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HOCHSCHULE DARMSTADT
UNIVERSITY OF APPLIED SCIENCES

fbeit
FACHBEREICH ELEKTROTECHNIK
UND INFORMATIONSTECHNIK

Anlage 5

Modulhandbuch des Studiengangs

Module handbook of the study programme

Electrical Engineering and Information Technology - international

Master of Science

des Fachbereichs Elektrotechnik und Informationstechnik
/ Department Electrical Engineering and Information Technology
der Hochschule Darmstadt – University of Applied Sciences

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Contents

Preamble for the module handbook

Definition of competence levels for entering the goals (point 3)

This module handbook uses competence level to design the description of goals (point 3) in a concise and transparent manner. The competence levels indicate the level of in-depth content conveyed, i.e. knowledge (theory and/or factual knowledge) and skills (the practical and/or cognitive application of methods, processes and procedures) and to what extent the students should be able to use this knowledge or these skills at work and in everyday life. Depending on the classification of the content in point 2, one of the competence levels of to know, to understand, to apply and to transfer are specified in point 3 as the learning and qualification goal for the main topics and, where applicable, for their sub-topics. If it makes sense, a level should also be stated for competences and skills implicitly arising from the content. For topics/competencies/skills which are dealt with in several successive modules, a higher qualification level can be achieved in the course of the degree program. If, for example, a topic in a module which is specified as a (recommended) prerequisite (point 7 or 8) is given the competence level to know, and if the topic is covered again in a later module, the competence level for this topic can be set to to understand. Using the competence levels, a differentiation between the Bachelor and Master level can be made clearer, e.g.:

Bachelor's degree program: For most topics in the basic study program, the levels to know and to understand are strived for. For topics which are dealt with again in the major, the next level up –to understand or to apply–can be strived for.

Master's degree program: Topics where prior knowledge from the previous Bachelor's degree program is required, can have the competence level of to apply or to transfer.

The competence levels also offer a specific basis for the competence-orientated recognition of credit points, as well as proven extracurricular competencies, for the modules of the degree program.

Competence level	Definition	Definition of work	Time required*
Lowest **to know**	Reproduction and allocation of terms, processes, structures and conventions from the subject area	The students have already heard something about the topic and can allocate the topic to the right subject area. They can only apply methods to solve problems relating to this topic in a repetitive manner to known problems. They are not able to transfer any knowledge.	1 – 3 1 to 2 blocks
Third highest **to understand**	Reproducible solving of equivalent or similar problems; confident handling of conventions and terms	The students can recognize standard problems relating to the topic and solve them by the confident application of methods. They are able to transfer knowledge if it concerns a very similar problem.	> 3 – 7 3 to 5 blocks
Second highest **to apply**	Solving specific problems from the whole subject area; inversion of problems; forming of analogies	The students can solve problems from the subject area which they are not familiar with. For this purpose, they can independently combine and modify the methods they have learned. They are able to transfer knowledge.	> 7 – 12 6 to 8 blocks
Highest **to transfer**	Solving general technical problems with the aid of knowledge gained; routine application and critical evaluation of knowledge, processes and methods	Students can develop solutions for technical problems, not restricted to the subject area, using the knowledge acquired and the methods and processes learned in the subject area. They are able to develop and implement solutions in a team.	> 12 – 25 9 to 19 blocks

* Number of hours required to achieve the competence level (reference)

Table 1: Definition of the competence levels to describe the learning and qualification goals (point 3)

The table contains the definitions of the competence levels. The levels and their definitions are based on an investigation to determine the core curriculum of electrical engineering, performed by the EIT Faculty Conference. The definitions of the competence levels have been made more specific for application in the module handbook (work definition).The final column states the time period in which the respective topic must be dealt with in the lessons (time required) to achieve the respective level. These values are taken from the same source as the competence levels and should be used as references.

In some modules, like the Master module, the existing classification methods are not applied, as, for example, no specific content can be provided. For these modules, the goals are specified according to the classification: knowledge, skills, competencies.

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Common Modules

M01 Technical Management

1	**Module Name** Technical Management
1.1	**Module Identifier** M01
1.2	**Module Type** Mandatory
1.3	**Course Names** Project Management - Lecture Engineering Responsibility - Lecture
1.4	**Semester** 1 or 2 (winter term)
1.5	**Module Responsible and Instructor** Prof. Dr. Fromm
1.6	**Additional Instructors** Prof. Dr. Haid, NN SuK
1.7	**Study Program** Master / all majors
1.8	**Teaching Language** English
2	**Module Content** <u>Content of course "Project Management"</u> This course provides an introduction to professional project management. It covers the areas - introduction into industry process models, e.g. CMMi and SPICE, - project structure, phases, roles and workflow, - relevant methods for requirements engineering, concept development, realization and testing - planning and estimation methods, - risk management, - project tracking metrics, - team building and team management, - change and configuration management, - quality assurance and reviews, - agile methods like SCRUM.

	<u>Content of course “Engineering Responsibility”</u> This course provides an introduction into legal aspects of engineering and discusses the aspect of engineering responsibility. It covers the areas - legal and ethical aspects of engineering responsibility - relevance of penal law, civil law and liability - patent rights - employment law - special liability for safety and security systems - relevant differences in German, European and international laws
3	**Learning Outcome / Competencies** **to understand:** - the most relevant laws related to engineering, such as o Intellectual Property rights (copyrightable and patentable subject matter, infringement of IP rights) o Contract, labor and data privacy law o Liability and warranty (including product liability, torts, misdemeanors and crimes, breach of contract) - the differences in German, European and international laws **to apply:** - industrial engineering and management processes - modern methods of project management - planning and estimation techniques - risk management techniques - configuration and change management techniques - quality assurance methods like reviews - professional team communication techniques - rules of law to product management **to transfer:** - the project management techniques into new project scenarios - legal awareness into product development and utility scenarios
4	**Course Organization and Structure** lecture (V) / seminar (S)
5	**Credits and Workload** 5 CP / 150 hours in total, including 56 hours classroom teaching. Project Management: 2 SWS V Engineering Responsibility: 2 SWS V
6	**Examination Modalities** **Examination Prerequisites:** none **Examination Type:** Written exam covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** 90 minutes

7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** None
9	**Duration and Frequency of Course** This module takes one semester and is offered once a year (see appendix 1 BBPO)
10	**Applicability /Utilization** This module is applicable for all majors.
11	**Literature** The following literature material will be provided: - Electronic lecture notes Further literature recommendations will be provided during the lecture.

M02 Team Project

1	**Module Name** Team Project
1.1	**Module Identifier** M02
1.2	**Module Type** Mandatory
1.3	**Course Names** Team Project - Project
1.4	**Semester** 1 or 2 (summer term)
1.5	**Module Responsible and Instructor** Prof. Dr. Fromm
1.6	**Additional Instructors** All instructors of the master's program
1.7	**Study Program** Master / all majors
1.8	**Teaching Language** English
2	**Module Content** **Content of course "Team Project"** In this course, the students execute a practical project using the methods presented in the module "Technical Management". It covers the areas: - practical development of a technical system (project work) - project management and work package agreement, - requirements engineering, system design, - implementation and testing, - team building and team communication, - and documentation and presentation of the results.
3	**Learning Outcome / Competencies** **to understand:** - project roles, phases and workflows **to apply:** - workpackage definition and assignment - modern methods of project management and engineering

	- professional team communication techniques - project presentation **to transfer:** - the project management and engineering techniques into new project scenarios
4	**Course Organization and Structure** Project
5	**Credits and Workload** 5 CP / 150 hours in total, project work including meetings with the instructors.
6	**Examination Modalities** The examination consists of the project work and the project presentation. As a consequence, a withdrawal from the project is only possible once within the first 2 weeks of the project. A later withdrawal will be marked as "not passed". For details, please check § 13 para. 5 BBPO. **Examination Prerequisites:** Successful fulfillment of prerequisites are measured by: - Attending Project - Project Progress **Examination Type:** - Project presentation and Report - Milestone review **Examination Duration:** Project presentation 30 minutes
7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** None
9	**Duration and Frequency of Course** This module takes one semester and is offered once a year (see appendix 1 BBPO).
10	**Applicability /Utilization** This module is applicable for all majors.
11	**Literature** Literature recommendations will be provided during the project.

M03 Internship

1	**Module Name** Internship
1.1	**Module Identifier** M03
1.2	**Module Type** Mandatory / 4 semester course
1.3	**Course Names** German Class 1 and 2 – Lecture Preliminary Seminar – Seminar Internship
1.4	**Semester** - German classes are offered during winter semester (extensive phase). Additional intensive courses will be offered in the month September and February/March (intensive phase). - The internship generally takes place in the third semester of the 4 semester course. The internship is offered in both winter and summer semester.
1.5	**Module Responsible and Instructor** Prof. Dr. Krauß, Head of the „Sprachenzentrum" (FB GW)
1.6	**Additional Instructors** All instructors of the master's program can act as academic supervisor for the internship part. instructors of the „Sprachenzentrum"
1.7	**Study Program** Master / all majors
1.8	**Teaching Language** English
2	**Module Content** **Content of German Class:** - German Class 1: A1 level or higher - German Class 2: higher than German Class 1 level, at least A2 level **Content of Preliminary Seminar:** - Preparative items (such as regulations and application matters) are presented. **Content of Internship:** The student has to solve an engineering task in the area of electrical engineering and information technology under the guidance of an industrial supervisor and an academic supervisor. This internship work can involve one of the following areas:

	- Research and development work - Project planning and design - Manufacturing, preparation of work - Assembly - Test bed, quality control
3	**Learning Outcome / Competencies** The objectives of the internship are as follows: - Create a linkage between the studies and the world of work - Orientation in the profession strived for - Get to know technical and organizational contexts - Involvement in the process of work - Practical training in the engineering trade in one or several projects.
4	**Course Organization and Structure** Lecture, seminar, practical work by fulfilling tasks of engineering work and documentation
5	**Credits and Workload** 30 CP / 900 hours in total - German class 1 and 2: 6 SWS in total, 84 hours classroom teaching in total. Additional intensive preparation courses will be offered during semester breaks. - Internship: 26 weeks full-time work in a company
6	**Examination Modalities** **German Classes** **Examination Prerequisites (German Class 2):** German Class 1 has been successfully passed. **Examination type**: A combined written and oral examination will be offered in each class. **Internship** **Examination Prerequisites:** The Preliminary Seminar must have been attended and at least German Class 1 (level A1 or higher) must have been successfully passed before the start of the internship. **Examination Type:** Students must prepare a technical report on their internship work with a range of 30 to 40 pages. The report shall be submitted to the academic supervisor at the latest 2 weeks after the work has ended (and otherwise at the latest before the master thesis starts). The report will be assessed and evaluated by the academic supervisor. The successful completion of the internship part is acknowledged by the academic supervisor, provided that the prerequisites defined in § 10 para. 4 are fulfilled.
7	**Necessary Prerequisites** The necessary prerequisites are defined in § 10 para. 2 BBPO
8	**Recommended Prerequisites** A total of 45 CP is recommend to be completed before the start of the internship work.

9	**Duration and Frequency of Course** The internship module consists of the internship part (practical work) itself and preparatory lectures. The internship part lasts 26 weeks. It may be undertaken any time.
10	**Applicability /Utilization** The module provides the prerequisites for the Master thesis. It is applicable for all majors.
11	**Literature** ---

M04 Master Module

1	**Module Name** Master Module
1.1	**Module Identifier** M04
1.2	**Module Type** Mandatory
1.3	**Course Names** Thesis Colloquium
1.4	**Semester** 3 semester course: 3 (winter term) 4 semester course: 4 (summer term)
1.5	**Module Responsible and Instructor** Head of the examination board
1.6	**Additional Instructors** All instructors of the master's program
1.7	**Study Program** Master / all majors
1.8	**Teaching Language** N/A
2	**Module Content** - Practically and/or theoretically oriented scientific work in the area of the chosen major - Written thesis - Colloquium
3	**Learning Outcome / Competencies** Students should demonstrate the following qualifications within the area of the defined topic: - Capability of independent work - Systematic analysis and solutions using engineering and scientific methods - Professional competence in scientific documentation and presentation of results
4	**Course Organization and Structure** final thesis (FT)

5	**Credits and Workload** 30 CP / 900 hours in total.
6	**Examination Modalities** **Examination type:** Master thesis under § 12 para. 4 and 5 BBPO Colloquium under § 12 para. 6 and 7 BBPO The assessment ratio of thesis and colloquium are defined in § 12 para. 8 BBPO.
7	**Necessary Prerequisites** The necessary prerequisites are defined in § 12 para. 3 BBPO.
8	**Recommended Prerequisites** All mandatory modules of study program
9	**Duration and Frequency of Course** The master thesis must not exceed 6 months. With the approval of the examination board, the master thesis may be undertaken at any time.
10	**Applicability /Utilization** This module is applicable for all majors.
11	**Literature** Will be recommended by supervisors.

MWP01 Elective 1

MWP02 Elective 2

MWP03 Elective 3

1	**Module Name** Elective 1 Elective 2 Elective 3
1.1	**Module Identifier** Major „Automation": MAWP01, MAWP02, MAWP03 Major „Communications": MCWP01, MCWP02, MCWP03 Major „Embedded and Microelectronics": MMWP01, MMWP02, MMWP03 Major „Power Engineering": MPWP01, MPWP02, MPWP03
1.2	**Module Type** Elective
1.3	**Course Names** Students have to choose at least 15 CP from the catalogue of their own major. The catalogues contain major specific subjects as well as subjects from other majors which are suitable for the certain major Major „Automation": MAwp Major „Communications": MCwp Major „Embedded and Microelectronics": MMwp Major „Power Engineering": MPwp For general rules regarding electives please check § 9 BBPO. To get an overview of the catalogues contents see appendix 2 BBPO. Descriptions of the elective subjects are included in this handbook (appendix 5 BBPO).
1.4	**Semester** summer term and winter term (see appendix 1 BBPO Study program)
1.5	**Module Responsible and Instructor** see descriptions of the elective subjects
1.6	**Additional Instructor** see descriptions of the elective subjects
1.7	**Study Program** Master / all majors
1.8	**Teaching Language** see descriptions of the elective subjects

2	**Module Content** see descriptions of the elective subjects
3	**Learning Outcome / Competencies** see descriptions of the elective subjects
4	**Course Organization and Structure** check descriptions of the elective subjects
5	**Credits and Workload** each module (Elective 1 to 3): 5 CP / 150 hours in total see descriptions of the elective subjects for the number of hours classroom teaching (SWS)
6	**Examination Modalities** see descriptions of the elective subjects
7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** see descriptions of the elective subjects
9	**Duration and Frequency of Course** Each elective subject will take one semester and may be offered once a year, but the department is not liable to offer all of them. A list of elective subjects will be published at the beginning of each semester.
10	**Applicability /Utilization** see descriptions of the elective subjects
11	**Literature** see descriptions of the elective subjects

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Common Elective Modules (general electives)

MGwp01 Research Project

1	**Module Name** Research Project
1.1	**Module Identifier** MGwp01
1.2	**Module Type** Elective
1.3	**Course Names** Research Project
1.4	**Semester** summer term or winter term
1.5	**Module Responsible and Instructor** Prof. Peter Fromm
1.6	**Additional Instructor** All instructors of the master's program
1.7	**Study Program** Master / all majors
1.8	**Teaching Language** English
2	**Module Content** In this course, the students execute a research focused project at the university. It covers the areas: - Introduction to research methodologies - Work on state of the art research questions - Development of a research strategy - Execution of the research work - Presentation of the results
3	**Learning Outcome / Competencies** **to understand:** - state of the art research topics **to apply:** - research methodology - professional team communication techniques - project presentation **to transfer:** - research techniques into new project scenarios

4	**Course Organization and Structure** Project
5	**Credits and Workload** 2,5 CP / 75 hours in total
6	**Examination Modalities** The examination consists of the project work and the project presentation. As a consequence, a withdrawal from the project is only possible once within the first 2 weeks of the project. A later withdrawal will be marked as "not passed". For details, please check § 13 para. 5 BBPO. **Examination Prerequisites:** Successful fulfillment of prerequisites are measured by: - Attending Project - Project Progress **Examination Type:** - Project presentation and Report - Milestone review **Examination Duration:** Project presentation 30 minutes
7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** None
9	**Duration and Frequency of Course** The elective will be offered based on availability of topics.
10	**Applicability /Utilization** All majors
11	**Literature** Project specific

MGwp02 Selected Research Topics

1	**Module Name** Selected Research Topics
1.1	**Module Identifier** MGwp02
1.2	**Module Type** Elective
1.3	**Course Names** Selected Research Topics
1.4	**Semester** summer term or winter term
1.5	**Module Responsible and Instructor** NN
1.6	**Additional Instructor** All instructors of the master's program
1.7	**Study Program** Master / all majors
1.8	**Teaching Language** English
2	**Module Content** In this course, the students will be introduced to selected state of the art research topics in the following areas - Automation, robotics, factory automation and (I)IoT - Communication systems and technologies, signal processing - Embedded systems, hardware and software engineering, SOC and FPGA development - Power generation and distribution, advanced control systems, e-mobility - Other topics upon availability
3	**Learning Outcome / Competencies** **to understand:** - Research methodologies **to apply:** - Working with literature and other information sources - Scientific writing skills - Scientific presentation skills and discussions

	to transfer: - The gained knowledge to own research work, e.g. master thesis
4	**Course Organization and Structure** lecture (V) 2 SWS V
5	**Credits and Workload** 2,5 CP / 75 hours in total
6	**Examination Modalities** **Examination Prerequisites:** - none **Examination Type:** - Scientific report and presentation followed by an oral colloquium **Examination Duration:** 45 min
7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** None
9	**Duration and Frequency of Course** see module description of Elective 1 to 3 (MWP01, MWP02, MWP03) The elective will be offered based on availability of topics.
10	**Applicability /Utilization** All majors
11	**Literature** Topic specific

MGwp03 Ethics, Engineering, and Ecology

1	**Module Name** Engineering Ethics
1.1	**Module Identifier** MGwp03
1.2	**Module Type** Elective
1.3	**Course Names** Ethics, Engineering, and Ecology
1.4	**Semester** summer term or winter term
1.5	**Module Responsible and Instructor** Prof. Dr. Bernd Steffensen (Dep. Social Sciences)
1.6	**Additional Instructor** ---
1.7	**Study Program** Master / all majors
1.8	**Teaching Language** English
2	**Module Content** This course provides an introduction to the topic of ethics in engineering with a special focus on challenges provide by ecological requirements. Future developments and the well-being of the world society will dependent on technical solutions. The development and the application of technical artifacts has numerous impacts beyond pure functioning. Therefore the course will cover the areas: - Why engineering ethics? - Engineering and Responsibility - A Matter of Moral - Individual Moral and the Organizational Context - Honesty, Integrity, and Reliability - Safety, Risk, and Liability - Solving Ethical Problems - Engineering and Environment - Ethics, Competing Values, and Stakeholders - Professionalism

3	**Learning Outcome / Competencies** **to understand:** - the importance of ethics in engineering - the basic philosophical concepts of an applied ethic - the competing, nevertheless, appropriate values of various stakeholder in society - the future impact of Sustainable Development Goals (SDGs) and environmental concerns for engineering in general and firms in particular. **to apply:** - theories and methods to identify ethical issues in real world situations. - theories and methods to develop an individual position and to argue accordingly **to transfer:** - ethical reasoning to various contexts in the workplace and the fields of individual engagement in the civil society.
4	**Course Organization and Structure** seminar (S)
5	**Credits and Workload** 2,5 CP / 75 hours, including 28 hours (20 hours on a weekly base, 8 hours as a block course on a single day) 2 SWS seminar
6	**Examination Modalities** **Examination Prerequisites:** - none **Examination Type:** - Written exam covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** - 90min
7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** None
9	**Duration and Frequency of Course** see module description of Elective 1 to 3 (MWP01, MWP02, MWP03)
10	**Applicability /Utilization** All majors

11	**Literature**
	The following literature material will be provided: - Harris, Ch.E., Jr./Pritchard, M.S./James, R.W./Englehardt, E.E./Rabins, M.J. (2019): Engineering Ethics, Concepts and Cases, Cengage, Boston On the learning platform operated by the Hochschule Darmstadt, an updated course is created for each semester, in which literature references are given and the necessary material is provided as far as possible.

