Module Guide

Electrical Engineering and Information Technology

Faculty Electrical Engineering and Media Technology

Examination regulations 26.11.2020

Date: Tue 21.10.2025 13:09

MET-01 ADVANCED PROGRAMMING TECHNIQUES

Module code	MET-01
Module coordination	Prof. Dr. Karsten Becker
Course number and name	MET 1101 Advanced Programming Techniques
Lecturer	Prof. Dr. Karsten Becker
Semester	1
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	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 examination
Weighting of the grade	5/90
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 software engineering and 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.

MET-02 NUMERICAL METHODS

Module code	MET-02
Module coordination	Prof. Dr. Christine Wünsche
Course number and name	MET 1102 Numerical Methods
Lecturer	Prof. Dr. Christine Wünsche
Semester	1
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	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.
Weighting of the grade	5/90
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 programme 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.

MET-03 FOREIGN LANGUAGE

Module code	MET-03
Module coordination	Tanja Mertadana
Course number and name	MET 1103 Foreign Language
Lecturer	Dozierende für AWP und Sprachen
Semester	1
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	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	See examination schedule AWP and languages
Weighting of the grade	5/90
Language of Instruction	Course dependent

Module Objective

The module "Foreign Language Course" aims to equip students with specialised language skills necessary for independent performance in a globalised field of electrical engineering and information technology. The module aims to familiarise students with the respective language so that they can effectively and efficiently implement the respective language as a practical means of communication.

International students earn ECTS points as part of the foreign language course, starting from level German B1/ part 1 + 2. Native speakers of German or international students with German language skills of level C1 may choose any two foreign language courses from the catalogue of the Language Centre.

Qualification objectives can be found in the corresponding course description on the homepage of the Language Centre:
https://th-deg.de/language-and-electives-centre

Applicability in this and other Programs

Applicable in other degree programmes.

Entrance Requirements

Proof of successful completion of the previous language level must be provided.

Learning Content

The course content can be found in the corresponding course description on the homepage of the Language Centre:
https://th-deg.de/language-and-electives-centre

Teaching Methods

The teaching and learning methods can be found in the corresponding course description on the homepage of the Language Centre:
https://th-deg.de/language-and-electives-centre

Remarks

All language courses require a compulsory attendance rate of 75% in order to be allowed to take the examination.

Recommended Literature

Recommended reading can be found in the corresponding course description on the homepage of the Language Centre:
https://th-deg.de/language-and-electives-centre

MET-04 COMPULSORY ELECTIVE

Module code	MET-04
Module coordination	Prof. Dr. Werner Bogner
Course number and name	ET 26 Control Engineering 2 ET 30 Power Electronics ET 34 RF-Electronics ET 37 Telecommunication 2 MET 1204 Advanced Circuits Lab MET 1204 Compulsory Elective MET 1204 Renewable Energies (Generation and Distribution) MET 1204 Optical Metrology and Optical Sensors MET 1204 Imaging Physics MET 1204 Hydrogen Technology MET 1204 Simulation and Modeling of Electric Transport Systems MET 1204 Fundamentals of Advanced Driver Assistance Systems
Lecturers	Prof. Dr. Jens Ebbecke Prof. Dr. Otto Kreutzer Prof. Dr. Bernd Kuhn Prof. Dr. Nikolaus Müller N.N. NN ET Felix Sepaintner Prof. Dr. Markus Straßberger Danny Wauri Prof. Dr. Matthias Wuschek Prof. Dr. Simon Zabler Prof. Jörg von Mankowski
Semester	1, 2
Duration of the module	2 semester
Module frequency	each semester
Course type	compulsory course, compulsory elective course, elective course
Level	Postgraduate
Semester periods per week (SWS)	92
ECTS	15
Workload	Time of attendance: 540 hours self-study: 810 hours virtual learning: 300 hours

	Total: 1,650 hours
Weighting of the grade	15/90
Language of Instruction	German, English

Module Objective

Varying according to chosen course

The students achieve the following learning objectives:

See description of the choosen 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 chosen course.

Courses can be selected from the elective catalog for the Master's program in Electrical Engineering and Information Technology. This can be viewed at https://www.th-deg.de/Fakultäten/emt/ET-master/wahl_der_wahlpflichtfaecher_met.pdf. The module descriptions can be found in the module manuals of the respective study programs.

A total of 15 ECTS courses must be selected.

Teaching Methods

Various, depending on the chosen course.

