (only for Master ET/IT, not CIT).

### **Literature:**

J. Proakis: Digital Communications; D. Tse, P. Viswanath: Fundamentals of Wireless Communications; A. Paulraj, R. Nabar, D. Gore: Introduction to Space-Time Wireless Communications; A. Goldsmith: Wireless Communications; D. Pozar: Microwave Engineering; C.A. Balanis: Antenna Theory

**Methods:** Groups of up to 4 students. Manuscripts are provided in English.  
Short examination of the preparation before the experiment.

### **Efficiency Statement:**

The preparation questions to the experiment have to be answered in hand-written form, required for each member of the group and presented at the beginning of each individual lab experiment. Otherwise taking part in the lab experiment is not possible. Hand-written protocols of the lab experiments have to be done during the lab.

### **Information, Downloads:**

[www.ant.uni-bremen.de/en/courses/](http://www.ant.uni-bremen.de/en/courses/) ; [www.comnets.uni-bremen.de](http://www.comnets.uni-bremen.de) ; [www.hf.uni-bremen.de](http://www.hf.uni-bremen.de)

**ECTS Credits:** 3 (6)  
**SWS:** 2 (4)  
**Workload:** 90 (180) hours

**Suggested for:** CIT 3<sup>rd</sup> term (compulsory course),  
Master ET/IT

# Integrated Circuits

01-15-03-InS-V

**Responsible:** Prof. Dr. Steffen Paul

**Lecturer:** Prof. Dr. Steffen Paul

## Aim:

Integrated circuits gives an survey on more complex analog circuits.

After this course, you should be able to:

- describe and characterize noise in electronics circuits
- apply the gm/Id sizing method to design amplifier circuits for advance CMOS technologies
- deal with process variations and mismatch
- \* understand the frequency behaviour of amplifier circuits
- \* understand and size compensation networks
- \* use feedback to modify circuit characteristics.
- \* design simple AD converters as integrated circuit

**Prerequisite:** Basics of electrical engineering and analog integrated circuits

## Content:

- |                 |                    |
|-----------------|--------------------|
| 1. Noise        | 4. two pole opamps |
| 2. gm/Id Method | 5. feedback        |
| 3. Mismatch     | 6. ad converter    |

## Literature:

T. Carusone: Analog integrated circuit design.

W. Sansen: Analog Design essentials.

**Methods:** Lecture, exercise in the clean room

**Efficiency Statement:** Written examination

## Information,

**Downloads:** Studip

**ECTS Credits:** 4

**SWS:** 3

**Workload:** 120 hours  
Lectures and courses 38%  
Design project 20%  
Reading, homework and preparation of exam 42%

**Suggested for:** CIT 1st term (elective), CMM 1st term (compulsory), ET/IT Master

# Intellectual Property, Patents and Further Protective Rights

## 01-15-03-Pat-V

**Responsible:** N.N.  
**Lecturer:** Dr. Matthias Hoener

### Aim:

Lectures in Intellectual Property is an independent one semester course which will give you a basic understanding in patent law, design law, trademark law and employee invention law. After this course, you should be able to:

- Name requirements for a patent, design, trademark
- Name purpose and advantages of protective rights
- evaluate possible infringement actions
- know how to apply for a patent, a design and a trademark
- Choose protective right for a certain invention
- search for prior art

**Prerequisite:** interest in intellectual property

### Content:

- |                           |                           |
|---------------------------|---------------------------|
| 1. Contents, Organisation | 4. Designs                |
| 2. Patents                | 5. Trademarks             |
| 3. Utility Models         | 6. Employee Invention Act |

### Literature:

- Intellectual Property Law in Germany, Beck Verlag 2007
- Grundlagen des Patentrechts: "Eine Einführung für Ingenieure, Natur- und Wirtschaftswissenschaftler", Teubner Verlag 2013

**Methods:** Lecture, exercises

**Efficiency Statement:** Written examination

### Information,

**Downloads:** [https://elearning.uni-bremen.de/meine\\_seminare.php](https://elearning.uni-bremen.de/meine_seminare.php)

**ECTS Credits:** 4  
**SWS:** 3

**Workload:** 120 hours  
Lectures and courses 38%  
Reading, homework and preparation of exam 62%

**Suggested for:** Master ET/IT, CIT , CMM (elective)

# Internet of Things

01-15-03-IoT-V

**Responsible: Prof. Dr. Anna Förster**

**Lecturer: Prof. Dr. Anna Förster**

## **Aim:**

The Internet of Things (IoT) is an independent one semester course which will give you a basic understanding of the communication protocols and research directions in the Internet of Things. It will cover a broad spectrum of protocols and concepts, including sensor networks, cyber-physical systems, Industry 4.0, local area networks, vehicular networks and opportunistic communications.

After this course, you should be able to:

- Name and describe the relevant standards
- Evaluate IoT applications and their communication requirements
- Design and deploy simple IoT applications
- Understand Future Developments and research challenges in the area of IoT

**Prerequisite:** No formal requirements, attending the lecture “Communication Networks: Systems” is recommended.

## **Content:**

- Basics of Wireless Communication
- Wireless sensor networks and their protocols (6LoWPAN, RPL, CoAP, Zigbee, EnOcean, ISA100, WirelessHART, etc.)
- Wireless LAN standards (IEEE 802.11)
- Vehicle-to-Vehicle networks (V2V)
- Opportunistic networks (Bluetooth, BLE, WiFi ad-hoc, etc.)

## **Literature:**

- Anna Förster: Introduction to Wireless Sensor Networks, Wiley 2016
- Jochen Schiller: Mobile Communications, 2<sup>nd</sup> ed., Addison-Wesley 2003
- IEEE 802 standards family, available on <http://standards.ieee.org/about/get/802/802.html>
- Zach Shelby, Carsten Bormann, 6LoWPAN: The Wireless Embedded Internet, John Wiley and Sons 2009

**Methods:** Lecture, project work

**Efficiency Statement:** Project work

## Lab 1 CMM - Lab

Responsible: Prof. Dr. Walter Lang  
Lecturer: Prof. Dr. Walter Lang

### Aim:

The students shall get practical experience with the topics of CMM

**Prerequisite:** None

### Content:

Four Lab courses are offered.

- Laboratory Design of Digital Systems
- Microsystems Laboratory
- Sensor Characterization Laboratory

Details of these Labs are given in Annex 1.

The students are attributed to the courses according to their choice and to availability of lab places.

### Literature:

Given in the specific course

**Methods:** Groups up to 5 students. Short examination of the preparation before the experiment. The experiments use MATLAB/Simulink.

**Efficiency Statement:** The preparation and the answers of the preparation questions have to be done carefully, they will be checked by the tutors. Without preparation, taking part in the lab is not possible. After each lab, a protocol has to be written and given to the tutors. This protocol will also be checked.

### Information,

**Downloads:** <https://elearning.uni-bremen.de/>

**ECTS Credits:** 3

**SWS:** 2

**Workload:** 60 hours

**Suggested for:** CMM 2<sup>nd</sup> term



## Lab 2 CMM - Lab

Responsible: Prof. Dr. Walter Lang  
Lecturer: Prof. Dr. Walter Lang

### Aim:

The students shall get practical experience with the topics of CMM

**Prerequisite:** None

### Content:

Four Lab courses are offered.