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Major Automation - mandatory

MA01 Safety in Industrial Automation

1	**Module Name** Safety in Industrial Automation
1.1	**Module Identifier** MA01
1.2	**Module Type** Mandatory
1.3	**Course Names** Safety in Industrial Automation – Lecture Safety in Industrial Automation - Lab
1.4	**Semester** 1 or 2 (winter term)
1.5	**Module Responsible and Instructor** Prof. Dr.. Simons
1.6	**Additional Instructors** ---
1.7	**Study Program** Master / Major Automation
1.8	**Teaching Language** English
2	**Module Content** **Content of course "Safety in Industrial Automation - Lecture":** Participants will be exposed to and gain working experience to design, implement, verify and validate safe systems in industrial automation. The course will cover - Introduction to safety systems in industrial automation - Basic terminology and standards concerning safety in industrial automation - Design of safe control systems - Measures to achieve safe processes and safe products incl. overview of safety devices - Development of safety related software using safety PLCs: configuration & programming of safety PLCs - Verification & validation of safety measures in accordance to a standard, e.g. EN ISO 13849 **Content of course "Safety in Industrial Automation - Lab":** Practical design and programming of safety programs using safety PLCs and practical verification of safety in accordance to a standard are part of this course: - Hardware configuration of safety PLCs

	- Design, implementation, testing and debugging of a safety program using a safety PLC - Calculating the safety level required, e.g. performance level required in accordance to EN ISO 13849 - Verification of safety systems e.g. by calculating the performance level achieved in accordance to EN ISO 13849
3	**Learning Outcome / Competencies** **to understand:** - the basics of safety in industrial automation - the basic standards and the terminology for safe systems in industrial automation - the different concepts to achieve safe systems - the structure of safety systems - the verification and validation process for safe systems **to apply the gained knowledge:** - to design safe control systems, i.e. to design the safety concept, to select meaningful safety devices, to implement the hardware of the system including where to place the safety devices and the electrical connection - to develop safety related software using safety PLCs including the hardware configuration, the programming, the testing and the debugging - to verify and validate safe systems in industrial automation in accordance to a standard, e.g. EN ISO 13849 **to transfer:** - the acquired knowledge to create, verify and validate safe systems in industrial automation.
4	**Course Organization and Structure** lecture (V) / laboratory (L)
5	**Credits and Workload** 5 CP / 150 hours in total, including 56 hours classroom teaching and lab. 3 SWS V / 0,5 (1) SWS L
6	**Examination Modalities** **Examination Prerequisites:** In order to participate in the module exam, it is required to successfully finish the lab part of the module. Successful fulfillment of prerequisites are measured by: - Attending Lab - Lab Progress **Examination Type:** Written exam covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** 90 minutes.
7	**Necessary Prerequisites** Participation in the preliminary course if no programming knowledge of Siemens S7 PLCs is available.
8	**Recommended Prerequisites** None

9	**Duration and Frequency of Course** This module takes one semester and is offered once a year (see appendix 1 BBPO).
10	**Applicability /Utilization** This module is applicable for the major Automation.
11	**Literature** The following literature material will be provided: - Electronic lecture notes (excerpt of slides) - Workbook for the lab Further literature recommendations will be provided during the lecture.

MA02 Adaptive Control, Modeling and Identification

1	**Module Name** Adaptive Control, Modeling, and Identification
1.1	**Module Identifier** MA02
1.2	**Module Type** Mandatory
1.3	**Course Names** Adaptive Control, Modeling, and Identification – Lecture Adaptive Control, Modeling, and Identification – Lab
1.4	**Semester** 1 or 2 (winter term)
1.5	**Module Responsible and Instructor** Prof. Dr. Kleinmann
1.6	**Additional Instructors** Prof. Dr. Weigl-Seitz
1.7	**Study Program** Master / Major Automation
1.8	**Teaching Language** English
2	**Module Content** The course covers the areas: - Introduction to and classification of Adaptive Control Systems - Adaptation of Optimal Controllers and Controller Design by Pole Placement - Dynamic Behavior of Adaptive Control Loops and Configuration Issues - Modeling of Linear and Non-linear Time-invariant and -variant Dynamic Systems - Algorithms and Filters for Online Process Identification - Neural Networks as Memory Blocks for Controller and Process Model in Learning Control Loops - Computer based applications using Matlab/Simulink
3	**Learning Outcome / Competencies** **to understand:** - the basic applications, concepts, components and challenges of adaptive control loops - the basic principles for modeling and identification of complex dynamic systems

	to apply the knowledge: - to classify a control application and select an appropriate approach for adaptive control - to know the advantages and disadvantages of modeling and identification algorithms and structures - to implement and simulate the components of an adaptive control loop **to transfer:** - the design process of adaptive control systems to problems from various domains in automation
4	**Course Organization and Structure** Lecture (V) / Laboratory (L)
5	**Credits and Workload** 5 CP / 150 hours in total, including 56 hours classroom teaching and lab. 3 SWS V and 0,5 (1) SWS L
6	**Examination Modalities** **Examination Prerequisites:** In order to participate in the module exam, it is required to successfully finish the lab part of the module. Successful fulfillment of prerequisites are measured by: • Attending Lab • Lab Progress **Examination Type:** Written exam covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** 90 minutes.
7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** None
9	**Duration and Frequency of Course** This module takes one semester and is offered once a year (see appendix 1 BBPO).
10	**Applicability /Utilization** This module is applicable for the major Automation and for the major embedded systems and microelectronics.

11	**Literature** The following literature material will be provided: - Electronic Script (excerpt of slides) - Workbook for the lab Further literature recommendations will be provided during the lecture.

MA03 Computer Vision

1	**Module Name** Computer Vision
1.1	**Module Identifier** MA03
1.2	**Module Type** Mandatory
1.3	**Course Names** Computer Vision Computer Vision Lab
1.4	**Semester** 1 or 2 (winter term)
1.5	**Module Responsible and Instructor** Prof. Dr. Neser
1.6	**Additional Instructors** Prof. Dr. Neubecker
1.7	**Study Program** Master / Major Automation
1.8	**Teaching Language** English
2	**Module Content** - Image Sensors - Image formation and digital images - 3D Sensors and point clouds - Image enhancement - Object recognition techniques - Pattern classification - Camera calibration - Stereo vision techniques and algorithms - Case studies of selected imaging solutions for Automation, Robotics and Industrial Image Processing

	Learning Outcome / Competencies **to understand:** - the mathematical and theoretical foundations of image processing and computer vision - the basic components and working principles of 2D- and 3D-Machine Vision Systems - the difference between image and point cloud based approaches to vision problems and their areas of application. - the uses and limitations of computer vision through practical case studies **to apply the knowledge:** - to know the advantages and disadvantages of different imaging sensors - to select appropriate hardware components for a given imaging scenario - to identify a suitable chain of algorithms for a given imaging problems **to transfer:** - the knowledge acquired in the lectures to new vision problems in Robotics, Automation and Production.
	Course Organization and Structure lecture (V) / laboratory (L)
5	**Credits and Workload** 5 CP / 150 hours in total, including 56 hours classroom teaching and lab. 3 SWS V and 0,5 (1) SWS L
6	**Examination Modalities** **Examination Prerequisites:** In order to participate in the module exam, it is required to successfully finish the lab part of the module. Successful fulfillment of prerequisites are measured by: • Attending Lab • Lab Progress **Examination Type:** Written exam covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** 90 minutes.
7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** Linear Algebra, Matlab
9	**Duration and Frequency of Course** This module takes one semester and is offered once a year (see appendix 1 BBPO).

10	**Applicability /Utilization** This module is applicable for the major Automation and for the major Embedded Systems and Microelectronics.
11	**Literature** - Hartley, Zissermann: Multiple View Geometry - Steeger Ulrich Widemann: Machine Vision Algorithms and Applications - Burger, Burge: Digital Image Processing Further literature recommendations will be provided during the lecture.

MA04 Advanced Programming Techniques

1	**Module Name** Advanced Programming Techniques
1.1	**Module Identifier** MM01 / MA04
1.2	**Module Type** Mandatory
1.3	**Course Names** Advanced programming Techniques - Lecture Advanced programming Techniques - Lab
1.4	**Semester** 1 or 2 (winter term)
1.5	**Module Responsible and Instructor** Prof. Dr. Lipp
1.6	**Additional Instructors** Prof. Dr. Fromm, Prof. Dr. Bürgy
1.7	**Study Program** Master / Major Embedded Systems and Microelectronics Master / Major Automation
1.8	**Teaching Language** English
2	**Module Content** **Content of course "Advanced Programming Techniques"** Review of fundamental concepts of a widely used object oriented programming language. The course will cover - introduction to the UML - OOA and OOD techniques - class design and class relations in C++, - C++ operator overloading, - advanced data structures, design patterns and algorithms - systematic test techniques Design aspects like modularity and software re-use will be discussed. Developing software designs using the UML and CASE tools as well as extensive hands-on programming assignments in C/C++ are an integral part of the course.

3	**Learning Outcome / Competencies** **to understand:** - the fundamentals of professional software design **to apply:** - the C++ programming language - the UML diagrams **to transfer:** - the design patterns and concepts to more complex architectures
4	**Course Organization and Structure** lecture (V) / laboratory (L)
5	**Credits and Workload** 5 CP / 150 hours in total, including 56 hours classroom teaching and lab. 2 SWS V and 2 SWS L
6	**Examination Modalities** **Examination Prerequisites:** In order to participate in the module exam, it is required to successfully finish the lab part of the module. Successful fulfillment of prerequisites are measured by: - attending Lab - code walkthrough during the lab 20% of the module grades are obtained by the laboratory during the term. **Examination Type:** Written exam covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** 90 minutes
7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** None
9	**Duration and Frequency of Course** This module takes one semester and is offered once a year (see appendix 1 BBPO).
10	**Applicability /Utilization** This module is applicable for the major Automation and for the major Embedded Systems and Microelectronics.

11	**Literature** The following literature material will be provided: - Electronic lecture notes - Workbook for the lab Further literature recommendations will be provided during the lecture.

MA05 Industry 4.0/IIoT and the Digital Factory

1	**Module Name** Industry 4.0/IIoT and the Digital Factory
1.1	**Module Identifier** MA05
1.2	**Module Type** Mandatory
1.3	**Course Names** Industry 4.0/IIoT and the Digital Factory – Lecture Industry 4.0/IIoT and the Digital Factory - Lab
1.4	**Semester** 1 or 2 (summer term)
1.5	**Module Responsible and Instructor** Prof. Dr. Simons
1.6	**Additional Instructors** ---
1.7	**Study Program** Master / Major Automation
1.8	**Teaching Language** English
2	**Module Content** **Content of course "Industry 4.0/IIoT and the Digital Factory":** Participants will be exposed to and gain working experience to design, implement, verify and validate safe systems in industrial automation. The course will cover - Goals and Key technologies for modern production - Basics of Industrie 4.0, IoT and Digital transformation, Structures of modern production - Product identification systems - Data acquisition and exchange, e.g. OPC UA - Product lifecycle management and product data management (PLM / PDM) - Simulation systems (HIL/SIL, virtual commissioning, material flow and energy consumption simulation) - Remote control - Security and safety in industrial automation - Manufacturing execution systems (MES) - Enterprise resource planning systems (ERP) - Assistance systems, e.g. using mixed reality

	- Cloud computing including e.g. IoT hubs, cloud services
3	**Learning Outcome / Competencies** **to understand:** - the goals and key technologies of the digital transformation - the structure of modern production - the possibilities, the advantages and the challenges of digitalized production - the basics of security for digitalized companies - the basics of MES, ERP, PLM/PDM, Assistance systems and cloud computing **to apply:** - implementing appropriate product identification systems - using simulation systems for virtual commissioning - developing ideas for new business processes of digitalized production companies **to transfer:** Students shall be able to play a significant role in the digital transformation of companies, by being able - to give impulses and develop scenarios for the digitalization of production companies - to choose appropriate information technologies, to judge about the advantages and challenges of these technologies and - to implement the communication between the information technology and the control system.
4	**Course Organization and Structure** lecture (V) / laboratory (L)
5	**Credits and Workload** 5 CP / 150 hours in total, including 56 hours classroom teaching and lab. 3 SWS V and 0,5 (1) SWS L
6	**Examination Modalities** **Examination Prerequisites:** In order to participate in the module exam, it is required to successfully finish the lab part of the module. Successful fulfillment of prerequisites are measured by: • Attending Lab • Lab Progress **Examination Type:** Written exam covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** 90 minutes.
7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** None
9	**Duration and Frequency of Course** This module takes one semester and is offered once a year (see appendix 1 BBPO).

10	**Applicability /Utilization** This module is applicable for the major Automation.
11	**Literature** The following literature material will be provided: - Electronic Script (excerpt of slides) - Workbook for the lab Further literature recommendations will be provided during the lecture.

MA06 Industrial Robotics

1	**Module Name** Industrial Robotics
1.1	**Module Identifier** MA06
1.2	**Module Type** Mandatory
1.3	**Course Names** Industrial Robotics – Lecture Industrial Robotics – Lab
1.4	**Semester** 1 or 2 (summer term)
1.5	**Module Responsible and Instructor** Dr. Koch
1.6	**Additional Instructors**
1.7	**Study Program** Master / Major Automation
1.8	**Teaching Language** English
2	**Module Content** The course covers the areas: - Overview on Applications, Systems and Technologies of Industrial Robotic Systems - Kinematic and Kinetic Models for Industrial Robots - Path Planning and Control Algorithms for Industrial Robots - Integration of Sensors and Multimodal Servoing - Force Control and Human-Robot Collaboration - Technological Aspects (e.g., Accuracy, Safety issues, Energy consumption)
3	**Learning Outcome / Competencies** **to understand:** - the basic applications, systems, and technologies of industrial robotic systems - the basic principles for the design of a robotic system with regard to a specific task

	to apply the knowledge: - to classify robotic applications and describe the necessary system architecture - to know and simulate the fundamental models and algorithms for industrial robots **to transfer:** - the control of 6-axis robots to new kinematics and cells with multiple arms
4	**Course Organization and Structure** Lecture (V) / Laboratory (L)
5	**Credits and Workload** 5 CP / 150 hours in total, including 56 hours classroom teaching and lab. 3 SWS V and 0,5 (1) SWS L
6	**Examination Modalities** **Examination Prerequisites:** In order to participate in the module exam, it is required to successfully finish the lab part of the module. Successful fulfillment of prerequisites are measured by: • Attending Lab • Lab Progress **Examination Type:** Written exam covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** 90 minutes.
7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** None
9	**Duration and Frequency of Course** This module takes one semester and is offered once a year (see appendix 1 BBPO).
10	**Applicability /Utilization** This module is applicable for the major Automation and for the major Embedded Systems and Microelectron-ics.
11	**Literature** The following literature material will be provided: - Electronic lecture notes (excerpt of slides) - Workbook for the lab Further literature recommendations will be provided during the lecture.

MA07 State Space Control Design

1	**Module Name** State-Space Control Design
1.1	**Module Identifier** MA07
1.2	**Module Type** Mandatory
1.3	**Course Names** State-Space Control Design – Lecture State-Space Control Design - Lab
1.4	**Semester** 1 or 2 (summer term)
1.5	**Module Responsible and Instructor** Prof. Dr. Weigl-Seitz
1.6	**Additional Instructors**
1.7	**Study Program** Master / Major Automation
1.8	**Teaching Language** English
2	**Module Content** **Content of Course „State-Space Control Design – Lecture“:** • Modelling of dynamic systems using state variables • State space representation of dynamic systems • Correlation between transfer functions and state space representation • Structural properties (stability, controllability, observability) • Canonical Forms • State space transformations • Solution of the time-invariant state-space equations • Design of state feedback controllers • Design of state observers • State feedback by optimal control • Computer based applications using Matlab/Simulink **Content of Course „State-Space Control Design – Lab“:** • Exercises on modelling and designing state-space control systems

	• Practical programming assignments for state-space applications in Matlab/Simulink
3	**Learning Outcome / Competencies** **to understand:** • the state-space concept **to apply:** • solve time-invariant state-space equations • design state-feedback systems by optimal control **to transfer :** • describe systems using state-space representations • analyze systems using state-space techniques • design state feedback controllers and state observers • programming of state-space applications in Matlab/Simulink
4	**Course Organization and Structure** lecture (V) / laboratory (L)
5	**Credits and Workload** 5 CP / 150 hours in total, including 56 hours classroom teaching and lab. 3 SWS V / 0,5 (1) SWS L
6	**Examination Modalities** **Examination Prerequisites:** In order to participate in the module exam, it is required to successfully finish the lab part of the module. Successful fulfillment of prerequisites are measured by: - Attending Lab - Exercises and Lab Progress - Documentation / Lab Report **Examination Type:** Written exam covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** 90 minutes
7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** None
9	**Duration and Frequency of Course** This module takes one semester and is offered once a year (see appendix 1 BBPO).

10	**Applicability /Utilization** This module is applicable for the major Automation
11	**Literature** The following literature material will be provided: - Electronic lecture notes and exercises Further literature recommendations will be provided during the lecture.

Module Handbook

Electrical Engineering and Information Technology - international

Master of Science

Major Automation - electives

MAwp01 Model-based Real-time Simulation of Mechatronic Systems

1	**Module Name** Model-based Real-time Simulation of Mechatronic Systems
1.1	**Module Identifier** MAwp01
1.2	**Module Type** Elective
1.3	**Course Names** Model-based Real-time Simulation of Mechatronic Systems – lecture Model-based Real-time Simulation of Mechatronic Systems – lab
1.4	**Semester** 1 or 2
1.5	**Module Responsible and Instructor** N.N.
1.6	**Additional Instructors** ---
1.7	**Study Program** Master / Major Automation
1.8	**Teaching Language** English
2	**Module Content** **Model-based Real-time Simulation of Mechatronic Systems – lecture** This course provides the concepts of model-based real-time simulation and system design. The course covers the areas: - Modelling and classification of mechatronic systems - Application areas, requirements - Real-time simulation and rapid prototyping methods - Hardware-in-the-loop, software-in-the-loop and processor-in-the-loop - Experimental validation and testing methods - Summary, Conclusion and future prospects **Model-based Real-time Simulation of Mechatronic Systems – lab** This lab provides projects to design model-based real-time simulation and system design. The lab covers the areas: - Introduction MATLAB/SIMULINK

	- Software and function development process - Real-time simulation and rapid prototyping applications - Automatic code generation - Experimental validation and testing methods
3	**Learning Outcome / Competencies** **to understand:** - the structure of mechatronic systems - model-based development procedure of mechatronic systems - the improvement of the system's documentation and maintainability **to apply:** - model mechatronic systems - improve the design and implementation process of mechatronic systems **to transfer:** - exemplary model-based simulation and testing of mechatronic systems
4	**Course Organization and Structure** lecture (V) / laboratory (L)
5	**Credits and Workload** 5 CP / 150 hours in total, including 56 hours classroom teaching and lab. 3 SWS V/ 1 SWS L
6	**Examination Modalities** **Examination Prerequisites:** In order to participate in the module exam, it is required to successfully finish the lab part of the module. Successful fulfilment of prerequisites are measured by: • Attending Lab • Lab Progress **Examination Type:** Written exam covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** 90 minutes
7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** None
9	**Duration and Frequency of Course** see module description of Elective 1 to 3 (MWP01, MWP02, MWP03)

10	**Applicability /Utilization** This module is applicable for the major Automation. See appendix 2 BBPO (Compulsory options catalogues) for its suitability for other majors.
11	**Literature** The following literature material will be provided: - Electronic lecture notes - Workbook for the lab Further literature recommendations will be provided during the lecture.

MAwp02 High Level Language Frameworks

1	**Module Name** High Level Language Frameworks
1.1	**Module Identifier** MAwp02
1.2	**Module Type** Elective
1.3	**Course Names** --
1.4	**Semester** 1 or 2
1.5	**Module Responsible and Instructor** Prof. Dr. Lipp
1.6	**Additional Instructors**
1.7	**Study Program** Master / Major Automation
1.8	**Teaching Language** English
2	**Module Content** Participants will be introduced to the development of graphical applications using Android and JAVA. The course will cover - JAVA language basics - Threads and synchronization - Framework tools, f.ex. from Android - Graphical user interfaces Practical programming assignments in JAVA and Android will be part of the course.
3	**Learning Outcome / Competencies** **to understand:** - the JAVA language - threads - GUI Design - events

	to apply: - high level language, threading and events - interface definitions of a corresponding framework by implementing a small applications using Android.
4	**Course Organization and Structure** lecture (V) / laboratory (L)
5	**Credits and Workload** 5 CP / 150 hours in total, including 56 hours classroom teaching and lab. 3 SWS V/ 1 SWS L
6	**Examination Modalities** **Examination Prerequisites:** In order to participate in the module exam, it is required to successfully finish the lab part of the module. Successful fulfillment of prerequisites are measured by lab exercises. **Examination type:** Written exam covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** 90 minutes
7	**Necessary Prerequisites** Basic programming skills.
8	**Recommended Prerequisites** Object oriented programming.
9	**Duration and Frequency of Course** see module description of Elective 1 to 3 (MWP01, MWP02, MWP03)
10	**Applicability /Utilization** This module is applicable for the major Automation. See appendix 2 BBPO (Compulsory options catalogues) for its suitability for other majors.
11	**Literature** The following literature material will be provided: - Electronic lecture notes - Workbook for the lab Further literature recommendations will be provided during the lecture.

MAwp03 Human Machine Interfaces (HMI)

1	**Module Name** Human Machine Interfaces (HMI)
1.1	**Module Identifier** MAwp03
1.2	**Module Type** Elective
1.3	**Course Names** Human Machine Interfaces - lecture Human Machine Interfaces - laboratory
1.4	**Semester** 1 or 2
1.5	**Module Responsible and Instructor** Prof. Dr. Bürgy
1.6	**Additional Instructors** Prof. Dr.. Wirth
1.7	**Study Program** Master / Major Automation
1.8	**Teaching Language** English
2	**Module Content** • Human senses • Human perception • Interaction channels between humans and machines • General design aspects • Modeling of user interaction (UML-based architecture design) • Usability / user experience • Machine interfaces (widgets, IO, WIMP and post-WIMP interfaces) • Testing (software, user and field tests)
3	**Learning Outcome / Competencies** **to know:** • relevant definitions • design guidelines

	to understand: • mechanisms of human senses • capabilities and restrictions of human perception • foundation of user experience **to apply:** • usability aspects for designing user interaction with machines • selecting the right interface mechanisms and SW/HW interfaces **to transfer:** • modeling techniques, especially UML-based interface definition and documentation • choosing the right interface templates for human machine interaction • adapting interaction principles to multi-modal human machine interaction
4	**Course Organization and Structure** lecture (V) / laboratory (L)
5	**Credits and Workload** 2,5 CP / 75 hours in total, including 28 hours classroom teaching and lab. 2 SWS V
6	**Examination Modalities** **Examination Prerequisites:** In order to participate in the module exam, it is required to successfully finish the lab part of the module. Successful fulfillment of prerequisites are measured by: - Laboratory Workbook - Attending Lab **Examination Type:** continuous project covering the complete content of the module with a final presentation at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** 15 minutes presentation.
7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** Advanced Programming Techniques (MA04)
9	**Duration and Frequency of Course** see module description of Elective 1 to 3 (MWP01, MWP02, MWP03)
10	**Applicability / Utilization** All (software) design tasks; software and hardware architectures; mechatronics, WING. See appendix 2 BBPO (Compulsory options catalogues) for its suitability for other majors.