See description of the chosen course

Remarks

Students who choose the specialization "ENS" but had not taken the subjects "High Frequency Electronics" and "Communications Engineering 2" from the specialization

"Communications Engineering" in their bachelor studies must take the subjects "High Frequency Electronics" and "Communications Engineering 2" from the bachelor study program Electrical Engineering and Information Technology here to deepen their basic knowledge (harmonization courses).

Students who choose the specialization "AT", but did not take the subjects "Power Electronics" and "Control Engineering 2" from the specialization "Automation Technology" in their bachelor studies, must take the subjects "Power Electronics" and "Control Engineering 2" from the bachelor study program Electrical and Information Engineering here to deepen their basic knowledge (harmonization courses).

All other students and students who did not obtain their bachelor's degree in the bachelor's degree program in Electrical and Information Engineering at the THD must select elective subjects from the catalog of elective subjects listed in the study plan.

Recommended Literature

See description of the chosen course

ET 26 CONTROL ENGINEERING 2

Objectives

The aim is for the students to broaden their knowledge in control enginieering 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 analyze their behavior

Studenent 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.

ET 30 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. Mehrquadrantenumrichter

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.

ET 34 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 RFcomponents on their own and will be able to design, analyze, 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 analyze 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 analyze and apply modern components of RF technology. You can judge the possible uses of these components.

Students have the ability to analyze 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, 16. Auflage. Springer Verlag 2019

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, 3. Auflage. Hüthig Verlag, Bonn, 2004

H. Heuermann: Hochfrequenztechnik. 3. Auflage, Springer Verlag, 2018

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.

ET 37 TELECOMMUNICATION 2

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 analog 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 analog 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 analog 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
2. The faulty transmission channel
    - 2.1. Introduction
    - 2.2. Calculating with logarithmic quantities
    - 2.3. Linear and nonlinear distortions
    - 2.4. Crosstalk
    - 2.5. Noise
3. Introduction to the modulated signal transmission
    - 3.1. Advantages of modulated signal transmission

3.2. Overview of common modulation methods

3.3. Linear and non-linear modulation methods

3.4. Abbreviations

4. Analog modulation methods

4.1. The sine-wave carrier and his description

4.2. Amplitude modulation

4.3. Frequency modulation

4.4. Quadrature Amplitude modulation

4.5. Applications

5. Digital modulation methods

5.1. Basic methods

5.2. Basics

5.3. Amplitude shift keying ASK

5.4. Phase shift keying PSK

5.5. Frequency shift keying FSK

5.6. Minimum Shift Keying MSK

5.7. Hybrid modulation methods (QAM)

5.8. Synchronization method

5.9. Spread Spectrum methods

Type of Examination

written ex. 90 min.

Methods

Seminar-like instruction, exercises

Remarks

Lesson support through the onnline 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.

MET 1204 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 analyze the small signal behavior of semiconductor circuits as well as the transient behavior. They have the ability to analyze and apply analog semiconductor circuits for AF and RF. The students know oscillator circuits and dimension and analyze them.
The students have the ability to design analog semiconductor circuits.

Methodological Skills:

The students are able to dimension and optimize electronic analog 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. optional: Introduction to circuit simulation
   2.2. optional: 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. optional: 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

project work, Portfolio, written ex. 60 min.

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.

MET 1204 COMPULSORY ELECTIVE

Type of Examination

part of module exam

MET 1204 RENEWABLE ENERGIES (GENERATION AND DISTRIBUTION)

Type of Examination

written ex. 90 min.

MET 1204 OPTICAL METROLOGY AND OPTICAL SENSORS

Objectives

Objectives

This course will give the students an overview of the application driven field of optical metrology with optical sensors.

After completing the subject, the students have achieved the following learning objectives:

They are able to explain the specialities of the optical sensors used for distinct optical metrology fields.

The students are able to choose a certain optical sensor for a specified optical problem.

The students will learn to differentiate between the different optical metrology tasks.

Students are capable to solve complex problems in the field of optical metrology.

Learning Content

Learning Content

1. Optical basics and components
2. 3D shape detection
3. Temperature examination techniques
4. Measurements of fluid flows
5. Optical detection of mechanical vibrations and motion studies
6. Surface analysis
7. Optical determination of mechanical strain
8. Distance and velocity detection
9. Deformation measurement
10. Damage detection
11. Special applications of optical metrology

Entrance Requirements

Formally: none

Type of Examination

written ex. 90 min.

