

Anlage 5

Modulhandbuch des Studiengangs

Electrical Engineering and Information Technology - international Master of Science

des Fachbereichs Elektrotechnik und Informationstechnik
der Hochschule Darmstadt – University of Applied Sciences

vom 08.05.2018

Zugrundeliegende BBPO vom 08.05.2018 (Amtliche Mitteilungen Jahr 2018)

Contents

Präambel zum Modulhandbuch	5
Common Modules.....	7
M01 Technical Management	8
M02 Team Project.....	11
M03 Internship.....	13
M04 Master Module	16
MWP01 Elective 1	18
MWP02 Elective 2.....	18
MWP03 Elective 3.....	18
Major Automation - mandatory	20
MA01 Safety in Industrial Automation	21
MA02 Adaptive Control, Modeling and Identification	24
MA03 Computer Vision.....	27
MA04 Advanced Programming Techniques	30
MA05 Information Technology in Industrial Automation	33
MA06 Industrial Robotics	36
MA07 State Space Control Design.....	38
Major Automation - electives	41
MAwp01 Model-based Real-time Simulation of Mechatronic Systems	42
MAwp02 High Level Language Frameworks	45
MAwp03 Human Machine Interfaces (HMI).....	47
MAwp04 Autonomous Mobile Robots	50
Major Automation – electives from other majors	53
MCwp03 Network Security	53
MCwp06 (I)IoT and Cloud Networking	53
MMwp02 Safety in Embedded Control Systems	53
MMwp04 Advanced Software Design Techniques	53
MPwp03 Stationary & Mobile Energy Storage Systems	53
Major Communications - mandatory.....	54
MC01 Advanced Digital Signal Processing.....	55
MC02 Advanced Modulation.....	58
MC03 Microwave Components and Systems.....	61
MC04 Advanced Software Design and Development	63

MC05	System-Driven Hardware Design	66
MC06	Fields, Waves and Antennas	69
MC07	Information Networks.....	72
Major Communications - electives		75
MCwp01	Digital Signal Processing Applications	76
MCwp02	Wireless Systems (Technologies)	78
MCwp03	Network Security	80
MCwp04	Mobile Communications.....	83
MCwp05	Optical Communications	85
MCwp06	(I)IoT and Cloud Networking	88
MCwp07	Smart Home	91
MCwp08	Image and Video Processing	94
Major Communications – electives from other majors		96
MAwp03	Human Machine Interfaces (HMI).....	96
MMwp02	Safety in Embedded Control Systems	96
MMwp05	Security in Connected Embedded Systems	96
MPwp02	Automotive Electrical Power Train	96
MPwp09	Hydrogen Technique and Fuel Cells	96
Major Embedded and Microelectronics- mandatory.....		97
MM01	Advanced Programming Techniques	98
MM02	VLSI Design and Testing.....	99
MM03	Advanced Microcontroller Systems and Embedded Operating Systems	102
MM04	FPGA-based System on Chip Design	104
MM05	Embedded Architectures and Applications.....	107
MM06	System Driven Hardware Design	110
MM07	Embedded Signal Processing Systems	111
Major Embedded and Microelectronics- electives		114
MMwp01	CMOS Analog Circuits.....	115
MMwp02	Safety in Embedded Control Systems	118
MMwp03	Digital System Design	120
MMwp04	Advanced Software Design Techniques	123
MMwp05	Security in Connected Embedded Systems	126
Major Embedded and Microelectronics– electives from other majors		128
MAwp01	Model-based Real-time Simulation of Mechatronic Systems	128
MAwp03	Human Machine Interfaces (HMI).....	128
MCwp02	Wireless Systems (Technologies	128
MCwp06	(I)IoT and Cloud Networking	128

MCwp07	Smart Home	128
MCwp08	Image and Video Processing	128
MPwp02	Automotive Electrical Power Train	128
MPwp07	Embedded Programming & Design of Real-Time Control Systems.....	128
Major Power Engineering - mandatory		129
MP01	Advanced High Voltage Technology	130
MP02	Power System Operation	133
MP03	Renewable Energy Systems.....	136
MP04	Advanced Microcontroller Systems and Embedded Operating Systems	139
MP05	Power Electronics for Drives and Energy Systems.....	140
MP06	Advanced Control of Electrical Drives	142
MP07	System Driven Hardware Design	144
Major Power Engineering - electives		145
MPwp01	Model-Based Design, HiL & PiL Systems.....	146
MPwp02	Automotive Electrical Power Train	149
MPwp03	Stationary & Mobile Energy Storage Systems	151
MPwp04	Lab-Module on Power Electronics & Drives	154
MPwp05	Switch Gear	156
MPwp06	Power Systems Planning	159
MPwp07	Embedded Programming & Design of Real-Time Control Systems.....	162
MPwp08	Applied Programming.....	165
MPwp09	Hydrogen Technique and Fuel Cells	168
Major Power Engineering – electives from other majors		171
MAwp01	Model-based Real-time Simulation of Mechatronic Systems	171
MAwp04	Autonomous Mobile Robots	171
MCwp06	(I)IoT and Cloud Networking	171
MCwp07	Smart Home	171
MC04	Advanced Software Design and Development	171
MMwp02	Safety in Embedded Control Systems	171
MMwp04	Advanced Software Design Techniques	171

Präambel zum Modulhandbuch

Definition von Kompetenzstufen für den Eintrag in Ziele (Punkt 3)

Um die Beschreibung der **Ziele (Punkt 3)** kompakt und transparent zu gestalten, werden in diesem Modulhandbuch Kompetenzstufen verwendet. Die Kompetenzstufen geben an, in welcher Tiefe die Inhalte, d.h. Kenntnisse (Theorie- und/oder Faktenwissen) und Fertigkeiten (praktischer und/oder kognitiver Einsatz von Methoden, Verfahren, Vorgehensweisen) vermittelt werden und in welchem Maße die Studierenden in der Lage sein sollen, diese Kenntnisse und Fertigkeiten in Arbeits- und Lernsituationen zu verwenden.

Je nach Untergliederung der **Inhalte in Punkt 2** wird in Punkt 3 für die Hauptthemen und ggf. auch für deren Unterthemen eine der Kompetenzstufen **kennen**, **verstehen**, **anwenden** und **umsetzen** als Lern- und Qualifikationsziel angegeben. Wo sinnvoll, soll auch für implizit aus dem Inhalt hervorgehende Kompetenzen und Fertigkeiten eine solche Stufe angegeben werden. Für Themen/Kompetenzen/Fertigkeiten, die in mehreren aufeinander aufbauenden Modulen behandelt werden, kann im Laufe des Studiums eine immer höhere Qualifikationsstufe erreicht werden. Erreicht z.B. ein Thema in einem Modul, das als (empfohlene) Voraussetzung (Punkt 7 oder 8) angegeben wird, die Kompetenzstufe **kennen**, und wird das Thema in dem weiterführenden Modul wieder behandelt, so kann für das Thema die Kompetenzstufe **verstehen** als Ziel gesetzt werden.

Anhand der Kompetenzstufen lässt sich eine Abgrenzung des Bachelor- und Masterniveaus verdeutlichen, z.B.:

- **Bachelorstudiengang:** Für die meisten Themen im Grundlagenstudium werden die Stufen **kennen** (to know) und **verstehen** (to understand) angestrebt. Für Themen die im Vertiefungsstudium erneut aufgegriffen werden, kann die nächst höhere Stufe **verstehen** (to understand) bzw. **anwenden** (to apply) angestrebt werden.
- **Masterstudiengang:** Themen, in denen Vorkenntnisse aus dem vorangegangenen Bachelorstudiengang erforderlich sind, können bis zur Stufe **anwenden** (to apply) bzw. **umsetzen** (to transfer) geführt werden.