11	**Literature**
	• Dix, F.; Abowd, B.: Human-Computer Interaction, 3rd Edition, Pearson Education Ltd., 2004978-0130461094 • Norman, D.: The Design of Everyday Things, revised and expanded edition, Basic Books, 2013, ISBN: 978-0-465-05065-9 • Scott MacKenzie: Human-Computer Interaction: An Empirical Research Perspective, 2013, Morgan Kaufmann; ISBN: 978-0124058651

MAwp04 Autonomous Mobile Robots

1	**Module Name** Autonomous Mobile Robots
1.1	**Module Identifier** MAwp04
1.2	**Module Type** Elective
1.3	**Course Names** Autonomous Mobile Robots – Lecture Autonomous Mobile Robots - Lab
1.4	**Semester** 1 or 2
1.5	**Module Responsible and Instructor** Dr. Lübbers
1.6	**Additional Instructors**
1.7	**Study Program** Master / Major Automation
1.8	**Teaching Language** English
2	**Module Content** Introduction to - Application examples - Locomotion - Kinematics of mobile robots - Perception for mobile robots - Characteristics of mobile robots in structured and unstructured environments - Mobile robot localization methods, algorithms - Planning and navigation, incl. maps, methods for autonomous map generation and obstacle avoidance - Navigation architectures of autonomous mobile robots - Showcase demonstration and validation of methods using laboratory systems

3	**Learning Outcome / Competencies** **to understand:** - the basic applications, concepts, components and challenges of autonomous mobile robots - the basic locomotion principles for legged and wheeled robots **to apply the knowledge:** - to choose an appropriate locomotion concept for a new application - to develop the kinematic model for different mobile robots with wheels - to know the advantages and disadvantages of different sensors for mobile robots and to choose the appropriate sensors for an application - to implement the odometry method for localization to a wheeled mobile robot - to choose appropriate planning and navigation methods and a an appropriate navigation architecture **to transfer:** - the design patterns and concepts to other autonomous mobile robots for other applications.
4	**Course Organization and Structure** lecture (V) / laboratory (L)
5	**Credits and Workload** 5 CP / 150 hours in total, including 56 hours classroom teaching and lab. 3 SWS V/ 1 SWS L
6	**Examination Modalities** **Examination Prerequisites:** In order to participate in the module exam, it is required to successfully finish the lab part of the module. Successful fulfillment of prerequisites are measured by: - Attending Lab - Lab Progress **Examination Type:** Written exam covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** 90 minutes.
7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** None
9	**Duration and Frequency of Course** see module description of Elective 1 to 3 (MWP01, MWP02, MWP03)
10	**Applicability /Utilization** This module is applicable for the major automation. See appendix 2 BBPO (Compulsory options catalogues) for its suitability for other majors.

11	**Literature** The following literature material will be provided: - Electronic lecture notes (excerpt of slides) - Workbook for the lab Further literature recommendations will be provided during the lecture.

MAwp05 Advanced Graphical Programming of Control Systems

1	**Module Name** Advanced Graphical Programming of Control Systems
1.1	**Module Identifier** MAwp05
1.2	**Module Type** Elective
1.3	**Course Names** Advanced Graphical Programming of Control Systems - lecture
1.4	**Semester** 1 or 2
1.5	**Module Responsible and Instructor** Prof. Dr. Haid
1.6	**Additional Instructors** -
1.7	**Study Program** Master / Major Automation, Embedded and Power
1.8	**Teaching Language** English
2	**Module Content** • Modeling of user interaction • LabVIEW Queued Message Handler • One-to-many communication . • Managing Software Engineering in Graphical Languages • Advanced Architectures for Graphical Languages in LabVIEW • Object-Oriented Design and Graphical Programming • Performance of Graphical Languages
3	**Learning Outcome / Competencies** **to know:** • Realization of applications with the help of graphical programming languages • Different architectural approaches **to understand:** • Special features of graphical programming • Use of graphical libraries • Validation of graphical software applications

	to apply: • Develop a customized user interface prototype for initial usability testing. • Handle errors locally or globally depending on the severity of the error. • Develop, integrate, and test scalable, readable, and maintainable code modules. **to transfer:** • Graphical programming of industrial applications • Software validation and verification of graphical code • Error handling of graphical code
4	**Course Organization and Structure** lecture (V) / laboratory (L)
5	**Credits and Workload** 2,5 CP / 75 hours in total, including 14 hours classroom teaching and lab. 1 SWS V / 1 SWS L
6	**Examination Modalities** **Examination Prerequisites:** None **Examination Type:** Written exam covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** 90 minutes.
7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** Advanced Programming Techniques (MA04)
9	**Duration and Frequency of Course** see module description of Elective 1 to 3 (MWP01, MWP02, MWP03)
10	**Applicability /Utilization** All (software) design tasks; software and hardware architectures; mechatronics, WING. See appendix 2 BBPO (Compulsory options catalogues) for its suitability for other majors.
11	**Literature** • Dix, F.; Abowd, B.: Human-Computer Interaction, 3rd Edition, Pearson Education Ltd., 2004978-0130461094 • Norman, D.: The Design of Everyday Things, revised and expanded edition, Basic Books, 2013, ISBN: 978-0-465-05065-9 • Scott MacKenzie: Human-Computer Interaction: An Empirical Research Perspective, 2013, Morgan Kaufmann; ISBN: 978-0124058651

MAwp06 Advanced Sensors for the Internet of Things

1	**Module Name** Advanced Sensors for the Internet of Things
1.1	**Module Identifier** MAwp06
1.2	**Module Type** Elective
1.3	**Course Names** Advanced Sensors for the Internet of Things - lecture
1.4	**Semester** 1 or 2
1.5	**Module Responsible and Instructor** Prof. Dr. Haid
1.6	**Additional Instructors** -
1.7	**Study Program** Master / Major Automation, Embedded
1.8	**Teaching Language** English
2	**Module Content** • The principles of sensor systems • Sensor limits and restrictions • Sensor validation • Sensor types and placement • Data analysis and filtering • Sensor algorithms • Condition monitoring • Localization and navigation systems • Deep Learning and Machine Learning • Blockchain and smart contracting
3	**Learning Outcome / Competencies** **to know:** • Develop sensor applications. **to understand:** • Design sensor systems. **to apply:**

	• Apply signal-processing methods and algorithms **to transfer:** • The practical aspects of sensor use and type • The environmental benefits of condition monitoring techniques
4	**Course Organization and Structure** lecture (V)
5	**Credits and Workload** 2,5 CP / 75 hours in total, including 28 hours classroom teaching and lab. 2 SWS V
6	**Examination Modalities** **Examination Prerequisites:** None **Examination Type:** Written exam covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** 90 minutes.
7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** None
9	**Duration and Frequency of Course** see module description of Elective 1 to 3 (MWP01, MWP02, MWP03)
10	**Applicability /Utilization** All (software) design tasks; software and hardware architectures; mechatronics, WING. See appendix 2 BBPO (Compulsory options catalogues) for its suitability for other majors.
11	**Literature** The following literature material will be provided: - Electronic lecture notes (excerpt of slides) - Workbook for the lab Further literature recommendations will be provided during the lecture.

Major Automation – general electives / electives from other majors

MGwp01 Research Project

MGwp02 Selected Research Topics

MGwp03

MCwp01 Digital Signal Processing Applications

MCwp02 Wireless Systems (Technologies)

MCwp03 Network Security

MCwp04 Mobile Communications

MCwp05 Optical Communications

MCwp06 (I)Iot and Cloud Networking

MCwp08 Image and Video Processing

MMwp02 Safety in Embedded Control Systems

MMwp04 Advanced Software Design Techniques

MMwp05 Security in Connected Embedded Systems

MPwp02 Automotive Electrical Power Train

MPwp03 Stationary & Mobile Energy Storage Systems

MPwp05 Switch Gear

MPwp06 Power Systems Planning

MPwp09 Hydrogen Technique and Fuel Cells

Module Handbook

Electrical Engineering and Information Technology - international

Master of Science

Major Communications - mandatory

MC01 Advanced Digital Signal Processing

1	**Module Name** Advanced Digital Signal Processing
1.1	**Module Identifier** MC01
1.2	**Module Type** Mandatory
1.3	**Course Names** Advanced Digital Signal Processing – Lecture Advanced Digital Signal Processing - Lab
1.4	**Semester** 1 or 2 (winter term)
1.5	**Module Responsible and Instructor** Prof. Dr. Krauß
1.6	**Additional Instructors** Prof. Dr. Schultheiß, Prof. Dr. Wirth
1.7	**Study Program** Master / Major Communications
1.8	**Teaching Language** English
2	**Module Content** **Content of "Advanced Digital Signal Processing – Lecture"**: The course will cover • Discrete-time signal transforms (e.g. discrete-time Fourier transform, z-transform, DFT/FFT, DCT) • Principles and methods of digital filter design (IIR and FIR filters) • Implementation aspects of digital filters • Multi-rate systems (interpolation, decimation, sampling rate conversion) and filter banks • Adaptive digital systems • Spectral estimation methods **Content of "Advanced Digital Signal Processing – Lab"**: The lab exercises cover • Discrete-time signal transforms • Digital filter design and implementation • Multi-rate systems • Adaptive digital systems

3	**Learning Outcome / Competencies** **to understand:** - Principles of advanced digital signal processing methods **to apply:** - Design, implement and evaluate digital filters for different scenarios - Design and evaluate adaptive digital systems - Apply concepts of multi-rate systems and filter banks - Spectral estimation **to transfer:** - Apply and evaluate discrete-time signal transforms for various requirements
4	**Course Organization and Structure** lecture (V) / lab (L)
5	**Credits and Workload** 5 CP / 150 hours in total, including 56 hours classroom teaching and lab. 3 SWS V / 0.5 (1) SWS L
6	**Examination Modalities** **Examination Prerequisites:** In order to participate in the module exam, it is required to successfully finish the lab part of the module. Successful fulfillment of prerequisites are measured by: - Attending lab - Lab progress **Examination Type:** Written exam or oral exam (will be communicated upon start of the module) covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** Written exam: 90 minutes, oral exam: 30 minutes
7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** basic knowledge in digital signal processing from bachelor studies
9	**Duration and Frequency of Course** This module takes one semester and is offered once a year (see appendix 1 BBPO).
10	**Applicability /Utilization** This module is applicable for major Communications.

11	**Literature** The following literature material will be provided: - Electronic lecture notes Further literature recommendations will be provided during the lecture.

MC02 Advanced Modulation

1	**Module Name** Advanced Modulation
1.1	**Module Identifier** MC02
1.2	**Module Type** Mandatory
1.3	**Course Names** Advanced Modulation – Lecture Advanced Modulation – Lab
1.4	**Semester** 1 or 2 (summer term)
1.5	**Module Responsible and Instructor** Prof. Dr. Kuhn
1.6	**Additional Instructors** ---
1.7	**Study Program** Master / Major Communications
1.8	**Teaching Language** English
2	**Module Content** Content of course "Advanced Modulation - Lecture" Participants will be exposed to and gain working experience with advanced modulation schemes, multiple antenna transmitters and receivers, parameter and synchronization techniques, and channel coding schemes. The course will cover - Detection and estimation of parameters in white Gaussian noise - Multicarrier modulation - OFDM - Vector coding - Synchronization and parameter estimation - Capacity of wireless channels - Water-filling optimization - Multi-antenna systems (SIMO, MISO, MIMO) Content of course "Advanced Modulation - Lab" Lab exercises with Matlab and software-defined radio (SDR) modules will cover

	- Implementation of transmitter and receiver (QAM and OFDM) - Channel capacity and waterfilling optimization Multi-antenna systems
3	**Learning Outcome / Competencies** **to understand:** - the concepts of estimation theory - the difference between various multicarrier schemes (advantages/problems) - the channel capacity of MIMO and multicarrier systems - multi-antenna concepts **to apply:** - the gained knowledge to design, implement, and evaluate multicarrier transmitters and receivers - the gained knowledge to calculate the channel capacity of frequency-flat and frequency-selective channels - the concept of waterfilling (margin-adaptive and rate-adaptive) - peak-to-average-power reduction techniques - the gained knowledge to define the parameters of OFDM systems (e.g. pilot patterns, cyclic prefix length, subcarrier spacing, etc.) - multiple-antenna schemes **to transfer:** - the concepts of optimization approaches to similar parameter estimation, detection, and synchronization problems in communications
4	**Course Organization and Structure** lecture (V) / lab (L)
5	**Credits and Workload** 5 CP / 150 hours in total, including 56 hours classroom teaching and lab. 3 SWS V / 0.5 (1) SWS L
6	**Examination Modalities** **Examination Prerequisites:** In order to participate in the module exam, it is required to successfully finish the lab part of the module. Successful fulfillment of prerequisites are measured by: - Attending Lab - Lab Progress - Completion of lab preparation tasks **Examination Type:** Written exam covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** 90 minutes
7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** None

9	**Duration and Frequency of Course** This module takes one semester and is offered once a year (see appendix 1 BBPO).
10	**Applicability /Utilization** This module is applicable for the major Communications.
11	**Literature** The following literature material will be provided: - Electronic lecture notes - Workbook for the lab Further literature recommendations will be provided during the lecture and are listed in the lecture notes.

MC03 Microwave Components and Systems

1	**Module Name** Microwave Components and Systems
1.1	**Module Identifier** MC03
1.2	**Module Type** Mandatory
1.3	**Course Names** Microwave Components and Systems – Lecture Microwave Components and Systems - Laboratory
1.4	**Semester** 1 or 2 (winter term)
1.5	**Module Responsible and Instructor** Prof. Dr. Gaspard
1.6	**Additional Instructors** Prof. Dr. Schmiedel
1.7	**Study Program** Master / Major Communications
1.8	**Teaching Language** English
2	**Module Content** **Content of course „Microwave Components and Systems – Lecture“:** 1. Components: - Transmission lines and waveguides - Microwave network analysis - Power dividers and directional couplers - Microwave filters 2. Systems: - Noise and nonlinear distortion - Systems aspects of antennas and wireless communications - Synthesizers and mixers - Receiver architectures **Content of course “Microwave Components and Systems – Lab”:** Gaining in depth practical measurement experiences in RF and microwaves in chosen topics of the lecture

3	**Learning Outcome / Competencies** **to understand:** design principles and key components of RF and microwave systems **to apply:** methods to analyze, develop and test of RF and microwave components and systems **to transfer:** the concepts of noise and nonlinear distortion to more complex systems; testing of complex microwave systems by modern measurement equipment (e.g. network analyzers)
4	**Course Organization and Structure** lecture (V) / laboratory (L)
5	**Credits and Workload** 5 CP / 150 hours in total, including 56 hours classroom teaching and lab. 3 SWS V / 0,5 (1) L
6	**Examination Modalities** **Examination Prerequisites:** In order to participate in the module exam, it is required to successfully finish the lab part of the module. Successful fulfillment of prerequisites are measured by: - Attending laboratory - Laboratory Progress **Examination Type:** Written exam covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** 90 minutes
7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** None
9	**Duration and Frequency of Course** This module takes one semester and is offered once a year (see appendix 1 BBPO).
10	**Applicability /Utilization** This module is applicable for the major Communications.
11	**Literature** The following literature material will be provided: - Electronic lecture notes - Description for the laboratory measurements Further literature recommendations will be provided during the lecture.

MC04 Advanced Software Design and Development

1	**Module Name** Advanced Software Design and Development
1.1	**Module Identifier** MC04
1.2	**Module Type** Mandatory
1.3	**Course Names** Advanced Software Design and Development - Lecture Advanced Software Design and Development - Lab
1.4	**Semester** 1 or 2 (winter term)
1.5	**Module Responsible and Instructor** Prof. Dr. Wirth
1.6	**Additional Instructors** Prof. Dr. Krauß
1.7	**Study Program** Master / Major Communications
1.8	**Teaching Language** English
2	**Module Content** Object oriented programming applied to selected communication systems of medium level complexity, e.g. C++ and Matlab. The course will cover - introduction to selected examples of Application Programming Interfaces (APIs) and protocols commonly used in the field of communication; - introduction to and application of the UML, OOA and OOD techniques in order to design the communication systems using APIs and protocols; - introduction to and application of design patterns in order to implement the communication systems; - systematic test techniques. Requirements of the selected systems, technical basics of the APIs and protocols as well as the software techniques mentioned above are introduced and discussed during the lecture. The design of the example communication systems is jointly done during the lecture as well as in individual work or in teamwork. Hands-on programming is done individually in preparation of the labs and during the labs.

3	**Learning Outcome / Competencies** **to understand:** technical principles of selected communication APIs and protocols, the principles of a good software design **to apply:** object oriented programming in C++, using UML for design and documentation purposes **to transfer:** general principles of using APIs and design patterns to other software systems
4	**Course Organization and Structure** lecture (V) / laboratory (L) Media: software development environment
5	**Credits and Workload** 5 CP / 150 hours in total, including 56 hours classroom teaching and lab. 2 SWS V / 2 SWS L
6	**Examination Modalities** **Examination Prerequisites:** In order to participate in the module exam, it is required to successfully finish the lab part of the module. Successful fulfillment of prerequisites are measured by: - Attending Lab - Lab Progress - Completion of lab preparation tasks **Examination Type:** Practical exam on PC covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** 120 minutes
7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** None
9	**Duration and Frequency of Course** This module takes one semester and is offered once a year (see appendix 1 BBPO).
10	**Applicability /Utilization** This module is applicable for all modules of the major Communications which include software topics (application/development).

11	**Literature** The following literature material will be provided: • Electronic lecture notes • Workbook for the lab Further literature recommendations will be provided during the lecture.

MC05 System-Driven Hardware Design

1	**Module Name** System-Driven Hardware Design
1.1	**Module Identifier** MC05 / MM06 / MP07
1.2	**Module Type** mandatory
1.3	**Course Names** System Driven Hardware Design – Lecture System Driven Hardware Design - Lab
1.4	**Semester** 1 or 2 (summer term)
1.5	**Module Responsible and Instructor** Prof. Dr. Bannwarth
1.6	**Additional Instructors** Prof. Dr. Krauß, Prof. Dr. Kuhn
1.7	**Study Program** Master / Major Communications Master / Major Embedded Systems and Microelectronics
1.8	**Teaching Language** English
2	**Module Content** **Content of the course "System Driven Hardware Design – Lecture"** Participants will gain work experience in developing hardware and software of an electronic system. The course will cover: - Partitioning of a system in hardware, software parts and necessary peripherals components - interface design to peripheral components, to other systems and to humans - designing of a PCB, taking signal integrity, hardware and software test possibilities and production rules into account - software development for hardware test - view on mechanical constraints - production methods **Content of the course "System Driven Hardware Design – Lab"** Development of a system consisting of software and hardware parts: - Developing a PCB

	- Soldering a PCB - test of hardware – software interaction - hardware and software start-up - debugging
3	**Learning Outcome / Competencies** **to understand:** - system partitioning and interaction of software and hardware - the importance of designing for test of hardware and software **to apply:** - systematically developing a PCB - taking into account software and hardware testability during hardware design - layout rules for signal integrity and producibility - taking into account mechanical aspects of pcb development - software code to test software-hardware interaction - hardware debugging of serial interfaces - systematic start-up of a PCB consisting of hardware and software parts **to transfer:** - design patterns and processes to other hardware-software-systems, consisting of different central processing units e.g. microcontrollers, fpgas, psocs or ASIC and peripheral components.
4	**Course Organization and Structure** lecture (V) / laboratory (L)
5	**Credits and Workload** 5 CP /150 hours in total, including 56 hours classroom teaching and lab. 2 SWS V / 2 SWS L
6	**Examination Modalities** **Examination Prerequisites:** In order to participate in the module exam, it is required to successfully finish the lab part of the module. Successful fulfillment of prerequisites are measured by: - Attending Lab - Lab progress **Examination Type:** Written exam covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester.. **Examination Duration:** 90 minutes
7	**Necessary Prerequisites** None.

8	**Recommended Prerequisites** None.
9	**Duration and Frequency of Course** This module takes one semester and is offered once a year (see appendix 1 BBPO).
10	**Applicability /Utilization** This module is applicable for the major Communications and the major Embedded Systems and Microelectronics
11	**Literature** The following literature material will be provided: - Electronic lecture notes - Workbook for the lab Further literature recommendations will be provided during the lecture.