- Advanced Control Lab
- Laboratory Design of Digital Systems
- Microsystems Laboratory
- Sensor Characterization Laboratory

Details of these Labs are given in Annex 1.

The students are attributed to the courses according to their choice and to availability of lab places.

### Literature:

Given in the specific course

**Methods:** Groups up to 5 students. Short examination of the preparation before the experiment. The experiments use MATLAB/Simulink.

**Efficiency Statement:** The preparation and the answers of the preparation questions have to be done carefully, they will be checked by the tutors. Without preparation, taking part in the lab is not possible. After each lab, a protocol has to be written and given to the tutors. This protocol will also be checked.

### Information,

**Downloads:** <https://elearning.uni-bremen.de/>

**ECTS Credits:** 3

**SWS:** 2

**Workload:** 60 hours

**Suggested for:** CMM 3<sup>rd</sup> term

## **Low Power Strategies in Wireless Sensor Networks**

### **01-15-03-LPWSN-V**

**Responsible: Prof. Dr.-Ing. Alberto García-Ortiz**  
**Lecturer: Dr. Yanqiu Huang**

**Aim:** •

After this course, you should be able to:

- understand the principle of wireless sensor networks,
- understand related techniques for power management,
- get familiar with the mote operation and current research in WSNs.

**Prerequisite:** No formal requirements. Fundamentals of electronics engineering and information technologies.

**Content:**

Introduction of wireless sensor networks from node to network; overview of techniques for nodes power management including communication protocols, data processing algorithms; introduction of WSN mote operation

**Literature:**

- Walteneus Dargie and Christian Poellabauer: „Fundamentals of Wireless Sensor Networks, theory and practice“, John Wiley and Sons Ltd, 2010
- Further references will be announced in lecture

**Methods:** Lecture and exercise

**Efficiency Statement:** Oral examination

**ECTS Credits:** 4  
**SWS:** 3

**Workload:** 120 hours  
Lectures and exercise 35%  
Follow-up, reading, homework and preparation of exam 65%

**Suggested for:** CMM 2<sup>nd</sup> term (elective), Master ET/IT

## Master Seminar

**Responsible:** Prof. Walter Lang  
**Lecturer:** Prof. Walter Lang

### Aim:

The aim of the first master seminar is to constitute a group out of the new students, to establish cooperation with other students and with the professors. Furthermore, the student should learn to prepare and to perform oral presentations.

**Prerequisite:** None

### Content:

In the master seminar students give an oral presentation. The first part of this presentation contains general information about their background, their home country, their home university, their previous scientific and professional activities. The second part is about some of their previous scientific work done by the student in the past. This may be about their bachelor thesis, or about some other professional activities.

### Literature:

Within the Master Seminar a printout of general information about the Master Program is given to the students and discussed.

**Methods:** Presentation  
**Efficiency Statement:** Oral Presentation in the seminar

**Information,  
Downloads:** None

**ECTS Credits:** 2  
**SWS:** 2

**Workload:** 60 hours  
Presence in the seminar 40%  
Preparation of the presentation 60%

**Suggested for:** CIT and CMM 1<sup>st</sup> term, (compulsory course).

## Master's Thesis

**Responsible:** Professors of Electrical Engineering  
**Lecturer:** Professors of Electrical Engineering

### Aim:

The master's thesis is an autonomous work of research done with the guidance of a supervisor. The aim is to learn how to plan, to perform and to document scientific work. After the master's thesis, the student should be able to do research within industrial surroundings or within a PhD project.

**Prerequisite:** Achievement of min 72 CP.

### Content:

The master's thesis is an autonomous, though supervised scientific work of considerable content. In each case a specific topic is defined by the student together with the supervisor. The master's thesis is an independent work of research. It is documented in a master thesis report. The master's thesis is concluded with an oral presentation.

**Literature:** Every student reads his/her topic related publications

**Methods:** Scientific research methods such as measurements, simulations, calculations and modelling.

**Efficiency Statement:** Master's thesis report and presentation

### Information,

**Downloads:** Provided by the supervisor in the specific case. Searching for sources and study of the literature is part of the work.

**ECTS Credits:** 30

**SWS:** -

**Workload:** 900 hours  
Scientific work 70%  
Documentation and presentation 30%

**Suggested for:** CIT and CMM 4<sup>th</sup> term, (compulsory).

# Microfluidic Devices

01-15-03-MiD-V

**Responsible:** Prof. Dr. Michael Vellekoop

**Lecturer:** Prof. Dr. Michael Vellekoop

## Aim:

In the course an overview is given of the developments in the area of microfluidic devices from the early start (where especially silicon integrated valves and pumps were investigated) to the lab-on-a-chip devices of today. The functionality of the sensors and actuators, the technologies applied, and the design of fluidic chips will be discussed. Some basic fluidics aspects will be presented and a practical (Laborübung) in which COMSOL is used for the simulation of microfluidic elements is included. Lastly, a series of examples of currently investigated microfluidic devices will be shown, e.g. chips for capillary electrophoresis, coulter counter, cytometry and optofluidics.

Practical: "Introduction to COMSOL based fluidic simulations" (Dr. S. van den Driesche).

After this course, you should be able to:

- understand the basics of microfluidics
- understand and explain the functioning of microfluidic devices
- apply characterization parameters for (elements of) microfluidic devices
- understand fabrication technologies for microfluidic devices

**Prerequisite:** Basic knowledge of microtechnology. This can be acquired by: the course on "Introduction to Micro Technology" by M. Vellekoop, or the course "Sensors and Measurement Systems" by W. Lang, or studying a textbook such as "Introduction to Microfabrication" (S. Franssila)

## Content:

- |   |   |
|---|---|
| 7. Contents, Organisation, Introduction | 10. Sensors and analysis in $\mu$ fluidic devices |
| 8. Basics of microfluidics              | 11. Examples of $\mu$ fluidic devices             |
| 9. Flow control: valves and pumps       | 12. Technology for $\mu$ fluidic devices          |

## Literature:

M. Koch, A. Evans, A. Brunnschweiler, Microfluidic Technology and Applications, RSP  
H. Bruus, Theoretical Microfluidics, Oxford University Press

**Methods:** Lecture, practical

**Efficiency Statement:** Written examination

## Information,

**Downloads:** Stud.IP

**ECTS Credits:** 4

**SWS:** 3

**Workload:** 120 hours

Lectures and practical 33%

Homework, practical preparation and exam preparation 67%

**Suggested for:** CIT 3<sup>rd</sup> term and CMM 3<sup>rd</sup> term (elective), M. Sc. ET/IT

## **Microsystems**

### **01-15-03-MST-V**

**Responsible:** Prof. Dr. Walter Lang

**Lecturer:** Prof. Dr. Walter Lang

#### **Aim:**

Microsystems is an introduction to MEMS (Micro Electromechanical Systems) devices.