Methods

Lecture, seminar-like instructions, exercises

Remarks

Lessons supported by the online learn-management-system iLearn

Recommended Literature

Recommended Literature

S. Donati: Electro-Optical Instrumentation: Sensing and Measuring with Lasers; Prentice Hall

K. J. Gåsvik: Optical Metrology; Wiley

M. Schuth + W. Buerakov: Handbuch Optische Messtechnik; Hanser Verlag

G. Booker: Sensors for Ranging and Imaging; Scitech Publishing

MET 1204 IMAGING PHYSICS

Objectives

"Scientific Discoveries expressed as Images" is not just a feature of Astronomy or Biology. Physicists and Physics Engineers have a large range of methods at hand for capturing physical phenomena and the structure of condensed matter in digital images. This lecture gives an overview with a lot of hands on examples on imaging methods such as thermal, laser, X-ray, neutron, electron, nuclear resonance and ultrasonic imaging. Seminar presentations by students on select topics shall round up the course which addresses Master students in electrical engineering, Media Science and Applied Computer Science.

Learning Content

1. Digital pixel arrays /cameras /sensors
2. Physical probes for imaging and their interaction with matter
3. Scanning versus Full-field imaging techniques
4. Basics of Digital image processing
5. Resolving power of different imaging systems
6. Signal versus Noise
7. Retrieving and imaging "the phase"
8. Applications of Machine Learning in Scientific Imaging
9. Volume Image reconstruction in CT and MRI
10. Motion pictures - examples of time-resolved imaging

Entrance Requirements

Differential Anaylsis /Mathematics

Basics Computer Science and C. Vision

Basics Solid State Physics

Type of Examination

written ex. 90 min.

Methods

Short student seminar presentations on select topics, Hands-on examples and practical exercises.

MET 1204 HYDROGEN TECHNOLOGY

Objectives

Aim

The series of lectures deals with technologies for the production, storage, transport and utilization of hydrogen such as electrolysis and fuel cells, compression and liquefaction as well as tank and pipeline technology. In addition, electrochemical, thermodynamic and materials science basics are covered, which are necessary to classify the technological issues of a future hydrogen economy.

Objectives

Expertise

The students learn about hydrogen technologies and will be enabled to classify the development stages and research needs in the individual technology fields. Not only purely technical issues will be covered, but also economic aspects can be individually assessed and planned by the students. In addition to production, the storage, distribution and use of (primarily, but not exclusively) renewable hydrogen in all areas of life will be covered: from renewable mobility, application in the chemical industry and food technology to metallurgy and regenerative heating and cooling of buildings. By preparation and presentation of a poster on a selected topic of the lecture, independent research, elaboration and presentation skills are trained.

Methodological competence

Posters will be elaborated by groups of students as a part of the lecture series. By doing so, students deepen their skills for independent scientific research, comprehendible preparation of technical facts and teamworking skills. Finally, the written exam checks the ability of the students to apply the technical and methodological lessons learned to questions of hydrogen technology.

Personal skills

The acquisition of personal competence focuses on the students' ability as future engineers to develop viable techno-economic solutions for problems of future regenerative hydrogen economy.

Learning Content

Preface: Hydrogen

- o H2 facts: Chemical and physical properties, natural occurrence
- o Historical: Discovery and preparation
- o Today: Significance for today´s technology and economy, color theory of Hydrogen

Production of Hydrogen

Conventional (grey) technologies (State of the art)

- o Steam Methane Reforming (SMR)
- o Partial Oxidation (POX) of coal, oil, natural gas
- o CO2-sequestration and storage (Carbon Capture and Storage, CCS)
- o How to transform these technologies to produce green Hydrogen

Alternative technologies (Research and development, first commercial systems)

- o Pyrolysis of natural gas (Kvaerner process, liquid metal bubble column reactors)
- o Plasmalysis of waste water and manure
- o Thermochemical cycles

Electrolysis

- o Alkaline electrolysis (AEL)
- o Alkaline pressure electrolysis (APEL)
- o Alkaline anion exchange membrane electrolysis (AEM)
- o Polymer electrolyte membrane electrolysis (PEM)
- o High temperature electrolysis (Solid Oxide Electrolysis, SOE), incl. CO2-electrolysis

Storage and transport

Thermodynamical and chemical basics

- o for physical storage: Gas laws, critical point, Joule-Thomson effect
- o for chemical storage: types of chemical bonds, crystal structures, enthalpy of bonds and reactions