MC06 Fields, Waves and Antennas

1	**Module Name** Fields, Waves and Antennas
1.1	**Module Identifier** MC06
1.2	**Module Type** Mandatory
1.3	**Course Names** Fields, Waves and Antennas – Lecture, Seminar, Laboratory
1.4	**Semester** 1 or 2 (summer term)
1.5	**Module Responsible and Instructor** Prof. Dr. Chen, Prof. Dr. Gaspard
1.6	**Additional Instructor** Prof. Dr. Schmiedel, Prof. Dr. Gerdes
1.7	**Study Program** Master / Major Communications
1.8	**Teaching Language** English
2	**Module Content** **Lecture:** The goal of the module is to treat electromagnetic (EM) theory concepts in depth, which were used in a variety of applications in different communications engineering fields like microwave engineering, optical communications, electromagnetic compatibility, mobile and satellite communications, radar technology, antenna engineering etc. Students will be enabled to apply these concepts both theoretically and practically, e.g. by using simulation software systems (CST Microwave Studio, Sonnet, EZNEC, etc.) and measurement verification. The course consists of: 1) A lecture part covering topics like Maxwell's equations, fields in different media, the wave equation and basic plane wave solution, plane wave reflection from a media interface, polarization, basic antenna concepts, transmission lines and waveguides, simulation methods, e.g. method of moments, etc.; 2) A laboratory part where different state-of-the-art CAD (computer aided design) tools are applied to design and analysis of exemplary applications of the concepts covered in the lecture, e.g. • Design and analysis of single element linear antennas and multiple element antennas with feeding networks or radiation coupled elements (e.g. Yagi antenna) by the use of e.g. EZNEC.

	• Analysis of transmission lines and waveguides (RF and optical) with e.g. CST. • Design and analysis of microwave components: e.g. design & analysis of couplers based on microstrip transmission lines by the aid of e.g. Sonnet. • Radiation by aperture antennas e.g. by CST. • Measurements and comparison with the numerical simulation results. Thus this course provides fundamental concepts for other courses in communications master program, e.g. for modules "Optical Communications", "Microwave Components and Systems", "Mobile Communications" and "Wireless Systems". **Laboratory:** • Simulations of the fields, waves and antennas by using numerical simulation programs; • Measurement of certain chosen antennas and comparison of the measurement results with the numerical results.
3	**Learning Outcome / Competencies** **Knowledge:** After successful completion of this module the student will be able to better understand EM phenomena and applications in order to analyze, design and characterize RF transmission lines and circuits of transmission lines, waveguides (both in spectral optical and microwave frequency ranges), and antennas. **Skills**: Capabilities to analyze the fields, wave guides and wave propagation problems and to design the antennas. **Competences:** Knowledge about and application of concepts of electromagnetic theory based on Maxwell's Equations in complete microwave and optical spectral range. Exemplary design and investigation of transmission line/waveguide and antenna structures by using different simulation software packages.
4	**Course Organization and Structure** lecture (V), laboratory (L)
5	**Credits and Workload** 5 CP / 150 hours in total, including 56 hours classroom teaching and lab. 3 SWS V / 0.5 (1) SWS L
6	**Examination Modalities** **Examination Prerequisites:** In order to participate in the module exam, it is required to successfully finish the lab part of the module. Successful fulfillment of prerequisites are measured by: - Attending Lab - Lab Progress **Examination Type:**

	Written exam covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** 90 minutes
7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** Basic knowledge of fundamentals of communication technology of the Bachelor program.
9	**Duration and Frequency of Course** This module takes one semester and is offered once a year (see appendix 1 BBPO).
10	**Applicability /Utilization** This module is applicable for the major Communications.
11	**Literature** The following literature material will be provided: - Electronic Lecture Notes - Descriptions for the laboratory for numerical simulations or measurements Further literature recommendations will be provided during the lecture.

MC07 Information Networks

1	**Module Name** Information Networks
1.1	**Module Identifier** MC07
1.2	**Module Type** Mandatory
1.3	**Course Names** Information Networks-Lecture Information Networks-Lab
1.4	**Semester** 1 or 2 (summer term)
1.5	**Module Responsible and Instructor** Prof. Dr. Gerdes
1.6	**Additional Instructors** Prof. Dr. Chen
1.7	**Study Program** Master / Major Communications
1.8	**Teaching Language** English
2	**Module Content** **Content of course "Information Networks - Lecture"** Participants will be exposed to gain experience of network structures and protocols in the WAN. The course will cover - Actual trends and developments in WAN-technology - OSI protocol stack for the WAN - Optical transport networks (Layer 1 and 2 in WAN) - Layer 2 protocols for network access - MPLS in transport networks - Development from IPv4 to IPv6 - Dynamic Routing in the WAN - Introduction to Software defined networks (SDN) - Quality of Service and Delay analysis of packet networks (Queue Theory) **Content of course " Information Networks - Lab"** Practical assignments related to WAN technology are part of the course.

	- Configuration of Dynamic Routing and router firewalls - Configuration of virtual servers and software defined networks (SDN) - Measurement of QoS-Parameters under varying network conditions
3	**Learning Outcome / Competencies** **to know:** - about actual developments and specialised Layer2-WAN protocols - about trends and development directions of SDN **to understand:** - the usage of MPLS networks in WAN - the differences between IPv4 and IPv6 - the influence of network parameters on QoS **to apply:** - Design of dynamic routing environments - Migration from IPv4 networks to IPv6 - Estimation and measurement of QoS **to transfer:** - the learned protocols and network principles to new services and cloud networks under considera-tion of interworking and QoS
4	**Course Organization and Structure** lecture (V) / laboratory (L)/
5	**Credits and Workload** 5 CP / 150 hours in total, including 56 hours classroom teaching and lab. 3 SWS V / 0,5 (1) L
6	**Examination Modalities** **Examination Prerequisites:** In order to participate in the module exam, it is required to successfully finish the lab part of the module. Successful fulfillment of prerequisites are measured by: - Lab attendance - Lab exam **Examination Type:** Written exam covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** 90 minutes
7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** None

9	**Duration and Frequency of Course** This module takes one semester and is offered once a year (see appendix 1 BBPO).
10	**Applicability /Utilization** This module is applicable for the major Communications.
11	**Literature** The following material will be provided - Electronic lecture notes - Workbook for the Lab Further literature recommendations will be provided in the lecture notes.

Module Handbook

Electrical Engineering and Information Technology - international

Master of Science

Major Communications - electives

MCwp01 Digital Signal Processing Applications

1	**Module Name** Digital Signal Processing Applications
1.1	**Module Identifier** MCwp01
1.2	**Module Type** Elective
1.3	**Course Names** Digital Signal Processing Applications – Lecture
1.4	**Semester** 1 or 2
1.5	**Module Responsible and Instructor** Prof. Dr. Krauß
1.6	**Additional Instructors** Prof. Dr. Bannwarth
1.7	**Study Program** Master / Major Communications
1.8	**Teaching Language** English
2	**Module Content** The course will cover the following areas: Application of several digital signal processing techniques in the fields of communications, speech, audio and image processing (including medical imaging) based on e.g. • Multi-rate signal processing techniques and filter bank applications • Special transforms (e.g. Gabor transform, Wavelet transform, Radon transform)
3	**Learning Outcome / Competencies** **to know:** - Special transforms and their application for different application domains **to understand:** - Multi-rate signal processing techniques and filter bank applications for different application domains **to apply:** - Capability to evaluate digital signal processing techniques in communications, speech and audio processing

4	**Course Organization and Structure** lecture (V) with integrated exercises
5	**Credits and Workload** 2.5 CP / 75 hours in total, including 28 SWS hours classroom teaching. 2 SWS V
6	**Examination Modalities** **Examination Prerequisites:** None **Examination Type:** Written exam or oral exam (will be communicated upon start of the module) covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** Written exam: 60 minutes, oral exam: 30 minutes
7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** Advanced Digital Signal Processing
9	**Duration and Frequency of Course** see module description of Elective 1 to 3 (MWP01, MWP02, MWP03)
10	**Applicability /Utilization** This module is applicable for major Communications. See appendix 2 BBPO (Compulsory options catalogues) for its suitability for other majors.
11	**Literature** The following literature material will be provided: - Electronic lecture notes Further literature recommendations will be provided during the lecture.

MCwp02 Wireless Systems (Technologies)

1	**Module Name** Wireless Systems (Technologies)
1.1	**Module Identifier** MCwp02
1.2	**Module Type** Elective
1.3	**Course Names** Wireless Systems – Lecture
1.4	**Semester** 1 or 2
1.5	**Module Responsible and Instructor** Prof. Dr. Gaspard
1.6	**Additional Instructors** Prof. Dr. Bannwarth, Prof. Dr. Chen, Prof. Dr. Krauß, Prof. Dr. Kuhn
1.7	**Study Program** Master / Major Communications
1.8	**Teaching Language** English
2	**Module Content** **Content of course „Wireless Systems (Technologies) – Lecture“:** - Basic principles: use cases, frequencies, propagation channels for wireless systems, modulation and coding principles, standardization bodies - Communication systems: short range devices, wireless local area and wide range network technologies - Broadcast systems: e.g. DVB and DAB, multi frequency and single frequency networks - Radar technologies for automotive and industrial applications
3	**Learning Outcome / Competencies** **Knowledge:** use cases and application fields of different technologies **Skills:** capability to evaluate and compare wireless systems with respect to their application and use cases **Competences:** comparison, design, planning and dimensioning of wireless systems
4	**Course Organization and Structure** lecture (V) with integrated exercises

5	**Credits and Workload** 2,5 CP / 75 hours in total, including 28 SWS hours classroom teaching. 2 SWS V
6	**Examination Modalities** **Examination Type:** Written exam covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** 60 minutes
7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** None
9	**Duration and Frequency of Course** see module description of Elective 1 to 3 (MWP01, MWP02, MWP03)
10	**Applicability /Utilization** This module is applicable for the major Communications.
11	**Literature** The following literature material will be provided: - Electronic lecture notes Further literature recommendations will be provided during the lecture.

MCwp03 Network Security

1	**Module Name** Network Security
1.1	**Module Identifier** MCwp03
1.2	**Module Type** Elective
1.3	**Course Names** Network Security – Lecture, Seminar, Demonstration Lab
1.4	**Semester** 1 or 2
1.5	**Module Responsible and Instructor** Prof. Dr. Chen
1.6	**Additional Instructors** Prof. Dr. Gerdes
1.7	**Study Program** Master / Major Communications
1.8	**Teaching Language** English
2	**Module Content** **Lecture:** • Concept and functionalities of network security • Specific QoS and security requirements of the mission-critical real-time applications and broadband multimedia network technologies • Advanced network security technologies (Encryption, Digital Signature, Authentication, Firewall, VPN, Security Gateways etc.) • Network management systems TMN and SNMP **Demo Lab during the lecture:** Demonstration Lab helps to better understand the above-mentioned security aspects and functionalities.
3	**Learning Outcome / Competencies** **Knowledge:** After completing the course, the student will be able to understand the basic network security aspects, QoS requirements, and to utilize network security gateways and network management systems.

	Skills : Capabilities to analyze the network security functionalities and requirements, and configure the network security gateways. **Competences:** Evaluation and analysis of network and service requirements of different applications, and utilization and configuration of corresponding network security gateways solutions and network management systems.
4	**Course Organization and Structure** lecture (V), seminar, demonstration lab during the lecture and seminar
5	**Credits and Workload** 2.5 CP / 75 hours in total, including 28 hours classroom teaching. 2 SWS V
6	**Examination Modalities** **Examination Prerequisites:** none **Examination Type:** Written exam, oral exam, and/or presentation (will be communicated upon start of the module) covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** Written exam: 90 minutes, oral exam: 30 minutes, presentation: 15 minutes
7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** Basic knowledge of fundamentals of communication technology of the Bachelor program.
9	**Duration and Frequency of Course** see module description of Elective 1 to 3 (MWP01, MWP02, MWP03)
10	**Applicability /Utilization** This module is applicable for the major Communications. See appendix 2 BBPO (Compulsory options catalogues) for its suitability for other majors.

11	**Literature** The following literature material will be provided: - Electronic Lecture Notes - Descriptions for the Demo lab Further literature recommendations will be provided during the lecture.

MCwp04 Mobile Communications

1	**Module Name** Mobile Communications
1.1	**Module Identifier** MCwp04
1.2	**Module Type** Elective
1.3	**Course Names** Mobile Communications
1.4	**Semester** 1 or 2
1.5	**Module Responsible and Instructor** Prof. Dr. Kuhn
1.6	**Additional Instructors** Prof. Dr. Chen, Prof. Dr. Gaspard, Prof. Dr. Krauß
1.7	**Study Program** Master / Major Communications
1.8	**Teaching Language** English
2	**Module Content** **Lecture:** • Use-cases, applications of mobile Systems • Signals and signal propagation in mobile applications • Mobile channels • Multiplexing, modulation, spread spectrum, cellular system • Mobile communication systems (2G, 3G, 4G, 5G) • Basics of network planning
3	**Learning Outcome / Competencies** **Knowledge:** - the concepts of signal propagation - the concepts of mobile communication systems - the differences between different systems as well as their pro and cons. **Skills:** - network planning for simple use-cases

	Competences: - Evaluation and selection of appropriate system depending on application and use-case - Definition of relevant parameters
4	**Course Organization and Structure** lecture (V)
5	**Credits and Workload** 2.5 CP / 75 hours in total, including 28 hours classroom teaching. 2 SWS V
6	**Examination Modalities** **Examination Prerequisites:** none **Examination Type:** Written exam, oral exam, and/or presentation (will be communicated upon start of the module) covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** Written exam: 60 minutes, oral exam: 30 minutes, presentation: 15 minutes
7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** Module Advanced Modulation
9	**Duration and Frequency of Course** see module description of Elective 1 to 3 (MWP01, MWP02, MWP03)
10	**Applicability /Utilization** This module is applicable for the major Communications. See appendix 2 BBPO (Compulsory options catalogues) for its suitability for other majors.
11	**Literature** The following literature material will be provided: - Electronic lecture notes Further literature recommendations will be provided during the lecture.

MCwp05 Optical Communications

1	**Module Name** Optical Communications
1.1	**Module Identifier** MCwp05
1.2	**Module Type** Elective
1.3	**Course Names** Optical Communications – Lecture, Seminar, Demonstration Lab
1.4	**Semester** 1 or 2
1.5	**Module Responsible and Instructor** Prof. Dr. Loch, Prof. Dr. Chen
1.6	**Additional Instructor** ---
1.7	**Study Program** Master / Major Communications
1.8	**Teaching Language** English
2	**Module Content** **Lecture:** • Advanced characteristics and production technologies of optical fibers • Solutions of the electromagnetic wave equations • Advanced analyses of the mechanisms for dispersions and attenuations • Nonlinear effects and their impacts and applications (e.g. soliton) • Optical fiber connections: theoretical and practical considerations • Advanced theoretical considerations and optimizations of optical sources (Laser Diode / LED) and detectors (PIN-, APD-Photodiode), receivers for optical communications • Optical amplifiers: characterization and comparison of different principles • Polarization: theoretical and practical fundamentals and their influence to fiber optical systems (e.g. polarization modal dispersion PMD) • Fiber optical systems: fundamentals and limitations • Basics of coherent optical communication systems • Special optical communication devices and modern systems **Demo Lab during the lecture:** Demonstration Lab helps to better understand the above-mentioned optical communication system aspects and functionalities.

3	**Learning Outcome / Competencies** **Knowledge:** After completing the course, the student will be able to understand the advanced optical communication systems, and the corresponding components. **Skills :** Capabilities to analyze and design the optical communication systems by considering the given conditions. **Competences:** Apply the theoretical knowledge learned in the lecture to design an optical communication system and optimize the transmission performance to achieve the maximum data rates.
4	**Course Organization and Structure** lecture (V), seminar, demonstration lab during the lecture and seminar
5	**Credits and Workload** 2.5 CP / 75 hours in total, including 28 hours classroom teaching. 2 SWS (V)
6	**Examination Modalities** **Examination Prerequisites:** none **Examination Type:** Written exam, oral exam, and/or presentation (will be communicated upon start of the module) covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** Written exam: 90 minutes, oral exam: 30 minutes, presentation: 15 minutes
7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** Basic knowledge of fundamentals of communication technology of the Bachelor program.
9	**Duration and Frequency of Course** see module description of Elective 1 to 3 (MWP01, MWP02, MWP03)
10	**Applicability /Utilization** This module is applicable for the major Communications. See appendix 2 BBPO (Compulsory options catalogues) for its suitability for other majors.

11	**Literature** The following literature material will be provided: - Electronic Lecture Notes - Descriptions for the Demo lab Further literature recommendations will be provided during the lecture.

MCwp06 (I)Iot and Cloud Networking

1	**Module Name** (I)Iot and Cloud Networking
1.1	**Module Identifier** MCwp06
1.2	**Module Type** Elective
1.3	**Course Names** (I)Iot and Cloud Networking -Lecture
1.4	**Semester** 1 or 2
1.5	**Module Responsible and Instructor** Prof. Dr. Gerdes
1.6	**Additional Instructors** ---
1.7	**Study Program** Master / Major Communications
1.8	**Teaching Language** English
2	**Module Content** Participants will be exposed to gain experience in Internet of Things (IoT) networking, in particular Smart Home and Cloud-Networks, Smart-Grid-Communication and Cloud based industrial networks. The course will cover: **Lecture:** - Development trends of the IoT and technological roadmap - Reference model for IoT networks and Industrial Internet - General terminology, structure and components of IoT and Cloud networks - Technological challenges of IoT - Assessment of network technologies and (new) protocols for Fog and Cloud networks - Security assessment of IoT networks - Design cases of Smart Grid/Smart Home and Industrial Internet **IoT-Demo-Lab:** Networks for Smart Home and Smart Industry

3	**Learning Outcome / Competencies** **to know:** - about actual developments and specialised IoT network structures and protocols **to understand:** - the different types of cloud networks and network structures - the usage of protocols for connecting Smart Grid and Smart Home items to the Internet - the requirements on communications and components in Smart Industry networks **to apply:** - Design of Smart Grid, Smart Home and Smart Industry networks - Selection of adequate network components and protocols for local and distributed data transmission - Evaluate the security requirements of Cloud networks **to transfer:** - Application of the learned protocols and network principles to new evolving services in the Internet of things in private and in industry networks
4	**Course Organization and Structure** lecture (V) and IOT-demo lab during lecture
5	**Credits and Workload** 2,5 CP / 75 hours, including 28 hours classroom teaching. 2 SWS V
6	**Examination Modalities** **Examination Prerequisites:** None **Examination Type:** Written exam and/or presentation (will be communicated upon start of the module) covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** written exam: 90 minutes, presentation: 15 minutes
7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** None
9	**Duration and Frequency of Course** see module description of Elective 1 to 3 (MWP01, MWP02, MWP03)
10	**Applicability /Utilization** This module is applicable for the major Communications. See appendix 2 BBPO (Compulsory options catalogues) for its suitability for other majors.

11	**Literature** The following material will be provided - Electronic lecture notes Further literature recommendations will be provided in the lecture notes.

MCwp07 Smart Home

1	**Module Name** Smart Home
1.1	**Module Identifier** MCwp07
1.2	**Module Type** Elective
1.3	**Course Names** Smart Home – Lecture Smart Home- Lab
1.4	**Semester** 1 or 2
1.5	**Module Responsible and Instructor** Prof. Dr. Kuhn
1.6	**Additional Instructors** Prof. Dr. Bannwarth
1.7	**Study Program** Master / Major Communications
1.8	**Teaching Language** English
2	**Module Content** **Lecture:** - Introduction to smart home systems and applications - Wired and wireless channels and models - EIB/KNX - PLC-systems (e.g. Homeplug) - Wireless technologies for building (e.g. M-Bus, ZigBee, Enocean, WiFi, Homematic) - Regulatory issues - Security - EMC **Lab:** - Network planning and range measurements for different smart home systems - Qivicon smart home system - Security in smart home systems

3	**Learning Outcome / Competencies** **Knowledge:** - The differences between various systems as well as their pro and cons. - Regulatory issues **Skills :** - Network planning for smart home systems - Configuration of smart home systems **Competences:** - Assessment of security and applicability of solution - Evaluation and selection of appropriate system depending on application and use-case
4	**Course Organization and Structure** lecture (V) / lab (L)
5	**Credits and Workload** 2.5 CP / 75 hours in total, including 28 hours classroom teaching. 1 SWS V / 0.5 (1) SWS L
6	**Examination Modalities** **Examination Prerequisites:** In order to participate in the module exam, it is required to successfully finish the lab part of the module. Successful fulfillment of prerequisites are measured by: - Attending Lab - Lab Progress **Examination Type:** Written exam, oral exam, and/or presentation (will be communicated upon start of the module) covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** Written exam: 60 minutes, oral exam: 30 minutes, presentation: 15 minutes
7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** none
9	**Duration and Frequency of Course** see module description of Elective 1 to 3 (MWP01, MWP02, MWP03)
10	**Applicability /Utilization** This module is applicable for the major Communications. See appendix 2 BBPO (Compulsory options catalogues) for its suitability for other majors.

11	**Literature** The following literature material will be provided: - Electronic lecture notes - Workbook for the lab Further literature recommendations will be provided during the lecture.