After the course you should:

- Know important applications of microsystems.
- Know how to combine single process steps to full process flows.
- Understand process control and measurement techniques.
- Have a deepened knowledge in the fields of:
  - Microactuators
  - Energy in Microsystems
  - Sensor networks

**Prerequisite:** Basic knowledge of microtechnology. This can be acquired by the course on “Microtechnology” by M. Vellekoop  
Or The course “Sensors and Measurement Systems”  
Or Studying a textbook such as “Introduction to Microfabrication” by Sami Franssila

#### **Content:**

- Application areas of Microsystems
- Process integration, process measurement, housing techniques, process cost estimation at the example of a pressure sensor
- Microactuators
- Energy in Microsystems
- Sensor networks

#### **Literature:**

Sami Franssila: Introduction to microfabrication  
Völklein, Zetterer: Einführung in die Mikrosystemtechnik.

**Methods:** Lecture, Tutorial

**Efficiency Statement:** Written examination

**Information, Downloads:** Studip

**ECTS Credits:** 4

**SWS:** 3

**Workload:** 120 hours  
Lectures and courses 38%  
Reading, homework and preparation of exam 62%

**Suggested for:** CIT 2<sup>nd</sup> Semester (elective), CMM 2<sup>nd</sup> Semester (compulsory),  
Master ET/IT

## Micro Technology

### 01-15-04-IMT-V

**Responsible:** Prof. Dr. Michael Vellekoop  
**Lecturer:** Prof. Dr. Michael Vellekoop

#### **Aim:**

Micro Technology is an independent one semester course in which you will obtain a basic understanding of the technology and processes used to fabricate microsensors, microactuators, microelectromechanical systems (MEMS), and microfluidic devices.

After this course, you should be able to:

- Understand and explain important sensor fabrication processes
- Relate specific material properties to microstructuring abilities and to sensor functions
- Understand the function of structures in microsensors and -actuators
- Design structures for a specific sensor function

**Prerequisite:** Basics of electrical engineering and electrical measurement methods

#### **Content:**

13. Contents, Organisation, Introduction	17. Structures
14. Manufacturing and Clean Room	18. Integration
15. Materials	19. Tools
16. Basic Processes	20. Future aspects

#### **Literature:**

Sami Franssila, Introduction to microfabrication, Wiley, ed. 2010

**Methods:** Lecture, practical in small group in the clean room

**Efficiency Statement:** Written examination

#### **Information,**

**Downloads:** Stud.IP

**ECTS Credits:** 4

**SWS:** 3

**Workload:** 120 hours  
Lectures and practical 38%  
Homework, practical preparation and exam preparation 62%

**Suggested for:** CIT 2<sup>nd</sup> term and CMM 2<sup>nd</sup> term (elective)  
Bachelor Elektrotechnik (5<sup>th</sup> semester)

# **Modeling and Simulation of Sensors, Circuits and Systems in Automotive Electronics**

**01-15-03-MSAE-V**

Responsible: PD Dr.-Ing. habil. Ajoy K. Palit

Lecturer: PD Dr.-Ing. habil. Ajoy K. Palit

Aim:

Automotive electronics must work in a very harsh environment which includes the wide temperature range from  $-40^{\circ}\text{C}$  up to at least  $+85^{\circ}\text{C}$ . Without the deep understanding of theoretical and practical behaviors of sensors and their associated electronic circuits in such extreme operating conditions the reliability of automotive electronic systems cannot be guaranteed. Modeling and simulation of sensors, circuits and systems in Automotive Electronics is an independent one semester course which will give you an opportunity to grasp and pursue further the theoretical analysis behind the practical behavior of different sensors and associated electronic system in such extreme temperature and environmental conditions. The course will give you a basic understanding of Finite Elements Method (FEM) and its application to modeling, simulation, parameter extraction and design of inductive, capacitive, resistive and magnet based Automotive Sensors etc., which are often used in automotive electronics fields for the measurement/sensing of linear & angular positions, vibrations, speed, acceleration, pressure and current measurement etc. The sensor's signal conditioner generates a wide range of output around its nominal output value both due to manufacturing tolerances of electronic components and their temperature dependencies. Hence, Monte-Carlo simulations of sensors' associated electronic circuits are addressed to estimate such tolerance range for some selected sensors. Reliability issues of automotive electronic systems are also addressed.

After this course, you should be able to:

- Understand the Finite Elements Methods (FEM) and its application to inductive, capacitive, resistive sensors and magnet based Hall automotive sensors modeling etc.
- Understand the stationary, frequency domain and time dependent studies and parametric simulation of aforementioned sensors using COMSOL-Multiphysics/CST-Tool.
- Estimate the sensor's signal conditioner output (mV or mA) using transfer function blocks
- Verify the sensors' signal output using circuit simulation (LTSPICE) software
- Processing of sensor's signal (MATLAB/C++ programming) in order to estimate linear & angular positions etc. and linearity test of sensor
- Estimate the tolerance band of sensor's signal conditioner circuit using Monte-Carlo simulation and worst case simulation method for the entire operating temperature range
- Perform magnetic field simulation of a current carrying conductor for the measurement of current using Hall sensor
- Model, design and extract the NFC-antenna parameter for matching circuit design,
- Measure the NFC-antenna (S11) parameter with VNA (Smith Chart) and design the suitable



matching circuit (for Texas Instruments, NXP & Melexis Transceiver) using RF-simulation.

- Simulate & analyze the heat dissipation technique for automotive power electronic system
- Calculate the reliability (FIT/MTTF/MTBF) of automotive electronic circuits and systems.

Prerequisite: Electrical circuit theory, Mathematics and C++ / MATLAB programming

Content:

- FEM applications in automotive electronics
- Inductive, capacitive, resistive and magnet based automotive sensors modeling
- Stationary, time dependent and frequency domain modeling of automotive sensors
- Monte-Carlo & Worst-Case simulations
- Modeling & simulation of NFC-antenna
- NFC-antenna measurements using VNA & matching circuit design using RF-simulation
- Thermal simulation of automotive electronics using FEM
- Theoretical estimation of sensor signal using transfer function blocks (Laplace transform)
- LTSPICE simulation of sensor circuit
- Reliability calculation of automotive systems

#### Literatures/Reference Books:

- Understanding Automotive Electronics, An Engineering Perspective, Authors: W. B. Ribbens, Butterworth-Heinemann-Elsevier, MA, USA, 6<sup>th</sup> Ed., 2003.
- Sensoren in Kraftfahrzeug, Konrad Reif (Hrsg.), Bosch Technik fürs Leben, Viewweg+Teubner, Wiesbaden, 2010.
- Reliability Engineering, Theory & Practice, Alessandro Birolini, 5th Ed., Springer 2006.

**Methods:** Lecture, Modeling/Simulation/Programming exercises

**Efficiency Statement:** Written examination, Modeling/Simulation Exercises

**Information, Course Materials:** E-mail: [palit \(at\) uni-bremen.de](mailto:palit@uni-bremen.de) & see the Ref. Book

**ECTS Credits:** 4

**SWS:** 3

**Workload:** 120 hours

Lectures and courses 40%

Lecture, homework and preparation of exam 60%

**Suggested for:** CIT and CMM, 2<sup>nd</sup> or 3<sup>rd</sup> term (elective course)

## **Network Simulation (previous title: Stochastic Simulation of Communication Networks and their Protocols)**

**01-15-03-StS-V (as of winter semester 2018/2019)**

**Responsible:** Prof. Dr. Anna Förster  
**Lecturer:** Prof. Dr. Anna Förster

### **Aim:**

The goal of this lecture is to understand the design and programming of network simulators as well as the statistical evaluation of the results. The lecture provides a large amount of hands-on exercises where you will work with the OMNET simulator. We look at different types of networks, non-technical ones such as the spreading of biological viruses, traditional Internet-based networks and mobility-based opportunistic networks. Finally, you will work on a small project where you have to solve a given problem by means of simulations.