Die Kompetenzstufen bieten außerdem eine konkretere Grundlage für die kompetenzorientierte Anerkennung von Leistungsnachweisen sowie von nachgewiesenen außerhochschulischen Kompetenzen für die Module des Studiengangs.

Kompetenzstufe	Definition	Arbeitsdefinition	Präsenzzeit*
Niedrigste „Kennen“ to know	Reproduktion und Einordnung von Begriffen, Verfahren, Strukturen und Konventionen aus dem Themenkreis	Die Studierenden haben schon mal etwas über das Thema gehört und können das Thema dem Themengebiet zuordnen. Methoden zur Lösung von Problemstellungen zum Thema können sie nur reproduzierend auf bekannte Probleme anwenden. Sie können keinerlei Transferleistung erbringen.	1 – 3 1 bis 2 Blöcke
Dritthöchste „Verstehen“ to understand	Reproduzierende Lösung gleicher oder ähnlicher Aufgabenstellungen; selbstverständlicher Umgang mit Konventionen und Begriffen	Die Studierenden können Standardproblemstellungen zum Thema erkennen und durch die sichere Anwendung von Methoden lösen. Transferleistung können sie erbringen, wenn es sich um sehr ähnliche Aufgabenstellungen handelt.	> 3 – 7 3 bis 5 Blöcke
Zweithöchste „Anwenden“ to apply	Lösen konkreter Probleme aus dem engeren Themenkreis; Umkehrung von Aufgabenstellungen; Bilden von Analogien	Die Studierenden können ihnen unbekannte Problemstellungen aus dem Themengebiet lösen. Dazu können sie die erlernten Methoden selbstständig kombinieren und modifizieren. Sie sind fähig, Transferleistung zu erbringen.	> 7 – 12 6 bis 8 Blöcke
Höchste „Umsetzen“ to transfer	Lösen allgemeiner technischer Aufgabenstellung mit Hilfe des Erlernten; Routinierter Einsatz und kritisches Beurteilen von Kenntnissen, Verfahren und Methoden	Die Studierenden können mit den erworbenen Kenntnissen und erlernten Methoden und Verfahren aus dem Themengebiet Lösungskonzepte für technische Probleme erarbeiten, die sich nicht allein auf das Themengebiet beschränken. Sie können Lösungskonzepte im Team weiterentwickeln und umsetzen.	> 12 – 25 9 bis 19 Blöcke

* Anzahl Präsenzstunden zum Erreichen der Kompetenzstufe (Richtwert)

Tabelle 1: Definition der Kompetenzstufen zur Beschreibung der Lern- und Qualifikationsziele (Punkt 3)

Die Tabelle enthält die Definition der Kompetenzstufen. Die Stufen und deren Definition basieren auf einer Untersuchung zur Ermittlung des Kerncurriculums Elektrotechnik, die vom Fachbereichstag EIT durchgeführt worden sind. Die Definitionen der Kompetenzstufen wurden zur Anwendung im Modulhandbuch konkretisiert (Arbeitsdefinition). In der letzten Spalte ist

jeweils die Dauer angegeben, für die das jeweilige Thema in den Lehrveranstaltungen behandelt werden muss (Präsenzzeit), um die jeweilige Stufe zu erreichen. Diese Werte sind der gleichen Quelle entnommen, wie die Kompetenzstufen und sie sollen als Richtwert dienen.

In einigen Modulen, wie z.B. dem Mastermodul lässt sich die vorstehende Metrik nicht anwenden, da z.B. keine konkreten Inhalte angegeben werden können. Für diese Module werden die Ziele nach der Metrik **Kenntnisse, Fertigkeiten, Kompetenzen** angegeben.

Module Handbook

Electrical Engineering and Information Technology - international

Master of Science

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 <ul style="list-style-type: none"> - 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.

	<p><u>Content of course “Engineering Responsibility”</u></p> <p>This course provides an introduction into legal aspects of engineering and discusses the aspect of engineering responsibility. It covers the areas</p> <ul style="list-style-type: none"> - 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	<p>Learning Outcome / Competencies</p> <p>to understand:</p> <ul style="list-style-type: none"> - the most relevant laws related to engineering, such as <ul style="list-style-type: none"> 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 <p>to apply:</p> <ul style="list-style-type: none"> - 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 <p>to transfer:</p> <ul style="list-style-type: none"> - the project management techniques into new project scenarios - legal awareness into product development and utility scenarios
4	<p>Course Organization and Structure</p> <p>lecture (V) / seminar (S)</p>
5	<p>Credits and Workload</p> <p>5 CP / 150 hours in total, including 56 hours classroom teaching.</p> <p>Project Management: 2 SWS V Engineering Responsibility: 2 SWS V</p>
6	<p>Examination Modalities</p> <p>Examination Prerequisites: none</p> <p>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.</p> <p>Examination Duration: 90 minutes</p>

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: <ul style="list-style-type: none"> - Electronic Script 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: <ul style="list-style-type: none"> - 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: <ul style="list-style-type: none"> - project roles, phases and workflows to apply: <ul style="list-style-type: none"> - workpackage definition and assignment - modern methods of project management and engineering

	<ul style="list-style-type: none"> - professional team communication techniques - project presentation <p>to transfer:</p> <ul style="list-style-type: none"> - the project management and engineering techniques into new project scenarios
4	<p>Course Organization and Structure</p> <p>Project</p>
5	<p>Credits and Workload</p> <p>5 CP / 150 hours in total, project work including meetings with the instructors.</p>
6	<p>Examination Modalities</p> <p>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.</p> <p>Examination Prerequisites: Successful fulfillment of prerequisites are measured by:</p> <ul style="list-style-type: none"> - Attending Project - Project Progress <p>Examination Type:</p> <ul style="list-style-type: none"> - Project presentation and Report - Milestone review <p>Examination Duration: Project presentation 30 minutes</p>
7	<p>Necessary Prerequisites</p> <p>None</p>
8	<p>Recommended Prerequisites</p> <p>None</p>
9	<p>Duration and Frequency of Course</p> <p>This module takes one semester and is offered once a year (see appendix 1 BBPO).</p>
10	<p>Applicability /Utilization</p> <p>This module is applicable for all majors.</p>
11	<p>Literature</p> <p>Literature recommendations will be provided during the project.</p>

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 <ul style="list-style-type: none"> - 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: <ul style="list-style-type: none"> - German Class 1: A1 level or higher - German Class 2: higher than German Class 1 level, at least A2 level Content of Preliminary Seminar: <ul style="list-style-type: none"> - 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:

	<ul style="list-style-type: none"> - Research and development work - Project planning and design - Manufacturing, preparation of work - Assembly - Test bed, quality control
3	Learning Outcome / Competencies <p>The objectives of the internship are as follows:</p> <ul style="list-style-type: none"> - 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 <p>Lecture, seminar, practical work by fulfilling tasks of engineering work and documentation</p>
5	Credits and Workload <p>30 CP / 900 hours in total</p> <ul style="list-style-type: none"> - 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 <p>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.</p> <p>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.</p> <p>The successful completion of the internship part is acknowledged by the academic supervisor, provided that the prerequisites defined in § 10 para. 4 are fulfilled.</p>
7	Necessary Prerequisites <p>The necessary prerequisites are defined in § 10 para. 2 BBPO</p>
8	Recommended Prerequisites <p>A total of 45 CP is recommend to be completed before the start of the internship work.</p>

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“: MPwpS (Elective 1 Software), MPwp (Elective 2 and 3) 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

Module Handbook

Electrical Engineering and Information Technology - international

Master of Science

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 <ul style="list-style-type: none"> - 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: <ul style="list-style-type: none"> - Hardware configuration of safety PLCs

