Module Description
Master Electrical Engineering and Information Technology

Faculty Electrical Engineering and Media Technology

Examination regulations 25.07.2013

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CM-01 ADVANCED PROGRAMMING TECHNIQUES

Module code	CM-01
Module coordination	Prof. Dr. Andreas Fischer
Course number and name	CM 1101 Advanced Programming Techniques
Lecturer	Prof. Dr. Andreas Fischer
Semester	1
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Niveau	Postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	student project
Language of Instruction	English

Module Objective

Students of this course extend their software programming abilities by creating and maintaining a complex computer program in a development team. They learn the interplay between the design, maintenance and extension steps as applied to a complex software project.

The students achieve the following learning objectives:

Professional Skills

The students know the elementary workings as well as the application area of versioning control software. They are able to make good use of such a system in the context of a software development process.

The students extend their knowledge in the area of object-oriented programming and are able to confidently apply this programming paradigm to solve complex problems. The know the basic UML tools and can use them to design an appropriate software architecture to solve simple problems.

The students are familiar with basic programming patterns. They are able to implement them where appropriate in their own code. They know about the development method of test-driven development and are able to create software tests with which they can estimate the reliability of the software they are developing.

Methodological Skills

The students are able to realize and extend a software project. They can quickly acquaint themselves with a pre-existing code-base and identify appropriate points for extending this code-base. They are able to perform a requirements analysis for these extensions and to develop the respective solutions.

Soft Skills

The students realize a complex software project embedded in a development team. They are able to coordinate the development process appropriately with their team members. They can take professional feedback and implement the appropriate changes to their work.

Applicability in this and other Programs

For this degree program:

Compulsory subject in Electrical Engineering and Information Technology (Master); joint study, both main subjects

For any other degree program:

Elective for Master Applied Research in Engineering Sciences

Entrance Requirements

Formally: none

In terms of content: Basic education in computer science, proficiency in an object-oriented programming language

Learning Content

Using versioning control software

The software development process

Requirements analysis

Software architecture with UML

Software design patterns

Unit tests

Test-driven development

Teaching Methods

Lecture with practical exercises

Remarks

Contribution to open-source projects

Recommended Literature

R. Martin: Clean Code: A Handbook of Agile Software Craftsmanship, 1. Auflage, Prentice Hall 2008.

M. Fowler: Patterns of Enterprise Application Architecture, 1. Auflage, Addison Wesley 2002.

E. Gamma / R. Helm / R. Johnson / J. Vlissides: Design Patterns. Elements of Reusable Object-Oriented Software, 1. Auflage, Prentice Hall 1994.

A. Hunt / David Thomas / W. Cunningham: The Pragmatic Programmer. From Journeyman to Master, 1. Auflage, Addison Wesley 1999.

CM-02 NUMERICAL METHODS

Module code	CM-02
Module coordination	Prof. Dr. Reinhard Schlosser
Course number and name	CM 1102 Numerical Methods
Lecturer	Prof. Dr. Reinhard Schlosser
Semester	1
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Niveau	Master
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Language of Instruction	English

Module Objective

In the mathematical treatment of technical problems, the following tasks are common: solving systems of linear equations, interpolation and extrapolation, solving nonlinear equations and systems of nonlinear equations, calculating definite integrals, solving ordinary differential equations and systems of ordinary differential equations. The aim of this module is to enable students to successfully apply numerical methods to solving the tasks listed above. After completion of the module students will: know which fundamental numerical methods correspond to the above tasks, they understand how, why and when they work, they can program algorithms corresponding to the methods and can apply them to examples and exercises. They can analyse different methods which serve the same purpose and can evaluate advantages and disadvantages (simplicity, accuracy, computing time, robustness).

Applicability in this and other Programs

For this degree program:

Compulsory subject in Electrical Engineering and Information Technology (Master); joint study, both main subjects

For any other degree program:

Elective for Master Applied Research in Engineering Sciences

Entrance Requirements

Formally: none

In terms of content: Calculus and linear algebra for engineers

Learning Content

Systems of Linear Equations (Direct Methods)

Interpolation and Extrapolation

Nonlinear Equations and Systems of Nonlinear Equations

Systems of Linear Equations (Iterative Methods)

Numerical Quadrature

Ordinary Differential Equations and Systems of Ordinary Differential Equations

Teaching Methods

During the lectures, the numerical methods are propelled, derived and applied to illustrative and instructive examples. Whenever possible analytically solvable examples are used in order to demonstrate the accuracy, the behaviour and speed of convergence of numerical methods on numerical results. For every method a pseudocode is formulated. Students are motivated to translate the pseudocodes into their preferred programming language and to test them using the examples presented. Generally, several alternative numerical methods are derived from one problem. In these cases, a guiding example serves for comparison.

Recommended Literature

H. Schwarz: Numerische Mathematik, 4. Auflage. Teubner, Stuttgart 1997.

H. Schwarz: Numerical Analysis. John Wiley & Sons, New York 1989.

J. Faires / R. Burden: Numerische Methoden. Näherungsverfahren und ihre praktische Anwendung. Spektrum, Heidelberg 1995.

R. Burden / J. Faires / A. Burden: Numerical Analysis, 10th Edition. Cengage Learning, Boston 2015.

E. Cheney / D. Kincaid: Numerical Mathematics and Computing, 7th Edition. Brokes/Cole, Boston 2012.

CM-03 SPECIAL MATHEMATICAL METHODS

Module code	CM-03
Module coordination	Prof. Dr. Johann Plankl
Course number and name	CM 2103 Special mathematical Methods
Lecturer	Prof. Dr. Johann Plankl
Semester	2
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Niveau	Postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Language of Instruction	English

Module Objective

The students basically deal with methods of probability calculation. They learn the necessary steps to work out independent solutions for corresponding problems in the field of engineering, whereby in particular they are enabled to critically question the selection of the corresponding methods and calculation procedures.

The students achieve the following learning objectives:

Students get to know typical models, methods and tasks from engineering practice, which can be processed with probability theory and statistics, together with corresponding solution methods and strategies. A stochastic way of thinking is anchored.

Professional Skills

The students have knowledge of algebra, analysis and probability theory. In addition, they know the concepts of discrete and continuous random variables. Students are able to work conceptually and methodically. They know the most important discrete and continuous probability distributions and have applied them in practical exercises. In particular, they know the basic assumptions and models behind the individual distributions. They are therefore able to select a suitable probability distribution on the basis of a problem description and to systematically work out the solution on the basis of this distribution. They have the knowledge to interpret data statistically. In summary, the students can apply their acquired knowledge to engineering tasks in a practice-oriented way.

Methodological Skills

Depending on the task, the students are able to identify and successfully apply appropriate calculation methods from a range of calculation methods. They are able to use scientific calculators and probability tables and, if necessary, computer algebra software. The students have the ability to carry out independent research on the basis of extensive exercises and to develop their existing knowledge independently.

Soft Skills

The students are aware of their responsibility as future engineers. They are in a position to discursively question problems among themselves, to justify the solutions argumentatively and to critically evaluate the results of their calculations.

Applicability in this and other Programs

For this degree program:

Compulsory subject in Electrical Engineering and Information Technology (Master); joint study, both main subjects

For any other degree program:

Elective for Master Applied Research in Engineering Sciences

Entrance Requirements

Formally: none

Learning Content

1. Set Theory and Probability
    - 1.1. Set Operations and Venn Diagrams
    - 1.2. Applying Set Theory to Probability
    - 1.3. Relative Frequency, 4-Field-Tableau
    - 1.4. Probability Axioms
    - 1.5. Conditional Probability, Law of Total Probability, Bayes Theorem
    - 1.6. Independent Events
    - 1.7. Sequential Experiments and Tree Diagrams
    - 1.8. Counting Methods (Combinatorics)

1.9. Reliability Problems

2. Discrete Random Variables

    2.1. Discrete Random Variable

    2.2. Probability Mass Function (PMF)

    2.3. Cumulative Distribution Function (CDF)

    2.4. Averages

    2.5. Functions of a Discrete Random Variable

    2.6. Derived Random Variables

    2.7. Variance and Standard Deviation

    2.8. Important Discrete Probability Mass Functions

3. Continuous Random Variables

    3.1. Motivation and Overview

    3.2. Probability Density Function (PDF)

    3.3. Expected Value and Variance in the Continuous Case

    3.4. Functions of a Continuous Random Variable

    3.5. Special Continuous Probability Distributions

Teaching Methods

Lectures and seminaristic lessons in alternation, solving problems during the lecture and independent extended training of the computing competence on the basis of weekly exercise sheets, detailed solutions to the exercise sheets are each given with a time delay of one week and are to be compared with the own solutions, if questions arise these are clarified in the lecture.

Remarks

The active participation of the students during the lecture and in the processing of the exercise sheets is particularly important through a discursive style. Challenge and encourage is the motto, so that they are catapulted from an initial passive attitude into a mode of activity.

Recommended Literature

H. Schwarzlander: Probability – Concepts and Theory for Engineers. Wiley 2011.

J. A. Gubner: Probability and Random Processes for Electrical and Computer Engineers. Cambridge University Press 2006.

W. W. Hines / D. C. Montgomery / D. M. Goldsman / C. M. Borror: Probability and Statistics in Engineering, 4th ed. Wiley 2003.

A. Papoulis / S. U. Pillai: Probability, Random Variables, and Stochastic Processes, 4th ed. McGraw-Hill 2002.

R. D. Yates / D. J. Goodman: Probability and Stochastic Processes: A Friendly Introduction for Electrical and Computer Engineers. Wiley 1998.

CM-04 HARMONISATION COURSE ENS

Module code	CM-04
Module coordination	Prof. Dr. Werner Bogner
Course number and name	C 6143 RF-Electronics C 6146 Telecommunication II
Lecturers	Prof. Dr. Werner Bogner Prof. Dr. Matthias Wuschek
Semester	1
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Niveau	Postgraduate
Semester periods per week (SWS)	8
ECTS	10
Workload	Time of attendance: 120 hours self-study: 180 hours Total: 300 hours
Language of Instruction	German

Module Objective

The master's degree program allows students to deepen the focus of the Bachelor's degree program or broaden the knowledge base to another focus. Ensuring a comparable entry level into the focus is ensured in this case by harmonization courses, which must be compulsory for students wishing to broaden their studies. Students seeking further education must choose two electives instead of the harmonization courses.

The students achieve the following learning objectives in the Harmonisation Course ENS:

In the subject RF Electronics, students learn the necessary steps to independently use radio frequency (RF) components and RF cables and to develop RF amplifiers. They are able to analyse and evaluate RF circuits. Students gain the ability to design, simulate, and optimize RF semiconductor amplifiers.

In the subject Telecommunications II, the students become acquainted with all important analogue and digital modulation methods and their main practical application fields. The students have in-depth knowledge of transmitter and receiver technology.

Applicability in this and other Programs

For this degree program:

Compulsory subject within Master-Program Electrical Engineering and Information Technology, both focuses

For any other degree program:

None

Entrance Requirements

Students choosing the key focus area „ENS“, but not having had the key focus „Communications Engineering“ or „Technical Electronics“ in their Bachelor study course have to attend the modules „ RF Electronics“ und „Telecommunications II“ of the Bachelor curriculum Electrical Engineering and Information Technology to deepen their basic knowledge. Students choosing the key focus „ENS“ and already having had the key focus „Communications Engineering“ or „Technical Electronics“ in their Bachelor study have to choose two optional subjects from the compulsory electives catalogue listed in the curriculum instead.