We expect from you some programming experience, preferably with C or C++.

After the lecture you will be able to design and develop simulation models of current and future networking technologies and identify resp. tackle performance issues in such networks.

**Prerequisite:** No formal requirements

### **Content:**

- Discrete Event Simulation
- Radio transmission models
- Mobility models
- Traffic generation
- Interference models
- Power consumption and battery models
- OMNeT++
- Simulation speedup

### **Literature:**

- Modeling and Tools for Network Simulation by Klaus Wehrle, Mesut Günes, James Gross (Editors), Springer, 2010.
- The Art of Computer Systems Performance Analysis by Raj Jain John Wiley & Sons Inc., 1991

**Methods:** Lecture, exercises

**Efficiency Statement:** Combination examination (project, presentation, exercises)

**ECTS Credits:** 4

**SWS:** 3

**Workload:** 120 hours  
Lectures and courses 35%  
Reading, homework and preparation of lectures, exercises, exam 65%

**Suggested for:** CIT 2<sup>nd</sup> or 3<sup>rd</sup> term, (elective course), M. Sc. ET/IT

# Next Generation Cellular Networks

01-15-03-NGCN-V

**Responsible:** Prof. A. Dekorsy

**Lecturer:**

**Aim:**

New Standards for Cellular Networks is an independent one semester course which will give you a basic understanding of cellular networks, their history, the system structure, the protocols and the future developments of mobile communications.

**Prerequisite:** Communications Technology, Communication Networks

**Content:**

- Mobile Communications  
History and Principles
- Second Generation (2G): GSM Overview
- Third Generation (3G): UMTS Services and Applications, System Architecture, Air Interface
- UMTS Evolution  
High Speed Packet Access (HSPA)
- Beyond 3G systems  
UMTS Long Term Evolution (LTE)
- Network Planning and Optimization  
Targets, Challenges, Modeling

**Literature:**

WCDMA for UMTS, H. Holma and A. Toskala, Wiley.

Radio Network Planning and Optimization for UMTS, J. Laiho and A. Wacker and T. Novosad, Wiley

LTE, S. Sesia and I. Toufik and M. Baker, Wiley.

LTE for UMTS, H. Holma and A. Toskala, Wiley.

**Methods:** Lecture, exercises

**Efficiency Statement:** Oral examination

**Information, Downloads:** Literature is given in the lectures,  
Please also refer to [www.comnets.uni-bremen.de](http://www.comnets.uni-bremen.de)

**ECTS Credits:** 4

**SWS:** 3

**Workload:** 120 hours  
Lectures and courses 38%  
Reading, homework and preparation of exam 62%

**Suggested for:** CIT and CMM 2<sup>nd</sup> or 3<sup>rd</sup> term, (elective course)

## Nonlinear Systems

01-15-03-NLS-V

**Responsible:** Prof. Dr.-Ing. Kai Michels

**Lecturer:** Prof. Dr.-Ing. Kai Michels

### Aim:

Based on the lecture „Grundlagen der Regelungstechnik“ (Basics of Control Engineering), where only linear systems were discussed, this lecture will concentrate on nonlinear systems with their special features and suitable control solutions. The students shall learn to handle nonlinearities in simple control loops.

**Prerequisite:** Lecture „Grundlagen der Regelungstechnik“ or equivalent knowledge about basics of control (bode diagrams, nyquist plots, nyquist stability criterion, PID controller design)

### Content:

- Basics and features of nonlinear systems
- Switching functions as transfer elements
- Definition of stability for nonlinear systems
- Direct method of Lyapunov
- Describing function
- Popov criterion, circle criterion, hyperstability
- Sliding-mode control
- Gain Scheduling

### Literature:

- K. Michels: Control Engineering (Script in German and English)
- O. Föllinger: Nichtlineare Regelungen I und II (German)
- K. Michels: Fuzzy Control (English)
- Wassim M. Haddad: Nonlinear Dynamical Systems and Control: A Lyapunov-Based Approach (English)
- Sejid Tesnjak: Nonlinear Control Systems (English)

**Methods:** Lectures, tutorial

**Efficiency Statement:** Written or oral examination, depending on the number of participants

### Information, Downloads:

**ECTS Credits:** 4

**SWS:** 3

**Workload:** 120 hours  
Lectures and courses 35%  
Reading, homework and preparation of exam 65%

**Suggested for:** CMM 2<sup>nd</sup> term (compulsory course), CIT 2<sup>nd</sup> term (elective course)

## Optimisation Theory

01-15-03-OpT-V

**Responsible:** Dr.-Ing. Dagmar Peters-Drolshagen

**Lecturer:** Dr.-Ing. Dagmar Peters-Drolshagen

### Aim:

Optimisation Theory is a one semester elective course. The aim is to provide a basic understanding of operations research methods necessary for engineers to solve their technical problems in an efficient and innovative manner.

After this course, you should be able to:

- Describe a generic optimisation strategy which fits to almost all optimisation strategies
- Depict the procedure of local direct & indirect as well as global optimisation methods
- Handle constraints efficiently
- Understand the meaning of one dimensional optimisation methods
- Grade the performance of different operations research approaches
- Apply optimisation to engineering problems

**Prerequisite:** Basics of linear algebra and differential calculus

### Content:

- |   |   |
|---|---|
| - Organisation, Topics  | - One dimensional Methods                             |
| - Mathematical Basics, Step width control   | (interpolation based & direct)                        |
| - Task Formulation, Auxiliary Conditions & Constraints, Generic Optimisation Strategy | - Local, multi dimensional, direct & indirect Methods |
| - Necessary & sufficient Optimum Conditions   | - Global Optimisation Methods                         |
| - Classification & Transformation Methods   | - Project (matlab)                                    |

### Literature:

H.-P. Schwefel: Evolution and Optimum Seeking.

J. Nocedal et al.: Numerical Optimization.

S. S. Rao: Engineering Optimization – Theory and Practice.

**Methods:** Lecture, exercises partially using Matlab, student project concluding with a small talk

### Efficiency Statement:

Portfolio Assessment consisting of: 1. Student project concluded with a talk  
2. Written Exam

**ECTS Credits:** 4

**SWS:** 3

**Workload:** 120 hours  
Lectures and exercises 35%  
Reading, project and preparation of exam 65%

**Suggested for:** CIT and CMM 1<sup>st</sup>, 2<sup>nd</sup> or 3<sup>rd</sup> term, (elective course)

**Presenting science****01-95-03-PSc-V****Responsible:** Walter Lang**Lecturer:** Walter Lang**Aim:**

In this course you will train the presentation of scientific results.

There will be a tutorial introduction on giving presentation and on making slides.

Then, every student will prepare and give a presentation on a current research topic.

The presentation will be analysed together, an improved version will be made.