MCwp08 Image and Video Processing

1	**Module Name** Image and Video Processing
1.1	**Module Identifier** MCwp08
1.2	**Module Type** Elective
1.3	**Course Names** Image and Video Processing – Lecture
1.4	**Semester** 1 or 2
1.5	**Module Responsible and Instructor** Prof. Dr. Krauß
1.6	**Additional Instructors** ---
1.7	**Study Program** Master / Major Communications
1.8	**Teaching Language** English
2	**Module Content** The course will cover an introduction to the following areas: • Image processing techniques such as e.g. - Fundamentals of digital image representation - Intensity transformations and spatial filtering - Frequency domain processing - Edge detection - Image restoration - Pattern recognition • Video processing techniques such as e.g. - Fundamentals of video sampling and digital video representation - Motion estimation and compensation - Video enhancement and noise reduction
3	**Learning Outcome / Competencies** **to know:**

	- Sophisticated methods for image and video processing. **to understand:** - Fundamentals of digital image and video representation **to apply:** - Basic image and video processing and enhancement algorithms **to transfer:**
4	**Course Organization and Structure** lecture (V) with integrated exercises
5	**Credits and Workload** 2.5 CP / 75 hours in total, including 28 hours classroom teaching. 2 SWS V
6	**Examination Modalities** **Examination Prerequisites:** None **Examination Type:** Written exam or oral exam (will be communicated upon start of the module) covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** Written exam: 60 minutes, oral exam: 30 minutes
7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** Advanced Digital Signal Processing
9	**Duration and Frequency of Course** see module description of Elective 1 to 3 (MWP01, MWP02, MWP03)
10	**Applicability /Utilization** This module is applicable for the major Communications. See appendix 2 BBPO (Compulsory options catalogues) for its suitability for other majors.
11	**Literature** The following literature material will be provided: - Electronic lecture notes Further literature recommendations will be provided during the lecture.

MPwp01 Lab Module on Power Electronics

Major Communications – general electives / electives from other majors

MGwp01 Research Project

MGwp02 Selected Research Topics

MGwp03

MAwp03 Human Machine Interfaces (HMI)

MAwp06 Advanced Sensors for the Internet of Things

MMwp02 Safety in Embedded Control Systems

MMwp05 Security in Connected Embedded Systems

MPwp01 Lab Module on Power Electronics

MPwp01 Lab Module on Power Electronics

1	**Module Name** Lab Module on Power Electronics
1.1	**Module Identifier** MPwp01
1.2	**Module Type** Elective
1.3	**Course Names** Lab-Module on Power Electronics - Lab
1.4	**Semester** 1 or 2
1.5	**Module Responsible and Instructor** Prof. Dr. Krontiris
1.6	**Additional Instructors** Prof. Dr. Weiner
1.7	**Study Program** Master / Major Power Engineering
1.8	**Teaching Language** English

2	**Module Content** The students should gain practical experience with regards to the contents of the corresponding theory modules on Power Electronics for Drives and Energy Systems. The students will carry out different lab experiments on power electronic systems and electrical drives with the measurement of the characteristic electrical, mechanical and other physical values. Each lab exercise is accompanied by a simulation exercise which includes the development of a simulation model. Each lab exercise will be completed with a lab report.
3	**Learning Outcome / Competencies** **to understand:** The students are able to carry out practical measurements on power electronic for drives and energy systems and model the analyzed system with a suitable simulation program. **to apply:** They are able to connect and operate the necessary measurement equipment (in particular power analyzer and digital oscilloscope) in order to get meaningful results. They can present the experiment and evaluate and compare (with regards to theory and simulation) the obtained results in a technical report. The students are thus able to test, describe and evaluate the function and behavior of power electronic for drives and energy systems by means of measurements. **to transfer:** The students are able to define measured quantities and test set-up for the testing and evaluation of other power electronic and electric drives systems. They are able to specify the required measuring equipment. They are able to set-up and refine simulation models of practical systems.
4	**Course Organization and Structure** laboratory (L)
5	**Credits and Workload** 2,5 CP / 75 hours in total, including 14 lab hours. 1 SWS L
6	**Examination Modalities** **Examination Prerequisites:** In order to participate in the module exam, it is required to successfully finish the lab part of the module. Successful fulfillment of prerequisites are measured by: - Successful completion (including report) of all lab and simulation exercises **Examination Type:** written exam / oral exam / practical exam (will be communicated upon start of the module) covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** written exam: 90 minutes; oral exam: 30 minutes; practical exam: 60 minutes
7	**Necessary Prerequisites** Parallel attendance of the modules Power Electronics for Drives and Energy Systems and Advanced Control of electric Drives
8	**Recommended Prerequisites**

	None
9	**Duration and Frequency of Course** This module takes one semester and is offered once a year (see appendix 1 BBPO).
10	**Applicability /Utilization** This module is applicable for the major Power Engineering.
11	**Literature** Workbook for exercises and lab.

MPwp02 Automotive Electrical Power Train

MPwp03 Stationary & Mobile Energy Storage Systems

MPwp05 Switch Gear

MPwp06 Power Systems Planning

MPwp08 Applied Programming

MPwp09 Hydrogen Technique and Fuel Cells

Module Handbook

Electrical Engineering and Information Technology - international
Master of Science

Major Embedded and Microelectronics- mandatory

MM01 Advanced Programming Techniques

see MA04 Advanced Programming Techniques

MM02 VLSI Design and Testing

1	**Module Name** VLSI Design and Testing
1.1	**Module Identifier** MM02
1.2	**Module Type** Mandatory
1.3	**Course Names** VLSI Design and Testing – Lecture VLSI Design and Testing - Lab
1.4	**Semester** 1 or 2 (winter term)
1.5	**Module Responsible and Instructor** Prof. Dr. Schumann
1.6	**Additional Instructors** ---
1.7	**Study Program** Master / Major Embedded Systems and Microelectronics
1.8	**Teaching Language** English
2	**Module Content** **Content of course "VLSI Design and Testing - Lecture"** This course aims at the design perspective of CMOS circuits and the testing of integrated circuits. The course will cover - combinational circuit design, - memory circuit design, - design methods (from full-custom to model-based design), - design verification, - IC fabrication, - IC testing **Content of course "VLSI Design and Testing - Lab"** Practical design assignments on different hardware platforms are part of the course. - Model-based design on SoC/MPSoC platforms - Design verification using FIL - Design for testability

3	**Learning Outcome / Competencies** **to understand:** - design of digital CMOS logic - the design of volatile and non-volatile memory devices - the design methods on different level of abstraction - IC testing procedures and design features to improve testability **to apply :** - the gained knowledge to design high-speed, low-power digital circuits - choose a design method based on design constraints - perform design verification based on performance parameters - select the proper testing method in early design stage of IC **to transfer:** the circuit design concepts to more complex systems using new CMOS technologies and SoC platforms.
4	**Course Organization and Structure** lecture (V) / laboratory (L)
5	**Credits and Workload** 5 CP / 150 hours in total, including 56 hours classroom teaching and lab. 3 SWS V/ 0.5 (1) SWS L
6	**Examination Modalities** **Examination Prerequisites:** In order to participate in the module exam, it is required to successfully finish the lab part of the module. Successful fulfillment of prerequisites are measured by: • Attending Lab • Lab Progress • Lab Report **Examination Type:** Written exam covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** 90 minutes
7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** None
9	**Duration and Frequency of Course** This module takes one semester and is offered once a year (see appendix 1 BBPO).
10	**Applicability /Utilization** This module is applicable for the major Embedded Systems and Microelectronics.

11	**Literature**
	The following literature material will be provided: - lecture notes - Workbook for the lab Further literature recommendations will be provided during the lecture.

MM03 Advanced Microcontroller Systems and Embedded Operating Systems

1	**Module Name** Advanced Microcontroller Systems and Embedded Operating Systems
1.1	**Module Identifier** MM03 / MP04
1.2	**Module Type** Mandatory
1.3	**Course Names** Advanced Microcontroller Systems and Embedded Operating Systems (Lecture) Advanced Microcontroller Systems and Embedded Operating Systems (Lab)
1.4	**Semester** 1 or 2 (winter term)
1.5	**Module Responsible and Instructor** Prof. Dr. Schaefer
1.6	**Additional Instructors** Prof. Dr. Fromm
1.7	**Study Program** Master / Major Embedded Systems and Microelectronics
1.8	**Teaching Language** English
2	**Module Content** Content of the course Advanced Micro-Controller Systems - Hardware Architecture of current Micro-Controller Systems - RTOS implementation - Tasks, Events, Messages, Semaphores - Critical Sections , Priority Ceiling, Deadlocks - Scheduling algorithms - Safety and Memory-Protection - Hardware Security Features - Hardware Device-Driver development - Efficient Implementation of DSP algorithms Content of the course Advanced Micro-Controller Systems and Embedded Operating Systems (Lab) - Design and implementation of deep embedded software on a 32-bit Micro-controller - Configuration and application of embedded operating system services

3	**Learning Outcome / Competencies** **to understand:** Distinct features of current Micro-Controllers **to apply :** Design and Implementation of Device-Drivers, DSP-Algorithms and Control Software for deep embedded applications.
4	**Course Organization and Structure** lecture (V) / laboratory (L)
5	**Credits and Workload** 5 CP / 150 hours in total, including 56 hours classroom teaching and lab. 3 SWS V/ 0.5 (1) SWS L
6	**Examination Modalities** In order to participate in the module exam, it is required to successfully finish the lab part of the module. Successful fulfillment of the prerequisites are measured by: Attending Lab Lab Progress **Examination Type:** Written exam covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** 90 minutes
7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** none
9	**Duration and Frequency of Course** This module takes one semester and is offered once a year (see appendix 1 BBPO).
10	**Applicability /Utilization** This module is applicable for the major Embedded Systems and Microelectronics.
11	**Literature** Electronic lecture notes will be provided. Further literature recommendations will be provided during the lecture.

MM04 FPGA-based System on Chip Design

1	**Module Name** FPGA-based System on Chip Design
1.1	**Module Identifier** MM04
1.2	**Module Type** Mandatory
1.3	**Course Names** FPGA-based System on Chip Design - Lecture FPGA-based System on Chip Design - Lab
1.4	**Semester** 1 or 2 (winter term)
1.5	**Module Responsible and Instructor** Prof. Dr. Jakob
1.6	**Additional Instructors** ---
1.7	**Study Program** Master / Major Embedded Systems and Microelectronics
1.8	**Teaching Language** English
2	**Module Content** **FPGA-based System on Chip Design - Lecture** The aim of this course is to provide students with a solid understanding of designing complex FPGA System on Chip (SoC) architectures, starting with the creation of high-level functional specifications up to the design, implementation and testing on FPGA SoC platforms using hardware description and software programming languages. In particular, the course will cover - an introduction to FPGA based System on Chip design – Applications, limitations and challenges. - the anatomy of modern embedded System on Chip architectures: The hard processor system and FPGA fabric, booting and configuration, PCB issues and design strategies. - RTL hardware design including simulation, and verification using SystemVerilog HDL. - methodologies for successful timing closure, multi-clock domains and synchronization techniques. - design strategies for architecting for performance, area and power. - embedded processors in SoC FPGAs: Hard and soft-processor systems, on-chip bus systems

	- the design and implementation of custom hardware accelerators: Integration of co-processors, ISA customization in soft-processor systems, design of customized HW/SW interfaces. - the optimizing of design metrics using HW/SW co-design approaches. - High-Level-Synthesis: Algorithm and interface synthesis, design evaluation and optimization. **FPGA-based System on Chip Design – Lab** The lab focuses on teaching practical skills related to FPGA based SoC design using C and SystemVerilog: - Design and implementation of custom hardware accelerators (Co-Processors, ISA extensions). - HW/SW integration of custom accelerators into existing FPGA based SoC architectures followed by profiling and benchmarking of the respective solutions.
3	**Learning Outcome / Competencies** **to understand:** - the structure of SoC FPGAs and their role in the design of modern electronic systems. - the tools and methodologies for FPGA-based SoC design. - the basic principles of hardware/software co-design and co-verification. **to apply:** - the gained knowledge to partition simple software programs into dedicated hard- and software components. - the gained knowledge to analyse existing HW/SW architectures, to identify possible performance bottlenecks and to optimize them by finding the optimal HW/SW mapping. - the gained knowledge to optimize existing HW/SW architectures by transformations on hardware and software components. - the gained knowledge to evaluate the implementation results (e.g. timing, resource usage, power consumption) and correlate them with the corresponding high level design. **to transfer:** - the patterns and methodologies to application specific design issues in order to find optimal FPGA SoC HW/SW solutions with respect to performance, power or resource constraints.
4	**Course Organization and Structure** lecture (V) / laboratory (L)
5	**Credits and Workload** 5 CP / 150 hours in total, including 56 hours classroom teaching and lab. 3 SWS V / 0.5 (1) SWS L
6	**Examination Modalities** **Examination Prerequisites:** In order to participate in the module exam, it is required to successfully finish the lab part of the module. Successful fulfilment of prerequisites are measured by: ▪ Lab attendance ▪ Lab entry test ▪ Lab progress 25% of the module grade is obtained by the laboratory. **Examination Type:** Written exam covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** 90 minutes

7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** None
9	**Duration and Frequency of Course** This module takes one semester and is offered once a year (see appendix 1 BBPO).
10	**Applicability /Utilization** This module is applicable for the major Embedded Systems and Microelectronics.
11	**Literature** The following literature material will be provided: - Electronic lecture notes - Laboratory Workbook Further literature recommendations will be provided during the lecture.

MM05 Embedded Architectures and Applications

1	**Module Name** Embedded Architectures and Applications
1.1	**Module Identifier** MM05
1.2	**Module Type** Mandatory
1.3	**Course Names** Embedded Architectures and Applications - Lecture Embedded Architectures and Applications - Lab
1.4	**Semester** 1 or 2 (summer term)
1.5	**Module Responsible and Instructor** Prof. Dr. Fromm
1.6	**Additional Instructors** Prof. Dr. Schaefer
1.7	**Study Program** Master / Major Embedded Systems and Microelectronics
1.8	**Teaching Language** English
2	**Module Content** **Content of course "Embedded Architectures and Applications - Lecture"** Participants will be exposed to and gain working experience with complex embedded systems and architecture development. The course will cover - introduction to multitasking concepts and operating systems, - structure and functionality of selected industrial embedded Operating Systems - design of reactive systems, state machine design and coding, - architectural development of embedded, realtime, multitasking systems - analysis of embedded industrial architectures and design patterns (Basic Software, Application Software, Runtime Environment) - automotive architectures, AUTOSAR - embedded control system design - multicore architectures - safety architectures **Content of course "Embedded Architectures and Applications - Lab"**

	Practical programming assignments in C/C++ using state of the art operating systems are part of the course. - Configuring an embedded Operating System - Developing a simple multithreading, reactive application - Separating basic software and application software introducing a runtime environment
3	**Learning Outcome / Competencies** **to understand:** - the functionality of embedded operating systems - the challenges and risks of multithreading architectures - the structure of multicore controllers - key design patterns of industrial embedded architectures **to apply:** - the gained knowledge to implements tasks and intertask communication on embedded controllers - design and implement flat statemachines - review, test and debug multithreading applications - separate base and application software using the concepts of embedded runtime environments **to transfer:** - the design patterns and concepts to more complex embedded architectures using new operating systems and controllers.
4	**Course Organization and Structure** lecture (V) / laboratory (L)
5	**Credits and Workload** 5 CP / 150 hours in total, including 56 hours classroom teaching and lab. 3 SWS V/ 0.5 (1) SWS L
6	**Examination Modalities** **Examination Prerequisites:** In order to participate in the module exam, it is required to successfully finish the lab part of the module. Successful fulfillment of prerequisites are measured by: - Attending Lab - Lab Progress **Examination Type:** Written exam covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** 90 minutes
7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** None

9	**Duration and Frequency of Course** This module takes one semester and is offered once a year (see appendix 1 BBPO).
10	**Applicability /Utilization** This module is applicable for the major Embedded Systems and Microelectronics.
11	**Literature** The following literature material will be provided: - Electronic lecture notes - Workbook for the lab Further literature recommendations will be provided during the lecture.

MM06 System Driven Hardware Design

see MC05 System-Driven Hardware Design

MM07 Embedded Signal Processing Systems

1	**Module Name** Embedded Signal Processing Systems
1.1	**Module Identifier** MM07
1.2	**Module Type** Mandatory
1.3	**Course Names** Embedded Signal Processing Systems - Lecture Embedded Signal Processing Systems - Lab
1.4	**Semester** 1 or 2 (summer term)
1.5	**Module Responsible and Instructor** Prof. Dr. Jakob
1.6	**Additional Instructors** ---
1.7	**Study Program** Master / Major Embedded Systems and Microelectronics
1.8	**Teaching Language** English
2	**Module Content** **Embedded Signal Processing Systems - Lecture** The aim of this course is to provide students with a solid understanding of designing complex embedded signal processing systems using modern µC and FPGA architectures. Key subjects are the design, modelling and simulation of fixed-point DSP algorithms as well as their HW/SW implementation on state-of-the-art processing platforms. In particular, the course will cover - an introduction to modern DSP systems – Emerging applications, architectures and challenges. - the theory of discrete-time systems and fixed-point mathematics. - the design and implementation of digital filters (FIR/IIR digital filter design and specification, retiming: cut-set and delay scaling, the transpose FIR, pipelining and multichannel architectures). - the synthesis of digital signals (NCO Design, DDFS, CORDIC algorithm, IIR oscillators). - digital correlator architectures (Auto/cross-correlation techniques). - the Discrete Fourier Transform, various FFT algorithms and architectures, as well as design issues related to FFT word-length growth and accuracy. - HLS and Model based DSP design: Synthesis of custom DSP accelerators.

	- Design and implementation of digital control systems: Mapping analog control loops to digital platforms. **Embedded Signal Processing Systems - Lab** The lab focuses on teaching practical skills related to the design and implementation of embedded signal processing systems using C and SystemVerilog: - Analysis, modelling and simulation of various DSP algorithms. - Mapping DSP algorithms (Filters, signal synthesisers) to µC and FPGA platforms followed by profiling and benchmarking of the respective HW/SW solutions.
3	**Learning Outcome / Competencies** **to understand:** - the architectural features of modern DSP processing systems. - the tools and methodologies for embedded DSP design. - the basic strategies for mapping algorithms to HW and SW platforms. **to apply:** - the gained knowledge to analyse, model and simulate dedicated DSP algorithms. - the gained knowledge to map a given floating-point DSP algorithm to its fixed-point equivalent. - the gained knowledge to implement fixed-point algorithms on state-of-the-art HW/SW platforms. - the gained knowledge to explore design trade-offs in real-time performance vs. implementation complexity. - the gained knowledge to evaluate the implementation results (e.g. timing, resource usage, power consumption) and correlate them with the corresponding high level design. **to transfer:** - the patterns and methodologies to more complex DSP design scenarios in order to find optimal HW/SW solutions with respect to constraints such as costs, performance or power consumption.
4	**Course Organization and Structure** lecture (V) / laboratory (L)
5	**Credits and Workload** 5 CP / 150 hours in total, including 56 hours classroom teaching and lab. 3 SWS V/ 0.5 (1) SWS L
6	**Examination Modalities** **Examination Prerequisites:** In order to participate in the module exam, it is required to successfully finish the lab part of the module. Successful fulfilment of prerequisites are measured by: ▪ Lab Attendance ▪ Lab Test ▪ Lab Progress 25% of the module grade is obtained by the laboratory. **Examination Type:** Written exam covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** 90 minutes

7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** None
9	**Duration and Frequency of Course** This module takes one semester and is offered once a year (see appendix 1 BBPO).
10	**Applicability /Utilization** This module is applicable for the major Embedded Systems and Microelectronics.
11	**Literature** The following literature material will be provided: - Electronic lecture notes - Laboratory Workbook Further literature recommendations will be provided during the lecture.

Module Handbook

Electrical Engineering and Information Technology - international

Master of Science

Major Embedded and Microelectronics- electives

MMwp01 CMOS Analog Circuits

1	**Module Name** CMOS Analog Circuits
1.1	**Module Identifier** MMwp01
1.2	**Module Type** Elective
1.3	**Course Names** CMOS Analog Circuits – Lecture CMOS Analog Circuits - Lab
1.4	**Semester** 1 or 2
1.5	**Module Responsible and Instructor** Prof. Dr. Hoppe
1.6	**Additional Instructors** ---
1.7	**Study Program** Master / Major Embedded Systems and Microelectronics
1.8	**Teaching Language** English
2	**Module Content** This module provides an introduction to CMOS analog circuit design. It covers the areas - CMOS-technology, - MOS-transistors and passive components, - Integrated circuit layout, - CMOS device modelling (large signal and small signal), SPICE-simulation - Analog subcircuits: Switches, sinks/sources, current mirrors, references - CMOS amplifiers: single transistor amplifiers, differential amplifiers, cascode amplifiers - Operational amplifiers, OpAmps: Compensation, two-stage-architectures, cascade OpAmps) - Digital-analog and analog-digital converters (flash, sequential and oversampling converters)
3	**Learning Outcome / Competencies** Students should know after completion of this module the most important principles of CMOS process technology and basics of deep submicron device models They should understand the design flow for CMOS-analogue circuits, which differs qualitatively from the digitial counterpart

	They should be able to apply the design recipes to develop analogue circuits according to given They should be able to transfer the design methods from this module to other fields of analogue design tasks After the completion of the module the student has all the relevant **skills** which are needed to design analog building blocks and integrated analog systems starting from a specification to a verified integrated circuit layout. Since the module covers complex design problems students **know** about the common mistakes made by beginning engineers. Design **competencies** are developed by taking the student step by step through the creation of real circuits.
4	**Course Organization and Structure** The course is taught using classroom lectures (V) and lab classes (L)
5	**Credits and Workload** 5 CP / 150 hours in total, including 56 hours classroom teaching and lab. 3SWS V / 1 SWS L
6	**Examination Modalities** **Examination Prerequisites:** In order to participate in the module exam, it is required to successfully finish the lab part of the module. Successful fulfillment of prerequisites are measured by: - Laboratory Workbook - Attending Lab 30% of the module grade are obtained by the laboratory / project during the term. **Examination Type:** Written exam 90 minutes covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** 90 minutes
7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** None
9	**Duration and Frequency of Course** see module description of Elective 1 to 3 (MWP01, MWP02, MWP03)
10	**Applicability /Utilization** This module is applicable for the major Embedded Systems and Microelectronics. See appendix 2 BBPO (Compulsory options catalogues) for its suitability for other majors.