Learning Content

See submodule description

Teaching Methods

See submodule description

Remarks

See submodule description

Recommended Literature

See submodule description

C 6143 RF-ELECTRONICS

Objectives

In the subject RF Electronics, students generally deal with the special features of radio frequency (RF) components and circuits with a focus on RF amplifiers. They will learn the steps needed to deploy RF components on their own and will be able to design, analyse, optimize and evaluate circuits.

The students learn the necessary steps to independently apply RF components and RF cables as well as to develop RF amplifiers. They are able to analyse and evaluate RF circuits. Students gain the ability to design, simulate, and optimize RF semiconductor amplifiers.

The students achieve the following learning objectives:

Professional Skills

The students know the most important modern components of RF technology and understand how it works.

The students understand the peculiarities of RF circuits, can describe them and are familiar with scatter parameters and their application. They know programs for the simulation of RF circuits and RF structures.

Students are familiar with different line structures for RF applications and can dimension, rate and select them for the application.

Methodological Skills

The students can analyse and apply modern components of RF technology. You can judge the possible uses of these components.

Students have the ability to analyse and apply RF circuits, in particular to adapt and optimize RF amplifiers. They have the ability to design and dimension simple RF circuits.

Soft Skills

The students are able to critically evaluate RF components and circuits.

Learning Content

1. Active components of RF technology
2. Transmission lines (waveguide)
    - 2.1. TEM waveguide
    - 2.2. Basics of Transmission Line Theory
    - 2.3. Waveguide (hollow waveguide)
    - 2.4. Planar microwave lines – stripline

3. Basics of RF circuit development

   3.1. Impedance transformation

   3.2. Presentation and dimensioning of linear circuits

Type of Examination

written ex. 90 min.

Methods

Seminar-like instructions, exercises, computer simulations

Recommended Literature

Tietze / Schenk / Gamm: Halbleiter-Schaltungstechnik, 15. Auflage. Springer Verlag 2016.

H. H. Meinke / F. W. Gundlach: Taschenbuch der Hochfrequenztechnik, 5. Auflage. Springer Verlag, Berlin 1992.

W. Bächtold: Mikrowellenelektronik. Vieweg Verlag, Braunschweig 2002.

W. Bächtold: Mikrowellentechnik. Vieweg Verlag, Braunschweig 1999.

B. Huder: Grundlagen der Hochfrequenz-Schaltungstechnik. Oldenbourg Wissenschaftsverlag, Berlin 2018.

E. Voges: Hochfrequenztechnik, 2. Auflage. Hüthig Verlag, Heidelberg 1991.

H. Heuermann: Hochfrequenztechnik. Vieweg Verlag, Wiesbaden 2005.

Vetter: Schaltungstechnische Praxis. Verlag Technik 2001.

Kurz / Mathis: Oszillatoren. Hüthig-Verlag 1994.

Maas: The RF and Microwave Circuit Handbook. Artech House 1998.

Cripps: RF Power Amplifiers for Wireless Communications, 2nd edition. Artech House 2006.

Pozar: Microwave and RF Design of Wireless Systems. John Wiley & Sons 2001.

C 6146 TELECOMMUNICATION II

Objectives

In the subject Telecommunication II, the students first deal with the disturbed transmission channel. Students will learn important description variables for distortion, crosstalk and noise. In the next step, important analogue modulation methods will be introduced, whereby their description variables and signal form as well as examples of modulators and demodulators will be presented and explained. Then important methods of digital modulation of a sine-wave carrier (ASK, FSK, MSK, M-PSK, M-QAM) are presented and compared with each other. For all important analogue and digital modulation methods, the students get to know essential practical fields of application. After a presentation of the spread spectrum transmission an introduction into the transmitter and receiver technology takes place.

The students achieve the following learning objectives:

Professional Skills

The students know and understand important fault phenomena occurring during signal transmission as well as their description variables.

The students know and understand important methods of analogue or digital modulation of a sine-wave carrier and can compare these with regard to their performance.

The students know and understand elementary methods for spread spectrum signal transmission

The students know and understand the functionality of the various modules in the transmitter and receiver. They know the advantages and disadvantages of a heterodyne receiver compared to the straight receiver.

Methodological Skills

The students are able to dimension simple analogue or modulated transmission links (in particular with regard to bandwidth requirements and interference immunity).

The students can explain the functionality of elementary circuits for the generation of modulated signals or for demodulation.

The students have the ability to independently research and develop existing basic knowledge.

Soft Skills

The students are able to explain the basic procedures of the analogue and digital modulation methods, to justify them reasonably and to critically evaluate them.

Learning Content

1. Introduction to the lecture

Type of Examination

written ex. 90 min.

Methods

Seminar-like instruction, exercises

Remarks

Lesson support through the online learnmanagementsystem iLearn

Recommended Literature

J. Göbel: Kommunikationstechnik. Hüthig Verlag.

E. Herter / W. Lörche: Nachrichtentechnik. Hanser Verlag.

M. Werner: Nachrichtentechnik. Vieweg Verlag.

E. Pehl: Digitale und analoge Nachrichtenübertragung. Hüthig Verlag.

M. Meyer: Kommunikationstechnik. Vieweg Verlag.

R. Mäusl / J. Göbel: Analoge und digitale Modulationsverfahren. Hüthig Verlag.

H. Weidenfeller / A. Vlcek: Digitale Modulationsverfahren mit Sinusträger. Springer Verlag.

CM-04 HARMONISATION COURSE AET

Module code	CM-04
Module coordination	Prof. Dr. Werner Bogner
Course number and name	C 6130 Control Engineering II C 6134 Power Electronics
Lecturers	Prof. Dr. Günter Keller Prof. Dr. Nikolaus Müller
Semester	1
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Niveau	Postgraduate
Semester periods per week (SWS)	8
ECTS	10
Workload	Time of attendance: 120 hours self-study: 180 hours Total: 300 hours
Type of Examination	written examination
Language of Instruction	German

Module Objective

The master's degree program allows students to deepen the focus of the Bachelor's degree program or broaden the knowledge base to another focus. Ensuring a comparable entry level into the focus is ensured in this case by harmonization courses, which must be compulsory for students wishing to broaden their studies. Students seeking further education must choose two electives instead of the harmonization courses.

The students achieve the following learning objectives in Harmonisation Course AET:

The aim of the course Control Technology is that the students widen their control engineering knowledge and be prepared for typical tasks in the industry. They can construct root loci and thereby develop control units. Furthermore, they are able to explain the special effects of a digital controller. They know the basics of the analysis of control circuits with switching regulators and can represent controlled systems in the state space. Students can also model and analyse the behaviour of dynamic control paths in Matlab / Simulink. They have achieved the ability to solve complex problems in the field of control engineering. They are also capable to apply their theoretical skills onto simulations.

The aim of the course Power Electronics is that the students learn the structure and operation of passive and active components of power electronics. Here, the parasitic properties are in the foreground. Circuits are subdivided into network-controlled and self-guided circuits. The students know not only the circuits themselves but also the mode of action and their design. The self-guided circuits are the focus. The students have acquired substantial knowledge on how to use electronic switches. They are capable to understand the structure, design and principle of operation of passive and active elements in the field of power electronics.

Students get to know typical models, methods and tasks from engineering practice, together with corresponding solution methods and strategies.

Applicability in this and other Programs

For this degree program:

Compulsory subject within Master-Program Electrical Engineering and Information Technology, key focus Electronic and Telecommunication Systems (ENS)

For any other degree program:

None

Entrance Requirements

Students choosing the key focus area „AET“, but not having had the key focus „Automation“ or „Power Systems Engineering“ in their Bachelor study course have to attend the modules „Power Electronics“ und „Control Engineering 2“ of the Bachelor-curriculum Electrical Engineering and Information Technology to deepen their basic knowledge. Students choosing the key focus area „AET“ and having had already the key focus „Automation“ or „Power Systems Engineering“ in their Bachelor study have to choose two optional subjects from the compulsory electives catalogue listed in the curriculum instead.

Learning Content

See subject description

Recommended Literature

See subject description

C 6130 CONTROL ENGINEERING II

Objectives

The aim is for the students to broaden their knowledge in control engineering and to be prepared for typical tasks in the industry.

After completing the subject, the students have achieved the following learning objectives:
They are able to construct root loci and thereby develop control units
Students can explain the special effects of a digital controller
They know the basics of the analysis of control circuits with switching regulators
Students are capable to represent controlled systems in state space
They can model dynamic control paths in Matlab / Simulink and analyse their behaviour

Students are capable to solve complex problems in the field of control engineering

Learning Content

1. Root locus
   1.1. Design rules
   1.2. Analysis and synthesis of control circuits
2. Digital control circuits
   2.1. Description in the z-area
   2.2. Quasi-continuous design
3. Switching regulators
   3.1. Analysis for first-order control paths
   3.2. Analysis for second-order control paths
4. Controller in state space
   4.1. Establishment of state equations
   4.2. Draft according to the pole placement method

Type of Examination

written ex. 120 min.

Methods

Seminar-like instruction, exercises

Recommended Literature

J. Lunze: Regelungstechnik 1, 10. Auflage. Springer/Vieweg 2014.

H. Lutz / W. Wendt: Taschenbuch der Regelungstechnik, 10. Auflage. Verlag Harri Deutsch 2014.

H. Mann / H. Schiffelgen / R. Froriep / K. Webers: Einführung in die Regelungstechnik, 12. Auflage. Hanser Verlag 2019.

M. Reuter / S. Zacher: Regelungstechnik für Ingenieure, 15. Auflage. Springer/Vieweg 2017.

G. Schulz / K. Graf : Regelungstechnik I, 5. Auflage. DeGruyter Studium 2015.

G. Schulz / K. Graf : Regelungstechnik II, 3. Auflage. DeGruyter Studium 2013.

R.C. Dorf / R.H. Bishop: Modern Control Systems, 13. Auflage. Pearson 2017.

C 6134 POWER ELECTRONICS

Objectives

The course covers power electronics, their components, circuits and applications.

In the field of power electronics, students learn the application of the components and circuits of the power electronics and their applications.

The students achieve the following learning objectives:

Professional Skills

The students learn the structure and mode of operation of passive and active components of power electronics. Here, the parasitic properties are in the foreground.

The circuits are subdivided into network-controlled and self-commutated circuits. Here, the students know not only the circuits themselves but also the mode of operation and their design. The self-guided circuits are the focus.

Methodological Skills

The students learn the structural composition of components in circuit technology as well as in systems engineering. You can apply the component design methodology to a variety of circuits.

Soft Skills

Skills lie in the detailed application of mathematical and technical procedures.

Learning Content

1. Components
   1.1. Capacitors
   1.2. Choke
   1.3. Transformers
   1.4. Diodes
   1.5. MOSFET
   1.6. IGBT
   1.7. Thyristor
2. Mains-controlled converters
   2.1. Overview
   2.2. Center tap circuits
   2.3. Bridge circuits
   2.4. Cyclo converter
3. Self-commutated power converters
   3.1. DC chopper basic circuits
   3.2. H-Bridge
   3.3. Single-phase pulse converter
   3.4. Three-phase pulse converter
   3.5. Applications for pulse converters
   3.6. Multilevel converters
   3.7. Matrix converter

Type of Examination

written ex. 90 min.

Methods

Seminar-like instructions

During lectures the simulations program LTspice is being used. This software is a helpful tool to study independently.

Recommended Literature

F. Zach: Leistungselektronik, Band I und Band II, 5. Auflage. Springer/Vieweg 2015.

J. Specovius: Grundkurs Leistungselektronik, 9. Auflage. Springer/Vieweg 2018.

D. Schröder / R. Marquardt: Leistungselektronische Schaltungen: Funktion, Auslegung und Anwendung, 4. Auflage. Springer/Vieweg 2019.