**Prerequisite:** None**Content:**

- Introduction to giving talks and preparing slides -
- Choosing a topic
- Preparing and presenting a speech
- Analysis, improvement

**Literature :**

Literature will be provided in the lectures

**Methods:** See content**Efficiency Statement:** Speech, corrected slides**Information,****Downloads:** -**ECTS Credits:** 2**SWS:** 2**Workload:**

60 hours

Lectures and courses 30%

Homework and preparation of exam 70%

**Suggested for:** CIT and CMM 2<sup>nd</sup> term, (elective course)

When combined with “Understanding Germany”, then both courses together will have 4 ECTS and can be used as an elective in CIT and CMM.

## Process Automation

01-15-03-PAut-V

**Responsible:** Prof. Dr.-Ing. Johanna Myrzik

**Lecturer:** Prof. Dr.-Ing. Johanna Myrzik

### Aim:

The lecture on process automation is an independent one-semester course which will give you a basic knowledge in the wide field of process automation. After the course you will be able to understand the basic structures, operation and control principles of automation processes. You will understand the working principle of the most used sensors, actuators and programming logic controllers. You will be able to program small control tasks. The second part of the course will be focus on the process automation in electrical power supply networks. Beside the required field and data components you will get a broad understanding into the network operation principles and tasks of the grid operators.

**Prerequisite:** BSc. or BEng.

### Content:

- Basics on process automation operation and control principles
- Sensor and actuators
- Power electronic interfaces
- Programming logic controllers
- Process automation in electrical power systems
- Data and field components
- Network operation principles

### Literature:

- B. R. Mehta, Y. J. Reddy: Industrial Process Automation Systems - Design and Implementation, Elsevier 2015
- Stephen F. Bush: SMART GRID COMMUNICATION-ENABLED INTELLIGENCE FOR THE ELECTRIC POWER GRID, Wiley 2014

**Methods:** Lectures, exercises

**Efficiency Statement:** Final written examination; Exam performance: Successful presence in all weekly exercises and delivering graded exercises

### Information,

**Downloads:** <https://elearning.uni-bremen.de/>

**ECTS Credits:** 4

**SWS:** 3

**Workload:** 120 hours

Lectures and courses 38%

Reading, homework and preparation of exam 62%

**Suggested for:** CIT, CMM (elective course)

## Project

**Responsible:** Professors of Electrical Engineering  
**Lecturer:** Professors of Electrical Engineering

### Aim:

Within the project, the student learns to perform scientific investigations and to document them in the form of a thesis and to present the results. The student also learns how to work in a group of scientists.

After the project, the student should be prepared for the master thesis.

**Prerequisite:** None

### Content:

The project is an autonomous, though supervised scientific work. It can be done in a group of students or as the work of one single student. In each case a specific topic is defined by the student together with the supervisor. The project is an independent work of research. It is documented in a project thesis. The project will also be presented, generally in the seminar of the institute of the supervisor as an oral presentation.

**Literature:** Literature linked especially to the project will be handed out to the students when beginning the specific project.

**Methods:** Scientific research methods such as measurements, simulations, calculations and modelling.

**Efficiency Statement:** Project report and presentation

### Information,

**Downloads:** Provided by the supervisor in the specific case. Searching for sources and study of the literature is part of the work.

**ECTS Credits:** 18

**SWS:** 12

**Workload:** 540 hours  
 Scientific work 70%  
 Documentation and presentation 30%

**Suggested for:** CIT and CMM 3<sup>rd</sup> term, (compulsory course).



## RF Frontend Devices and Circuits

01-15-03-RFC-V

**Responsible:** Prof. Dr.-Ing. Martin Schneider

**Lecturer:** Prof. Dr.-Ing. Martin Schneider

### Aim:

This course aims at teaching the fundamental working principles of analogue RF frontend devices and circuits that are the main building blocks of fixed and mobile devices for wireless communications (GSM, WLAN, UMTS, RFID, etc.) as well as for sensors like radar sensors. After this course you should understand the basic principles of RF devices like amplifiers, mixers, oscillators, PLL's, and frequency synthesizers. The fundamentals of two-port circuits, electronic noise, and effects of non-linearities are addressed at first. Based on these theoretical parts you should be able to discuss the pros and cons of different RF frontend architectures and to design first basic analogue RF frontend circuits.

**Prerequisite:** Basic system and communication theory

### Content:

- Two-port circuits
- Noise in electronic circuits
- Fundamentals of non-linear devices
- RF devices
- RF circuits and frontends

### Literature:

Ulrich L. Rohde, David P. Newkirk, "RF/Microwave Circuit Design for Wireless Applications," John Wiley & Sons, 2000.

David M. Pozar, "Microwave Engineering," John Wiley & Sons, third edition, 2005.

David M. Pozar, "Microwave and RF Design of Wireless Systems," New York, NY: Wiley, 2001.

J. Laskar, B. Matinpour, S. Chakraborty, "Modern Receiver Front-Ends: Systems, Circuits, and Integration," Hoboken, NJ: Wiley-Interscience, 2004.

B. Razavi, "RF Microelectronics," Upper Saddle River, NJ, Prentice Hall, 1st edition, 1998.

L. E. Larson, "RF and microwave circuit design for wireless communications," Boston, Mass.: Artech House, 1997.

**Methods:** 2h lecture, 1h exercises and tutorial

**Efficiency Statement:** Written examination

**Information, Downloads:** <http://www.hf.uni-bremen.de>

**ECTS Credits:** 4

**SWS:** 3

**Workload:** 120 hours

Lectures and courses 38%

Reading, homework and preparation of exam 62%

**Suggested for:** CIT 1<sup>st</sup> term (compulsory course), CMM (elective), Master ET/IT

## Robotics I

### 01-15-03-Rob1-V

**Responsible:** Dr. Danijela Ristić - Durrant  
**Lecturer:** Dr. Danijela Ristić - Durrant

#### Aim:

Robots are complex mechanical, automatic and informatics systems which are of growing interest not only in industrial robotics but also in other areas such as service robotics, mobile robotics and medical robotics. This module deals with the most important fundamental concepts of the robotics and provides students with the knowledge about the basis of this fascinating and future oriented area. The knowledge gained in lectures, students can apply for solving the practical examples considered in practical exercises.

**Prerequisite:** BSc. or Beng.

#### Content:

The module starts with the mathematical preliminaries and the consideration of a manipulator kinematics. In connection to that, direct (forward) as well as inverse kinematics will be investigated. As an important concept for the solution of direct kinematics the so-called Denavit-Hartenberg convention will be introduced. Regarding the solution of inverse kinematics problems both the analytical and numerical solution will be examined. An important topic of the module is also the trajectory planning. The module ends with the consideration of different methods for robot control and basic control strategies for robotic systems.

#### Literatur:

- Crane, C. D., Duffy, J., Kinematic Analysis of Robot Manipulators, Cambridge University Press, 1998.
- Sciavicco, L., Siciliano, B., Modelling and Control of Robot Manipulators, Springer-Verlag London Limited, 2000.
- Paul, R., Robot Manipulators: Mathematics, Programming and Control, The MIT Press, Cambridge, 1981.
- Craig, J. J., Introduction to Robotics, Mechanics and Control, Addison-Wesley Publishing Company, Massachusetts, 1986.
- Spong, W. M., Robot Dynamics and Control, John Wiley & Sons, 1989.
- LaValle M. S., Planning Algorithms, Cambridge University Press, 2006.
- Saeed, B. N., Introduction to Robotics Analysis, Systems, Applications, Prentice Hall, 2001.