	<ul style="list-style-type: none"> - 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	<p>Learning Outcome / Competencies</p> <p>to understand:</p> <ul style="list-style-type: none"> - 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 <p>to apply the gained knowledge:</p> <ul style="list-style-type: none"> - 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 <p>to transfer:</p> <ul style="list-style-type: none"> - the acquired knowledge to create, verify and validate safe systems in industrial automation.
4	<p>Course Organization and Structure</p> <p>lecture (V) / laboratory (L)</p>
5	<p>Credits and Workload</p> <p>5 CP / 150 hours in total, including 56 hours classroom teaching and lab. 3 SWS V / 0,5 (1) SWS L</p>
6	<p>Examination Modalities</p> <p>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:</p> <ul style="list-style-type: none"> - Attending Lab - Lab Progress <p>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.</p> <p>Examination Duration: 90 minutes.</p>
7	<p>Necessary Prerequisites</p> <p>Participation in the preliminary course if no programming knowledge of Siemens S7 PLCs is available.</p>
8	<p>Recommended Prerequisites</p> <p>None</p>

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: <ul style="list-style-type: none">- Electronic Script (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 <p>The course covers the areas:</p> <ul style="list-style-type: none"> - 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 <p>to understand:</p> <ul style="list-style-type: none"> - the basic applications, concepts, components and challenges of adaptive control loops - the basic principles for modeling and identification of complex dynamic systems

	<p>to apply the knowledge:</p> <ul style="list-style-type: none"> - 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 <p>to transfer:</p> <ul style="list-style-type: none"> - the design process of adaptive control systems to problems from various domains in automation
4	<p>Course Organization and Structure</p> <p>Lecture (V) / Laboratory (L)</p>
5	<p>Credits and Workload</p> <p>5 CP / 150 hours in total, including 56 hours classroom teaching and lab. 3 SWS V and 0,5 (1) SWS L</p>
6	<p>Examination Modalities</p> <p>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:</p> <ul style="list-style-type: none"> • Attending Lab • Lab Progress <p>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.</p> <p>Examination Duration: 90 minutes.</p>
7	<p>Necessary Prerequisites</p> <p>None</p>
8	<p>Recommended Prerequisites</p> <p>None</p>
9	<p>Duration and Frequency of Course</p> <p>This module takes one semester and is offered once a year (see appendix 1 BBPO).</p>
10	<p>Applicability /Utilization</p> <p>This module is applicable for the major Automation and for the major embedded systems and microelectronics.</p>

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. Naser
1.6	Additional Instructors Prof. Dr. Neubecker
1.7	Study Program Master / Major Automation
1.8	Teaching Language English
2	Module Content <ul style="list-style-type: none"> - 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

	<p>Learning Outcome / Competencies</p> <p>to understand:</p> <ul style="list-style-type: none"> - 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 <p>to apply the knowledge:</p> <ul style="list-style-type: none"> - 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 <p>to transfer:</p> <ul style="list-style-type: none"> - the knowledge acquired in the lectures to new vision problems in Robotics, Automation and Production.
	<p>Course Organization and Structure</p> <p>lecture (V) / laboratory (L)</p>
5	<p>Credits and Workload</p> <p>5 CP / 150 hours in total, including 56 hours classroom teaching and lab. 3 SWS V and 0,5 (1) SWS L</p>
6	<p>Examination Modalities</p> <p>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:</p> <ul style="list-style-type: none"> • Attending Lab • Lab Progress <p>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.</p> <p>Examination Duration: 90 minutes.</p>
7	<p>Necessary Prerequisites</p> <p>None</p>
8	<p>Recommended Prerequisites</p> <p>Linear Algebra, Matlab</p>
9	<p>Duration and Frequency of Course</p> <p>This module takes one semester and is offered once a year (see appendix 1 BBPO).</p>

10	Applicability /Utilization This module is applicable for the major Automation and for the major Embedded Systems and Microelectronics.
11	Literature <ul style="list-style-type: none">- 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. Fromm
1.6	Additional Instructors Prof. Dr. Lipp, 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 <ul style="list-style-type: none"> - 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

	<p>to understand:</p> <ul style="list-style-type: none"> - the fundamentals of professional software design <p>to apply:</p> <ul style="list-style-type: none"> - the C++ programming language - the UML diagrams <p>to transfer:</p> <ul style="list-style-type: none"> - the design patterns and concepts to more complex architectures
4	<p>Course Organization and Structure</p> <p>lecture (V) / laboratory (L)</p>
5	<p>Credits and Workload</p> <p>5 CP / 150 hours in total, including 56 hours classroom teaching and lab. 2 SWS V and 2 SWS L</p>
6	<p>Examination Modalities</p> <p>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:</p> <ul style="list-style-type: none"> - attending Lab - code walkthrough during the lab <p>20% of the module grades are obtained by the laboratory during the term.</p> <p>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.</p> <p>Examination Duration: 90 minutes</p>
7	<p>Necessary Prerequisites</p> <p>None</p>
8	<p>Recommended Prerequisites</p> <p>None</p>
9	<p>Duration and Frequency of Course</p> <p>This module takes one semester and is offered once a year (see appendix 1 BBPO).</p>
10	<p>Applicability /Utilization</p> <p>This module is applicable for the major Automation and for the major Embedded Systems and Microelectronics.</p>

11	Literature The following literature material will be provided: <ul style="list-style-type: none">- Electronic Script- Workbook for the lab Further literature recommendations will be provided during the lecture.
-----------	---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

MA05 Information Technology in Industrial Automation

1	Module Name Information Technology in Industrial Automation
1.1	Module Identifier MA05
1.2	Module Type Mandatory
1.3	Course Names Information Technology in Industrial Automation – Lecture Information Technology in Industrial Automation - 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 “Information Technology in Industrial Automation”: Participants will be exposed to and gain working experience to design, implement, verify and validate safe systems in industrial automation. The course will cover <ul style="list-style-type: none"> - 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: <ul style="list-style-type: none"> - 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: <ul style="list-style-type: none"> - implementing appropriate product identification systems - using simulation systems for virtual commissioning - developing ideas for new business processes of digitalized production companies to transfer: <p>Students shall be able to play a significant role in the digital transformation of companies, by being able</p> <ul style="list-style-type: none"> - 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: <ul style="list-style-type: none"> • 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: <ul style="list-style-type: none">- 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 Prof. Dr. Weber
1.7	Study Program Master / Major Automation
1.8	Teaching Language English
2	Module Content <p>The course covers the areas:</p> <ul style="list-style-type: none"> - 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 <p>to understand:</p> <ul style="list-style-type: none"> - 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

	<p>to apply the knowledge:</p> <ul style="list-style-type: none"> - to classify robotic applications and describe the necessary system architecture - to know and simulate the fundamental models and algorithms for industrial robots <p>to transfer:</p> <ul style="list-style-type: none"> - the control of 6-axis robots to new kinematics and cells with multiple arms
4	<p>Course Organization and Structure</p> <p>Lecture (V) / Laboratory (L)</p>
5	<p>Credits and Workload</p> <p>5 CP / 150 hours in total, including 56 hours classroom teaching and lab. 3 SWS V and 0,5 (1) SWS L</p>
6	<p>Examination Modalities</p> <p>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:</p> <ul style="list-style-type: none"> • Attending Lab • Lab Progress <p>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.</p> <p>Examination Duration: 90 minutes.</p>
7	<p>Necessary Prerequisites</p> <p>None</p>
8	<p>Recommended Prerequisites</p> <p>None</p>
9	<p>Duration and Frequency of Course</p> <p>This module takes one semester and is offered once a year (see appendix 1 BBPO).</p>
10	<p>Applicability /Utilization</p> <p>This module is applicable for the major Automation and for the major Embedded Systems and Microelectronics.</p>
11	<p>Literature</p> <p>The following literature material will be provided:</p> <ul style="list-style-type: none"> - Electronic Script (excerpt of slides) - Workbook for the lab <p>Further literature recommendations will be provided during the lecture.</p>