Physical storage and transport solutions

- H2-pipelines
- Significance of existing natural gas grid
- Cavern storage
- Pressurized storage
- Liquid storage
- Zeolites

Chemical storage and transport solutions

- Ammonia
- Methanation
- Liquid Organic Hydrogen Carriers (LOHC)
- Metal hydrides

Utilization

Energetic use by means of Fuel Cells (FC)

- Alkaline Fuel Cell (AFC)
- Polymeric electrolyte membrane FC (PEMFC)
- High temperature FC (i.e. Solid Oxide Fuel Cell, SOFC)

Energetic use by means of conventional technologies

- Gas turbines
- Gas- and steam combined cycles power plants
- conventional gas heaters
- internal combustion engines for combined heat and power (CHP) and heavy-duty vehicles
- Generation of (process)steam

Industrial application

- Significance of industrial application for overall Hydrogen consumption (today vs. future)
- Reducing agent in steel production

- Basic material for chemical industry (production of fertilizers, fuel desulfurization, food production)
- Auxiliary material in electrical industry (reduction and cleaning agent in semiconductor manufacturing and metallurgy, anti-oxidant)

Outlook

Scenarios of future production, storage, distribution and utilization of Hydrogen

- regenerative production
- Energy transition = Electricity transition AND heat transition
- Sector coupling and storage solutions
- individual and industrial utilization

Entrance Requirements

Recommended admission requirements

Formal: none

Topical: Basic knowledge of thermodynamics and chemical reaction technology and, ideally, a personal interest in tackling the major technological issues of the energy transition.

Type of Examination

written ex. 90 min.

Methods

- Power Point presentations by lecturer
- Discussion of topics for active participation of students
- Preparation and presentation of posters on selected topics of the lecture by groups of students

Recommended Literature

Ball, Michael; Wietschel, Martin; The Hydrogen Economy - Opportunities and Challenges; Cambridge University Press, January 2010; online ISBN: 9780511635359, DOI: https://doi.org/10.1017/CBO9780511635359

The Future of Hydrogen - Seizing todays opportunities; IEA (2019), Paris; https://www.iea.org/reports/the-future-of-hydrogen; Licence: CC BY 4.0

The Hydrogen Economy: Opportunities, Costs, Barriers and R&D Needs; National Academies Press (2004), ISBN 978-0-309-38810-8 | DOI 10.17226/10922

IRENA (2019), Hydrogen: A renewable energy perspective, International Renewable Energy Agency, Abu Dhabi; https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Sep/IRENA_Hydrogen_2019.pdf

Fuel Cell Handbook (7th Edition), EG&G Technical Services; Inc., 2004, https://www.netl.doe.gov/sites/default/files/netl-file/FCHandbook7.pdf

Minh, N., Q.; Science and Technology of Ceramic Fuel Cells; Elsevier Ltd. 1995; ISBN 978-0-444-89568-4; DOI: https://doi.org/10.1016/B978-0-444-89568-4.X5001-4

MET 1204 SIMULATION AND MODELING OF ELECTRIC TRANSPORT SYSTEMS

Objectives

In the face of global challenges such as climate change, urbanisation and resource scarcity, it is essential to find sustainable and efficient transport solutions. However, integrating these solutions into the existing infrastructure is complex and requires precise planning. The simulation and modelling of electric transport and traffic systems are essential for achieving sustainable mobility in the future. They make it possible to realistically map and optimise complex interrelationships such as energy consumption, charging infrastructure and traffic flows. This allows cities and municipalities to make well-informed decisions, such those regarding the optimal positioning of charging stations or the conversion of bus fleets to electric drives. The load on the grid caused by the simultaneous charging of many vehicles can also be simulated and optimised using intelligent control systems. Overall, simulation and modelling seem to be indispensable tools for successfully shaping the transition to a sustainable, electric transport system. They facilitate data-driven, transparent and resilient planning that meets the ecological, economic and social requirements of the future.