CM-05 COMPULSORY ELECTIVE

Module code	CM-05
Module coordination	Prof. Dr. Werner Bogner
Course number and name	Compulsory Elective 512 Advanced Automation 514 Contract and Employment Law 515 Digital TV- and Audio-Broadcast 516 Advanced Circuits Lab 517 Power Supply Circuits
Lecturers	Michael Benisch Prof. Dr. Werner Bogner Prof. Dr. Günter Keller Prof. Dr. Josef Langenecker NN ET Prof. Dr. Terezia Toth
Semester	1
Duration of the module	1 semester
Module frequency	SS/WS
Course type	compulsory elective course, elective course
Niveau	Postgraduate
Semester periods per week (SWS)	24
ECTS	5
Workload	Time of attendance: 360 hours self-study: 540 hours Total: 900 hours
Language of Instruction	German, English

Module Objective

Varying according to chosen course

The students achieve the following learning objectives:

See description of the chosen elective

Applicability in this and other Programs

For this degree program:

Elective within Master-Program Electrical Engineering and Information Technology, focus Electronic and Telecommunication Systems (ENS)

For any other degree program:

Elective for Master Applied Research in Engineering Sciences

Entrance Requirements

Formally: none

Learning Content

Various, depending on the selected course

Courses may be selected from the elective compulsory subject catalogue for the master program Electrical Engineering and Information Technology.

Exemplary extract from the selectable modules:

Name / restriction / module from study program

Selected topics in Micro- and Nanoelectronics / only AET / MET

Selected topics in Optoelectronics and Lasertechnology / only AET / MET

Modern RF and Radio Systems / AET / MET only

Special devices and circuits / only AET / MET

Signals and Systems in Communication Technology / only AET / MET

Advanced Modelling and Simulation / only ENS / MET only

Selected chapters in Control Engineering / only ENS / MET

Special topics of Contactless Sensor Systems / only ENS / MET

Automotive and Industrial Drive Systems / only ENS / MET

Renewable Energies / only ENS / MET

Audio Production / MMT

Hearing and Psychoacoustics / MMT

Web Engineering / MMT

Methods of Visualization / MMT

Theoretical Computer Science / MAI

Practical Computer Science / MAI

Selected topics of Embedded Software Development 1 / MAI

FPGA programming / MAY

IT Security / MAY

Higher Mathematics / MMB

Technical Databases / MMB

Drive System Technology / MMB

Legend:

MET: Degree: Master Electrical Engineering and Information Technology

MMT: Degree: Master Media Technology and Production

MAI: Degree: Master Applied Computer Science

MMB: Degree: Master Mechanical Engineering

Further selectable modules can be viewed on the selection list when selecting the optional modules. The module descriptions can be found in the module manuals of the respective study programs.

Teaching Methods

See description of the chosen course

Remarks

Courses are held in German and English

Recommended Literature

See description of the chosen course

COMPULSORY ELECTIVE

Type of Examination

part of module exam

512 ADVANCED AUTOMATION

Objectives

In the subject Advanced Automation students obtain an overview on how programmable logic controllers (PLCs) work, as well as basic hardware and software requirements.

They learn the standardized (IEC61131-3) and manufacturer-specific (TIA Portal) programming options. They learn how to use visualization software for the user interface.

The students acquire the basic competence to understand automated processes in the automotive industry, power plants, chemical industry, building technology and transportation. Thus the students are able to shape the digital transformation of the industry.

The students achieve the following learning objectives:

Professional Skills

The students are familiar with the concepts and components of a modern automation system including the structure and functionality of industrial communication systems, also with regard to safety and security.

They are able to analyse, classify and solve simple tasks in automation technology.

The students know the requirements of hardware and software for a Programmable Logic Controller (PLC). They know the structure and the way a PLC operates. They are able create PLC programs. By using visualization software, they can demonstrate the processes.

Methodological Skills

The application-oriented knowledge allows the students to compare advantages and disadvantages of the individual industrial bus systems, to examine in contrast the advantages and disadvantages of the individual programming languages to find optimal solutions.

Soft Skills

The students work on problems in a focused and independent way.

They can communicate their solutions both verbally and in writing in appropriate technical language.

They learn from mistakes, can assess and improve their own abilities.

They are able to work actively as a team.

Learning Content

1. Function of SPS
    1.1. Hardware requirements
    1.2. Current embodiments
    1.3. Environmental conditions
    1.4. Real-time requirements
2. Programming languages
3. Presentation of automation technology with regard to industrial communication
    3.1. ISO / OSI model in industrial communication
    3.2. Automation pyramid
    3.3. Vertical communication
    3.4. Structure and functionality of common communication systems

Entrance Requirements

Formally: none

Type of Examination

written ex. 90 min.

Methods

Seminars with practical experience

Work studies in the lab

Recommended Literature

R. Laubner / P. Göhner: Prozessautomatisierung I. Springer Verlag 1999.

G. Wellenreuther / D. Zastrow: Steuerungstechnik mit SPS, Springer/Vieweg 2015.

G. Wellenreuther: Automatisieren mit SPS - Übersichten und Übungsaufgaben, Springer/Vieweg 2015.

K. John / M. Tiegelkamp: SPS-Programmierung mit IEC, Springer Verlag 2009.

G. Schnell: Bussysteme in der Automatisierungstechnik, 4. Auflage. Vieweg Verlag 2000.

W. Kriesel / O. Madelung: AS-Interface – Das Aktuator-Sensor-Interface für die Automation. Hanser Verlag 1999.

M. Popp: Profibus-DP/DPV1, 2. Auflage. Hüthig Verlag 2000.

M. Popp: Das PROFINET IO-Buch: Grundlagen und Tipps für Anwender, 2. Auflage. VDE Verlag 2010.

Ausbildungsunterlagen der Fa. Siemens: www.siemens.com/global/de/home/unternehmen/nachhaltigkeit/ausbildung/sce.html

514 CONTRACT AND EMPLOYMENT LAW

Objectives

The students should receive an overarching basic understanding of German contract law and employment law. They should be able to apply basic legal provisions in connection with the management and the handling of employees.

The students achieve the following learning objectives:

Professional Skills

The students have basic knowledge of German contract law and employment law. They know the essential provisions for the establishment of a contract, recognize risks in contract negotiations and are in a position to avoid damage to their company due to knowledge of provisions relevant to damages. Under the Labor Law section, they learn methods for the secure recruitment of employees, the drafting of legally binding employment contract documents and the termination of employment contracts. They also learn basic skills in the areas of temporary employment, industrial property law and collective bargaining.

Methodological Skills

The students are able to find legal texts in the field of contract and employment law, to understand the essential basic statements and thus to work in practice. They learn to judge supreme court judgments from the mentioned areas of contract and employment law and to understand legal changes regarding their legal and economic content.

Soft Skills

The students learn management competencies that support the area of contract design as well as the leadership and recruitment of employees.

Learning Content

1. Contract law:

    1.1. Differentiation between private law - public law

1.2. Conclusion of contracts, presentation of the different types of contract in the BGB and HGB

1.3. Contestability and nullity of contracts

1.4. Legal capacity, capacity to contract, liability in torts

1.5. Law of unauthorized actions

1.6. Product liability law

2. Labor Law:

2.1. Introduction to labor law

2.2. From application to recruitment

2.3. Justification, modification and termination of employment

2.4. Special forms of employment

2.5. Basic principles of collective bargaining

2.6. Law on Temporary Work

Entrance Requirements

Formally: none

Type of Examination

written ex. 90 min.

Methods

Lecture, case analysis, individual and group work

Remarks

The lecture is also helpful for the students for a career entry in the foreseeable future due to the use of current decisions.

Recommended Literature

Contract law:

1. Script material in association to lectures

2. Klunzinger: Einführung in das Bürgerliche Recht, 16. Auflage. Vahlen Verlag 2013.

3. Musielak / Hau: Grundkurs BGB, 15. Auflage. C.H. Beck Verlag 2017.

4. Klunzinger: Grundzüge des Handelsrechts, 14. Auflage. Vahlen Verlag 2011.

Commentaries:

1. Paland: Bürgerliches Gesetzbuch, 78. Auflage. C.H. Beck Verlag 2019.

2. Münchener Kommentar zum Bürgerlichen Gesetzbuch, 8. Auflage. C.H. Beck Verlag, Gesamtwerk in 11 Bänden.

Databases / Legislative text:

1. https//:beck-online.beck.de

2. www.gesetze-im-internet.de

3. Scherer: Verträge - Praxiswissen Vertragsmanagement, RTW-Medienverlag 2005.

Labor law:

1. Langenecker / Maurer / Englert: Handbuch des Bauarbeitsrechts. Werner Verlag 2004.

2. Schaub: Arbeitsrechtshandbuch, 17. Auflage. C.H. Beck Verlag 2017.

3. Küttner: Personalbuch 2018. C.H. Beck Verlag.

515 DIGITAL TV- AND AUDIO-BROADCAST

Objectives

The student will receive insight into the requirements, physics, technology and structure of digital television and sound broadcast networks.

The students achieve the following learning objectives:

Professional Skills

The students know and understand the requirements and the structure of television and sound broadcast networks; they know and understand structure, anatomical and physical background of information carried by broadcast networks (video and audio signals, teletext, etc.). They understand the source coding mechanisms for video and audio compression. Students can explain modulation and channel coding techniques used in broadcast networks. They know all typically in broadcast networks used transportation links (terrestrial, cable, satellite, IP-networks) and transmission standards (DVB, DAB/DAB+, etc.).

Methodological Skills

Students can calculate and estimate practical data rates in a digital television and sound broadcast networks and they can describe the structure of a broadcast multiplex signal. Physical requirements of a broadcast network can be listed (min. signal to noise ratios, RF levels, measurement parameters, interferences, etc.).

Soft Skills

Students are able to reasonably justify and critically evaluate the basic characteristics and structure of digital television and broadcast networks.

To start with, students learn in the subject Digital TV- and Audio-Broadcast the basic structure and requirements of a broadcast network (sound broadcast and television) as well as the historical background of sound broadcast and television. Starting with analogue sound broadcast and analogue television digital television and sound broadcast will be introduced. The lecture consists of the parts „broadcast video and audio baseband“ and „broadcast transmission technology“. In the part „baseband“ structure, physics and the principle of source coding (video and audio compression) is discussed and the principle of the MPEG-2 transport stream in detail will be explained. Inside the part „transmission technology“ all in digital sound and TV broadcast networks used modulation technologies (single carrier QAM, multicarrier/OFDM) and the forward error correction (channel coding) will be described. All main digital television and sound broadcast standards like DVB-C, DVB-S/S2, DVB-T/T2, DAB/DAB+ are part of the lecture.

Learning Content

Definition of the term „broadcast“ = sound broadcast and video broadcast from point to multipoint

Structure and requirements of a broadcast network

Analog and digital sound broadcasting

From analogue television to digital video broadcasting

Structure and physics of video and audio signals

Compression (source coding) of video and audio signals

Teletext, subtitles, electronic program guide, HbbTV, Smart TV

Terms SDTV, HDTV, UHDTV, HDMI, ...