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 Prof. Dr. Schnell
1.7	Study Program Master / Major Automation
1.8	Teaching Language English
2	Module Content Content of Course „State-Space Control Design – Lecture“: <ul style="list-style-type: none"> • 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“: <ul style="list-style-type: none"> • Exercises on modelling and designing state-space control systems

	<ul style="list-style-type: none"> Practical programming assignments for state-space applications in Matlab/Simulink
3	Learning Outcome / Competencies to understand: <ul style="list-style-type: none"> the state-space concept to apply: <ul style="list-style-type: none"> solve time-invariant state-space equations design state-feedback systems by optimal control to transfer : <ul style="list-style-type: none"> 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: <ul style="list-style-type: none"> - 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 Script 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 (winter term)
1.5	Module Responsible and Instructor Prof. Dr. Schnell
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: <ul style="list-style-type: none"> - 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: <ul style="list-style-type: none"> - Introduction MATLAB/SIMULINK

	<ul style="list-style-type: none"> - 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: <ul style="list-style-type: none"> - the structure of mechatronic systems - model-based development procedure of mechatronic systems - the improvement of the system's documentation and maintainability to apply: <ul style="list-style-type: none"> - model mechatronic systems - improve the design and implementation process of mechatronic systems to transfer: <ul style="list-style-type: none"> - 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: <ul style="list-style-type: none"> • 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 Script - 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 (winter term)
1.5	Module Responsible and Instructor Prof. Dr. Rücklé
1.6	Additional Instructors Prof. Dr. Lipp
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: <ul style="list-style-type: none"> - the JAVA language - threads - GUI Design - events to apply:

	<ul style="list-style-type: none"> - 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: <ul style="list-style-type: none"> - Electronic Script - 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 <ul style="list-style-type: none"> • 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: <ul style="list-style-type: none"> • relevant definitions • design guidelines

	<p>to understand:</p> <ul style="list-style-type: none"> mechanisms of human senses capabilities and restrictions of human perception foundation of user experience <p>to apply:</p> <ul style="list-style-type: none"> usability aspects for designing user interaction with machines selecting the right interface mechanisms and SW/HW interfaces <p>to transfer:</p> <ul style="list-style-type: none"> 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	<p>Course Organization and Structure</p> <p>lecture (V) / laboratory (L)</p>
5	<p>Credits and Workload</p> <p>2,5 CP / 75 hours in total, including 28 hours classroom teaching and lab. 1 SWS V / 1 SWS L</p>
6	<p>Examination Modalities</p> <p>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:</p> <ul style="list-style-type: none"> Laboratory Workbook Attending Lab <p>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.</p> <p>Examination Duration: 15 minutes presentation.</p>
7	<p>Necessary Prerequisites</p> <p>None</p>
8	<p>Recommended Prerequisites</p> <p>Advanced Programming Techniques (MA04)</p>
9	<p>Duration and Frequency of Course</p> <p>see module description of Elective 1 to 3 (MWP01, MWP02, MWP03)</p>
10	<p>Applicability / Utilization</p> <p>All (software) design tasks; software and hardware architectures; mechatronics, WING. See appendix 2 BBPO (Compulsory options catalogues) for its suitability for other majors.</p>

11	Literature <ul style="list-style-type: none">• 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. Koch
1.6	Additional Instructors Prof. Dr. Weber
1.7	Study Program Master / Major Automation
1.8	Teaching Language English
2	Module Content <ul style="list-style-type: none"> 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: <ul style="list-style-type: none"> - the basic applications, concepts, components and challenges of autonomous mobile robots - the basic locomotion principles for legged and wheeled robots to apply the knowledge: <ul style="list-style-type: none"> - 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 an appropriate navigation architecture to transfer: <ul style="list-style-type: none"> - 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: <ul style="list-style-type: none"> - 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 Script (excerpt of slides)
- Workbook for the lab

Further literature recommendations will be provided during the lecture.

Major Automation – electives from other majors

MCwp03 Network Security

MCwp06 (I)IoT and Cloud Networking

MMwp02 Safety in Embedded Control Systems

MMwp04 Advanced Software Design Techniques

MPwp03 Stationary & Mobile Energy Storage Systems

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 <ul style="list-style-type: none"> • 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 <ul style="list-style-type: none"> • Discrete-time signal transforms • Digital filter design and implementation • Multi-rate systems • Adaptive digital systems

3	Learning Outcome / Competencies to understand: <ul style="list-style-type: none"> - Principles of advanced digital signal processing methods to apply: <ul style="list-style-type: none"> - 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: <ul style="list-style-type: none"> - 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: <ul style="list-style-type: none"> - 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 script

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 <p>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</p> <ul style="list-style-type: none"> - 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) <p>Content of course “Advanced Modulation - Lab” Lab exercises with Matlab and software-defined radio (SDR) modules will cover</p>

	<ul style="list-style-type: none"> - Implementation of transmitter and receiver (QAM and OFDM) - Channel capacity and waterfilling optimization <p>Multi-antenna systems</p>
3	<p>Learning Outcome / Competencies</p> <p>to understand:</p> <ul style="list-style-type: none"> - the concepts of estimation theory - the difference between various multicarrier schemes (advantages/problems) - the channel capacity of MIMO and multicarrier systems - multi-antenna concepts <p>to apply:</p> <ul style="list-style-type: none"> - 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 <p>to transfer:</p> <ul style="list-style-type: none"> - the concepts of optimization approaches to similar parameter estimation, detection, and synchronization problems in communications
4	<p>Course Organization and Structure</p> <p>lecture (V) / lab (L)</p>
5	<p>Credits and Workload</p> <p>5 CP / 150 hours in total, including 56 hours classroom teaching and lab. 3 SWS V / 0.5 (1) SWS L</p>
6	<p>Examination Modalities</p> <p>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:</p> <ul style="list-style-type: none"> - Attending Lab - Lab Progress - Completion of lab preparation tasks <p>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.</p> <p>Examination Duration: 90 minutes</p>
7	<p>Necessary Prerequisites</p> <p>None</p>
8	<p>Recommended Prerequisites</p> <p>None</p>

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: <ul style="list-style-type: none">- Electronic script- Workbook for the lab Further literature recommendations will be provided during the lecture and are listed in the script.

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“: <ol style="list-style-type: none"> 1. Components: <ul style="list-style-type: none"> - Transmission lines and waveguides - Microwave network analysis - Power dividers and directional couplers - Microwave filters 2. Systems: <ul style="list-style-type: none"> - 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: <ul style="list-style-type: none"> - 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: <ul style="list-style-type: none"> - 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 <p>Object oriented programming applied to selected communication systems of medium level complexity, e.g. C++ and Matlab.</p> <p>The course will cover</p> <ul style="list-style-type: none"> - 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. <p>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.</p>
3	Learning Outcome / Competencies <p>to understand: technical principles of selected communication APIs and protocols, the principles of a good</p>

	<p>software design</p> <p>to apply: object oriented programming in C++, using UML for design and documentation purposes</p> <p>to transfer: general principles of using APIs and design patterns to other software systems</p>
4	<p>Course Organization and Structure</p> <p>lecture (V) / laboratory (L)</p> <p><u>Media:</u> software development environment</p>
5	<p>Credits and Workload</p> <p>5 CP / 150 hours in total, including 56 hours classroom teaching and lab. 2 SWS V / 2 SWS L</p>
6	<p>Examination Modalities</p> <p>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:</p> <ul style="list-style-type: none"> - Attending Lab - Lab Progress - Completion of lab preparation tasks <p>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.</p> <p>Examination Duration: 120 minutes</p>
7	<p>Necessary Prerequisites</p> <p>None</p>
8	<p>Recommended Prerequisites</p> <p>None</p>
9	<p>Duration and Frequency of Course</p> <p>This module takes one semester and is offered once a year (see appendix 1 BBPO).</p>
10	<p>Applicability /Utilization</p> <p>This module is applicable for all modules of the major Communications which include software topics (application/development).</p>
11	<p>Literature</p> <p>The following literature material will be provided:</p> <ul style="list-style-type: none"> • Electronic Script • 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: <ul style="list-style-type: none"> - 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: <ul style="list-style-type: none"> - Developing a PCB