Professional skills

- Creation of mathematical models for electric vehicles, charging infrastructure and traffic flows
- Modelling traffic behaviour and mobility patterns
- Integration of electric vehicles into existing transport networks
- Carrying out simulations to analyse energy consumption, charging behaviour and grid load
- Interplay between vehicle technology, energy technology and transport infrastructure

Methodological skills

- Understanding of how electric transport systems, electric drives, battery models and charging infrastructure work
- Ability to model and simulate complex systems
- Awareness about the application of simulation software for analysis and optimisation
- Knowledge of evaluating energy efficiency, grid load, charging behaviour
- Acquiring skills in scenario analysis for traffic flows and infrastructure requirements
- Ability to integrate electric vehicles into existing transport networks as models

Personal skills

- Analytical thinking: understanding, analysing and evaluating complex systems.
- Problem-solving skills: developing the ability to recognise and solve technical challenges systematically.
- Independence and individual responsibility: training in how to work independently on tasks through independent research.
- Ability for practical application: handling tools, using methods and technologies

Social skills

- Teamwork: learning to collaborate effectively on group projects.
- Communication skills: acquiring the ability to present arguments for complex technical content in a comprehensible manner during discussions, for example.
- Ability to take criticism and feedback culture: giving and accepting constructive feedback, for example through discussions about possible solutions.
- Sense of responsibility: taking sustainability and social relevance into account when making technical decisions.

Application in this course and other courses

There is no technological dependency of the topics in other areas. The module provides an in-depth insight into the simulation and modelling of electric transport and traffic systems, making it suitable for use in courses featuring the areas of vehicle technology, e-mobility or charging infrastructure

Learning Content

- Basics of modelling and simulation

- Introduction to the terms model, simulation, system boundaries, parameters
- Workflow of a simulation study: problem definition, modelling, validation, simulation, evaluation
- Difference between discrete and continuous models

- Basics of scenario planning
  - Difference between prediction (quantitative, selective) and scenario (qualitative, consistent).
  - Presentation of possible future developments in the transport and traffic sector
  - Methodical steps in scenario development
- Modelling and simulation of electric vehicles
  - Modelling of the energy consumption and range
  - Consideration of driving resistances: rolling, air, climbing and acceleration resistance
  - Simulation of driving cycles (NEDC, WLTC, constant speed)
  - Influence of parameters such as vehicle weight, distance profile, auxiliary consumers
- Types of traffic models
  - Macroscopic models: viewing traffic as a continuous flow
  - Microscopic models: simulation of individual vehicles and their interactions
  - Stochastic models: incorporation of random processes for modelling uncertainties
  - Disaggregated models: detailed determination of demand based on individual decisions
- Modelling transport and traffic demand
  - Importance and objectives of traffic planning and traffic models
  - Relationship between spatial design, mobility behaviour and traffic
  - Four-stage model
- Application in electrical traffic and transport systems
  - Simulation of energy consumption, recuperation, battery management in electric vehicles

- Modelling of charging infrastructure and grid interaction
- Traffic flow simulation and traffic demand modelling

Entrance Requirements

Formal: none

Type of Examination

oral examination, part of module exam

Methods

Seminar-based lesson. In class, the course content is worked out with the participation of students and illustrated with examples. Students learn the content and methods by working on suitable exercises.

Recommended Literature

Elektromobilität im städtischen Verteilnetz Modellierung und Auswirkungen, author: Simon Kreutmayr (TUM, Dissertation 2023)

Modellierung und Simulation der Reichweite eines Elektrofahrzeugs, authors: Wolfgang Strasser & Harald Neudorfer

Energetische Simulation und Echtzeitsimulation von elektrischen Fahrzeugantrieben, author: Andreas Bernd Thanheiser (Technical University of Munich)

Modellierung und Simulation von Lastprofilen batterieelektrischer Fahrzeuge, author: Guntram Preßmair (BOKU Vienna)

Verkehrsdynamik und -simulation, authors: Martin Treiber & Arne Kesting

Einführung in die Verkehrssimulation Mikroskopische Modelle mit zellulären Automaten, author: Michael Moltenbrey

Modellierung und Simulation von Mobilität und Verkehr, author: Johannes Weyer (SpringerLink, 2025)

Agent-based simulation model for e-mobility diffusion, Education and Futures Research Division at the Freie Universität Berlin (Institut Futur)

MET 1204 FUNDAMENTALS OF ADVANCED DRIVER ASSISTANCE SYSTEMS

Objectives

Advanced Driver Assistance Systems (ADAS) are a vital component of the mobility of the future. They play a significant role in improving road safety by preventing accidents through automated warnings and interventions. At the same time, they make everyday life easier for drivers, for example with lane departure warning systems and automatic emergency braking functions. As we transition to autonomous driving, the importance and complexity of ADAS is increasing. The automotive industry as well as tech-companies are increasingly looking for specialists with expertise in sensor technology, software development and system integration. ADAS combines classic engineering skill with modern IT. The "Fundamentals of Advanced Driver Assistance Systems" module is designed to equip students with the relevant basics that enable them to build further in-depth knowledge in the skill areas of ADAS.