**Methods:** Lecture, exercises, laboratory experiments

**Efficiency Statement:** Written examination; The successful attendance of the laboratory exercises is the prerequisite for taking part in the written exam.

#### Information,

**Downloads:** <https://elearning.uni-bremen.de/>

**ECTS Credits:** 4  
**SWS:** 3

**Workload:** 120 hours  
Lectures and courses 38%  
Reading, homework and preparation of exam 62%

**Suggested for:** CIT and CMM 2<sup>nd</sup> or 3<sup>rd</sup> term, (elective course)

## Robotics II

### 01-15-03-Rob2-V

**Responsible:** Dr. Danijela Ristić - Durrant  
**Lecturer:** Dr. Danijela Ristić - Durrant

#### Aim:

Robots are complex mechanical, automatic and informatics systems which are of growing interest not only in industrial robotics but also in other areas such as service robotics, mobile robotics and medical robotics. Starting from the basic robot control strategies, this module is focused on the specific (advanced) aspects of robotics such as Visual Robot Control. As such, the module provides students with the knowledge about the basis of this fascinating and future oriented robotics area. Although focused on robotics, the knowledge gained in lectures concerning digital image processing, camera technologies and stereo vision students can apply in a variety of different engineering fields such as biomechanics and car driver assistance systems.

**Prerequisite:** BSc. or Beng., Robotic I recommended

#### Content:

The module is focused on the specific aspects of robotics such as:

- Visual robot control (Visual servoing)

and related fields:

- Digital image processing
- Projective transformations
- Camera models
- Stereo vision (epipolar geometry and 3D reconstruction)

#### Literatur:

- Corke P. I.: Visual Control of Robots: high-performance visual servoing, Research Studies Press LTD, 1996.
- Hartley R., Zisserman A.: Multiple View Geometry in Computer Vision, Cambridge University Press, 2002.
- Niku B. S.: Introduction to Robotics: Analysis, Systems, Applications, Prentice Hall, 2001.
- Klein, F.: Elementary Mathematics from an advanced Standpoint: Geometry, Dover Publications Inc., ISBN 0-486-43481-8
- Gonzales, R. C., Woods R. E.: Digital Image Processing, Prentice-Hall, 2002.

**Methods:** Lecture, exercises, laboratory exercises

**Efficiency Statement:** Written examination. The successful attendance of two laboratory exercises is the prerequisite for taking part in the written exam.

#### Information,

**Downloads:** <https://elearning.uni-bremen.de/>

**ECTS Credits:** 4

**SWS:** 3

**Workload:** 120 hours  
Lectures and courses 38%

Reading, homework and preparation of exam 62%

**Suggested for:** CIT 2<sup>nd</sup> or 3<sup>rd</sup> term, CMM 3<sup>rd</sup> or 4<sup>th</sup> term, (elective course)

## Selected Topics in Sustainable Communication Networks

01-15-03-STSCN-S

**Responsible:** Prof. Dr. Anna Förster

**Lecturer:** Prof. Dr. Anna Förster

**Aim:**

The students will learn about various research fields and applications of communication networks, which target the sustainable development goals (SDG) of the United Nations. The students will individually explore a given topic (with the help of research publications or other scientific materials) and prepare a presentation which will be discussed in class with the lecturer and the peers.

**Prerequisite:** No formal requirements

**Content:**

This module offers the opportunity to learn and discuss various aspects and research fields of sustainability for communication networks, such as:

- Wireless (underground) sensor networks
- Environmental monitoring
- Smart agriculture
- Opportunistic networks
- Energy efficiency in communication networks
- Societal aspects of modern communications

**Literature:**

To be announced at the start of the semester

**Methods:** Seminar

**Efficiency Statement:** Presentation and report

**Information,**

**Downloads:** Studip

**ECTS Credits:** 2

**SWS:** 2

**Workload:** 60 hours  
Lectures and courses 50%  
Reading, homework and preparation of exam 50%

**Suggested for:** CIT (elective), CMM (elective), ETIT Master

## Sensors and Measurement Systems

### 01-15-03-SAMS-V

**Responsible:** Prof. Dr. Walter Lang  
**Lecturer:** Prof. Dr. Walter Lang

#### Aim:

Sensors and measurement systems is an independent one semester course which will give you a basic understanding in sensors, measurement and microsystems technology.

After this course, you should be able to:

- Name and explain important sensors
- Apply characterization parameters for sensors
- Choose sensors for a given application and apply them
- Analyze sensor systems
- Understand micromachining technologies for sensors

**Prerequisite:** Basics of electrical engineering and electrical measurement

#### Content:

- |                           |   |
|---------------------------|---|
| 1. Contents, Organisation | 4. Pressure sensors and bulk micromachining |
| 2. Thermal sensors        | 5. Inertial sensors                         |
| 3. Thin film technology   | 6. Flow Sensors                             |

#### Literature:

Walter Lang: Sensors and Measurement Systems, ISBN-10: 877022028X

**Methods:** Lecture, exercise in the clean room

**Efficiency Statement:** Written examination

#### Information,

**Downloads:** Studip

**ECTS Credits:** 4

**SWS:** 3

**Workload:** 120 hours  
 Lectures and courses 38%  
 Reading, homework and preparation of exam 62%

**Suggested for:** CIT 1st term (elective), CMM 1st term (compulsory course), ETIT Master

## Sensor Science

01-15-03-SSc-V

**Responsible:** Prof. Dr. Michael Vellekoop  
**Lecturer:** Prof. Dr. Michael Vellekoop, Dr. Sander van den Driesche

### Aim:

In the course an introduction is given on science in the field of sensors. It is discussed what is specifically essential for research in the area of sensors and how research articles (literature) are useful for the design of sensors. Each student investigates an own sensor topic.

After this course, you should be able to:

- To conduct an efficient literature search
- To be able to discriminate between the main and minor aspects of a research topic
- To study and understand the physical and electronic fundamentals of a specific sensor
- To be able to report in word and in writing

**Prerequisite:** Basic knowledge of microtechnology. This can be acquired by: the course on “Introduction to Micro Technology” by M. Vellekoop, or the course “Sensors and Measurement Systems” by W. Lang, or studying a textbook such as “Introduction to Microfabrication” (S. Franssila)

### Content:

- |  |   |
|--|---|
| 1 Conduct a literature search on a spec. topic               | 3 Study specific aspects of sensor science through the found literature |
| 2 Reading of scientific publications in the field of sensors | 4 Write a report on the study   |
|  | 5 Oral presentation   |

### Literature:

Handout (given in the lecture)

**Methods:** Lecture, practical

**Efficiency Statement:** Oral examination

### Information,

**Downloads:** Stud.IP

**ECTS Credits:** 4

**SWS:** 3

**Workload:** 120 hours

Lectures and practical 33%

Homework, practical preparation and exam preparation 67%

**Suggested for:** CIT 3<sup>rd</sup> term and CMM 3<sup>rd</sup> term (elective), Elektrotechnik Master (SoSe)



## Speech and Audio Signal Processing I

01-15-03-SAS1-V

**Responsible:** A. Dekorsy

**Lecturer:** S. Götze

**Aim:**

Basic Understanding of Speech- and Audio-Signal-Processing

**Prerequisite:** -

**Content:**

1. Introduction
2. Room Acoustics
3. Speech Generation and Perception
4. Noise Reduction
5. Acoustic Echo Cancellation / Adaptive Filtering
6. Listening Room Compensation / Dereverberation

**Literature:**

P. Vary, R. Martin: "Digital Speech Transmission", Wiley, 2006.

Rabiner, Schafer: "Digital Processing of Speech Signals", Prentice-Hall, Zwicker, Fastl: "Psychoacoustics", Springer.