11	**Literature** Slides for the lecture and lab instructions are available (Moodle) Slides contain references for additional literature and online-material.

MMwp02 Safety in Embedded Control Systems

1	**Module Name** Safety in Embedded Control Systems
1.1	**Module Identifier** MMwp02
1.2	**Module Type** Elective
1.3	**Course Names** Safety in Embedded Control Systems - Lecture
1.4	**Semester** 1 or 2
1.5	**Module Responsible and Instructor** Prof. Dr. Fromm
1.6	**Additional Instructors** ---
1.7	**Study Program** Master / Major Embedded Systems and Microelectronics
1.8	**Teaching Language** English
2	**Module Content** **Content of course "Safety in Embedded Control Systems"** Participants will be exposed to and gain working experience with safety standards and safety architectures for embedded control systems. The course will cover - introduction to safety standards like IEC61508 and ISO26262, - analysis of safety cases, - fundamental concepts for functional safety, - development of fail safe and fail operational architectures - concepts for avoiding systematic software errors (coding standards like MISRA, reviews, test strategies), - concepts for dealing with sporadic errors, - design patterns for freedom from interference, - analysis of the features of modern safety controllers.
3	**Learning Outcome / Competencies** **to understand:** - the structure and concept of safety standards

	- the development of a safety case **to apply:** - the gained knowledge to implements an embedded safety architecture (fail safe) - systematic methods to limit systematic software errors (coding standards) **to transfer:** - the design patterns and concepts to more complex fail operational architectures.
4	**Course Organization and Structure** lecture (V) / laboratory (L)
5	**Credits and Workload** 2,5 CP / 75 hours in total, including 28 hours classroom teaching. 2 SWS V
6	**Examination Modalities** **Examination Prerequisites:** none **Examination Type:** Written exam covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** 60 minutes
7	**Necessary Prerequisites** Good programming skills (C, C++)
8	**Recommended Prerequisites** Knowledge of microcontrollers and embedded OS
9	**Duration and Frequency of Course** see module description of Elective 1 to 3 (MWP01, MWP02, MWP03)
10	**Applicability /Utilization** This module is applicable for the major Embedded Systems and Microelectronics. See appendix 2 BBPO (Compulsory options catalogues) for its suitability for other majors.
11	**Literature** The following literature material will be provided: - Electronic lecture notes - Workbook for the lab Further literature recommendations will be provided during the lecture.

MMwp03 Digital System Design

1	**Module Name** Digital System Design
1.1	**Module Identifier** MMwp03
1.2	**Module Type** Elective
1.3	**Course Names** Digital System Design – Lecture Digital System Design - Lab
1.4	**Semester** 1 or 2
1.5	**Module Responsible and Instructor** Prof. Dr. Schumann
1.6	**Additional Instructors** ---
1.7	**Study Program** Master / Major Embedded Systems and Microelectronics
1.8	**Teaching Language** English
2	**Module Content** **Content of course "Digital System Design - Lecture"** This course aims at the design of digital systems using SoC platforms. The course will cover - pipelining and parallel processing, - arithmetic circuits, - power dissipation in CMOS, - synchronous vs. asynchronous design, - design automation, - hardware description language VHDL **Content of course "Digital System Design - Lab"** Practical design assignments on different hardware platforms are part of the course. - image processing on SoC/MPSoC platforms - hardware/software-codesign for FPGA-based systems - design automation using state-of-the–art design tools

3	**Learning Outcome / Competencies** **to understand:** - the high-throughput design concepts - the advantages/disadvantages of a clock-based design - the levels of abstraction for system design - the concept of a hardware description language **to apply:** - implement the concept of parallel processing to digital filters - use different clocking strategies for performance improvement - select a SoC design flow for a specified hardware platform - define systems on different levels of abstraction **to transfer:** - develop digital systems on emerging new platforms
4	**Course Organization and Structure** lecture (V) / laboratory (L)
5	**Credits and Workload** 5 CP / 150 hours in total, including 56 hours classroom teaching and lab. 3 SWS V/ 1 L
6	**Examination Modalities** **Examination Prerequisites:** In order to participate in the module exam, it is required to successfully finish the lab part of the module. Successful fulfillment of prerequisites are measured by: • Attending Lab • Lab Progress • Lab Report **Examination Type:** Written exam covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** 90 minutes
7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** None

9	**Duration and Frequency of Course** see module description of Elective 1 to 3 (MWP01, MWP02, MWP03)
10	**Applicability /Utilization** This module is applicable for the major Embedded Systems and Microelectronics. See appendix 2 BBPO (Compulsory options catalogues) for its suitability for other majors.
11	**Literature** The following literature material will be provided: - lecture notes - Workbook for the lab Further literature recommendations will be provided during the lecture.

MMwp04 Advanced Software Design Techniques

1	**Module Name** Advanced Software Design Techniques
1.1	**Module Identifier** MMwp04
1.2	**Module Type** Elective
1.3	**Course Names** Advanced Software Design Techniques - Lecture Advanced Software Design Techniques - Lab
1.4	**Semester** 1 or 2
1.5	**Module Responsible and Instructor** Prof. Dr. Fromm
1.6	**Additional Instructors** Prof. Dr. Lipp, Prof. Dr. Bürgy
1.7	**Study Program** Master / Major Embedded Systems and Microelectronics
1.8	**Teaching Language** English
2	**Module Content** **Content of course "Advanced Software Design Techniques"** Review of fundamental concepts of a widely used object oriented programming language. The course will cover - advanced data and class structures - differences and interoperability of C and C++ - polymorphism, - generic programming, - introduction to the STL, string and stream library of C++, - coding standards (MISRA), - software metrics, - design patterns, - refactoring techniques, - extensions of the C++ standard.

	Design aspects like modularity, performance and software re-use will be discussed. Developing software designs using the UML and CASE tools as well as extensive hands-on programming assignments in C/C++ are an integral part of the course.
3	**Learning Outcome / Competencies** **to understand:** - complex design patterns **to apply:** - complex design patterns - assess design quality of complex software - refactoring methods - combined C/C++ modules **to transfer:** - the design patterns and concepts to more complex architectures
4	**Course Organization and Structure** lecture (V) / laboratory (L)
5	**Credits and Workload** 5 CP / 150 hours in total, including 56 hours classroom teaching and lab. 3 SWS V/ 1 L
6	**Examination Modalities** **Examination Prerequisites:** In order to participate in the module exam, it is required to successfully finish the lab part of the module. Successful fulfillment of prerequisites are measured by: - Attending Lab - Lab Progress **Examination Type:** Written exam covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** 90 minutes
7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** None
9	**Duration and Frequency of Course** see module description of Elective 1 to 3 (MWP01, MWP02, MWP03)

10	**Applicability /Utilization** This module is applicable for the major Embedded Systems and Microelectronics. See appendix 2 BBPO (Compulsory options catalogues) for its suitability for other majors.
11	**Literature** The following literature material will be provided: - Electronic lecture notes - Workbook for the lab Further literature recommendations will be provided during the lecture.

MMwp05 Security in Connected Embedded Systems

1	**Module Name** Security in Connected Embedded Systems
1.1	**Module Identifier** MMwp05
1.2	**Module Type** Elective
1.3	**Course Names** Security in Connected Embedded Systems - Lecture
1.4	**Semester** 1 or 2
1.5	**Module Responsible and Instructor** NN
1.6	**Additional Instructors** Prof. Dr. Fromm
1.7	**Study Program** Master / Major Embedded Systems and Microelectronics
1.8	**Teaching Language** English
2	**Module Content** **Content of course "Security in Connected Embedded Systems"** Participants will be exposed to and gain working experience with security requirements and solutions for connected embedded systems. The course will cover - introduction to encryption - case study "security breaches in connected embedded systems", - analysis of embedded hardware encryption modules, - elementary security concepts (secure boot concepts, authentification, encryption, key management) - analysis of existing security protocols, - design of a secure embedded architecture.
3	**Learning Outcome / Competencies** **to understand:** - the basic concepts of encryption - the need for securing connected embedded systems **to apply:**

	- the gained knowledge to design a security architecture (elementary services) **to transfer:** - the gained knowledge to new security concepts and standards.
4	**Course Organization and Structure** lecture (V)
5	**Credits and Workload** 2,5 CP / 75 hours in total, including 28 hours classroom teaching. 2 SWS V
6	**Examination Modalities** **Examination Prerequisites:** none **Examination Type:** Written exam **Examination Duration:** 60 minutes
7	**Necessary Prerequisites** Good programming skills (C, C++)
8	**Recommended Prerequisites** Knowledge of microcontrollers
9	**Duration and Frequency of Course** see module description of Elective 1 to 3 (MWP01, MWP02, MWP03)
10	**Applicability /Utilization** This module is applicable for the major Embedded Systems and Microelectronics. See appendix 2 BBPO (Compulsory options catalogues) for its suitability for other majors.
11	**Literature** The following literature material will be provided: - Electronic lecture notes - Workbook for the lab Further literature recommendations will be provided during the lecture.

MMwp06 Digital Signal Processing Chain

1	**Module Name** Digital Signal Processing Chain
1.1	**Module Identifier** MMwp06
1.2	**Module Type** Elective
1.3	**Course Names** Digital Signal Processing Chain - Lecture
1.4	**Semester** WS or SS
1.5	**Module Responsible and Instructor** Prof. Hermann Meuth, Ph.D.
1.6	**Additional Instructors** Prof. Dr. Christian Jakob
1.7	**Study Program** Master / suitable for all Majors
1.8	**Teaching Language** English
2	**Module Content** The module is aimed at both a theoretical and a hardware design perspective of the entire signal processing chain and the interdependencies of hardware design parameters. Topics covered will be: Anti-aliasing and reconstruction filters, sampling (in time), bit quantization (in value), conversion and reconstruction, slew rate, sample and hold, over-sampling, under-sampling, precision of algorithms and respective errors and error propagation. Digital signal generation. CORDIC. Sigma-Delta-principles, noise shaping. Digital filter design principles. Digital control systems. Z-transform and bit-true representations in time and frequency domain. Actual hardware implementation schemes.
3	Participants will learn to specify and configure constituent components of modern signal processing systems, especially in regards to their interdependencies in performance and design parameters. The generic approach will leave room for various implementation and application schemes. Having completed the course, participants will - know the salient characteristics of the signal processing components - understand, how such components and the choice of their parameters will influence the performance of the entire chain - be able to apply such systems in various hardware schemes and to assess their usability

	- be able to transfer these competencies to various applications regardless of any details of hardware or processing technologies, as digital signal processing schemes are ubiquitous in modern electrical engineering and IT applications.
4	**Course Organization and Structure** lecture (V) with a seminar component (Sem)
5	**Credits and Workload** 2,5 CP / 75 hours in total, including 28 hours classroom teaching. 2 SWS V
6	**Examination Modalities** Written exam at the end of the term. Possible changes to the examination modalities may be communicated upon start of the module. 70% of the module grade is based on the written exam and 30% on the seminar presentation. **Examination Prerequisites:** In order to write the end-of-term exam, each participant is required to have individually presented a seminar of ½ hour covering a subject related to the scope of the course. **Examination Type:** Written paper-and-pencil open-book exam plus seminar presentation **Examination Duration:** 90 Minutes
7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** None
9	**Duration and Frequency of Course** see module description of Elective 1 to 3 (MWP01, MWP02, MWP03)
10	**Applicability /Utilization** Due to the generic approach and philosophy, the module should be suitable for all majors.
11	**Literature** Course material: Tablet-based course transcripts

	Texts: Emmanuel C. Ifeachor, Barrie W. Jervis, Digital Signal Processing, a practical approach. Prentice. Richard J. Higgins, Digital Signal Processing in VLSI, Prentice. Out of print, thus use of mimeographed excerpts. Journals and patent disclosures: Various current journal articles and reprint volumes.

MPwp01 Lab Module on Power Electronics

Major Embedded and Microelectronics– general electives / electives from other majors

MGwp01 Research Project

MGwp02 Selected Research Topics

MGwp03

MAwp01 Model-based Real-time Simulation of Mechatronic Systems

MAwp02 High Level Language Frameworks

MAwp03 Human Machine Interfaces (HMI)

MAwp05 Advanced Graphical Programming of Control Systems

MAwp06 Advanced Sensors for the Internet of Things

MCwp01 Digital Signal Processing Applications

MCwp02 Wireless Systems (Technologies

MCwp03 Network Security

MCwp04 Mobile Communications

MCwp05 Optical Communications

MCwp06 (I)Iot and Cloud Networking

MCwp07 Smart Home

MCwp08 Image and Video Processing

MPwp01 Lab Module on Power Electronics

MPwp01 Lab Module on Power Electronics

1	**Module Name** Lab Module on Power Electronics
1.1	**Module Identifier** MPwp01
1.2	**Module Type** Elective
1.3	**Course Names** Lab-Module on Power Electronics - Lab
1.4	**Semester** 1 or 2

1.5	**Module Responsible and Instructor** Prof. Dr. Krontiris
1.6	**Additional Instructors** Prof. Dr. Weiner
1.7	**Study Program** Master / Major Power Engineering
1.8	**Teaching Language** English
2	**Module Content** The students should gain practical experience with regards to the contents of the corresponding theory modules on Power Electronics for Drives and Energy Systems. The students will carry out different lab experiments on power electronic systems and electrical drives with the measurement of the characteristic electrical, mechanical and other physical values. Each lab exercise is accompanied by a simulation exercise which includes the development of a simulation model. Each lab exercise will be completed with a lab report.
3	**Learning Outcome / Competencies** **to understand:** The students are able to carry out practical measurements on power electronic for drives and energy systems and model the analyzed system with a suitable simulation program. **to apply:** They are able to connect and operate the necessary measurement equipment (in particular power analyzer and digital oscilloscope) in order to get meaningful results. They can present the experiment and evaluate and compare (with regards to theory and simulation) the obtained results in a technical report. The students are thus able to test, describe and evaluate the function and behavior of power electronic for drives and energy systems by means of measurements. **to transfer:** The students are able to define measured quantities and test set-up for the testing and evaluation of other power electronic and electric drives systems. They are able to specify the required measuring equipment. They are able to set-up and refine simulation models of practical systems.
4	**Course Organization and Structure** laboratory (L)
5	**Credits and Workload** 2,5 CP / 75 hours in total, including 14 lab hours. 1 SWS L

6	**Examination Modalities** **Examination Prerequisites:** In order to participate in the module exam, it is required to successfully finish the lab part of the module. Successful fulfillment of prerequisites are measured by: - Successful completion (including report) of all lab and simulation exercises **Examination Type:** written exam / oral exam / practical exam (will be communicated upon start of the module) covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** written exam: 90 minutes; oral exam: 30 minutes; practical exam: 60 minutes
7	**Necessary Prerequisites** Parallel attendance of the modules Power Electronics for Drives and Energy Systems and Advanced Control of electric Drives
8	**Recommended Prerequisites** None
9	**Duration and Frequency of Course** This module takes one semester and is offered once a year (see appendix 1 BBPO).
10	**Applicability /Utilization** This module is applicable for the major Power Engineering.
11	**Literature** Workbook for exercises and lab.

MPwp01 Lab Module on Power Electronics

MPwp02 Automotive Electrical Power Train

MPwp03 Stationary & Mobile Energy Storage Systems

MPwp05 Switch Gear

MPwp06 Power Systems Planning

MPwp09 Hydrogen Technique and Fuel Cells

Module Handbook

Electrical Engineering and Information Technology - international

Master of Science

Major Power Engineering - mandatory

MP01 Advanced High Voltage Technology

1	**Module Name** Advanced High Voltage Technology
1.1	**Module Identifier** MP01
1.2	**Module Type** Mandatory
1.3	**Course Names** Advanced High Voltage Technology – Lecture Advanced High Voltage Technology – Lab
1.4	**Semester** 1 or 2 (winter term)
1.5	**Module Responsible and Instructor** Prof. Dr. Betz
1.6	**Additional Instructors** ---
1.7	**Study Program** Master / Major Power Engineering
1.8	**Teaching Language** English
2	**Module Content** **Content of course „Advanced High Voltage Technology – Lecture":** Participants will be exposed to and gain theoretical experience with high voltage systems for high AC and high DC voltages. The course will cover: - Introduction into HVAC and HVDC applications. - Short repetition of breakdown in gases, in solids and in liquids. - Electromagnetic field calculations and breakdown behavior influenced by homogeneous, quasi-homogeneous- and in-homogeneous arrangements and by polarity effect. - Dimensioning of high voltage components based on dimensioning rules of gases, solids and liquids. For identical technical requirements three different high voltage systems shall be dimensioned and compared critically: cable versus gas-insulated switchgear versus air-insulated switchgear. The aspects like size, weight and life time shall be taken into account. - Generation of high impulse voltages using a marx-generator: calculation of a 4 stage-design and evaluation of different methods to improve to an 8-stage-design. - Sources of over-voltages in networks and countermeasures like surge MO-surge arresters or additional lightning protection such as double-earth conductors on top of overhead lines.

- Design and calculation of impulse-current test-circuits to test surge arresters.
- Measuring methods of impulse currents and their limitations.
- Partial discharge recognition in AC-systems to prevent failure occurrence in medium and high voltage components and systems. Use of phase-resolved-pattern-recognition of partial discharges to classify the failure source.
- Special challenge of detecting and interpretation of partial discharges in DC-systems. Students shall investigate partial discharge measuring methods in a self-contained literature study and present their results group-wise in the lecture. The effect and a detection solution are demonstrated afterwards within the high voltage lab.
- Development process based on the development steps of an gas-insulated switchgear (GIS) product. Main focus hereby is the patent disclosure process.

Content of course „Advanced High Voltage Technology – Lab":
Participants will gain practical experience in the following topics:
Performing and measuring of impulse voltage and impulse current tests:

- Performing impulse voltage tests with an 800 kV-marx-generator.
- Measuring and comparison of impulse voltages provided by a compensated ohmic divider and a damped capacitive divider. Influence of the earthing network will be demonstrated. Students shall optimize the given earthing system. The gained measuring results shall be proven by calculation of the divider ratios based on the used components of the dividers.
- Calculation and performing of impulse current tests.

Performing and measuring of partial discharge measurements based on samples and real products

- Students shall built-up the partial discharge measuring system by their own.
- Calibration and check of ground noise of the partial discharge measuring system.
- Investigations on different samples and real products. Comparison and critical discussion of the measuring results.
- Interpretation of phase resolved pattern recognition and classification of failure sources.

- Introduction into the complex area of partial discharges at DC. Students will get publications about partial discharge effects at DC and shall prepare the physical background by themselves. Students getting familiar with phenomenon of DC-failure and difficulties of partial discharge measurement at DC-voltages.

3 Learning Outcome / Competencies

to understand:

- The functionality of high voltage AC and DC –systems.
- Influence of technical parameters which determine the dielectric, mechanical and thermal behavior of high voltage components and systems.
- Influence of geometry and polarity on the electromagnetic phenomenon.
- Specialties of an development process including patent disclosures

to apply:

- The gained knowledge to dimension high voltage components (cables, GIS, AIS).
- The dimensioning rules to calculate an impulse voltage generator.
- The dimensioning rules to calculate an impulse current generator
- To apply different methods for partial discharge measurements for AC and DC systems.
- To dimension suited surge arresters to limit over-voltages.

	to transfer: - To classify failure sources based on partial discharge measuring methods for AC and DC systems. - To change existing geometries to optimized geometries. - Measuring results can be adapted to other products taking the chain of tolerances into account. - To transfer life acceleration tests into real products like high voltage cables using solid insulations. - To transfer existing countermeasures (to prevent over-voltages) to other designs and applications.
4	**Course Organization and Structure** lecture (V) / laboratory (L)
5	**Credits and Workload** 5 CP / 150 hours in total, including 56 hours classroom teaching and lab. 3 SWS V/0,5 (1) L
6	**Examination Modalities** **Examination Prerequisites:** In order to participate in the module exam, it is required to successfully finish the lab part of the module. Successful fulfillment of prerequisites are measured by: - Attending and Documentation of the Lab - Lab progress **Examination Type:** Written exam or presentation covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** 90 minutes (written exam), 20 minutes (presentation)
7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** None
9	**Duration and Frequency of Course** This module takes one semester and is offered once a year (see appendix 1 BBPO).
10	**Applicability /Utilization** This module is applicable for the major Power Engineering and as elective course of master WING.
11	**Literature** The following literature material will be provided: - Electronic lecture notes - Workbook for the Lab Further literature recommendations will be provided during the lecture.