Professional skills

- Obtaining an overview of driver assistance systems and how they work.
- Classification of ADAS functions into the five levels of autonomous driving, based on the classification of SAE International (Society of Automotive Engineers).
- Understanding technological trends in digitised vehicles
- Acquiring background knowledge on the most common functions and their impact on road safety.
- In-depth insights into programming codes using the example of driver drowsiness detection.

Methodological skills

- Understanding the interrelationships between the technological foundations of digitised vehicles
- Understanding of various sensors (radar, lidar, camera, ultrasound)
- Understanding of system analysis and design
- Knowledge of norms and standards
- Classification of effects and impacts of Advanced Driver Assistance Systems

Personal

- Analytical thinking: understanding, analysing and evaluating complex systems.
- Problem-solving skills: developing the ability to recognise and solve technical challenges systematically.
- Independence and individual responsibility: training in how to work independently on tasks through independent research.

Social skills

- Teamwork: learning to collaborate effectively on group projects.

- Communication skills: acquiring the ability to present complex technical content in a comprehensible manner during project presentations or discussions, for example.
- Ability to take criticism and feedback culture: giving and accepting constructive feedback, for example through discussions about possible solutions.

Application in this course and other courses

There is no technological dependency of the topics in other areas. The module provides an in-depth insight into the extensive field of driver assistance systems, making it suitable for use in courses featuring the areas of autonomous vehicles or vehicle communication

Learning Content

- Basics and motivation
  - Introduction to ADAS: definition, objectives and uses
  - Historical development and future trends
  - Motivation through safety, comfort and efficiency
- System architecture and sensor technology
  - Sensors: camera, radar, lidar, ultrasound
  - Sensor fusion and environment recognition
  - Real-time systems and BUS systems in vehicles
- Communication and networking
  - Car2X communication and satellite positioning
  - Network architectures in vehicles
  - Data management and tracking
- Automation and AI
  - Levels of driving automation (SAE levels)
  - Use of artificial intelligence and machine learning
  - Electronic stability control and human-machine interaction (HMI)
- Legal and ethical aspects
  - Legal framework conditions and approval

    - Liability issues and ethical considerations
    - Differentiation from fully automated driving functions
- Practical applications and projects
    - Analysis of existing ADAS systems (e.g., collision avoidance system, lane departure warning system)

Entrance Requirements

Formal: none

Type of Examination

written ex. 90 min.

Methods

Seminar-based lesson. In class, the course content is worked out with the participation of students and illustrated with examples. Students learn the content and methods by working on suitable exercises.

Recommended Literature

Advanced Driver Assistance Systems and Autonomous Vehicles: From Fundamentals to Applications, editors: Yan Li, Hualiang Shi, publishing house: Springer (2022)

Handbuch Fahrerassistenzsysteme: Grundlagen, Komponenten und Systeme für aktive Sicherheit und Komfort, editors: Hermann Winner, Stephan Hakuli, Felix Lotz, Christina Singer, publishing house: Springer Vieweg

ADAS and Automated Driving Systems Engineering, author: Plato Pathrose

Advanced Driving Assistance Systems IJETA Journal (2024), https://www.ijetajournal.org/volume-11/issue-3/IJETA-V11I3P45.pdf

Impact Analysis of ADAS Regarding Road Safety European Transport Research Review (2024), https://etrr.springeropen.com/counter/pdf/10.1186/s12544-024-00654-0.pdf

MET-05 SPECIAL MATHEMATICAL METHODS

Module code	MET-05
Module coordination	Prof. Dr. Johann Plankl
Course number and name	MET 2101 Special mathematical Methods
Lecturer	Prof. Dr. Johann Plankl
Semester	2
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	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.
Weighting of the grade	5/90
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 Funktion (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.

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

Module code	MET-06
Module coordination	Prof. Dr. Werner Bogner
Course number and name	MET 3101 Selected Topics in Business Administration and Human Resource Management
Lecturers	Jürgen Hoffmann NN ET
Semester	3
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	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.
Weighting of the grade	5/90
Language of Instruction	English
Lecturer	Hoffmann, Jürgen

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. Human Resources Management
    - 1.1. Recruiting
    - 1.2. Personnel selection
    - 1.3. Employee compensation
    - 1.4. Employment contracts - mutual rights and obligations
    - 1.5. 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 financial accounting
    - 5.2. Principles of cost accounting

Teaching Methods

Lectures with lecture notes, handouts, exercises, case studies

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.