MPEG – Moving Pictures Expert Group

PES – Packetized Elementary Stream

MPEG-2 transport stream

Multiplexing, transportation and synchronization of video and audio content

PSI/SI tables

Modulation technology (AM, FM, QAM, OFDM) used in sound and video broadcasting

Forward error correction/channel coding used in digital video and audio broadcasting

DVB - Digital Video Broadcasting

DVB-C, DVB-S, DVB-S2, DVB-T, DVB-T2, DAB/DAB+

Structure of broadband cable networks (CATV)

Transmission of broadcast signals over satellite, cable and terrestrial networks

Interferences in digital broadcast networks

Measurements on digital video and audio signals, RF measurements

Type of Examination

written ex. 90 min.

Methods

Teaching in the form of seminars, exercises

Recommended Literature

W. Fischer: Digitale Fernseh- und Hörfunktechnik in Theorie und Praxis, Springer Verlag (German Version)

W. Fischer: Digital Video and Audio Broadcasting Technology – A Practical Guide for Engineers, Springer (English, International Version)

516 ADVANCED CIRCUITS LAB

Objectives

In the subject Advanced Circuits Lab students obtain an insight into analogue electronic circuits.

The students achieve the following learning objectives:

Professional Skills:

The students know and understand the functionality of different typical analogue electronics circuits. They understand the importance of the bias point and are able to dimension the bias point for various circuits. They can dimension and analyse the small signal behaviour of semiconductor circuits as well as the transient behaviour.

They have the ability to analyse and apply analogue semiconductor circuits for AF and RF. The students know oscillator circuits and dimension and analyse them.
The students have the ability to design analogue semiconductor circuits.

Methodological Skills:

The students are able to dimension and optimize electronic analogue circuits with the help of theoretical considerations and simulation. The students are able to differentiate between various circuits and can assess the advantages and disadvantages of different amplifiers and oscillators. The students have the ability to independently research and develop existing basic knowledge. Students can evaluate the properties of electronic circuits by measurements.

Soft Skills:

Students are able to reasonably justify and critically evaluate the basic properties of analogue electronic circuits. In lab teams the students learn to substantiate their simulation and measurement results. The students are able to present and explain their measurement results and theoretical findings in a convincing, informative and comprehensible way.

Learning Content

1. **Lessons for introduction of specific topics**
   - 1.1. Applications of analogue circuits
   - 1.2. Diodes and Transistors
   - 1.3. Amplifiers
   - 1.4. RF circuits (Oscillators, PLL)
2. **Lab Experiments**
   - 2.1. Introduction to circuit simulation
   - 2.2. Introduction to basic electronics measurement equipment
   - 2.3. Diode circuits: voltage doubler (Villard and Greinacher circuit), voltage cascade, diode as switch
   - 2.4. Integrated circuits: Timer circuit NE555
   - 2.5. Design of AF-amplifier according to specification
   - 2.6. Differential amplifier: Characteristics, current source, application
   - 2.7. Operational Amplifier

2.8. Quasi-linear AF-power-amplifier: Class A, B, AB operation, biasing, output power, efficiency

2.9. Phase locked loop – PLL

2.10. RF-Oscillators: Phase-shift oscillator, Wien-bridge oscillator, Colpitts-oscillator, LC-oscillators, Franklin-oscillator

2.11. RF-measurements: S-Parameter and time domain reflectometry

Entrance Requirements

Formally: Admission test

Lab seats will be assigned based on the test. Content of the test: General basics of electrical engineering, basics of semiconductor devices, and basics of electronic networks.

In terms of content: Fundamentals of electrical engineering, basic knowledge of solid state devices (bipolar junction transistors, diodes), basics of electronic networks

Type of Examination

written student research project

Methods

Practical work and lesson style lectures to introduce specific topics

Recommended Literature

Tietze / Schenk: Electronic Circuits: Handbook for Design and Application, 2nd edition. Springer Verlag, 2008.

Streetman / Banerjee: Solid State Electronic Devices, 6th edition. Prentice Hall, 2006.

Comer / Comer: Fundamentals of electronic circuit design. Wiley, 2002.

Comer / Comer: Advanced electronic circuits design. Wiley, 2003.

Scherz / Monk: Practical electronics for inventors. McGraw Hill, 2016.

Horowitz / Hill: The art of electronics. 3rd edition. Cambridge University Press, 2015.

517 POWER SUPPLY CIRCUITS

Objectives

Power Supplies are the part of power electronics, which deals with circuits for supplying electronic circuits in the power range from 1 mW for battery powered devices up to usually 1 kW for industrial applications. The course power supply circuits addresses active and passive components as capacitors, magnetics and semiconductors, like silicon based MOSFET or GaN or SiC devices. In this course the students will learn to design basic converters with or without isolation. Beside basic methods and characteristics the students will learn to handle parasitic characteristics of the components and circuits. The students will learn to model converters as well as to design the controller in voltage-mode and current-mode. The students will use LTspice for simulations.

Learning Content

1. Components
    - 1.1. Passive Components
        - 1.1.1. Capacitors
        - 1.1.2. Magnetics
    - 1.2. Semiconductors
        - 1.2.1. Diodes
        - 1.2.2. MOSFETs
2. Basic Converters
    - 2.1. Buck Converter
    - 2.2. Boost Converter
    - 2.3. Buck-Boost Converter
3. Isolated Converters
    - 3.1. Flyback Converter
    - 3.2. Forward Converter
    - 3.3. Push-Pull Converter
    - 3.4. Full-Bridge Converter

4. Soft-Switching Converter
    4.1. Overview
    4.2. Converter
    4.3. ZCS Buck Converter
    4.4. ZVT Boost Converter
5. Resonant Converters
    5.1. Overview
    5.2. LLC Converter
6. EMC
    6.1. Legal Requirements
    6.2. Coupling Mechanisms
    6.3. Origin of Interferences
    6.4. EMC Design
7. Modelling
    7.1. State-Space Averaging
    7.2. Transfer Functions
8. Analog Control
    8.1. Controller Design
    8.2. Controller Realization
9. Digital Control
    9.1. Controller Design
    9.2. Controller Realization

Entrance Requirements

Formally: none

Type of Examination

written ex. 90 min.

Methods

The course is based on theory, examples and simulations. In the theoretical part the students will get to know components and circuits and their characteristics. Worked examples will explain the theory. The students have to implement the circuits in a widely used freeware simulation environment. They will get to know the circuits in detail and in addition they learn to handle the simulation tool.

Recommended Literature

Erickson / Maksimovic: Fundamental of Power Electronics, 2nd edition. Kluwer Academic Publishers, New York, 2004.

Pressman / Billings / Morey: Switching Power Supply Design, McGraw Hill, New York, 2009.

S. Maniktala: Switching Power Supplies A to Z. Elsevier, New York, 2006.

F. Zach: Leistungselektronik, 5. Auflage. Springer/Vieweg, Wiesbaden, 2015.

CM-06 SELECTED TOPICS IN BUSINESS ADMINISTRATION AND HUMAN RESOURCE MANAGEMENT

Module code	CM-06
Module coordination	Prof. Dr. Werner Bogner
Course number and name	CM 3106 Selected Topics in Business Administration and Human Resource Management
Lecturer	NN ET
Semester	3
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Niveau	Postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Language of Instruction	English

Module Objective

Students develop a realistic understanding of the ins and out of companies and what an employer expects from an employee.

The students achieve the following learning objectives in the module Selected Topics in Business Administration and Human Resource Management:

Professional Skills
The students have an insight into the entrepreneurial environment in which they will find themselves as future engineers. They understand the operational constraints under which they will work as engineers in the future.

Applicability in this and other Programs

For this degree program:

Compulsory subject in Electrical Engineering and Information Technology (Master); joint study, both main subjects

For any other degree program:

Elective for Master Applied Research in Engineering Sciences

Entrance Requirements

Formally: none

Learning Content

What is a company and what are its goals?

The different functions of a company:

1. Corporate Human Resources
    1.1. Recruitment
    1.2. Personnel selection
    1.3. Employee compensation
    1.4. Employment contracts - mutual rights and obligations
    1.5. Personnel development
    1.6. Leading employees and teams
2. Business Marketing
    2.1. Positioning and business models
    2.2. Planning and financing
3. Structure and process organization
    3.1. Business processes
    3.2. Data Protection (DSGVO)
4. Product development
    4.1. Challenges in the course of digitization
5. Business accounting
    5.1. Principles of accounting and reporting

Teaching Methods

Script, handouts, exercises, case examples

Recommended Literature

W. Benzel / E. Wolz: Businessplan für Existenzgründer. Walhalla Fachverlag, Regensburg 2000.

R. Bleiber: Existenzgründung, 6. Auflage. Haufe-Lexware GmbH & Co. KG., Freiburg 2010.

M. Dowling / H. Drumm: Gründungsmanagement – vom erfolgreichen Unternehmensstart zu dauerhaftem Wachstum, 2. Auflage. Springer Verlag, Berlin 2003.

R. Gill: Theory and practice of leadership, 2. Auflage. SAGE Publications Ltd., London 2010.

H. Hungenberg / T. Wulf: Grundlagen der Unternehmensführung, 4. Auflage. Springer Verlag, Berlin 2011.

A. Kieser / P. Walgenbach: Organisation, 6. Auflage. Schäffer-Poeschel Verlag, Stuttgart 2010.

R. Lussier: Management Fundamentals – Concepts, Applications, Skill Development, 5. Auflage. Cengage Learning, Springfield, Massachusetts, USA 2008.

H. Schuler: Lehrbuch der Personalpsychologie, 2. Auflage. Hogrefe Verlag GmbH & Co. KG, Göttingen 2006.

L. von Rosenstiel / E. Regnet / M. Domsch: Führung von Mitarbeitern – Handbuch für erfolgreiches Personalmanagement, 6. Auflage. Schäffer-Poeschel Verlag, Stuttgart 2009.

CM-07 FOREIGN LANGUAGE

Module code	CM-07
Module coordination	Tanja Mertadana
Course number and name	CM 1207 Foreign Language
Semester	1
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Niveau	Postgraduate
Semester periods per week (SWS)	4
ECTS	4
Workload	Time of attendance: 60 hours self-study: 60 hours Total: 120 hours
Type of Examination	written ex. 90 min., written ex. 60 min.
Duration of Examination	150 min.
Language of Instruction	German

Module Objective

The module Foreign Language aims to equip students with specialized language skills necessary for independent performance in a globalized sector of Electrical Engineering and Information Technology.

Students learn technical and business topics depending on the type of course, expand their needed vocabulary and learn how to use it. Furthermore, the students will learn how to summarise reading and listening texts orally, how to comment fluently in discussions and how to prepare short presentations.

To this end, the module targets instruction of the four cardinal language skills (listening, reading, speaking, and writing). Central to the module is optimizing fluency and communication skills; so too is cultivating a clear understanding of the finer points of textual meaning and meaning produced in dialogue with others. Through a variety of task-based speaking, listening and writing activities, students enhance their oral and aural production and expand their ability to produce clear, concise and coherent pieces of writing – be they in the form of emails and reports. Particular emphasis will be placed on honing students' public speaking and team skills.

The students achieve the following learning objectives:

Professional Skills

Students use the English language to discuss current trends in Electrical Engineering and Information Technology.
Students are able to express their knowledge in an appropriate written form.

Methodological Skills

Students will have enhanced their abilities to structure the acquisition of specialized terminology and grammatical items and practiced ways to internalize new language that yield optimal learning benefits.

Soft Skills

Students will have gained valuable experience in training personal effectiveness skills such as team work, integrity, and reliability.
They will have enhanced their written and oral language skills.