MP02 Power System Operation

1	**Module Name** Power System Operation
1.1	**Module Identifier** MP02
1.2	**Module Type** Mandatory
1.3	**Course Names** Power System Operation - Lecture Power System Operation - Lab
1.4	**Semester** 1 or 2 (winter term)
1.5	**Module Responsible and Instructor** Prof. Dr. Graf
1.6	**Additional Instructors** ---
1.7	**Study Program** Master / Major Power Engineering
1.8	**Teaching Language** English
2	**Module Content** This course provides an introduction to professional power system operations including operational planning based on standard tools like SCADA and Training Systems. The course covers the theoretical side and explains the grid operations in real time on a training system using an industry standard control system. The lab covers fundamental concepts of power grid operations in real situations. **Power System Operation – Lecture** - Review of the relevant component models of power systems - Structure of power systems and Interaction of power system components in the system context - Architecture of control centers including information technology (RTU) - SCADA and EMS software functions in control centers - Strategies for operational planning and optimization - Significance and means of voltage and reactive power control - Power frequency control and power system stability - Power system faults and functions of protection relays - Strategies for clearing power system emergencies

	Power System Operation – Lab The participants will use a power system training simulator to get experience of basic operational tasks including normal operation and handling of disturbances. - Analyzing power system components and their interaction in the system context - Operational tasks during normal operation - Exploring component limits - Reactions of power system components during power system disturbances - Analyzing power system faults, operational tasks during emergencies - Control center operational handling in coordination with grid service staff
3	**Learning Outcome / Competencies** **to understand:** - behavior of power system components in the system context - power system operational tasks and planning - voltage control and reactive power resources and demand - power frequency control and active power balance - fault clearing by protection devices **to apply:** - handling control center software (SCADA) - solving operational tasks in the training simulation - execute fault localization and service restoration on the training system **to transfer:** - optimization of the system state by finding suitable control actions - assess the impact of renewable energy sources on the power system - do the master thesis with a utility company
4	**Course Organization and Structure** lecture (V) / laboratory (L)
5	**Credits and Workload** 5 CP / 150 hours in total, including 56 hours classroom teaching and lab. 3 SWS (V) / 0,5 (1) SWS L
6	**Examination Modalities** **Examination Prerequisites:** In order to participate in the module exam, it is required to successfully finish the lab part of the module. Successful fulfillment of prerequisites are measured by: - Attending Lab - Lab report 20% of the module grades are obtained by the laboratory during the term. **Examination Type:** Written exam covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester.

	Examination Duration: 90 minutes
7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** - good knowledge of basic properties power and models of system components such as transformers, transmission lines and generators - good knowledge of circuit analysis methods
9	**Duration and Frequency of Course** This module takes one semester and is offered once a year (see appendix 1 BBPO).
10	**Applicability /Utilization** This module is applicable for the major Power Engineering.
11	**Literature** The lab lecture notes and further material are provided in electronic form. Further literature recommendations will be provided during the lecture.

MP03 Renewable Energy Systems

1	**Module Name** Renewable Energy Systems
1.1	**Module Identifier** MP03
1.2	**Module Type** Mandatory
1.3	**Course Names** Renewable Energy Systems - Lecture
1.4	**Semester** 1 or 2 (winter term)
1.5	**Module Responsible and Instructor** Prof. Dr. Glotzbach
1.6	**Additional Instructors**
1.7	**Study Program** Master / Major Power Engineering
1.8	**Teaching Language** English
2	**Module Content** Todays and future societies crucially rely on a secure, stable and uninterruptible energy supply. A key factor in this context represents the strategic expansion and integration of renewable energy systems in present and future energy systems. Besides providing students with up-to-date and advanced knowledge of renewable energy techniques and systems, the lecture also addresses contemporary and future challenges such as net-integration or the storage of electricity generated by fluctuating renewable power generation systems. In detail, the course covers the following subjects: - Analysis of current energy needs and future energy demands as well as the resulting environmental, social, social-economic and political implications. - Review of the basic physics used in RE studies (Energy fundamentals, heat transfer mechanisms, laws of thermodynamics, conservation of energy and momentum,). - Comparison to conventional energy systems (fossil fuels and nuclear energy) and their underlying conversion processes. - Fundamentals of renewable energy sources like solar radiation, wind-, geothermal power. - Use of solar power by solar thermal and solar thermal electricity systems - Power generation by photovoltaic, photovoltaic system design (stand-alone and grid connected systems), photovoltaic power electronics.

	- Wind energy resources, site analysis, wind energy conversion systems, onshore and offshore wind park design. - Besides the main topics of solar and wind energy conversion systems, the lecture addresses geothermal power systems, hydro and tidal power systems as well as biomass power systems. - The role of energy storage in renewable energy systems: Possible options and solutions: From pumped hydro storage up to power-to-gas technology. - Future outlook on renewable energy: Potentials and limitations, drivers and future challenges, policy and planning - Simulation of renewable energy systems - Economics of renewable energy systems
3	**Learning Outcome / Competencies** **to understand:** The students understand the physical calculation and simulation methods of solar radiation. Furthermore, they understand the structure, the technology and the behavior of the treated regenerative power generation plants and of steam power plants. **to apply:** The students apply calculation and simulation methods for the design of regenerative energy generation plants and steam power plants and can thus determine, for example, the energy yield. **to transfer:** Application to new regenerative energy systems by calculation and simulation methods. In addition, students are qualified in planning and designing complex systems of different renewable energy systems.
4	**Course Organization and Structure** lecture (V)
5	**Credits and Workload** 5 CP / 150 hours in total, including 56 hours classroom teaching. 4 SWS V
6	**Examination Modalities** **Examination Prerequisites:** None **Examination Type:** Written exam or presentation covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** 90 minutes (written exam), 20 minutes (presentation)
7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** None

9	**Duration and Frequency of Course** This module takes one semester and is offered once a year (see appendix 1 BBPO).
10	**Applicability /Utilization** This module is applicable for the major Power Engineering.
11	**Literature** The following literature material will be provided: - Volker Quaschning: Under-standing Renewable Energy Systems - Kaltschmitt Martin: Renewable Energy Systems Further literature recommendations will be provided during the lecture.

MP04 Embedded Programming & Design of Real-Time Control Systems

1	**Module Name** Embedded Programming & Design of Real-Time Control Systems
1.1	**Module Identifier** MP04
1.2	**Module Type** Mandatory
1.3	**Course Names** Embedded Programming & Design of Real-Time Control Systems – Lecture Embedded Programming & Design of Real-Time Control Systems – Lab
1.4	**Semester** 1 or 2 (winter term)
1.5	**Module Responsible and Instructor** Prof. Dr. Jakob
1.6	**Additional Instructors** ---
1.7	**Study Program** Master / Major Power Engineering
1.8	**Teaching Language** English
2	**Module Content** **Embedded Programming & Design of Real-Time Control Systems - Lecture** The aim of this course is to provide students with a solid background of embedded system fundamentals for the application in modern power electronic control systems. In particular, the course will cover - an introduction to real-time control systems for power electronic applications – Basic principles and typical application scenarios. - a review of basic control principles: design and analysis of closed loop control systems. - general embedded system attributes: Real-time capabilities, concurrency, responsiveness, reliability and fault handling, diagnostics and system-constraint metrics (costs, power consumption and performance). - the anatomy of state-of-the-art microcontroller systems: an introduction to the working principles of the CPU sub-system, internal memories as well as typical peripherals such as GPIOs, ADCs, Timers, PWM cores and communication interfaces. - the software development ecosystem for embedded control design: A short introduction to compilers, assemblers, linkers, loaders and debuggers.

	- the fundamentals of low-level, hardware-related programming in C. - the fundamentals of using fixed-point arithmetic's for digital signal processing. - interrupts and interrupt service routine concepts – state machine based program control and low-power design techniques. - an introduction to real-time operating systems: Basic principles, scheduling, inter-task communication and resource sharing. - Model based design techniques: automatic code generation for embedded control systems. - advanced µC solutions for digital power applications: Dedicated peripherals for optimizing digital control systems. - a design example: Digital control techniques for synchronous DC/DC buck converters. **Embedded Signal Processing Systems - Lab** The lab focuses on teaching practical skills related to programming of embedded systems using C: - Software design and interfacing of simple external components such as buttons, switches and LEDs. - Design and implementation of a simple interrupt driven digital control loop using peripherals such as ADCs, comparators or PWM units. - Model-based design of embedded control systems using high-level design, simulation and code generation tools for rapid prototyping, and hardware-in-the-loop testing.
3	**Learning Outcome / Competencies** **to understand:** - the architectural features of state-of-the art microcontroller systems. - the basic operating principles as well as the interplay of microcontroller internal components. - the basic design patterns for designing interrupt based program control. **to apply:** - the gained knowledge to analyse and define the real-time requirements of a given application. - the gained knowledge to set-up and configure the microcontroller as well as its peripherals for the use in a dedicated application scenario. - the gained knowledge to map a given floating-point control algorithm to its fixed-point equivalent. - the gained knowledge to implement simple fixed-point control algorithms on state-of-the-art µC platforms. - the gained knowledge to evaluate the implementation results (e.g. timing, resource usage, power consumption) and correlate them with the corresponding high level design. **to transfer:** - the patterns and methodologies to more complex power electronic control design scenarios in order to find optimal solutions with respect to system constraints such as costs, performance or power consumption.
4	**Course Organization and Structure** lecture (V) / laboratory (L)
5	**Credits and Workload** 5 CP / 150 hours in total, including 56 hours classroom teaching and lab. 2 SWS V / 2 SWS L

6	**Examination Modalities** **Examination Prerequisites:** In order to participate in the module exam, it is required to successfully finish the lab part of the module. Successful fulfilment of prerequisites are measured by: ▪ Lab Attendance ▪ Lab Progress 25% of the module grade is obtained by the laboratory. **Examination Type:** Written exam covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** 90 minutes
7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** None
9	**Duration and Frequency of Course** This module takes one semester and is offered once a year (see appendix 1 BBPO).
10	**Applicability /Utilization** This module is applicable for the major Power Engineering. See appendix 2 BBPO (Compulsory options catalogues) for its suitability for other majors.
11	**Literature** The following literature material will be provided: - Electronic lecture notes - Laboratory Workbook Further literature recommendations will be provided during the lecture.

MP05 Power Electronics for Drives and Energy Systems

1	**Module Name** Power Electronics for Drives and Energy Systems
1.1	**Module Identifier** MP05
1.2	**Module Type** Mandatory
1.3	**Course Names** Power Electronics for Drives and Energy Systems - Lecture
1.4	**Semester** 1 or 2 (summer term)
1.5	**Module Responsible and Instructor** Prof. Dr. Krontiris
1.6	**Additional Instructors** Prof. Dr. Weiner
1.7	**Study Program** Master / Major Power Engineering
1.8	**Teaching Language** English

2	**Module Content**
	- Basic Principles and Issues of Power Electronics
	- Mathematical Analysis and Computer Simulation
	- Semiconductor Switches, passive Components, Converter Design and recent Advances
	- Basic and Advanced Converter Topologies, Modulation and Control
	- Power Electronic Systems for Drives
	  - Voltage Source Converter for Electric Drives
	  - Active Front End
	- Power Electronic Systems for Renewables and Distribution
	  - Converter for Wind Energy Conversion System
	  - Converter for Photovoltaic Energy Conversion Systems
	  - Converter for High-Voltage DC Transmission
	  - Active Power Filter

3	**Learning Outcome / Competencies** **to understand:** - the function and operation principles of power electronic systems for drives and energy systems - the implications of power electronics on source and load - the common design principles for power electronic converter and the impact of advanced components and technologies on converter design **to apply:** - set-up, simulate and compare power systems for drives and energy systems - dimension and design power electronic equipment **to transfer:** - suggest solutions for applications and implications in power electronics
4	**Course Organization and Structure** lecture (V)
5	**Credits and Workload** 5 CP / 150 hours in total, including 56 hours classroom teaching. 4 SWS V
6	**Examination Modalities** **Examination Prerequisites:** none **Examination Type:** Written exam covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** 90 minutes
7	**Necessary Prerequisites** Students should be familiar with the basics of power electronics and electrical machines.
8	**Recommended Prerequisites** None
9	**Duration and Frequency of Course** This module takes one semester and is offered once a year (see appendix 1 BBPO).
10	**Applicability /Utilization** This module is applicable for the major Power Engineering.
11	**Literature** Literature recommendations will be provided during the lecture.

MP06 Advanced Control of Electrical Drives

1	**Module Name** Advanced Control of Electrical Drives
1.1	**Module Identifier** MP06
1.2	**Module Type** Mandatory
1.3	**Course Names** Advanced Control of Electrical Drives - Lecture
1.4	**Semester** 1 or 2 (summer term)
1.5	**Module Responsible and Instructor** Prof. Dr. Weiner
1.6	**Additional Instructors** Prof. Dr. Klesen
1.7	**Study Program** Master / Major Power Engineering
1.8	**Teaching Language** English

2	**Module Content**
	This module explores advanced modelling and modern control strategies of electric drive systems, focusing on induction and permanent magnet synchronous machines.
	- structure and components of controlled drives, application areas
	- description of the dynamic behaviour of electrical machines
	- development of transfer functions, structural diagrams and simulation models for electric drive systems
	- control schemes for electrical machines
	  - field-orientated control
	  - direct torque control
	  - introduction to sensorless control
	  - introduction to predictive control
	- controller design and optimisation
	  - controller structures
	  - stability criteria
	  - standard optimisation methods
	  - introduction to parameter estimation and adaptive control

3	**Learning Outcome / Competencies** **to understand:** The students understand the function and control principles of controlled electrical drives **to apply:** They are able to design and model controlled electrical drive systems and to optimise the controller with regards to structure and parameter settings. **to transfer:** The students are able to further develop and refine control strategies and to implement the control on experimental test drives.
4	**Course Organization and Structure** lecture (V)
5	**Credits and Workload** 5 CP / 150 hours in total, including 56 hours classroom teaching. 4 SWS V
6	**Examination Modalities** **Examination Prerequisites:** none **Examination Type:** Written exam covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** 90 minutes
7	**Necessary Prerequisites** Students should be familiar with the basics of power electronics, electrical machines and control theory.
8	**Recommended Prerequisites** None
9	**Duration and Frequency of Course** This module takes one semester and is offered once a year (see appendix 1 BBPO).
10	**Applicability /Utilization** This module is applicable for the major Power Engineering.
11	**Literature** Literature recommendations will be provided during the lecture.

MP07 Model-Based Design, HiL & PiL Systems

1	**Module Name** Model-Based Design, HiL & PiL Systems
1.1	**Module Identifier** MP07
1.2	**Module Type** Mandatory
1.3	**Course Names** Model-Based Design, HiL & PiL Systems – Lecture Model-Based Design, HiL & Pil Systems - Lab
1.4	**Semester** 1 or 2 (summer term)
1.5	**Module Responsible and Instructor** Prof. Dr. Jakob
1.6	**Additional Instructors** Prof. Dr. Weiner
1.7	**Study Program** Master / Major Power Engineering
1.8	**Teaching Language** English
2	**Module Content** The aim of this course is to provide students with a solid background in Model-based design (MBD) methods with a strong focus on Hardware-in-the-Loop (HIL) and Processor-in-the-Loop (PIL) techniques. The course concentrates on embedded control software development for electrical drive and power electronic applications. In particular, the course covers: - The system design challenge: Managing complexity in highly competitive market segments. - Reviewing conventional development methodologies for digital control system design. - An introduction to Model-based design: Motivation, basic principles and application areas. - Modelling power electronic and electrical drive systems. - Model-in-the-Loop (MIL) simulations. - Software-in-the-Loop (SIL) simulations. - Real-Time Simulations using standard PC hardware. - Processor-in-the-Loop (PIL) simulations. - Hardware-in-the-Loop (HIL) simulations. - Automatic code generation. - Model verification and validation, design of experiments, model refinement.

3	**Learning Outcome / Competencies** **to understand:** - the advantages and benefits of Model-based design strategies in virtual prototyping of embedded control software. **to apply:** - the gained knowledge to develop offline and real-time simulation models for power electronics and drive systems. - the gained knowledge to develop Model-based software code for dedicated target systems, - the gained knowledge to specify interface requirements related to sampling or synchronization (PMW unit, sensor interface etc.). **to transfer:** - the patterns and methodologies to more complex control design scenarios in order to manage increasing performance, quality and safety requirements as well as to enable faster time-to-market.
4	**Course Organization and Structure** lecture (V) / laboratory (L)
5	**Credits and Workload** 5 CP / 150 hours in total. 56 SWS hours classroom teaching and lab. 3 SWS V / 0,5 (1) SWS L
6	**Examination Modalities** **Examination Prerequisites:** In order to participate in the module exam, it is required to successfully finish the lab part of the module. Successful fulfilment of prerequisites are measured by: ▪ Lab Attendance ▪ Lab Progress 25% of the module grade is obtained by the laboratory. **Examination Type:** Written exam covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** 90 Minutes
7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** None
9	**Duration and Frequency of Course** This module takes one semester and is offered once a year (see appendix 1 BBPO).
10	**Applicability /Utilization** This module is applicable for the major Power Engineering.

11	**Literature** The following literature material will be provided: - Electronic lecture notes - Guided set of exercises Further literature recommendations will be provided during the lecture.

Module Handbook

Electrical Engineering and Information Technology - international

Master of Science

Major Power Engineering - electives

MPwp01 Lab Module on Power Electronics

1	**Module Name** Lab Module on Power Electronics
1.1	**Module Identifier** MPwp01
1.2	**Module Type** Elective
1.3	**Course Names** Lab-Module on Power Electronics - Lab
1.4	**Semester** 1 or 2
1.5	**Module Responsible and Instructor** Prof. Dr. Krontiris
1.6	**Additional Instructors** Prof. Dr. Weiner
1.7	**Study Program** Master / Major Power Engineering
1.8	**Teaching Language** English
2	**Module Content** The students should gain practical experience with regards to the contents of the corresponding theory modules on Power Electronics for Drives and Energy Systems. The students will carry out different lab experiments on power electronic systems and electrical drives with the measurement of the characteristic electrical, mechanical and other physical values. Each lab exercise is accompanied by a simulation exercise which includes the development of a simulation model. Each lab exercise will be completed with a lab report.
3	**Learning Outcome / Competencies** **to understand:** The students are able to carry out practical measurements on power electronic for drives and energy systems and model the analyzed system with a suitable simulation program. **to apply:** They are able to connect and operate the necessary measurement equipment (in particular power analyzer and digital oscilloscope) in order to get meaningful results. They can present the experiment and evaluate and compare (with regards to theory and simulation) the obtained results in a technical report. The students are thus able to test, describe and evaluate the function and behavior of power electronic for drives and energy systems by means of measurements.

	to transfer: The students are able to define measured quantities and test set-up for the testing and evaluation of other power electronic and electric drives systems. They are able to specify the required measuring equipment. They are able to set-up and refine simulation models of practical systems.
4	**Course Organization and Structure** laboratory (L)
5	**Credits and Workload** 2,5 CP / 75 hours in total, including 14 lab hours. 1 SWS L
6	**Examination Modalities** **Examination Prerequisites:** In order to participate in the module exam, it is required to successfully finish the lab part of the module. Successful fulfillment of prerequisites are measured by: - Successful completion (including report) of all lab and simulation exercises **Examination Type:** written exam / oral exam / practical exam (will be communicated upon start of the module) covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** written exam: 90 minutes; oral exam: 30 minutes; practical exam: 60 minutes
7	**Necessary Prerequisites** Parallel attendance of the modules Power Electronics for Drives and Energy Systems and Advanced Control of electric Drives
8	**Recommended Prerequisites** None
9	**Duration and Frequency of Course** This module takes one semester and is offered once a year (see appendix 1 BBPO).
10	**Applicability /Utilization** This module is applicable for the major Power Engineering.
11	**Literature** Workbook for exercises and lab.

MPwp02 Automotive Electrical Power Train

1	**Module Name** Automotive Electrical Power Train
1.1	**Module Identifier** MPwp02
1.2	**Module Type** Elective
1.3	**Course Names** Automotive Electrical Power Train - Lecture
1.4	**Semester** 1 or 2
1.5	**Module Responsible and Instructor** Prof. Dr. Weiner
1.6	**Additional Instructors** Prof. Dr. Klesen
1.7	**Study Program** Master / Major Power Engineering
1.8	**Teaching Language** English

2	**Module Content**
	- power train topologies of electric and hybrid vehicles
	- components of the electrical power train
	  - electrical on-board power network
	  - energy storage – technology, selection criteria and comparison
	  - power electronics, electrical machines and motor control – technology, selection criteria and comparison
	- component sizing
	  - physical basics and dynamic vehicle model
	  - tractive effort, power flow and energy consumption
	- control strategies

3	**Learning Outcome / Competencies** **to understand:** The students understand the concepts and the interaction of the different components of the electrical power train. **to apply:** The students are able to design and dimension the components of a power train according to the requirements on the performance of the vehicle. They are able to rate and benchmark different technologies.

	to transfer: The students are able to develop simulation models of the drive train of electric and hybrid vehicles.
4	**Course Organization and Structure** lecture (V)
5	**Credits and Workload** 2,5 CP / 75 hours in total, including 28 hours classroom teaching. 2 SWS V
6	**Examination Modalities** **Examination Prerequisites:** none **Examination Type:** Written exam or presentation covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** 90 minutes (written exam), 20 minutes (presentation)
7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** Students should be familiar with the basics of power electronics and electrical machines.
9	**Duration and Frequency of Course** see module description of Elective 1 to 3 (MWP01, MWP02, MWP03)
10	**Applicability /Utilization** This module is applicable for the major Power Engineering. See appendix 2 BBPO (Compulsory options catalogues) for its suitability for other majors.
11	**Literature** Literature recommendations will be provided during the lecture.