Thuis, P: Business Administration, 1. Edition, Wolters-Noordhoff B.V., Amsterdam 2014

Derek Torrington et.al. Human Resources Management, 11th Edition, Pearson Education Limited, London 2020

Andrew Thomas, Anne Amrie Ward, Introduction to Financial Accounting, 9th Edition, McGraw-Hill Education (UK) London 2019

MET-07 MASTERMODUL

Module code	MET-07
Module coordination	Prof. Dr. Werner Bogner
Course number and name	MET 3102 Masterseminar MET 3103 Master Thesis
Lecturer	Prof. Dr. Jens Ebbecke
Semester	3
Duration of the module	1 semester
Module frequency	each semester
Course type	required course
Level	postgraduate
Semester periods per week (SWS)	2
ECTS	25
Workload	Time of attendance: 30 hours self-study: 720 hours Total: 750 hours
Weighting of the grade	25/90
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 Mastermodule:

Professional Skills
The students are able to familiarize themselves with technical / economic tasks and to independently analyze 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.

MET 3102 MASTERSEMINAR

Objectives

The Masterseminar 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.
The Masterseminar is taken place in parallel to the Master Thesis: Your Registration of the Master's thesis must be completed, at least half of the Master's thesis should have been completed at the time of the Masterseminar presentation.

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

Seminaristic 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.

MET 3103 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.

MET-08 SELECTED TOPICS IN OPTOELECTRONICS AND LASER TECHNOLOGY

Module code	MET-08
Module coordination	Prof. Dr. Franz Daiminger
	Elektronische und nachrichtentechnische Systeme (ENS)
Course number and name	MET 1105 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
Level	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.
Weighting of the grade	5/90
Language of Instruction	English

Module Objective

The students gain the following educational goals:

Prossional 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 tehy 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 themself 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.

MET-09 SELECTED TOPICS IN MIRCRO- AND NANOELECTRONICS

Module code	MET-09
Module coordination	Prof. Dr. Günther Benstetter
	Elektronische und nachrichtentechnische Systeme (ENS)
Course number and name	MET 2102 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
Level	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.
Weighting of the grade	5/90
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 & simulations, visualizer/ beamer

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.

MET-10 MODERN RF AND RADIO SYSTEMS

Module code	MET-10
Module coordination	Prof. Jörg von Mankowski
	Elektronische und nachrichtentechnische Systeme (ENS)
Course number and name	ET 2103 Modern RF and Radio Systems
Lecturer	N.N.
Semester	2
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	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.
Weighting of the grade	5/90
Language of Instruction	English

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

MET-11 SPECIAL DEVICES AND CIRCUITS

Module code	MET-11
Module coordination	Prof. Dr. Werner Bogner
	Elektronische und nachrichtentechnische Systeme (ENS)
Course number and name	MET 2104 Special Devices and Circuits
Lecturer	Prof. Dr. Werner Bogner
Semester	2
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	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.
Weighting of the grade	5/90
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 analog 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 analyze 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 analog 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 behavior

3.3. Second order effects

3.4. Electrical behavior 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 Modeling

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

Seminar based teaching, simulation examples, exercises

Remarks

Support by the e-learning platform

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 2012.

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

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

MET-12 SIGNALS AND SYSTEMS IN COMMUNICATION TECHNOLOGY

Module code	MET-12
Module coordination	Prof. Jörg von Mankowski
	Elektronische und nachrichtentechnische Systeme (ENS)
Course number and name	MET 2105 Signals and Systems in Communication Technology
Lecturers	N.N. Prof. Jörg von Mankowski
Semester	2
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	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.
Weighting of the grade	5/90
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 behavior of LTI systems in time and frequency domain. The last part of the module introduces the basics of analyzing random signals in time and frequency domain, as well as how to describe and determine the transmission behavior 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 behavior 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 behavior 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 behavior 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 behavior 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

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 behavior of LTI systems in time domain

   3.3. Signal transmission behavior 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

MET-13 ADVANCED MODELLING AND SIMULATION

Module code	MET-13
Module coordination	Prof. Dr. Mathias Hartmann
	Automatisierungstechnik (AT)
Course number and name	MET 1106 Advanced Modelling and Simulation
Lecturer	Prof. Dr. Mathias Hartmann
Semester	1
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	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 examination
Weighting of the grade	5/90
Language of Instruction	English

Module Objective

The digital transformation of industrial processes relies heavily on the availability of suitable models. These models are used in virtual product development, in the digitalization of plant operation and maintenance, but also in the virtual description of processes, e.g. in control systems or material flows. The focus of this course is therefore on the modelling of technical systems as a basis for system simulation.