Applicability in this and other Programs

For this degree program:

Compulsory subject in Electrical Engineering and Information Technology (Master); joint study, both main subjects

For any other degree program:

None

Entrance Requirements

The minimum entry-level requirement for Non-German-Speakers is an A2-level of German according to the Common European Framework of Reference for Language (CEFR).
The minimum entry-level requirement for German-Speakers in an English course is a B2-level of English according to the Common European Framework of Reference for Language (CEFR). B2-level approximately equates to a good mark in English exam of the German A-levels (Abitur).

Learning Content

See the subject description on the Homepage of the Language Centre.

Teaching Methods

Instruction and learning methods focus on training the four cardinal language skills (speaking, listening, reading, and writing) and on enhancing professional and social competencies. They include group discussions and group projects, individual and team work (e.g. individual and group presentations), real- and role-playing, close reading and listening activities, grammar games, method of loci, running dictations, translations, peer feedback and review, work with learning stations, and various follow-up viewing and writing activities.

Study assignments will be set on a weekly basis.

Remarks

German (for non-German speakers): According to the study regulations a German course B1/ part 1 and 2 has to be completed during studies (Level A2 German is required). 1 German course with 4 SWS, 4 ECTS
German native speakers can choose any foreign language offered by the Language and Electives Department. 2 language courses each with 2 SWS, 2 ECTS

In English the level of C1 has to be taken, for every other language the level can be chosen freely.

German (4 ECTS): 90-minute written final exam
All other language courses (2 ECTS): 60-minute written final exam

Recommended Literature

See the subject description on the Homepage of the Language Centre.

CM-08 MASTERMODUL

Module code	CM-08
Module coordination	Prof. Dr. Werner Bogner
Course number and name	CM 3208 Masterseminar CM 3208 Master Thesis
Lecturer	Prof. Dr. Martin Jogwich
Semester	3
Duration of the module	1 semester
Module frequency	Final semester
Course type	required course
Niveau	postgraduate
Semester periods per week (SWS)	2
ECTS	26
Workload	Time of attendance: 30 hours self-study: 750 hours Total: 780 hours
Language of Instruction	German, English

Module Objective

The master module covers one study semester. To obtain the master's degree, a master's thesis has to be prepared. Therewith, the students should demonstrate their ability to apply the knowledge acquired during their studies in an independent scientific work on projects from an in-field engineering experience.

Within a given period of time, a problem formulation should be independently structured, systematically processed according to scientific methods and finally documented transparently by the student.

The students achieve the following learning objectives in the Master module:

Professional Skills

The students are able to familiarize themselves with technical / economic tasks and to independently analyse and solve problems. They are able to handle and solve even complex tasks in interaction with interdisciplinary departments.

The students are able to present difficult technical-scientific relationships in the fields of electrical engineering, computer science, mechatronics in English in front of a team of scholars in the form of an oral presentation and answer questions regarding the presentation in a reasonable scope.

Methodological Skills

The students have the ability to independently work on and solve an intricate problem in the field of electrical engineering and information technology on a scientific basis.

After a seminar preparation at the beginning of the semester, the students can deliver a presentation in a professional format in front of an expert audience in a comprehensible manner within a given timeframe.

Soft skills
The students are able to process independently and self-disciplinary a practice-relevant (sub-) project in the field of electrical and information technology from a scientific and methodological point of view. They are also able to present the results in a written, independent documentation in the form of a scientific paper and to present it to a critical audience.

The presentation situation in front of a professional audience, is a reflection on many similar situations in their future professional life, in particular working with restrictive time limits and the focus on the key message. Therefore, is this seminar a preparation for comparable situations in their everyday work life.

Applicability in this and other Programs

For this degree program:

Compulsory subject within Master-Program Electrical Engineering and Information Technology

For other degree program:

None

Entrance Requirements

Only for students in the final 3rd semester

Learning Content

See the subject description.

Teaching Methods

Seminar paper, mostly in cooperation with industrial companies

In-depth discussion of the task and the solution with the supervisors of the company and the university

Presentation of the results. Seminaristic instruction for preparation, individual presentation, evaluation of other lectures by ILearn vote

Dealing with appropriate software

Remarks

Specific regulations for the preparation of the Master's thesis can be found in the document for the registration of the final thesis.

Recommended Literature

See the subject description.

CM 3208 MASTERSEMINAR

Objectives

The Master seminar is intended to give students the necessary tools to present the tasks and results from the master's thesis. The current status of their work is recorded and communicated in a presentation. Didactic and eloquence in a presentation are learned.

Learning Content

Presentation techniques for complex technical contexts

Entrance Requirements

Minimum requirement: Registration of the Master's thesis must be completed, most of the Master's thesis should have been completed

Type of Examination

presentation 15 - 45 min.

Methods

Seminar-like instruction for preparation, individual presentation, evaluation of other lectures by ILearn vote

Recommended Literature

Up-to-date information on relevant literature and lectures on the Internet is provided via the corresponding ILearn course.

CM 3208 MASTER THESIS

Objectives

In the master's thesis, students acquire the ability to work largely independently on an application-oriented but extensive and complex task in the field of electrical engineering and information technology. Engineering principles and methods must be applied. The planning and execution of the subtasks must be designed so that a given time frame is not exceeded. The work is documented and presented in a professional and scientific format.

Learning Content

Individual topics

Type of Examination

master thesis

Remarks

Language: German or English

Recommended Literature

Specific literature in accordance to the definition of the task

W. Lück: Technik des wissenschaftlichen Arbeitens,10. Auflage. De Gruyter Oldenbourg Verlag 2008.

U. Eco: Wie man eine wissenschaftliche Abschlussarbeit schreibt, 13. Auflage. UTB Verlag, Wien 2010.

G. Scheld: Anleitung zur Anfertigung von Praktikums-, Seminar- und Diplomarbeiten sowie Bachelor- und Masterarbeiten, 7. Auflage. Fachbibliothek Verlag, Büren 2008.

E. Standop / M. Meyer: Die Form der wissenschaftlichen Arbeit,18. Auflage. Quelle & Meyer, Wiebelsheim 2008.

W. Rossig / J. Prätsch: Wissenschaftliche Arbeiten: Leitfaden für Haus- und Seminararbeiten, Bachelor- und Masterthesis, Diplom- und Magisterarbeiten, Dissertationen, 7. Auflage. teamdruck Weyhe 2008.

CM-09 SELECTED TOPICS IN MIRCRO- AND NANOELECTRONICS

Module code	CM-09
Module coordination	Prof. Dr. Günther Benstetter
Course number and name	CM 2109 Selected Topics in Micro- and Nanoelectronics
Lecturer	Prof. Dr. Günther Benstetter
Semester	2
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Niveau	Postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Language of Instruction	English

Module Objective

The modul Selected Topics in Micro- and Nanoelectronics pushes students to deal with current issues of micro and nanolectronics. They learn the necessary steps to understand the technology and functionality of selected micro- and nanoelectronic systems and to design and assess test and characterization methods for highly integrated systems.

The students achieve the following learning objectives:

Professional Skills

Knowledge:

General understanding of functioning and technology of selected micro- and nanoelectronic devices and systems

Sound knowledge of selected physical analytical methods to characterize micro and nanostructures

Understanding of reliability testing fundamentals

Skills:

Ability to implement and assess physical and electrical analysis techniques to characterize micro- and nanoelectronic devices

Ability to independently implement and assess reliability investigations on integrated circuits

Competences:

Competence to classify semiconductor technologies and to identify individual process steps of complex systems

Competence to assess quality and reliability of highly integrated devices and systems

Methodological Skills

Based on their learned professional skills in the field of micro-and nanoelectronics characterization, the students are able to transfer their approaches to systematically analyse and evaluate complex systems.

Soft Skills

The students are able analyse complex technologies in both ways either individually or as member of international teams.

Applicability in this and other Programs

For this degree program:

Compulsory subject within Master-Program Electrical Engineering and Information Technology, focus Electronic and Telecommunication Systems (ENS)

For other degree program:

Master of Applied Computer Science

Elective for Master Applied Research in Engineering Sciences

Entrance Requirements

Formally none

Recommended: physics, materials sciences and electronic devices

In terms of content: basic knowledge of electronic components and integrated circuits

Learning Content

Micro- and nanochip manufacturing and technology

Analysis of highly integrated devices

Quality assurance of micro- and nanoelectronic systems

Trends in nanoelectronics and new technologies

Teaching Methods

Lecture and practical trainings in teams

Blackboard, PC presentations, projectors, overhead transparencies

Remarks

Independent work with analytical tools such as scanning electron microscope, scanning probe microscope or wafer probe station

Recommended Literature

M. Lanza: Conductive Atomic Force Microscopy: Applications in Nanomaterials. John Wiley & Sons 2017.

R. Waser: Nanoelectronics and information technology. John Wiley & Sons 2012.

S. Wolf: Microchip manufacturing. Lattice press, Sunset Beach, California 2004.

B. Streetman: Solid State Electronic Devices, 7th edition. Prentice Hall 2014.

S. Sze: Semiconductor Devices, 3rd edition. John Wiley & Sons 2006.

CM-10 SELECTED TOPICS IN OPTOELECTRONICS AND LASER TECHNOLOGY

Module code	CM-10
Module coordination	Prof. Dr. Franz Daiminger
Course number and name	CM 1110 Selected Topics in Optoelectronics and Laser Technology
Lecturer	Prof. Dr. Franz Daiminger
Semester	1
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Niveau	Postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Language of Instruction	English

Module Objective

The students gain the following educational goals:

Professional Skills

Basic knowledge of the quantum mechanical description of semi-conduc-tors. The students understand the basic concepts for the quantum mechanical description of semiconductors. They are able to work out new topics by his own. They are able to write scientific papers and use precise and correct expressions**.**

The students have knowledge about radiative and non-radiative recombination processes in semiconductors. The students know about the variety of recombi-nation processes. With this knowledge they are able to analyse the complex behaviour of opto-electronic devices and select suitable devices for different applications.

The students have knowledge of essential characteristics of the most important binary, ternary and quaternary semiconductor alloys. The students have an overview of the variety of different semiconductor materials and realizes the structure behind it. With the help of this knowledge they can analyse problems in reliability.

The students have knowledge of special designs of Light Emitting Diodes (LED's) and semiconductor devices, their advantages and disadvantages. The students understand the reasons for different special designs. They have acquired a base to analyse the constraints of different LED's and their different possible applications.

The students have an overview of current status of the technology of high power LED's. With this knowledge they are able to select suitable LED's for different applications and can analyse their behaviour in complex systems.

The students have knowledge of the basics of photometry. The students have acquired a base to judge the application possibilities of different LED's.

The students have an overview of aging mechanisms and reliability issues. The students have an understanding for the problems in reliability. Thus they are able to analyse open questions concerning reliability by their own, analyse quality problems and generate assessments for devices under test.

Methodological Skills

The students are able to apply the quantum mechanical description of semi-conduc-tors to different optoelectronic devices. They can analyse optoelectronic devices with respect to their quantum mechanical mode of operation.

The students have knowledge of optical and electrical measurement techniques of LED's and semiconductor devices and can apply these techniques to different devices. The students are able to design strategies to solve open analytical questions by their own.

The students have experimental experience in electrical and optical measurement techniques. The students can transform their theoretical knowledge into practical work

Soft Skills

The students can present themselves as a qualified engineer.