MPwp03 Stationary & Mobile Energy Storage Systems

1	**Module Name** Stationary & Mobile Energy Storage Systems
1.1	**Module Identifier** MPwp03
1.2	**Module Type** Elective
1.3	**Course Names** Stationary & Mobile Energy Storage Systems-Lecture
1.4	**Semester** 1 or 2
1.5	**Module Responsible and Instructor** Prof. Dr. Betz
1.6	**Additional Instructors** Dr. Bauer
1.7	**Study Program** Master / Major Power Engineering
1.8	**Teaching Language** English

2	**Module Content**
	Content of course „ Stationary & Mobile Energy Storage Systems":
	Participants will be exposed to and gain theoretical experience with energy storage systems (stationary and mobile solutions). The course will cover:
	- Importance of storage systems for modern energy systems and mobility
	- General characteristic parameters and technical requirements of energy storage systems.
	- Stationary energy storage systems:
	  - Design and dimensioning of compressed air energy storage systems and application examples in network protection (third level frequency control).
	  - Design and dimensioning of pump storage energy systems and their application limits.
	  - Potential of hydrogen energy storage systems: technical feasibility and burden.
	  - Power-to-Gas solutions and application experience.
	  - Innovative energy storage solutions (like thermo-electrical energy storage systems, inverse air compressed storage systems in deep water, pump storage in offshore environment) and critical comparison. Technical potential will be critical discussed against series production challenge.
	  - Methods to choose the most suited energy storage concept as a function of the technical requirement versus costs.

	- Mobile energy storage systems:
	  - Battery cell technologies. Design and dimensioning of battery energy storage systems and battery management systems.
	  - Design of fuel cells and hydrogen storage
	  - Double layer capacitors and design and dimensioning of super caps energy storage systems.
	  - Flywheel storage

3	**Learning Outcome / Competencies** **to understand:** - the functionality of different energy storage systems for stationary and mobile applications. - the impact of technical parameters like access time, maximum power, maximum energy, life cycle, cost) on the specific energy storage solution. **to apply:** - Dimensioning rules of different energy storage systems for stationary and mobile applications. - Cost evaluations of selected energy storage systems. **to transfer:** - the known technical characteristics to develop new energy storage products. - the existing storage solutions into bigger scaling. - and apply theoretical parameters of innovative solutions into practical designs
4	**Course Organization and Structure** lecture (V)
5	**Credits and Workload** 5 CP / 150 hours in total, including 56 hours classroom teaching. Stationary Energy Storage Systems: 2 SWS V Mobile Energy Storage Systems: 2 SWS V
6	**Examination Modalities** **Examination Prerequisites:** None **Examination Type:** Written exam or presentation covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** 90 minutes (written exam), 20 minutes (presentation)
7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** None

9	**Duration and Frequency of Course** see module description of Elective 1 to 3 (MWP01, MWP02, MWP03)
10	**Applicability /Utilization** This module is applicable for the major Power Engineering and as elective course of master WING. See appendix 2 BBPO (Compulsory options catalogues) for its suitability for other majors.
11	**Literature** Sven Bauer: Akkuwelt ISBN 978-3-8343-3409-1 VDE-study "Energy storage systems" and Instruction notes Further literature recommendations will be provided during the lecture.

MPwp04 Lab Module on Electric Drives

1	**Module Name** Lab Module on Electric Drives
1.1	**Module Identifier** MPwp04
1.2	**Module Type** Elective
1.3	**Course Names** Lab-Module on Electric Drives - Lab
1.4	**Semester** 1 or 2
1.5	**Module Responsible and Instructor** Prof. Dr. Weiner
1.6	**Additional Instructors** Prof. Dr. Klesen
1.7	**Study Program** Master / Major Power Engineering
1.8	**Teaching Language** English
2	**Module Content** The students should gain practical experience with regards to the contents of the corresponding theory modules on Advanced Control of electric Drives. The students will carry out different lab experiments on electrical drives with the measurement of the characteristic electrical, mechanical and other physical values. Each lab exercise is accompanied by a simulation exercise which includes the development of a simulation model. Each lab exercise will be completed with a lab report.
3	**Learning Outcome / Competencies** **to understand:** The students are able to carry out practical measurements on power electronic and electrical drive systems and model the analyzed system with a suitable simulation program. **to apply:** They are able to connect and operate the necessary measurement equipment (in particular power analyzer and digital oscilloscope) in order to get meaningful results. They can present the experiment and evaluate and compare (with regards to theory and simulation) the obtained results in a technical report. The students are thus able to test, describe and evaluate the function and behavior of electric drives systems by means of measurements.

	to transfer: The students are able to define measured quantities and test set-up for the testing and evaluation of other power electronic and electric drives systems. They are able to specify the required measuring equipment. They are able to set-up and refine simulation models of practical systems.
4	**Course Organization and Structure** laboratory (L)
5	**Credits and Workload** 2,5 CP / 75 hours in total, including 14 lab hours. 1 SWS L
6	**Examination Modalities** **Examination Prerequisites:** In order to participate in the module exam, it is required to successfully finish the lab part of the module. Successful fulfillment of prerequisites are measured by: - Successful completion (including report) of all lab and simulation exercises **Examination Type:** written exam / oral exam / practical exam (will be communicated upon start of the module) covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** written exam: 90 minutes; oral exam: 30 minutes; practical exam: 60 minutes
7	**Necessary Prerequisites** Parallel attendance of the modules Power Electronics for Drives and Energy Systems and Advanced Control of electric Drives
8	**Recommended Prerequisites** None
9	**Duration and Frequency of Course** This module takes one semester and is offered once a year (see appendix 1 BBPO).
10	**Applicability /Utilization** This module is applicable for the major Power Engineering.
11	**Literature** Workbook for exercises and lab.

MPwp05 Switch Gear

1	**Module Name** Switch gear
1.1	**Module Identifier** MPwp05
1.2	**Module Type** Elective
1.3	**Course Names** Switchgear -Lecture
1.4	**Semester** 1 or 2
1.5	**Module Responsible and Instructor** Prof. Dr. Betz
1.6	**Additional Instructors** ---
1.7	**Study Program** Master / Major Power Engineering
1.8	**Teaching Language** English
2	**Module Content** **Content of course „Switchgear – Lecture":** Participants will be exposed to and gain theoretical experience with switchgear for high voltage and medium voltage. Furthermore, special solutions for dc circuit breaker for medium voltages are covered. The course will cover: - Layouts and concepts of substations with respect to high-, medium- and low-voltage levels. - Integration of switchgear into substations and interaction with different substation layouts. - Functionality, technical requirements and application of circuit breakers, load disconnectors, disconnectors and earthing switches. - Arc quenching in circuit breakers (high voltage, medium voltage, low voltage) and load disconnectors with respect to AC and DC systems. Consideration of arc quenching in SF_6, Air and Vacuum. - Protection philosophy of switchgear (selectivity by rating and/or time scaling). - Design and of test facilities to obtain highest testing power: direct test circuits, synthetic test circuits with current or voltage superposition. Dimensioning of synthetic circuits with current superposition for power switching tests. - Normative regulations for type tests (like power switching or capacitive switching) and routine tests - Future trends

3	**Learning Outcome / Competencies** **to understand:** - Functionality of circuit breaker, load breaker, disconnector and earthing switches. - Physical behavior of arcing phenomenon and different arc quenching methods in SF_6, Air and Vacuum. **to apply:** - Test procedures for circuit breaker with respect to dielectric, thermal, dynamical, mechanical and switching performance. - Dimensioning rules to design switchgear. - Dimensioning rules for synthetic test circuits to generate i.e. higher short circuit currents or steeper rate of rise of the recovery voltage. **to transfer:** - Apply and transfer the known theoretical rules for protection devices to real applications. - To develop higher ratings based on dielectric and thermal behavior of existing switchgear. - Transfer the methods of increasing voltage strength (like pressure, gas medium, painting of conductors) to new designs of switchgear. - Transfer the knowledge of arc quenching methods to increase the short current rating of i.e. circuit breakers. - To transfer the lecture content into new switchgear design and to judge future trends in switchgear.
4	**Course Organization and Structure** lecture (V)
5	**Credits and Workload** 2,5 CP / 75 hours in total, including 28 hours classroom teaching. 2 SWS V
6	**Examination Modalities** **Examination Prerequisites:** None **Examination Type:** Written exam covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** 60 minutes
7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** None
9	**Duration and Frequency of Course** see module description of Elective 1 to 3 (MWP01, MWP02, MWP03)

10	**Applicability /Utilization** This module is applicable for the major Power Engineering and as elective course of master WING. See appendix 2 BBPO (Compulsory options catalogues) for its suitability for other majors.
11	**Literature** The following literature material will be provided: - Electronic lecture notes Further literature recommendations will be provided during the lecture.

MPwp06 Power Systems Planning

1	**Module Name** Power Systems Planning
1.1	**Module Identifier** MPwp06
1.2	**Module Type** Elective
1.3	**Course Names** Power Systems Planning – Lecture & Lab
1.4	**Semester** 1 or 2
1.5	**Module Responsible and Instructor** Prof. Dr. Krontiris
1.6	**Additional Instructors** ---
1.7	**Study Program** Master / Major Power Engineering
1.8	**Teaching Language** English
2	**Module Content** Participants will be exposed to and gain theoretical and practical experience with planning of power systems. Focus lies with distribution networks (medium and low voltage) under the presence of dispersed generation. The course covers: - Network topology for high, medium and low voltage - Voltage stability in power systems - Power quality - Voltage control in distribution networks for integration of dispersed generation (wind and solar) - Normative references - Future trends Theoretical knowledge is applied to study cases for computer-aided network planning (e.g. NEPLAN).
3	**Learning Outcome / Competencies** **to understand:** - Power quality in distribution grids - Design of harmonic filters - Voltage stability in power systems

	- Challenges arising by the connection of dispersed generation (wind and solar) to distribution networks **to apply :** - Load flow and short circuit algorithms to power systems for grid planning - Load modelling and load forecasting - Innovative network planning alternatives to distribution networks **to transfer:** - Choose the preferred network topology for distribution networks - Calculate flicker, harmonics and other power quality measures for simple study cases - Calculate voltage stability curves for simple study cases
4	**Course Organization and Structure** lecture (V) / Laboratory (L)
5	**Credits and Workload** 2,5 CP / 75 hours in total, including 28 hours classroom teaching. 1 SWS V / 1 SWS L (2,5 CP)
6	**Examination Modalities** **Examination Prerequisites:** None **Examination Type:** Written exam covering or oral presentation the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** 90 Minutes(written exam), 20 minutes (presentation)
7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** None
9	**Duration and Frequency of Course** see module description of Elective 1 to 3 (MWP01, MWP02, MWP03)
10	**Applicability /Utilization** This module is applicable for the major Power Engineering and as elective course of master WING. See appendix 2 BBPO (Compulsory options catalogues) for its suitability for other majors.

11	**Literature** Grisby: "Electric Power Engineering Handbook – Volume I (Power Systems)"; CRC Press; ISBN 0-8493-9288-8 Sallam & Malik: "Electric Distribution Systems"; Willey; ISBN 9780470276822 Sivanagaraju & Satyanarayana: "Electric Power Transmission and Distribution"; Pearson Education; ISBN 978-81-317-0791-3 National and international standards EN 50160, IEC 61000 series, VDE AR 4105, VDE 4100, VDE 4110 The following literature material will be provided: - Slides

MPwp07 Smart Grids

1	**Module Name** Smart Grids
1.1	**Module Identifier** MPwp07
1.2	**Module Type** Elective
1.3	**Course Names** Smart Grid Technology - Lecture Smart Grid Operational Training - Lab
1.4	**Semester** 1 or 2
1.5	**Module Responsible and Instructor** Prof. Dr. Graf
1.6	**Additional Instructors** ---
1.7	**Study Program** Master / Major Power Engineering
1.8	**Teaching Language** English
2	**Module Content** **Smart Grid Technology – Lecture** - challenges, chances, drivers, political targets, approaches of solutions - smart grid research projects and research funding - development of the contribution of renewable production, installed capacity versus energy produced - energy data evaluation, energy estimates, energy, power, energy density - forecast requirements, data analysis and approaches: consumption, production, price sensitivity - energy storage: properties, storage applications, design and management - virtual power plants, load management, demand response, electric vehicles as buffer storage - smart meter applications: transparency of consumption, energy market solutions, trading platforms - innovative energy tariffs, incentive models, prosumer, use acceptance, system requirements - distribution system automation, distribution system applications, voltage control in low voltage grid - increase of transmission capacity, flexible AC transmission systems - micro grids, energy supply of electrical islands

	Smart Grid Operational Training – Lab - The participants will use a power system training simulator to get experience of operational tasks in future energy systems based on renewable and distributed energy sources. - wind energy, storage management, virtual power plants, load management, weather depending renewable production
3	**Learning Outcome / Competencies** **to understand:** - overview of smart grid technology topics, discussed approaches and proposed solutions - challenges and approaches for future energy systems based on renewable and distributed resources - properties of the different renewable energy sources and storage technologies **to apply:** - analyze and evaluate approaches and building blocks of future energy concepts - analyze and evaluate storage management concepts - solving operational tasks in the training simulation **to transfer:** - assess the impact of renewable energy sources on the power system - do the master thesis with a utility company
4	**Course Organization and Structure** lecture (V) / laboratory (L)
5	**Credits and Workload** 5 CP / 150 hours in total, including 56 hours classroom teaching and lab. 3,5 SWS V / 0,5 SWS L
6	**Examination Modalities** **Examination Prerequisites:** In order to write the end-of term exam, it is required to successfully finished the scheduled lab dates. Successful fulfillment of prerequisites are measured by: - Attending Lab - Lab report 10% of the module grades are obtained by the laboratory during the term. **Examination Type:** Written exam or presentation covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** 90 minutes (written exam), 20 minutes (presentation)
7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** good knowledge of power systems and models of system components

9	**Duration and Frequency of Course** see module description of Elective 1 to 3 (MWP01, MWP02, MWP03)
10	**Applicability /Utilization** This module is applicable for the major Power Engineering. See appendix 2 BBPO (Compulsory options catalogues) for its suitability for other majors.
11	**Literature** The lab script and further material is provided in electronic form. Further literature recommendations will be provided during the lecture.

MPwp08 Applied Programming

1	**Module Name** Applied Programming
1.1	**Module Identifier** MPwp08
1.2	**Module Type** Elective
1.3	**Course Names** Applied Programming - Lecture Applied Programming - Exercises
1.4	**Semester** 1 or 2
1.5	**Module Responsible and Instructor** Prof. Dr. Graf
1.6	**Additional Instructors** ---
1.7	**Study Program** Master / Major Power Engineering
1.8	**Teaching Language** English
2	**Module Content** The module aims at software knowledge and skills of a power engineer who is working on general engineering tasks (but not in the development of complex software systems or software products). It also enables professional negotiation with software manufacturers during the acquisition of software solutions. The module covers the following topics: - Introduction of a universally applicable scripting language including (basic) graphical user interface support - development of small to medium size software tools with elementary graphical user interface for specific - engineering tasks (on the work group level), introduction to software testing - data formatting and preparation for application programs and visualization tools - transformation between different data formats (Excel, CSV, XML), merging data from different sources - Methods and tools for the analysis and visualization of measured data o different types of diagrams, advantages and disadvantages

	o methods of data quality assurance, bad data detection and elimination - Introduction of data base software o limitations of spread sheet software and characteristics of data base applications o data base setup and design, data bases queries (SQL) o use of data base software for typical engineering tasks - Methods and tools of requirements engineering o methods of software specification and description, introduction of UML diagrams o stakeholder, business process and use case identification, description, verification and management o architectural views, structure of big software systems, decomposition and interface design o criteria for the evaluation and selection of standard software The topics are introduced in the lecture and practiced in exercises
3	**Learning Outcome / Competencies** **to understand:** the participant understands - the industrial software engineering processes and development tasks - structure and potential of big data base applications - the requirements engineering and software specification processes **to apply:** the participant can - specify, develop and test small to medium size software tools - use a script language for day to day data preparation, analysis and visualization tasks - design a small data base and retrieve information by specifying data base queries **to transfer:** the participant can - prepare the setup and design of big data base applications - analyze requirements and specify application software for acquisitions and tenders - negotiate with software manufactures and manage the acceptance procedure
4	**Course Organization and Structure** lecture (V) / laboratory (L)
5	**Credits and Workload** 5 CP / 150 hours in total, including 56 hours classroom teaching and lab. 2 SWS V / 2 SWS L
6	**Examination Modalities** In order to write the end-of term exam, it is required to successfully present the results of the exercises **Examination Prerequisites:** In order to participate in the module exam, it is required to successfully present the results of the exercises. Successful fulfillment of prerequisites are measured by: - Presentation - Exercises

	Examination Type: Written exam or presentation covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** 90 minutes (written exam), 20 minutes (presentation)
7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** None
9	**Duration and Frequency of Course** see module description of Elective 1 to 3 (MWP01, MWP02, MWP03)
10	**Applicability /Utilization** This module is applicable for the major Power Engineering. See appendix 2 BBPO (Compulsory options catalogues) for its suitability for other majors.
11	**Literature** The lecture notes and further material are provided in electronic form. Further literature recommendations will be provided during the lecture.

MPwp09 Hydrogen Technique and Fuel Cells

1	**Module Name** Hydrogen Technique and Fuel Cells
1.1	**Module Identifier** MPwp09
1.2	**Module Type** Elective
1.3	**Course Names** Hydrogen Technique and Fuel Cells - Lecture
1.4	**Semester** 1 or 2
1.5	**Module Responsible and Instructor** Prof. Dr. Glotzbach
1.6	**Additional Instructors** Zijad Lemeš
1.7	**Study Program** Master / Major Power Engineering
1.8	**Teaching Language** English
2	**Module Content** The module gives an overview of hydrogen technology and fuel cells. Participants will gain experience with these technologies. The course will cover - Hydrogen, combustion, storage and handling - Hydrogen production and electrolysis - Hydrogen infrastructure - Fuel cells: basic function, thermodynamics and electrochemistry, efficiency, electrical behavior - Fuel cell types: AlkalineFuel Cell (AFC), Polymer Electrolyte Membrane Fuel Cell(PEMFC), Direct-Methanol Fuel Cell (DMFC), Phosphoric Acid Fuel Cell (PAFC), Molten Carbonate FuelCell (MCFC), Solid OxideFuelCell (SOFC) - Fuel cell systems - Components and assemblies for fuel cell systems

3	**Learning Outcome / Competencies** **to understand:** The students understand the physical and chemical properties of hydrogen, the handling of hydrogen and its storage. They understand the combustion processes energetically, chemically and in terms of mass flow and can calculate them. Furthermore, they understand the different fuel cells in their properties, in their construction and in their chemical combustion process and can calculate them. They understand the fuel cells in your applications with their advantages and disadvantages. Participants will have an in-depth understanding of the fundamental physical and technical concepts of fuel cell power systems and hydrogen technologies. **to apply:** Students are able to analyze and dimension fuel sell systems including the hydrogen tank systems. This includes the calculation of all mass flows, electrical power and efficiencies. **to transfer:** Transfer to new and more complex fuel cell systems. In addition, students are qualified in planning and designing complex systems of different fuel cell application and include these to renewable energy systems.
4	**Course Organization and Structure** lecture (V)
5	**Credits and Workload** 2,5 CP / 75 hours in total, including 28 hours classroom teaching. 2 SWS V
6	**Examination Modalities** **Examination Prerequisites:** None **Examination Type:** Written exam or Presentation covering the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester. **Examination Duration:** 60 minutes (Written Exam), 20min (Presentation)
7	**Necessary Prerequisites** None
8	**Recommended Prerequisites** None
9	**Duration and Frequency of Course** see module description of Elective 1 to 3 (MWP01, MWP02, MWP03)
10	**Applicability /Utilization** This module is applicable for the major Power Engineering. See appendix 2 BBPO (Compulsory options catalogues) for its suitability for other majors.

11	**Literature**
	The following literature material will be provided: - Johannes Töpler, Jochen Lehmann, "Hydrogen and Fuel Cell - Technologies and Market Perspectives", Springer - Andrew L. Dicks, David A. J. Rand, "Fuel Cell Systems Explained", Wiley - Ryan O'Hayre, Suk-Won Cha, Whitney Colella, Fritz B. Prinz, "Fuel Cell Fundamentals", Wiley Further literature recommendations will be provided during the lecture.

Major Power Engineering – general electives / electives from other majors

MGwp01 Research Project

MGwp02 Selected Research Topics

MGwp03

MAwp01 Model-based Real-time Simulation of Mechatronic Systems

MAwp04 Autonomous Mobile Robots

MAwp05 Advanced Graphical Programming of Control Systems

MAwp06 Advanced Sensors for the Internet of Things

MCwp01 Digital Signal Processing Applications

MCwp02 Wireless Systems (Technologies)

MCwp03 Network Security

MCwp04 Mobile Communications

MCwp05 Optical Communications

MCwp06 (I)Iot and Cloud Networking

MCwp07 Smart Home

MCwp08 Image and Video Processing

MMwp02 Safety in Embedded Control Systems

MMwp04 Advanced Software Design Techniques

MMwp05 Security in Connected Embedded Systems