The content of the "Advanced Modelling and Simulation" module enables students to select and design models of technical systems and processes for different applications. The technical and methodological skills described below are taught for this purpose.

After completing the Advanced Modelling and Simulation module, students will be able to

- model technical systems using simple balancing approaches.
- solve the system equations by application of appropriate numerical methods
- select the required methods from the methods learned for experimental modelling and incorporate them into a modelling process.
- apply methods for the experimental generation of models of dynamic systems analyze the model results in a targeted manner.

- assign and use the generated models to simulation tools in a suitable manner.

In the module Advanced Modelling and Simulation, the following competences are to be taught:

Professional competence:

- Understanding and applying methods of experimental modelling of dynamic systems.
- Consolidation (synthesis) of the model-building methods to complex overall models.
- Understanding different approaches to the design of simulation systems.

Methodological competence:

- Application of state machines for the modelling of technical systems.
- Verification (evaluation) of modelling results.
- Application of generated models in suitable simulation systems.
- Assessment of the suitability of models for the phases of a product development process.

Personal competence:

- Solution of complex modelling and simulation tasks.

Social competence:

- The students are able to look at the problems from different perspectives and to use their competences acquired in the module situation appropriately in individual and group discussions.

Applicability in this and other Programs

For this degree program:

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

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

I Mathematical Models of Physical Systems

- Differential Equations of Physical Systems
- Linear Approximation of Non Linear System Equations
- Block diagrams
- State Space Models of Linear Systems
- Discrete Time Systems

II Modeling of physical systems in the time domain

- Mechanical systems
- Electrical systems
- Electro-Mechanical systems
- Lagrange formalism

III Parameter Estimation

- The Steepest Descend Method
- Quasi Newton approaches

Teaching Methods

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

Remarks

Tutorial

E-learning plattform

Recommended Literature

Robert L. Woods, Kent L. Lawrence: Modeling and Simulation of Dynamic Systems. Prentice Hall, 1997

Isermann R.: Identification of dynamic systems. Springer-Verlag, 2011.

Ljung L., Glad T.: Modeling of dynamic systems. Prentice Hall, 1994

Ake Björck, Germund Dahlquist. Numerical methods. Dover Publications. 1974

MET-14 SELECTED TOPICS IN CONTROL ENGINEERING

Module code	MET-14
Module coordination	Prof. Dr. Nikolaus Müller
	Automatisierungstechnik (AT)
Course number and name	MET 2106 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
Level	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.
Weighting of the grade	5/90
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 engineering (AT)

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.

MET-15 SPECIAL TOPICS OF CONTACTLESS SENSOR SYSTEMS

Module code	MET-15
Module coordination	Prof. Dr. Simon Zabler
	Automatisierungstechnik (AT)
Course number and name	MET 2107 Special Topics of Contactless Sensor Systems
Lecturer	Prof. Dr. Simon Zabler
Semester	2
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	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.
Weighting of the grade	5/90
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 engineering (AT)

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 preprocessing)

Basics of sensor principles using electromagnetic radiation transfer (e.g. time of flight measurement, thicknesss 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 preprocessing 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.

MET-16 AUTOMOTIVE AND INDUSTRIAL DRIVE SYSTEMS

Module code	MET-16
Module coordination	Prof. Dr. Nikolaus Müller
	Automatisierungstechnik (AT)
Course number and name	MET 2108 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
Level	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.
Weighting of the grade	5/90
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 behavior

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 analyze 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 behavior 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 engineering (AT)

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. Fual-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. Industiral 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

MET-17 ADVANCED AUTOMATION

Module code	MET-17
Module coordination	Prof. Dr. Terezia Toth
	Automatisierungstechnik (AT)
Course number and name	MET 2109 Advanced Automation
Lecturers	Martin Fischer Prof. Dr. Terezia Toth
Semester	2
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	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.
Weighting of the grade	5/90
Language of Instruction	English

Module Objective

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. Thusthe 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 analyze, 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.

Applicability in this and other Programs

For this degree program:

Compulsory subject within Master-Program Electrical Engineering and Information Technology, key focus automation (AT)

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 of automation

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 comunication systems

Teaching Methods

Seminars with practical experience

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