	<ul style="list-style-type: none"> - Soldering a PCB - test of hardware – software interaction - hardware and software start-up - debugging
3	<p>Learning Outcome / Competencies</p> <p>to understand:</p> <ul style="list-style-type: none"> - system partitioning and interaction of software and hardware - the importance of designing for test of hardware and software <p>to apply:</p> <ul style="list-style-type: none"> - 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 <p>to transfer:</p> <ul style="list-style-type: none"> - 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	<p>Course Organization and Structure</p> <p>lecture (V) / laboratory (L)</p>
5	<p>Credits and Workload</p> <p>5 CP /150 hours in total, including 56 hours classroom teaching and lab. 2 SWS V / 2 SWS L</p>
6	<p>Examination Modalities</p> <p>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:</p> <ul style="list-style-type: none"> - Attending Lab - Lab progress <p>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..</p> <p>Examination Duration: 90 minutes</p>
7	<p>Necessary Prerequisites</p> <p>None.</p>
8	<p>Recommended Prerequisites</p>

	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: <ul style="list-style-type: none">- Electronic Script- 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: <p>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.</p> <p>The course consists of:</p> <ol style="list-style-type: none"> 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. <ul style="list-style-type: none"> • 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.

	<ul style="list-style-type: none"> • 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. <p>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".</p> <p>Laboratory:</p> <ul style="list-style-type: none"> • 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	<p>Learning Outcome / Competencies</p> <p>Knowledge:</p> <p>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.</p> <p>Skills:</p> <p>Capabilities to analyze the fields, wave guides and wave propagation problems and to design the antennas.</p> <p>Competences:</p> <p>Knowledge about and application of concepts of electromagnetic theory based on Maxwell's Equations in complete microwave and optical spectral range.</p> <p>Exemplary design and investigation of transmission line/waveguide and antenna structures by using different simulation software packages.</p>
4	<p>Course Organization and Structure</p> <p>lecture (V), laboratory (L)</p>
5	<p>Credits and Workload</p> <p>5 CP / 150 hours in total, including 56 hours classroom teaching and lab. 3 SWS V / 0.5 (1) SWS L</p>
6	<p>Examination Modalities</p> <p>Examination Prerequisites:</p> <p>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:</p> <ul style="list-style-type: none"> - Attending Lab - Lab Progress <p>Examination Type:</p>

	<p>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.</p> <p>Examination Duration: 90 minutes</p>
7	<p>Necessary Prerequisites</p> <p>None</p>
8	<p>Recommended Prerequisites</p> <p>Basic knowledge of fundamentals of communication technology of the Bachelor program.</p>
9	<p>Duration and Frequency of Course</p> <p>This module takes one semester and is offered once a year (see appendix 1 BBPO).</p>
10	<p>Applicability /Utilization</p> <p>This module is applicable for the major Communications.</p>
11	<p>Literature</p> <p>The following literature material will be provided:</p> <ul style="list-style-type: none"> - Electronic Lecture Notes - Descriptions for the laboratory for numerical simulations or measurements <p>Further literature recommendations will be provided during the lecture.</p>

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 <ul style="list-style-type: none"> - 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.

	<ul style="list-style-type: none"> - 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	<p>Learning Outcome / Competencies</p> <p>to know:</p> <ul style="list-style-type: none"> - about actual developments and specialised Layer2-WAN protocols - about trends and development directions of SDN <p>to understand:</p> <ul style="list-style-type: none"> - the usage of MPLS networks in WAN - the differences between IPv4 and IPv6 - the influence of network parameters on QoS <p>to apply:</p> <ul style="list-style-type: none"> - Design of dynamic routing environments - Migration from IPv4 networks to IPv6 - Estimation and measurement of QoS <p>to transfer:</p> <ul style="list-style-type: none"> - the learned protocols and network principles to new services and cloud networks under consideration of interworking and QoS
4	<p>Course Organization and Structure</p> <p>lecture (V) / laboratory (L)/</p>
5	<p>Credits and Workload</p> <p>5 CP / 150 hours in total, including 56 hours classroom teaching and lab. 3 SWS V / 0,5 (1) L</p>
6	<p>Examination Modalities</p> <p>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:</p> <ul style="list-style-type: none"> - Lab attendance - Lab exam <p>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.</p> <p>Examination Duration: 90 minutes</p>
7	<p>Necessary Prerequisites</p> <p>None</p>
8	<p>Recommended Prerequisites</p> <p>None</p>

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 <ul style="list-style-type: none">- Electronic script- Workbook for the Lab Further literature recommendations will be provided in the script.

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 <p>The course will cover the following areas:</p> <p>Application of several digital signal processing techniques in the fields of communications, speech, audio and image processing (including medical imaging) based on e.g.</p> <ul style="list-style-type: none"> • Multi-rate signal processing techniques and filter bank applications • Special transforms (e.g. Gabor transform, Wavelet transform, Radon transform)
3	Learning Outcome / Competencies <p>to know:</p> <ul style="list-style-type: none"> - Special transforms and their application for different application domains <p>to understand:</p> <ul style="list-style-type: none"> - Multi-rate signal processing techniques and filter bank applications for different application domains <p>to apply:</p> <ul style="list-style-type: none"> - 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 script 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“: <ul style="list-style-type: none"> - 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: <ul style="list-style-type: none"> - 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: <ul style="list-style-type: none"> • 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.

	<p>Skills : Capabilities to analyze the network security functionalities and requirements, and configure the network security gateways.</p> <p>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.</p>
4	<p>Course Organization and Structure</p> <p>lecture (V), seminar, demonstration lab during the lecture and seminar</p>
5	<p>Credits and Workload</p> <p>2.5 CP / 75 hours in total, including 28 hours classroom teaching. 2 SWS V</p>
6	<p>Examination Modalities</p> <p>Examination Prerequisites: none</p> <p>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.</p> <p>Examination Duration: Written exam: 90 minutes, oral exam: 30 minutes, presentation: 15 minutes</p>
7	<p>Necessary Prerequisites</p> <p>None</p>
8	<p>Recommended Prerequisites</p> <p>Basic knowledge of fundamentals of communication technology of the Bachelor program.</p>
9	<p>Duration and Frequency of Course</p> <p>see module description of Elective 1 to 3 (MWP01, MWP02, MWP03)</p>
10	<p>Applicability /Utilization</p> <p>This module is applicable for the major Communications. See appendix 2 BBPO (Compulsory options catalogues) for its suitability for other majors.</p>

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: <ul style="list-style-type: none"> • 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: <ul style="list-style-type: none"> - the concepts of signal propagation - the concepts of mobile communication systems - the differences between different systems as well as their pro and cons. Skills: <ul style="list-style-type: none"> - network planning for simple use-cases

	Competences: <ul style="list-style-type: none"> - 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 Script 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: <ul style="list-style-type: none"> • 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 (winter term)
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 <p>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:</p> <p>Lecture:</p> <ul style="list-style-type: none"> - 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 <p>IoT-Demo-Lab: Networks for Smart Home and Smart Industry</p>