Applicability in this and other Programs

For this degree program:

Compulsory subject within Master-Program Electrical Engineering and Information Technology, focus Electronic and Telecommunication Systems (ENS)

For any other degree program:

Master of Applied Computer Science

Elective for Master Applied Research in Engineering Sciences

Entrance Requirements

Formally: none

In terms of content:

Calculus for integrals and differentiation

Basics in mechanics and electrodynamics

Basics in geometrical optics

Basics in wave optics

Basics in semiconductor physics and electronic devices

Learning Content

1. Quantum mechanical description of semiconductors
   - 1.1. Wavefunctions and quantum numbers
   - 1.2. Energy band structure
   - 1.3. Direct and indirect semiconductors
   - 1.4. Emission of light
   - 1.5. Thermal velocity
2. Electronic properties of semiconductors
   - 2.1. Spectral density of states
   - 2.2. Quantum well structure
   - 2.3. Semiconductor structures 3D, 2D, 1D, 0D
   - 2.4. Thermodynamic equilibrium, Fermi level, quasi fermi level
3. Radiative and non-radiative recombination processes
   - 3.1. Radiative band-band recombination
   - 3.2. Shockley Read Hall recombination
   - 3.3. Recombination in low dimensional semiconductors
   - 3.4. Recombination of excitons

4. Semiconductor heterostructures

    4.1. Carrier injection at pn junctions

    4.2. Construction of energy band diagrams of heterostructures

    4.3. Different heterostructures

    4.4. Double heterostructures

5. Electrical properties of light emitting diodes and diode lasers

    5.1. Ideal and non-ideal current voltage characteristics

    5.2. Carrier loss in double heterostructures

    5.3. Carrier overflow in double heterostructures

    5.4. Blocking layers

    5.5. Diode voltage and its temperature dependence

6. Optical properties of light emitting diodes

    6.1. Internal-, extraction-, external- and power –efficiency

    6.2. Spontaneous emission

7. Material systems

    7.1. GaAsP, GaP, GaAsP:N, GaN:N

    7.2. AlGaAs/GaAs

    7.3. AlGaInP/GaAs

    7.4. GaInN/GaN

    7.5. GaInAsP/InP

    7.6. GaInAsSb/GaSb

    7.7. OLED (organic light emitting diodes)

8. Light emitting diodes (LED)

    8.1. General properties of current high power LED

    8.2. Light extraction, lambertian emission pattern

    8.3. Design aspects for high power LED, Thermal management of high power LED

9. Human Vision

   9.1. Eye sensitivity function, radiometric and photometric units

   9.2. Color matching functions and chromaticity diagram

   9.3. White light and color temperature

   9.4. Additive and subtractive color mixing

   9.5. Color rendering

10. Semiconductor based photodetectors

   10.1. pn-diode

   10.2. Solar cell

   10.3. Avalange photodiode (APD)

   10.4. PIN diode

   10.5. Non-semiconductor photodetectors

Teaching Methods

Lectures, laboratory course, exercise course

Remarks

Allocation to the curriculum: Compulsory subject within Master-Program Electrical Engineering and Information Technology, focus Electronic and Telecommunication Systems (ENS)

Recommended Literature

Li / Zhang: Light Emitting Diodes. Springer Series 2019.

Seong / Han / Amano / Morkoç: III-Nitride Bases Light Emitting Diodes And Applications. Springer Series 2017.

V. Protopopov: Practical Opto-Electronics: An Illustrated Guide For The Laboratory. Springer Series in optical sciences 2014.

S.Kasap: Optoelectronics and Photonics, Principles and Practices, 2nd edition. Prentice Hall, Upper saddle river 2013.

S. Sze: Semiconductor devices, 3rd edition. Wiley Interscience. Hoboken NJ 2013.

F. Schubert: Light Emitting Diodes, 2nd edition. Cambridge University Press, Cambridge 2010.

J. Singh: Electronic and Optoelectronics Properties of Semiconductor Structures, 1st edition. Cambridge University Press, Cambridge 2008.

E. Hecht: Optics, 4th edition. Addison-Wesley 2001.

Mc Cluney / Ross: Introduction to Radiometry and Photometry, 1st edition. Artech House, Boston 1994.

M. Bukshtab: Applied Photometry Radiometry and Measurement of Optical Loss, 1st edition. Springer, PU 2012.

S. Nakamura: Introduction to Nitride Semiconductor Blue Laser and Light Emitting Diodes, 1st edition. Crc Pr Inc 2000.

CM-11 MODERN RF AND RADIO SYSTEMS

Module code	CM-11
Module coordination	Prof. Dr. Matthias Wuschek
Course number and name	CM 2111 Modern RF and Radio Systems
Lecturer	Prof. Dr. Matthias Wuschek
Semester	2
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Niveau	Postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Language of Instruction	German

Module Objective

In the module Modern RF and Radio Systems the students first deal with important basics of Radar technology. You will also learn the characteristics and applications of the three basic types of Radar systems (Pulse, CW, FMCW). They then apply this knowledge when it comes to the practical dimensioning of the most important parameters of Radar systems. In addition, they become acquainted with special methods for target tracking and are introduced in methods of Radar signal theory. Finally, they get to know the mode of operation as well as advantages and disadvantages of Phased Array Antennas. The last part of the module introduces the basics of ground-based air navigation systems.

The students achieve the following learning objectives:

Professional Skills

The students know and understand basic processes of Radar technology.

The students know and understand the basic principles of target tracking, Radar signal processing and Phased Array Antennas.

The students are familiar with the functionality of important ground-based radio navigation systems in aviation.

Methodological Skills

Students can select or specify the most suitable Radar systems for specific technical tasks. Students can dimension the most important parameters of Radar systems. The students have the ability to independently research and develop existing basic knowledge.

Soft Skills

Students are able to reasonably justify and critically evaluate the basic characteristics of Radar and aeronautical navigation systems.

Applicability in this and other Programs

For this degree program:

Compulsory subject within Master-Program Electrical Engineering and Information Technology, focus Electronic and Telecommunication Systems (ENS)

For other degree program:

Master of Applied Computer Science

Elective for Master Applied Research in Engineering Sciences

Entrance Requirements

Formally: none

In terms of content: In the Bachelor Degree Course ET taught knowledge of subject basics ET, mathematics and fundamentals of communications engineering.

Learning Content

1. Introduction into the course
2. Radar Technology
   - 2.1. Introduction
   - 2.2. Basics
   - 2.3. Pulse Radar
   - 2.4. CW-Radar
   - 2.5. FMCW-Radar
   - 2.6. Pulse Doppler Radar
   - 2.7. Tracking Radar

2.8. Radar Signal processing

2.9. Phased Array Antennas

3. Ground-based air navigation systems

3.1. Overview

3.2. Instrument landing system (ILS)

3.3. Non directional Beacon (NDB)

3.4. VHF Omnidirectional Radio Range (VOR)

3.5. Distance Measuring Equipment (DME)

Teaching Methods

Teaching in the form of seminars, exercises

Remarks

Support by the e-learning platform

Recommended Literature

W. Mansfeld: Funkortungs- und Funknavigationsanlagen, Hüthig Verlag

M. I. Skolnik: Introduction to Radar Systems, MHHE Verlag

B. Huder: Einführung in die Radartechnik, Teubner Verlag

J. Göbel: Radartechnik: Grundlagen und Anwendungen, VDE-Verlag

CM-12 SPECIAL DEVICES AND CIRCUITS

Module code	CM-12
Module coordination	Prof. Dr. Werner Bogner
Course number and name	CM 2112 Special Devices and Circuits
Lecturer	Prof. Dr. Werner Bogner
Semester	2
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Niveau	Master
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Language of Instruction	English

Module Objective

In the module Special Devices and Circuits the students first deal with the special physical fundamentals of semiconductor technology by the example of special devices with negative differential resistance for high-frequency oscillators. They will also learn about the properties of modern MOS devices and their specific requirements in integrated technology design. Students will learn the necessary steps and peculiarities in IC design as well as the design of basic circuits for highly integrated analogue MOS circuits.

The students achieve the following learning objectives:

Professional Skills

The students know and understand the physical fundamentals of modern semiconductor devices.

They know various semiconductor devices with negative differential resistance and can analyse their properties. Students have the ability to apply such devices as high-frequency oscillators.

The students know the structure and understand special properties of integrated MOS circuits. They are able to apply characterization procedures and evaluate the results.

Methodological Skills

The students are able to differentiate the different properties of MOS transistor models by means of simulations. They can apply various basic circuits and circuit components of integrated analogue standard CMOS technology and merge them into more complex circuits and evaluate these by means of simulation. The students have the ability to independently research and develop existing basic knowledge.

Soft Skills

The students are able to substantiate and critically evaluate properties of various electronic components and analogue MOS circuits.

Applicability in this and other Programs

For this degree program:

Compulsory subject within Master-Program Electrical Engineering and Information Technology, focus Electronic and Telecommunication Systems (ENS)

For other degree program:

Master of Applied Computer Science

Elective for Master Applied Research in Engineering Sciences

Entrance Requirements

Formally: none

In terms of content: Knowledge acquired in Bachelor degree in the subjects electronic components, circuit technology 1, RF-electronics

Learning Content

1. Introduction
2. Negative Conductance Microwave Devices
    2.1. Esaki or tunnel diode
    2.2. IMPATT - diode
    2.3. Transferred Electron Devices
3. MOSFET
    3.1. The ideal MOS-structure
    3.2. Basic MOSFET behaviour

3.3. Second order effects

3.4. Electrical behaviour of short channel MOSFET

3.5. Comparison MOSFET - BJT

4. CMOS Technology and Layout Considerations

4.1. Physical structure of MOS-transistor

4.2. Passive Components

4.3. CMOS Considerations

4.4. Layout Considerations

5. Active Device Modelling

5.1. (C)MOS Simple Large-Signal Model (LEVEL 1)

5.2. (C)MOS Small-Signal Model

5.3. Computer Simulation Models

6. Analog CMOS Subcircuits

6.1. MOS Diode / Active Resistor

6.2. Current Sinks and Sources

6.3. Current Mirrors

6.4. Current and Voltage References

6.5. VT Referenced Source or Bootstrap Reference

6.6. Bandgap Reference

7. CMOS Amplifiers

7.1. Inverters

7.2. Differential Amplifier

7.3. Design of CMOS Operational Amplifier

7.4. Output Amplifier

Teaching Methods

Teaching in the form of seminars, simulation examples, exercises

Recommended Literature

Streetman / Banerjee: Solid State Electronic Devices, 6th edition. Prentice Hall 2006.

Muller / Kamins: Device Electronics for Integrated Circuits, John Wiley&Sons 2003.

Brennan / Brown: Theory of Modern Electronic Semiconductor Devices, John Wiley&Sons 2008.

Sze: Semiconductor Devices, 3rd edition. John Wiley & Sons 2012.

Allen / Holberg: CMOS Analog Circuit Design, 3rd edition. Oxford University Press 2011.

Comer / Comer: Fundamentals of Electronic Circuit Design, John Wiley&Sons 2003.

Razavi: Design of Analog CMOS Integrated Circuits, 2nd edition. McGraw-Hill Education 2016.

CM-13 SIGNALS AND SYSTEMS IN COMMUNICATION TECHNOLOGY

Module code	CM-13
Module coordination	Prof. Dr. Matthias Wuschek
Course number and name	CM 2113 Signals and Systems in Communication Technology
Lecturer	Prof. Dr. Matthias Wuschek
Semester	2
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Niveau	Postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Language of Instruction	English

Module Objective

In the module Signals and Systems in Communications Technology the students first deal with important basics of the description of signals in time and frequency domain and get to know the most important characteristics of signals. Furthermore, they become familiar with the essential laws of Fourier Transformation and their significance in signal theory. They then apply this knowledge when it comes to the transmission behaviour of LTI systems in time and frequency domain. The last part of the module introduces the basics of analysing random signals in time and frequency domain, as well as how to describe and determine the transmission behaviour of LTI systems in the case of random signals.