IEEE Signal Processing Letters,

<http://www.signalprocessingsociety.org/publications/periodicals/letters/>.

IEEE Transactions on Audio, Speech and Language Processing,

<http://www.signalprocessingsociety.org/publications/periodicals/taslp/>.

**Methods:** Lecture, exercises

**Efficiency Statement:** Written examination

**Information,**

**Downloads:** <http://www.ant.uni-bremen.de/en/courses/sasp/>

**ECTS Credits:** 4

**SWS:** 3

**Workload:** 120 hours

Lectures and courses 38%

Reading, homework and preparation of exam 62%

**Suggested for:** CIT and CMM 2<sup>nd</sup> or 3<sup>rd</sup> term, (elective course)

## Speech and Audio Signal Processing II

01-15-03-SAS2-V

**Responsible:** A. Dekorsy

**Lecturer:** S. Götze

### Aim:

The students

- learn foundations of digital signal processing for non-stationary signals like music and speech;
- learn methods for measurements of room impulse responses and for acoustic properties of rooms;
- acquire knowledge about the usability and the design of adaptive filters for signal enhancement of speech and audio signals (acoustic noise reduction, acoustic echo compensation, echo cancellation of speech signals);
- learn the connections between human speech

**Prerequisite:** Speech and Audio Processing I -

### Content:

- Adaptive Filtering
- Acoustic Echo Cancellation
- Listening Room Compensation / Dereverberation

### Literature:

**Methods:** Lecture, exercises

**Efficiency Statement:** Written examination

### Information, Downloads:

**ECTS Credits:** 4

**SWS:** 3

**Workload:** 120 hours  
Lectures and courses 38%  
Reading, homework and preparation of exam 62%

**Suggested for:** CIT and CMM 2<sup>nd</sup> or 3<sup>rd</sup> term, (elective course)

## Systems-on-Chip: Architectures and Design Methods

01-15-03-SoC-V

**Responsible:** Prof. Dr.-Ing. Alberto García-Ortiz

**Lecturer:** Prof. Dr.-Ing. Alberto García-Ortiz

**Aim:**

The students acquire specialized knowledge about the architectures of modern Systems-on-Chip using heterogeneous technologies (e.g., electrical and photonic) and heterogeneous modules (e.g., processors, accelerators, analog components). They learn the implementation strategies and skills required for the implementation of those Systems-on-Chip in nanometric technologies. They are able to read critically, assimilate, and analyze current research papers regarding systems-on-chip.

**Prerequisite:** None

**Content:** Introduction to Systems-on-Chip  
Low-Power techniques for SoCs in nanometric technologies  
On-Chip nano-photonic communication  
3D technologies

**Literature:**

- Lecture slides
- Selected research papers

**Methods:** Lecture  
Exercises and oral presentation of a research paper

**Efficiency Statement:** Oral examination

**Information,**

**Downloads:** <https://elearning.uni-bremen.de/>

**ECTS Credits:** 4

**SWS:** 3

**Workload:** 120 hours (lectures and courses 42h, homework 28h and preparation of exam and research paper 50h)

**Suggested for:** CIT and CMM, 2nd or 3rd term, (elective course)

## System Theory

### 01-95-03-STIT-V

**Responsible:** Dr. Dagmar Peters-Drolshagen

**Lecturer:** Dr. Dagmar Peters-Drolshagen

#### Aim:

System Theory is a one semester course. The aim is to provide a common level of knowledge concerning the basics of discrete signals and systems. The topics are used in many other courses in Information and Automation Engineering (CMM) as well as in Communication and Information Technology (CIT).

After this course, you should be able to:

- be familiar with Fourier, Laplace and z-transformations
- be familiar with stochastic processes (probabilities, densities, distributions, moments, ...)
- be familiar with tools of linear algebra (matrix decompositions, ...)

#### Prerequisite:

##### Content:

- |  |   |
|--|---|
| - Contents, Organisation                       | - Stochastic processes                                    |
| - Review on Fourier and Laplace transformation | - MIMO systems  |
| - Z-transformation                             | - Description of systems with multiple inputs and outputs |
| - Derivation and existence                     | - Tools of linear algebra (matrix decompositions, ...)    |
| - System description by z transformation       |   |

#### Literature :

Alan V. Oppenheim, Alan S. Willsky and S. Hamid Nawab: Signals & Systems, Prentice Hall, 1997.

I B. Gridod; R. Rabenstein: Signals and Systems, John Wiley & Sons Ltd., 2001.

**Methods:** Lecture, PC-exercises

**Efficiency Statement:** Written examination

**Information, Downloads:** -

**ECTS Credits:** 4

**SWS:** 3

**Workload:** 120 hours  
Lectures and courses 38%  
Reading, homework and preparation of exam 62%

**Suggested for:** CIT and CMM 1<sup>st</sup> term, (compulsory course)

## Understanding Germany

01-95-03-UGer-S

**Responsible:** Walter Lang  
**Lecturer:** Thomas Neumann

### Aim:

For studying, living and working in Germany it is useful to acquire some basic knowledge about the German culture, the mentality and the political system. So we will take a look at German history and some philosophical and cultural aspects in connection with current political problems and discussions. After that the students will have a deeper insight into the reasoning behind different political positions in Germany.

**Prerequisite:** None

### Content:

- methodic preliminaries
- the “ nationbuilding” of Germany, from microstates to a nation 1814-1914
- the path from nationalism to Hitler’s totalitarianism 1918 -1945
- the formation of the democratic Bundesrepublik Deutschland and its problems 1945 – until today

### Literature :

Literature will be provided in the lectures

**Methods:** lectures , group work, discussion. As an option we can probably visit the Tank Museum in Munster and the former concentration camp in Bergen – Belsen.

**Efficiency Statement:** Essay

### Information,

**Downloads:** -

**ECTS Credits:** 2

**SWS:** 2

**Workload:** 60 hours  
 Lectures and courses 30%  
 Homework and preparation of exam 70%

**Suggested for:** CIT and CMM 1<sup>st</sup> term, (elective course)

When combined with “Presenting Science”, both courses together will add up to 4 ECTS and can be used as an elective in CIT and CMM.