3	<p>Learning Outcome / Competencies</p> <p>to know:</p> <ul style="list-style-type: none"> - about actual developments and specialised IoT network structures and protocols <p>to understand:</p> <ul style="list-style-type: none"> - 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 <p>to apply:</p> <ul style="list-style-type: none"> - 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 <p>to transfer:</p> <ul style="list-style-type: none"> - Application of the learned protocols and network principles to new evolving services in the Internet of things in private and in industry networks
4	<p>Course Organization and Structure</p> <p>lecture (V) and IOT-demo lab during lecture</p>
5	<p>Credits and Workload</p> <p>2,5 CP / 75 hours, including 28 hours classroom teaching. 2 SWS V</p>
6	<p>Examination Modalities</p> <p>Examination Prerequisites: None</p> <p>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.</p> <p>Examination Duration: written exam: 90 minutes, presentation: 15 minutes</p>
7	<p>Necessary Prerequisites</p> <p>None</p>
8	<p>Recommended Prerequisites</p> <p>None</p>
9	<p>Duration and Frequency of Course</p> <p>see module description of Elective 1 to 3 (MWP01, MWP02, MWP03)</p>
10	<p>Applicability /Utilization</p> <p>This module is applicable for the major Communications. See appendix 2 BBPO (Compulsory options catalogues) for its suitability for other majors.</p>

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

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: <ul style="list-style-type: none"> - 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: <ul style="list-style-type: none"> - Network planning and range measurements for different smart home systems - Qivicon smart home system - Security in smart home systems

3	Learning Outcome / Competencies Knowledge: <ul style="list-style-type: none"> - The differences between various systems as well as their pro and cons. - Regulatory issues Skills : <ul style="list-style-type: none"> - Network planning for smart home systems - Configuration of smart home systems Competences: <ul style="list-style-type: none"> - 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: <ul style="list-style-type: none"> - 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 Script
- 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: <ul style="list-style-type: none"> • Image processing techniques such as e.g. <ul style="list-style-type: none"> - 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. <ul style="list-style-type: none"> - Fundamentals of video sampling and digital video representation - Motion estimation and compensation - Video enhancement and noise reduction
3	Learning Outcome / Competencies to know:

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

Major Communications – electives from other majors

MAwp03 Human Machine Interfaces (HMI)

MMwp02 Safety in Embedded Control Systems

MMwp05 Security in Connected Embedded Systems

MPwp02 Automotive Electrical Power Train

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 <ul style="list-style-type: none"> - 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. <ul style="list-style-type: none"> - Model-based design on SoC/MPSoC platforms - Design verification using FIL - Design for testability

3	<p>Learning Outcome / Competencies</p> <p>to understand:</p> <ul style="list-style-type: none"> - 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 <p>to apply :</p> <ul style="list-style-type: none"> - 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 <p>to transfer: the circuit design concepts to more complex systems using new CMOS technologies and SoC platforms.</p>
4	<p>Course Organization and Structure</p> <p>lecture (V) / laboratory (L)</p>
5	<p>Credits and Workload</p> <p>5 CP / 150 hours in total, including 56 hours classroom teaching and lab. 3 SWS V/ 0.5 (1) SWS L</p>
6	<p>Examination Modalities</p> <p>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:</p> <ul style="list-style-type: none"> • Attending Lab • Lab Progress • Lab Report <p>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.</p> <p>Examination Duration: 90 minutes</p>
7	<p>Necessary Prerequisites</p> <p>None</p>
8	<p>Recommended Prerequisites</p> <p>None</p>
9	<p>Duration and Frequency of Course</p> <p>This module takes one semester and is offered once a year (see appendix 1 BBPO).</p>
10	<p>Applicability /Utilization</p> <p>This module is applicable for the major Embedded Systems and Microelectronics.</p>

11 Literature

The following literature material will be provided:

- Script
- 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 An electronic script 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 <p>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</p> <ul style="list-style-type: none"> - 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

	<ul style="list-style-type: none"> - 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. <p>FPGA-based System on Chip Design – Lab</p> <p>The lab focuses on teaching practical skills related to FPGA based SoC design using C and SystemVerilog:</p> <ul style="list-style-type: none"> - 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	<p>Learning Outcome / Competencies</p> <p>to understand:</p> <ul style="list-style-type: none"> - 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. <p>to apply:</p> <ul style="list-style-type: none"> - 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. <p>to transfer:</p> <ul style="list-style-type: none"> - 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	<p>Course Organization and Structure</p> <p>lecture (V) / laboratory (L)</p>
5	<p>Credits and Workload</p> <p>5 CP / 150 hours in total, including 56 hours classroom teaching and lab. 3 SWS V / 0.5 (1) SWS L</p>
6	<p>Examination Modalities</p> <p>Examination Prerequisites:</p> <p>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:</p> <ul style="list-style-type: none"> ▪ Lab attendance ▪ Lab entry test ▪ Lab progress <p>25% of the module grade is obtained by the laboratory.</p> <p>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.</p> <p>Examination Duration: 90 minutes</p>

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: <ul style="list-style-type: none"> - Electronic Script - 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 <ul style="list-style-type: none"> - 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”

	<p>Practical programming assignments in C/C++ using state of the art operating systems are part of the course.</p> <ul style="list-style-type: none"> - Configuring an embedded Operating System - Developing a simple multithreading, reactive application - Separating basic software and application software introducing a runtime environment
3	<p>Learning Outcome / Competencies</p> <p>to understand:</p> <ul style="list-style-type: none"> - 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 <p>to apply:</p> <ul style="list-style-type: none"> - 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 <p>to transfer:</p> <ul style="list-style-type: none"> - the design patterns and concepts to more complex embedded architectures using new operating systems and controllers.
4	<p>Course Organization and Structure</p> <p>lecture (V) / laboratory (L)</p>
5	<p>Credits and Workload</p> <p>5 CP / 150 hours in total, including 56 hours classroom teaching and lab. 3 SWS V/ 0.5 (1) SWS L</p>
6	<p>Examination Modalities</p> <p>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:</p> <ul style="list-style-type: none"> - Attending Lab - Lab Progress <p>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.</p> <p>Examination Duration: 90 minutes</p>
7	<p>Necessary Prerequisites</p> <p>None</p>
8	<p>Recommended Prerequisites</p> <p>None</p>

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: <ul style="list-style-type: none">- Electronic Script- 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 <p>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</p> <ul style="list-style-type: none"> - 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, re-timing: cut-set and delay scaling, the transpose FIR, pipelining and multichannel architectures). - the synthesis of digital signals (NCO Design, DDS, 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.

	<ul style="list-style-type: none"> - Design and implementation of digital control systems: Mapping analog control loops to digital platforms. <p>Embedded Signal Processing Systems - Lab</p> <p>The lab focuses on teaching practical skills related to the design and implementation of embedded signal processing systems using C and SystemVerilog:</p> <ul style="list-style-type: none"> - 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	<p>Learning Outcome / Competencies</p> <p>to understand:</p> <ul style="list-style-type: none"> - 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. <p>to apply:</p> <ul style="list-style-type: none"> - 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. <p>to transfer:</p> <ul style="list-style-type: none"> - 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	<p>Course Organization and Structure</p> <p>lecture (V) / laboratory (L)</p>
5	<p>Credits and Workload</p> <p>5 CP / 150 hours in total, including 56 hours classroom teaching and lab. 3 SWS V/ 0.5 (1) SWS L</p>
6	<p>Examination Modalities</p> <p>Examination Prerequisites:</p> <p>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:</p> <ul style="list-style-type: none"> ▪ Lab Attendance ▪ Lab Test ▪ Lab Progress <p>25% of the module grade is obtained by the laboratory.</p> <p>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.</p> <p>Examination Duration: 90 minutes</p>