The students achieve the following learning objectives:

Professional Skills

The students know and understand important characteristics of signals in time and frequency domain.

The students know the most important laws of Fourier Transformation.

The students know the basic signal transmission behaviour of LTI systems in time and frequency domain.

The students know important characteristics of random signals in time and frequency domain (statistical parameters, density and distribution functions, auto and cross correlation function, power spectrum).

The students are familiar with the basic signal transmission behaviour of LTI systems in the case of random signals.

Methodological Skills

Students can determine the most important parameters of signals. The students can determine the spectrum of important elementary signals by means of the Fourier Transformation. Students can calculate the transmission behaviour of elementary LTI systems in time and frequency domain. The students are able to calculate important characteristics of random signals as well as the transmission behaviour of elementary LTI systems with random signals in time and frequency domain. The students have the ability to independently research and develop existing basic knowledge.

Soft Skills

Students are able to reasonably justify and critically evaluate the basic properties of deterministic and random signals as well as of LTI systems in time and frequency domain.

Applicability in this and other Programs

For this degree program:

Compulsory subject within Master-Program Electrical Engineering and Information Technology, focus Electronic and Telecommunication Systems (ENS)

For other degree program:

Master of Applied Computer Science

Elective for Master Applied Research in Engineering Sciences

Entrance Requirements

Formally: none

In terms of content: In the Bachelor Degree Course ET taught knowledge of subject basics ET, mathematics and fundamentals of communications engineering.

Learning Content

1. Signals and their characteristics
    1.1. Signal and message
    1.2. The communication system and its signals
    1.3. Classes of signals
    1.4. Characteristics of signals
    1.5. Test signals
    1.6. Transformation of signals in the time domain
    1.7. The signal spectrum
2. Relationships between signal and spectrum
    2.1. Summation theorem
    2.2. Spectrum and DC component of a signal
    2.3. Pulse area and spectrum
    2.4. Spectral area bandwidth of a signal
    2.5. Reciprocity between pulse duration and bandwidth of pulses
    2.6. Weighting of a signal
    2.7. Similarity theorem
    2.8. Shifting theorem (time domain)
    2.9. Shifting theorem (frequency domain)
    2.10. Even and odd signals
    2.11. Corresponding theorem
    2.12. Conjugate complex and mirrored signals
    2.13. Theorem of Parseval
    2.14. Energy theorem
    2.15. Commutation theorem
    2.16. Differentiation theorem (time domain)
    2.17. Differentiation theorem (frequency domain)

2.18. Integration theorem (time domain)

2.19. Integration theorem (frequency domain)

2.20. Convolution theorem (time domain)

2.21. Convolution theorem (frequency domain)

3. Basic transmission characteristics of communication systems

3.1. Theoretical classification of communication systems

3.2. Signal transmission behaviour of LTI systems in time domain

3.3. Signal transmission behaviour of LTI systems in frequency domain

3.4. Low-pass systems

3.5. High-pass systems

3.6. Band-pass Systems

3.7. Runtime systems

4. Random signals

4.1. Introduction

4.2. Momentary value properties of random signals

4.3. Characteristics of random signals in time and frequency domain

4.4. Transmission of random signals via LTI systems

Teaching Methods

Teaching in form of seminars, exercises

Remarks

Support by the e-learning platform

Recommended Literature

J.Prokais / M. Salehi: Communication Systems Engineering, ISBN 0-3130-95007-6

S. Haykin: Communication Systems, ISBN 0-471-17869-1

A. Oppenheim: Signals and Systems, ISBN 0-13-651175-9

Z. Gajic: Linear Dynamic Systems and Signals, ISBN 0-201-61854-0

T. Chon: Statistical Signal Processing, ISBN 1-85233-385-5

CM-14 ADVANCED MODELLING AND SIMULATION

Module code	CM-14
Module coordination	Prof. Dr. László Juhász
Course number and name	CM 1114 Advanced Modelling and Simulation
Lecturer	Prof. Dr. László Juhász
Semester	1
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Niveau	Postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	written ex. 120 min.
Duration of Examination	120 min.
Language of Instruction	English

Module Objective

The students deal first with problems related to mathematical modelling, parameter identification, simulation and digital control of technical and especially mechatronics systems. Furthermore, they learn about the basics of model-based control-design techniques. Here, not only the user's sight, but also the developer's tasks are discussed. Thus, students learn how to perform successful digital control-design and -testing using the model-based control-design methods. They are in position to successfully synthetize such control design as well as to critically evaluate it.

The students achieve the following learning objectives:

Professional Skills

The students are able to describe technical systems by means of mathematical modelling. They know the basic methods for parameter identification of technical and mechatronics systems and they apply such methods in practical exercises. They have the knowledge to create and verify parametrized mathematical models of technical systems.

Students have deep knowledge about digital control systems and their application during control-design for mechatronic systems.

Students learn about the basics and advanced methods of model-based digital control-design.

Students are familiar with the individual elements of the model-based design technology according to the V-cycle and understand the common elements and the differences in between them. They are able to evaluate the designed digital controller by means of offline- and real-time simulation according to the V-cycle standards. On this way they are able to uncover errors in the control design in the early development stage.

The Students learn about the software tool-chains based on MathWorks and dSPACE tools and can apply such tools using the earned knowledge and experience independently and holistically for the tasks of digital control-design and -testing.

Methodological Skills

Students are familiar with the common methods for mathematical modelling of technical and mechatronics systems and are able to apply such methods successfully.

Students learn about the methods of parameter identification in time and frequency domain and use these methods for practical exercises.

Furthermore, students are familiar with the most important methods used by digital control-design and are able to use these methods successfully.

Students are familiar with the common methods and tools used by the model-based control-design and are able to apply these methods successfully. Particularly, the stability criteria of digital simulation used for investigation of analogous and discrete plants and control systems are well-known. Students are familiar with guidelines for appropriate design of individual control functions regarding their later application in RCP, HIL and automatic production code. The earned skills are consolidated through practical exercises dealing with modelling, code generation and control of an example application.

Students are familiar with the meaning of real-time requirements and its impact on control-design and testing by RCP. They are able to apply thins knowledge both for software and hardware requirements during RCP process successfully. Thus, students are able to successfully perform function-prototyping by means of RCP for CPU-based systems and test their design appropriately. Especially he can clarify and analyze the problems of tasking, configuration of I/O devices and their impact on the real-time capability.

Students can overview the problems which may arise by the automatic production code generation and are able to apply optimization methods for minimization of the CPU-load and memory consumption of the ECU. Especially the design of the optimal numerical representation of the controller by means of fixed-point data types and scaling is treated here with emphasis. He is able to create optimal production code based on a functional model and to perform all the necessary steps on this way in successful manner. The student is familiar with the testing of the created production code by means of various simulation types, like MIL, SIL and PIL. He knows the basics of the integration of the ECU code towards the production prototype.

Students are familiar with the common methods of the HIL-Simulation and they are able to design and execute a HIL-Simulator for testing of production ECUs. Students can understand the synergies between the RCP and HIL and are able to apply test-automatization and virtualization.

Soft Skills

The students are aware their responsibility when work as developer in tasks of model-based control design and –testing. They are able to assess individual development steps and are prepared to give feedback and successfully work together in development teams.

Applicability in this and other Programs

For this degree program:

Compulsory subject within Master-Program Electrical Engineering and Information Technology, focus automation and power engineering (AET)

For other degree program:

Optional subject for General Engineering.

Elective for Master Applied Research in Engineering Sciences

Entrance Requirements

Formally: none

Essential thematic prerequisites: Mathematical modelling of linear time-invariant systems, physical basics and modelling approaches for mechanical and electrical systems, analogous and digital control design, advanced knowledge of programming language C.

Learning Content

1. Mathematical modelling of technical systems
   - 1.1. Common approaches for mathematical modelling of technical systems
   - 1.2. Mathematical modelling of mechanical systems
   - 1.3. Mathematical modelling of electrical systems
   - 1.4. Mathematical modelling of hydraulically systems
   - 1.5. Mathematical modelling of heat-transfer systems
   - 1.6. Mathematical modelling of mechatronic systems
   - 1.7. Linearization of non-linear systems in steady-state

1.8. Description of technical systems by means of state-space equations

2. Digital control

   2.1. Discrete description of technical systems and the digital control loop

   2.2. Discretization of analogue plants

   2.3. Difference equations and the Z-transformation

   2.4. Stability of discrete systems

   2.5. Methods of digital control-design

   2.6. Discrete state-space equations

3. Parameter-identification of technical and mechatronic systems

   3.1. Overview of methods for parameter-identification

   3.2. Parameter-identification using time-domain

   3.3. Parameter-identification using frequency-domain

   3.4. Parameter-identification methods based on spectroscopy

   3.5. Parameter-identification methods based on spectral analysis

4. Elements of model-based control-design and -testing

   4.1. Model-based control-design according to the V-model

   4.2. Offline Simulation

   4.3. Rapid Control Prototyping

   4.4. Production code generation

   4.5. Hardware-in-the-Loop Simulation

   4.6. Measurement and calibration

5. Practical exercises

   5.1. Modelling and simulation of technical systems: among others example of an electrical throttle-valve

   5.2. Model-based control design and –testing for the position-control of an electrical throttle-valve

5.3. Testing with RCP through example application: control of an electrical throttle-valve

5.4. Production-code generation, various examples (among others, control of an electrical throttle-valve)

Teaching Methods

Teaching lessons, practical exercises (modelling, simulation, control design, testing), individual and group work

Remarks

Tutorial

E-learning platform

Recommended Literature

R. Woods / K. Lawrence: Modeling and Simulation of Dynamic Systems. Prentice Hall 1997.

D. Abel / A. Bollig: Rapid Control Prototyping (in German). Springer 2013.

H. Schildt: C++ The Complete Reference, Part I: the C subset. Springer 2013.

Ljung: System Identification: Theory for the User, 2/E. Prentice Hall 1999.

Gajic: Linear Dynamic Systems and Signals. Prentice Hall 2002.

N. Nise: Control Systems Engineering. John Wiley & Sons 2004.

R. Dorf / R. Bishop: Modern Control Systems. Pearson Educational International 2005.

R. Isermann: Grundlegende Methoden, Identifikation dynamischer Systeme, Bd.1. Springer-Verlag 1992.

R. Isermann: Identifikation dynamischer Systeme II. Besondere Methoden, Anwendungen. Springer-Verlag 1992.

M. Gipser: Systemdynamik und Simulation. Teubner-Verlag 1999.

R. Nollau: Modellierung und Simulation Technischer Systeme (in German). Springer 2009.

CM-15 SELECTED CHAPTERS IN CONTROL ENGINEERING

Module code	CM-15
Module coordination	Prof. Dr. Nikolaus Müller
Course number and name	CM 2115 Selected Chapters in Control Engineering
Lecturer	Prof. Dr. Nikolaus Müller
Semester	2
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Niveau	Postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Language of Instruction	English

Module Objective

Students will be enabled to design suitable controllers and observers for challenging dynamic plants by means of the state-space method and implement it as a program.