## Wireless Communications

01-15-03-WCom-V

**Responsible:** Prof. Dr.-Ing. A. Dekorsy

**Lecturer:** Prof. Dr.-Ing. A. Dekorsy

### Aim:

This is the second part of a two semester course. After this course, the students will have a basic knowledge on modern digital modulation systems. They should be able to:

- Explain concepts of MAP und ML-designs.
- Apply the Viterbi-Algorithm on distorted modulation signals.
- Develop full system concepts for mobile communication scenarios.
- Apply knowledge on modern solutions for mobiles such as OFDM and CDMA.
- Combine existing Matlab-Modules for the simulation of mobile communication systems.

**Prerequisite:** Communications Technologies

### Content:

- |  |  |
|--|--|
| 1. Optimal Receiver for AGN                | 3. Mobile Radio Channels               |
| 1.1.Optimal AWGN Receiver                  | 3.1.Mulitpath Propagation              |
| 1.2.Generalization for coloured noise      | 3.2.Doppler Spreading                  |
| 1.3.Symbol / Bit Error Probability         | 4. Mobile Radio Transmission Concepts  |
| 2. Transmission under ISI Conditions       | 4.1.The OFDM System                    |
| 2.2.Optimal Receiver (MSLE, Forney)        | 4.2.Principles of Code Multiplex(CDMA) |
| 2.3.Viberbi Algorithm                      | 4.3.The GSM Mobil Radio System         |
| 2.4.Error Probability at Viterbi Detection |  |
| 2.5.Influence of Channel Impulse Response  |  |
| 2.6.Channel Estimation (Least Squares)     |  |

### Literature:

- David Tse, Pramond Viswanath: Fundamentals of Wireless Communications.
- Paulraj, Nabar, Gore: Introduction to Sapce-Time Wireless Communications.

**Methods:** Lecture, exercises with presentation by the students

**Efficiency Statement:** Written examination

### Information,

**Downloads:** <http://www.ant.uni-bremen.de/en/courses/ct2>

**ECTS Credits:** 4

**SWS:** 3

**Workload:** 120 hours

Lectures and courses 38%

Reading, homework and preparation of exam 62%

**Suggested for:** CIT 1<sup>st</sup> term, (compulsory course), CMM 1<sup>st</sup> or 3<sup>rd</sup> term, (elective course)

## **Annex 1: Details of the Labs for CMM**

### **Advanced Control Lab 01-15-03-LRT-P**

Responsible: Prof. Dr.-Ing. Kai Michels  
Lecturer: Prof. Dr.-Ing. Kai Michels

#### **Aim:**

The students shall get experience with the design and practical application of complex controllers.

**Prerequisite:** Lecture „Control Theory I“

#### **Content:**

1. Crane: Modelling, analysis, and state space control (pole placement method) of a crane
2. Inverted pendulum I: Swinging up of an inverted pendulum using different methods
3. Inverted pendulum II: Modelling, analysis, and state space control (pole placement method) for the stabilization of an inverted pendulum
4. Helicopter: Modelling, analysis, and state space control (Riccati method) of a helicopter model
5. Identification and control with an industrial plant control system

#### **Literature:**

Michels, K.: Script „Control Engineering“ (German and English)  
Scripts for each experiment in German and English

**Methods:** Groups up to 5 students. Short examination of the preparation before the experiment. All experiments use MATLAB/Simulink.

## Laboratory Design of Digital Systems 01-15-03-DDsy-P

Responsible: Prof. Dr.-Ing. Alberto García-Ortiz  
Lecturer: Prof. Dr.-Ing. Alberto García-Ortiz

### Aim:

Students shall get basic experience of methods for automated Digital System Design using CAD tools. Students learn special skills for the realization of function-specific digital modules and complex circuits.

**Prerequisite:** Architectures and Design Methodologies of Integrated Digital Systems

**Content:** Logic synthesis using synopsis-framework  
Place and Route using cadence-framework  
Verification of digital systems  
Design-for-test  
Realization of a computer game on FPGA  
    Design of function blocks  
    Test of modules  
    System integration

### Literature:

- Michael John Sebastian Smith, Application-Specific Integrated Circuits, Addison-Wesley Publishing Company ISBN 0-201-50022-1
- Charles Stroud, Nur Touba und Laung-Terng Wang, System-On-Chip Test Architectures: Nanometer Design for Testability, ISBN-10: 012373973X
- Laung-Terng Wang, Cheng-Wen Wu, Xiaoqing Wen, VLSI Test Principles and Architectures: Design for Testability, ISBN: 978-0-12-370597-6

**Methods:** Practical use of state-of-the-art industrial CAD design tools (Cadence, Synopsys, Mentor)  
Groups up to 3 students.  
Short examination of the preparation before the experiment.



**Microsystems Laboratory**  
**01-15-03-MiS-P**

Responsible: Prof. Dr. Walter Lang, Prof. Dr. M. Vellekoop  
Lecturer: Prof. Dr. Walter Lang, Prof. Dr. M. Vellekoop

**Aim:**

The students shall get experience in microtechnical processing.

**Prerequisite:** Lecture „Sensors and Measurement Systems (Lang) or Microtechnology (Vellekoop)“

**Content:**

1. How to work in a cleanroom
2. How to operate processing machines
3. Hands-on training in micromachining

**Literature:**

Script “Sensors and MEasurement Systems” by W. Lang

**Methods:** Groups up to 5 students. Short examination of the preparation before the experiment.

**Laboratory Design of Microelectronics**  
**01-15-03-MMK-P**

Responsible: Prof. Dr.-Ing. Steffen Paul  
Lecturer: Prof. Dr.-Ing. Steffen Paul

**Aim:**

Students shall get basic experience of methods for the design of analog and mixed signal integrated circuits using industrial CAD tools starting from a system level specification. Students learn special skills from verification, circuit simulation, synthesis, device sizing down to first steps for layout.

**Prerequisite:** Integrated Circuits

**Content:**

1. Matlab modelling of systems
2. circuit simulation, synthesis, digital layout
3. analog design by gm/id method
4. layout of analog circuits
5. Mixed signal chip design

**Literature:**

- Michael John Sebastian Smith, Application-Specific Integrated Circuits, Addison-Wesley Publishing Company ISBN 0-201-50022-1
- Charles Stroud, Nur Touba und Laung-Terng Wang, System-On-Chip Test Architectures: Nanometer Design for Testability, ISBN-10: 012373973X
- Laung-Terng Wang, Cheng-Wen Wu, Xiaoqing Wen, VLSI Test Principles and Architectures: Design for Testability, ISBN: 978-0-12-370597-6

**Methods:** Practical use of state-of-the-art industrial CAD design tools (Cadence, Synopsys, Mentor)  
Groups up to 3 students.  
Short examination of the preparation before the experiment.

**Sensor Characterization Laboratory**  
**01-93-03-SCL-P**

Responsible: Prof. Dr. Walter Lang  
Lecturer: Prof. Dr. Walter Lang

**Aim:**

The students shall get experience in using sensors and analyzing sensor data.

**Prerequisite:** Lecture „Sensors and Measurement Systems (Lang)“

**Content:**

A thermal sensor for infrared radiation (thermopile) is analyzed. The sensor is exposed to different thermal radiation of varying intensity. Sensitivity, time constant and noise are evaluated.

**Literature:**

Script “Sensors and Measurement Systems” by W. Lang

**Methods:** Groups up to 6 students. Short examination of the preparation before the experiment.