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: <ul style="list-style-type: none">- Electronic Script- 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 <p>This module provides an introduction to CMOS analog circuit design. It covers the areas</p> <ul style="list-style-type: none"> - 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 <p>Students should know after completion of this module the most important principles of CMOS process technology and basics of deep submicron device models</p> <p>They should understand the design flow for CMOS-analogue circuits, which differs qualitatively from the digital counterpart</p>

	<p>They should be able to apply the design recipes to develop analogue circuits according to given</p> <p>They should be able to transfer the design methods from this module to other fields of analogue design tasks</p> <p>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.</p>
4	<p>Course Organization and Structure</p> <p>The course is taught using classroom lectures (V) and lab classes (L)</p>
5	<p>Credits and Workload</p> <p>5 CP / 150 hours in total, including 56 hours classroom teaching and lab. 3SWS V / 1 SWS L</p>
6	<p>Examination Modalities</p> <p>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:</p> <ul style="list-style-type: none"> - Laboratory Workbook - Attending Lab <p>30% of the module grade are obtained by the laboratory / project during the term.</p> <p>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.</p> <p>Examination Duration: 90 minutes</p>
7	<p>Necessary Prerequisites</p> <p>None</p>
8	<p>Recommended Prerequisites</p> <p>None</p>
9	<p>Duration and Frequency of Course</p> <p>see module description of Elective 1 to 3 (MWP01, MWP02, MWP03)</p>
10	<p>Applicability /Utilization</p> <p>This module is applicable for the major Embedded Systems and Microelectronics. See appendix 2 BBPO (Compulsory options catalogues) for its suitability for other majors.</p>

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 (summer term)
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 <ul style="list-style-type: none"> - 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: <ul style="list-style-type: none"> - the structure and concept of safety standards

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

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 (summer 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 “Digital System Design - Lecture” This course aims at the design of digital systems using SoC platforms. The course will cover <ul style="list-style-type: none"> - 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. <ul style="list-style-type: none"> - image processing on SoC/MPSoC platforms - hardware/software-codesign for FPGA-based systems - design automation using state-of-the-art design tools

3	<p>Learning Outcome / Competencies</p> <p>to understand:</p> <ul style="list-style-type: none"> - 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 <p>to apply:</p> <ul style="list-style-type: none"> - 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 <p>to transfer:</p> <ul style="list-style-type: none"> - develop digital systems on emerging new platforms
4	<p>Course Organization and Structure</p> <p>lecture (V) / laboratory (L)</p>
5	<p>Credits and Workload</p> <p>5 CP / 150 hours in total, including 56 hours classroom teaching and lab. 3 SWS V/ 1 L</p>
6	<p>Examination Modalities</p> <p>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:</p> <ul style="list-style-type: none"> • Attending Lab • Lab Progress • Lab Report <p>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.</p> <p>Examination Duration: 90 minutes</p>
7	<p>Necessary Prerequisites</p> <p>None</p>
8	<p>Recommended Prerequisites</p> <p>None</p>

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: - Script - 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 Mandatory
1.3	Course Names Advanced Software Design Techniques - Lecture Advanced Software Design Techniques - Lab
1.4	Semester 1 or 2 (summer term)
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 <ul style="list-style-type: none"> - 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: <ul style="list-style-type: none"> - complex design patterns to apply: <ul style="list-style-type: none"> - complex design patterns - assess design quality of complex software - refactoring methods - combined C/C++ modules to transfer: <ul style="list-style-type: none"> - 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: <ul style="list-style-type: none"> - 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 BBP0 (Compulsory options catalogues) for its suitability for other majors.

11 Literature

The following literature material will be provided:

- Electronic Script
- 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 <ul style="list-style-type: none"> - introduction to encryption - case study "security breaches in connected embedded systems", - analysis of embedded hardware encryption modules, - elementary security concepts (secure boot concepts, authentication, encryption, key management) - analysis of existing security protocols, - design of a secure embedded architecture.
3	Learning Outcome / Competencies to understand: <ul style="list-style-type: none"> - the basic concepts of encryption - the need for securing connected embedded systems to apply:

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

Major Embedded and Microelectronics– electives from other majors

- MAwp01 Model-based Real-time Simulation of Mechatronic Systems
- MAwp03 Human Machine Interfaces (HMI)
- MCwp02 Wireless Systems (Technologies
- MCwp06 (I)IoT and Cloud Networking
- MCwp07 Smart Home
- MCwp08 Image and Video Processing
- MPwp02 Automotive Electrical Power Train
- MPwp07 Embedded Programming & Design of Real-Time Control Systems

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: <ul style="list-style-type: none"> - 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: <ul style="list-style-type: none"> - 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: <ul style="list-style-type: none"> - Attending and Documentation of the 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 Power Engineering and as elective course of master WING.
11	Literature The following literature material will be provided: <ul style="list-style-type: none"> - Electronic Script - 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 <ul style="list-style-type: none"> - 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

	<p>Power System Operation – Lab</p> <p>The participants will use a power system training simulator to get experience of basic operational tasks including normal operation and handling of disturbances.</p> <ul style="list-style-type: none"> - 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	<p>Learning Outcome / Competencies</p> <p>to understand:</p> <ul style="list-style-type: none"> - 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 <p>to apply:</p> <ul style="list-style-type: none"> - handling control center software (SCADA) - solving operational tasks in the training simulation - execute fault localization and service restoration on the training system <p>to transfer:</p> <ul style="list-style-type: none"> - 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	<p>Course Organization and Structure</p> <p>lecture (V) / laboratory (L)</p>
5	<p>Credits and Workload</p> <p>5 CP / 150 hours in total, including 56 hours classroom teaching and lab. 3 SWS (V) / 0,5 (1) SWS L</p>
6	<p>Examination Modalities</p> <p>Examination Prerequisites:</p> <p>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:</p> <ul style="list-style-type: none"> - Attending Lab - Lab report <p>20% of the module grades are obtained by the laboratory during the term.</p> <p>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.</p>

	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 script and further material is 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 Prof. Dr. Ritter
1.7	Study Program Master / Major Power Engineering
1.8	Teaching Language English
2	Module Content <p>Today's and future societies crucially rely on a secure, stable and uninterrupted 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:</p> <ul style="list-style-type: none"> - 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.

	<ul style="list-style-type: none"> - 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	<p>Learning Outcome / Competencies</p> <p>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.</p> <p>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.</p> <p>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.</p>
4	<p>Course Organization and Structure</p> <p>lecture (V)</p>
5	<p>Credits and Workload</p> <p>5 CP / 150 hours in total, including 56 hours classroom teaching. 4 SWS V</p>
6	<p>Examination Modalities</p> <p>Examination Prerequisites: None</p> <p>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.</p> <p>Examination Duration: 90 minutes</p>
7	<p>Necessary Prerequisites</p> <p>None</p>
8	<p>Recommended Prerequisites</p> <p>None</p>

9	Duration and Frequency of Course Once a year (see Anl. 1 BBPO)
10	Applicability /Utilization This module is applicable for the major Power Engineering.
11	Literature The following literature material will be provided: <ul style="list-style-type: none"> - Volker Quaschnig: Under-standing Renewable Energy Systems - Kaltschmitt Martin: Renewable Energy Systems Further literature recommendations will be provided during the lecture.