The students achieve the following learning objectives:

Professional Skills

They can formulate dynamic systems in state-space

They name the most important properties and can calculate them

They can compute controllers and observers for low system order according to the pole-placement method

They can describe how observers work and what is their benefit

They can determine a discrete time description of a plant

They can implement a program for observer and controller

They know how to depict a system description within Matlab/Simulink

Applicability in this and other Programs

For this degree program:

Compulsory subject within Master-Program Electrical Engineering and Information Technology, focus automation and power engineering (AET)

For any other degree program:

Elective for Master Applied Research in Engineering Sciences

Entrance Requirements

Formally: none

Learning Content

1. Description of dynamic systems in state-space
    - 1.1. Physical Modelling
    - 1.2. Set-up of State-Space Description from Other Models
    - 1.3. Methods for Solution of the Differential Equations
2. Properties
    - 2.1. Stability
    - 2.2. Controllability and Observability
    - 2.3. Canonical Forms
3. Design of Controllers
    - 3.1. Pole-Assignment Method for SISO Systems
    - 3.2. Pole-Assignment Method for MIMO Systems
    - 3.3. Other Design Methods
4. Design of Observers
5. Discrete-time description

Teaching Methods

Blended Learning, tuition in seminars, exercises

Recommended Literature

R. Dorf / R. Bishop: Modern Control Systems. 13. edition. Pearson, 2017.

K. Ogata: Modern Control Engineering. 5. edition. Pearson, 2010.

N. Nise: Control Systems Engineering. 6. edition. Wiley, 2011.

S. Chapman: Matlab® Programming with Applications for Engineers. Cengage Learning, 2013.

CM-16 SPECIAL TOPICS OF CONTACTLESS SENSOR SYSTEMS

Module code	CM-16
Module coordination	Prof. Dr. Martin Jogwich
Course number and name	CM 2116 Special Topics of Contactless Sensor Systems
Lecturer	Prof. Dr. Martin Jogwich
Semester	2
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Niveau	Postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Language of Instruction	English

Module Objective

The students achieve the following learning objectives:

Professional Skills

Students gain a thorough knowledge and a deep understanding of modern contactless sensors and sensor systems, especially of optical sensors

Methodological Skills

They learn to evaluate different tasks of industrial projects, when contactless measurements can help solving the problem.

The students develop a deep understanding of finding strategies for solving these problems, especially by applying analog and digital image processing techniques.

Soft Skills

The students learn to apply these strategies successfully in special case studies with problems, which they have solve e.g. during their master thesis and their projects in industry jobs.

Applicability in this and other Programs

For this degree program:

Compulsory subject within Master-Program Electrical Engineering and Information Technology, focus automation and power engineering (AET)

For any other degree program:

Elective for Master Applied Research in Engineering Sciences

Entrance Requirements

Formally: none

In terms of content: Deep knowledge of basic mathematics and its scientific and technical application, in particular trigonometry, coordinate systems, vector analysis, matrix calculus, differential and integral calculus, geometric transformations, fitting and interpolation techniques.
Deep knowledge of basic physics and its scientific and technical application in particular generation, transfer and measurement of electromagnetic radiation, in particular from the visible part of the spectrum.

Learning Content

Basics of sensor principles using geometrical optics (e.g. triangulation, image acquisition and image pre-processing)

Basics of sensor principles using electromagnetic radiation transfer (e.g. time of flight measurement, thickness measurement, photometry, fluorescence, interferometry, light barriers and light scanners)

Basics of sensor principles using electromagnetic radiation detection (e.g. photomultiplier, photo sensors, CCD and CMOS sensors)

Case studies of sensor application: Machine vision applications using image acquisition, image pre-processing and image processing

Teaching Methods

Lectures, practical exercise (software workshops), laboratory work

Recommended Literature

C. Demant et al: Industrial Image Processing bzw. Industrielle Bildverarbeitung, Springer.

R. Gonzalez / R. Woods: Digital Image Processing, Prentice Hall.

J. Haus: Optical Sensors, Wiley-VCH.

S. Hesse / G. Schnell: Sensoren für die Prozess- und Fabrikautomation, Vieweg.

A. Hornberg (editor): Handbook of Machine Vision, Wiley-VCH.

B. Jähne: Digital Image Processing bzw. Digitale Bildverarbeitung, Springer.

R. Jain / R. Kasturi, B.G / Schunck: Machine Vision, McGraw-Hill Book Company.

J. Niebuhr / G. Lindner: Physikalische Messtechnik mit Sensoren, Oldenbourg.

M. Petrou / P. Bosdigoianni: Image Processing, John Wiley & Sons.

E. Schiessle: Industriesensorik, Vogel Verlag.

C. Solomon / T. Breckon: Fundamentals of Digital Image Processing.

C. Steger / M. Ulrich / Chr. Wiedemann: Machine Vision Algorithms and Applications, Wiley-VCH.

CM-17 AUTOMOTIVE AND INDUSTRIAL DRIVE SYSTEMS

Module code	CM-17
Module coordination	Prof. Dr. Nikolaus Müller
Course number and name	CM 2117 Automotive and Industrial Drive Systems
Lecturers	Prof. Dr. Peter Firsching Prof. Dr. Nikolaus Müller
Semester	2
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Niveau	Postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Language of Instruction	English

Module Objective

The module Automotive and Industrial Drive Systems introduces diverse electrical drive systems, teaches the typical methods of control and shows the special requirements in an automotive or industrial environment, respectively. The subject offers an overview over electrical drive systems for industrial applications and in vehicles and introduces further sustainable drive concepts.

The students achieve the following learning objectives:

Professional Skills

Special subject Automobile Electrical Drive Systems

Students can list components of an electrical power train

They know how to calculate the pulse patterns of a space-vector modulation

They can describe the electrochemical processes in batteries and can explain their behaviour

They can oppose advantages and disadvantages of an electrical power train to a conventional combustion engine driven car

They can name hybrid vehicle concepts and alternative combustion engines

They can analyse alternative fuels for their applicability in cars

They can assess different power train concepts for their application

Special subject Industrial Electrical Drive Systems

Students understand the structure of a multi-axle motion control system

They master the mathematical methods of a field-oriented description of three-phase electrical machines

They can describe the dynamic behaviour of three-phase synchronous and asynchronous machines

They can name different design approaches for speed control systems of electrical drives

They can design speed control systems for electrical drives

Soft Skills

Students work out contents within groups

Applicability in this and other Programs

For this degree program:

Compulsory subject within Master-Program Electrical Engineering and Information Technology, focus automation and power engineering (AET)

For other degree program:

Elective for Master Applied Research in Engineering Sciences

Entrance Requirements

Formally: none

Learning Content

Special subject Automobile Electrical Drive Systems

1. Electrical Power Train
    1.1. Motors
    1.2. Inverter Control with Space Vector Modulation

1.3. Batteries

1.4. Charging Concepts

2. Fuel-assisted Electric Cars

2.1. Fuel-Cells

2.2. Hybrid Vehicles

3. Sustainable Combustion Engine Concepts

3.1. Alternative Fuels

3.2. Alternative Combustion Engines

Special subject Industrial Electrical Drive Systems

1. Industrial drives

1.1. General properties

1.2. Energy efficiency classes

1.3. Motion control

1.4. Charging Concepts

2. Dynamic models of electric machines

2.1. Modelling of the dynamic behaviour of electric machines

2.2. Clark / Park transformation

2.3. Dynamic model synchronous machine

2.4. Dynamic model asynchronous machine

3. Closed loop control of electric devices

3.1. General control system design

3.2. Speed control for DC machines

3.3. Control system design for 3~ machines

3.4. Direct torque control

Teaching Methods

Semenaristic lessons, group work

Recommended Literature

R. Jurgen: Electric and Hybrid-Electric Vehicles. SAE international 2011.

J. Beretta: Automotive Electricity. Wiley 2010.

M. Ehsani / Y. Gao / S. Longo/ K. Ebrahimi: Modern Electric, Hybrid Electric and Fuel Cell Vehicle, 3. edition. CRC-Press 2019.

A. Emadi: Advanced Electric Drive Vehicles. CRC-Press 2015.

J. Erjavec: Hybrid Electric & Fuel Cell Vehicles, 2. edition. Delmar 2013.

I. Husain: Electric and Hybrid Vehicles, 2. edition. CRC-Press 2011.

A. Khajepour / S. Fallah / A. Goodarzi: Electric and Hybrid Vehicles. Wiley 2014.

B. Bose: Modern Power Electronics and AC Drives. Prentice Hall 2002.

G. Henneberger: Electrical Machines I. Lecture notes. Technical University Aachen 2002.

R. Dorf / R. Bishop: Modern Control Systems, 13. edition. Pearson Prentice Hall 2017.

Different journals

Application notes

CM-18 RENEWABLE ENERGIES (GENERATION AND DISTRIBUTION)

Module code	CM-18
Module coordination	Prof. Dr. Günter Keller
Course number and name	CM 2118 Renewable Energies (Generation and Distribution)
Lecturer	Prof. Dr. Günter Keller
Semester	2
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Niveau	Postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 10 hours self-study: 140 hours Total: 150 hours
Type of Examination	student project
Language of Instruction	English

Module Objective

The module deals with renewable energies and their applications, in particular generation, storage and grid connection of solar and wind energy.

The students achieve the following learning objectives:

Professional Skills

The students identify application fields of renewable energies and their user-defined usage. Against this background there are four focus areas: solar energy, wind energy, technologies for long term, midterm and short term storages and grid connection.

The students learn technical and economic aspects of renewable energies. The technical part covers the technologies of the components as well as the energy conversion methods including their controlling.

Students learn to research work as self-study from the beginning of the course. They summarize their study in a scientific-technical report with a defined number of pages, which fulfils all requirements of an international conference paper.

Methodological Skills

The module will result in an examination paper. Against this background the students get well defined guidelines regarding form and content of the examination paper. The students select their topic by first researching their desired topic and suggesting it with a keyword list.

Soft Skills

The soft skills contain research work and summarizing their study in an examination paper.

Applicability in this and other Programs

For this degree program:

Compulsory subject within Master-Program Electrical Engineering and Information Technology, focus automation and power engineering (AET)

For other degree program:

Master Program: Applied Computer Science

Elective for Master Applied Research in Engineering Sciences

Entrance Requirements

Formally: none

In terms of content: Basic knowledge in power electronics

Learning Content

1. Solar Energy
    - 1.1. Solar Energy Supply
    - 1.2. Technology of Cells and Modules
    - 1.3. Solar Plant Construction
    - 1.4. Stand-alone Systems
    - 1.5. Thermal Electric Systems
2. Wind Energy
    - 2.1. Rotor Technologies
    - 2.2. Generators
    - 2.3. Wind Energy Plant Construction

2.4. Control of Wind Energy Systems

2.5. Offshore Systems

3. Grid Connection

3.1. Single-Phase Converters

3.2. Three-Phase Converters

3.3. Grid Current Control

3.4. Synchronization

3.5. Grid Codes

3.6. Converter Control

4. Storage Systems

4.1. Chemical Storage Systems

4.2. Mechanical Storage Systems

4.3. Electric Storage Systems

4.4. Costs

4.5. Grid Integration

4.6. Recycling

Teaching Methods

Blackboard, overhead transparencies, computers / projectors, simulation programs, individual examination paper

Remarks

In case of an examination paper the all requirements and procedure steps are defined during a kick-off meeting. This information and additional constraints and recommendations are shared via email.

Recommended Literature

Publications IEEE

V. Quaschning: Regenerative Energiesysteme, 9. Auflage. Carl Hanser Verlag 2015.

V. Quaschning: Erneuerbare Energien und Klimaschutz, 4. Auflage. Carl Hanser Verlag 2018.

F. Zach: Leistungselektronik, 5. Auflage. Springer/Vieweg 2015.

Sterner / Stadler: Energiespeicher, 2. Auflage. Springer/Vieweg 2017.