MP04 Advanced Microcontroller Systems and Embedded Operating Systems

see MM03 Advanced Microcontroller Systems and Embedded Operating Systems

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. Weiner
1.6	Additional Instructors ---
1.7	Study Program Master / Major Power Engineering
1.8	Teaching Language English
2	Module Content <ul style="list-style-type: none"> - 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 <ul style="list-style-type: none"> - Voltage Source Converter for Electric Drives - Active Front End - Power Electronic Systems for Renewables and Distribution <ul style="list-style-type: none"> - 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: <ul style="list-style-type: none"> - 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: <ul style="list-style-type: none"> - set-up, simulate and compare power systems for drives and energy systems - dimension and design power electronic equipment to transfer: <ul style="list-style-type: none"> - 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 <p>This module explores advanced modelling and modern control strategies of electric drive systems, focusing on induction and permanent magnet synchronous machines.</p> <ul style="list-style-type: none"> - 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 <ul style="list-style-type: none"> - field-orientated control - direct torque control - introduction to sensorless control - introduction to predictive control - controller design and optimisation <ul style="list-style-type: none"> - 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 48 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 System Driven Hardware Design

see MC05 System-Driven Hardware Design

Module Handbook

Electrical Engineering and Information Technology - international

Master of Science

Major Power Engineering - electives

MPwp01 Model-Based Design, HiL & PiL Systems

1	Module Name Model-Based Design, HiL & PiL Systems
1.1	Module Identifier MPwp01
1.2	Module Type Elective
1.3	Course Names Model-Based Design, HiL & PiL Systems – Lecture
1.4	Semester 1 or 2 (winter 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 <p>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:</p> <ul style="list-style-type: none"> - 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: <ul style="list-style-type: none"> - the advantages and benefits of Model-based design strategies in virtual prototyping of embedded control software. to apply: <ul style="list-style-type: none"> - 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: <ul style="list-style-type: none"> - 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) / exercise course (EC)
5	Credits and Workload 5 CP / 150 hours in total. 42 SWS hours classroom teaching.
6	Examination Modalities Examination Prerequisites: In order to participate in the module exam, it is required to successfully finish all exercise projects. Successful fulfilment of prerequisites is measured by Handing and passing all exercise projects. 30% of the module grade is obtained by the rated exercise projects. 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 Script
- Guided set of exercises

Further literature recommendations will be provided during the lecture.

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 (summer term)
1.5	Module Responsible and Instructor Prof. Dr. Weiner
1.6	Additional Instructors ---
1.7	Study Program Master / Major Power Engineering
1.8	Teaching Language English
2	Module Content <ul style="list-style-type: none"> - power train topologies of electric and hybrid vehicles - components of the electrical power train <ul style="list-style-type: none"> - 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 <ul style="list-style-type: none"> - 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 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 Students should be familiar with the basics of power electronics and electrical machines.
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 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 (summer term)
1.5	Module Responsible and Instructor Prof. Dr. Betz, Prof. Dr. Bauer
1.6	Additional Instructors ---
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: <ul style="list-style-type: none"> - Importance of storage systems for modern energy systems and mobility - General characteristic parameters and technical requirements of energy storage systems. - Stationary energy storage systems: <ul style="list-style-type: none"> - 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.

	<ul style="list-style-type: none"> - Mobile energy storage systems: <ul style="list-style-type: none"> - 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: <ul style="list-style-type: none"> - 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: <ul style="list-style-type: none"> - Dimensioning rules of different energy storage systems for stationary and mobile applications. - Cost evaluations of selected energy storage systems. to transfer: <ul style="list-style-type: none"> - 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 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 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 Script Further literature recommendations will be provided during the lecture.

MPwp04 Lab-Module on Power Electronics & Drives

1	Module Name Lab-Module on Power Electronics & Drives
1.1	Module Identifier MPwp04
1.2	Module Type Elective
1.3	Course Names Lab-Module on Power Electronics & Drives - Lab
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 The students should gain practical experience with regards to the contents of the corresponding theory modules on Power Electronics for Drives and Energy Systems and Advanced Control of electric Drives. 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 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 power electronic and electric drives

	<p>systems by means of measurements.</p> <p>to transfer:</p> <p>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.</p>
4	<p>Course Organization and Structure</p> <p>laboratory (L)</p>
5	<p>Credits and Workload</p> <p>5 CP / 150 hours in total, including 28 lab hours. 2 SWS L</p>
6	<p>Examination Modalities</p> <p>Examination Prerequisites:</p> <p>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:</p> <ul style="list-style-type: none"> - Successful completion (including report) of all lab and simulation exercises <p>30% of the module grade are obtained by graded lab reports during the term.</p> <p>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.</p> <p>Examination Duration: written exam: 90 minutes; oral exam: 30 minutes; practical exam: 60 minutes</p>
7	<p>Necessary Prerequisites</p> <p>Parallel attendance of the modules Power Electronics for Drives and Energy Systems and Advanced Control of electric Drives</p>
8	<p>Recommended Prerequisites</p> <p>None</p>
9	<p>Duration and Frequency of Course</p> <p>This module takes one semester and is offered once a year (see appendix 1 BBPO).</p>
10	<p>Applicability /Utilization</p> <p>This module is applicable for the major Power Engineering.</p>
11	<p>Literature</p> <p>Workbook for exercises and lab.</p>

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 (summer 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 „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: <ul style="list-style-type: none"> - 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 SF₆, 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	<p>Learning Outcome / Competencies</p> <p>to understand:</p> <ul style="list-style-type: none"> - Functionality of circuit breaker, load breaker, disconnecter and earthing switches. - Physical behavior of arcing phenomenon and different arc quenching methods in SF₆, Air and Vacuum. <p>to apply:</p> <ul style="list-style-type: none"> - 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. <p>to transfer:</p> <ul style="list-style-type: none"> - 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	<p>Course Organization and Structure</p> <p>lecture (V)</p>
5	<p>Credits and Workload</p> <p>2,5 CP / 75 hours in total, including 28 hours classroom teaching. 2 SWS V</p>
6	<p>Examination Modalities</p> <p>Examination Prerequisites: None</p> <p>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.</p> <p>Examination Duration: 60 minutes</p>
7	<p>Necessary Prerequisites</p> <p>None</p>
8	<p>Recommended Prerequisites</p> <p>None</p>
9	<p>Duration and Frequency of Course</p> <p>see module description of Elective 1 to 3 (MWP01, MWP02, MWP03)</p>

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: <ul style="list-style-type: none">- Electronic Script 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 (summer term)
1.5	Module Responsible and Instructor Prof. Dr. Ingo Jeromin
1.6	Additional Instructors ---
1.7	Study Program Master / Major Power Engineering
1.8	Teaching Language English
2	Module Content <p>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:</p> <ul style="list-style-type: none"> - 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 <p>Theoretical knowledge is applied to study cases for computer-aided network planning (e.g. NEPLAN).</p>
3	Learning Outcome / Competencies to understand: <ul style="list-style-type: none"> - Power quality in distribution grids - Design of harmonic filters - Voltage stability in power systems

	<ul style="list-style-type: none"> - Challenges arising by the connection of dispersed generation (wind and solar) to distribution networks <p>to apply :</p> <ul style="list-style-type: none"> - Load flow and short circuit algorithms to power systems for grid planning - Load modelling and load forecasting - Innovative network planning alternatives to distribution networks <p>to transfer:</p> <ul style="list-style-type: none"> - 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	<p>Course Organization and Structure</p> <p>lecture (V) with integrated laboratory exercises (computer-aided network planning e.g. NEPLAN)</p>
5	<p>Credits and Workload</p> <p>2,5 CP / 75 hours in total, including 28 hours classroom teaching. 2 SWS V (2,5 CP)</p>
6	<p>Examination Modalities</p> <p>Examination Prerequisites: None</p> <p>Examination Type: Written exam covering or oral exam (will be communicated upon start of the module) the complete content of the module at the end of the semester. A make-up exam will be offered during the following semester.</p> <p>Examination Duration: Written exam: 90 Minutes, oral exam: 45 minutes</p>
7	<p>Necessary Prerequisites</p> <p>None</p>
8	<p>Recommended Prerequisites</p> <p>None</p>
9	<p>Duration and Frequency of Course</p> <p>see module description of Elective 1 to 3 (MWP01, MWP02, MWP03)</p>
10	<p>Applicability /Utilization</p> <p>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.</p>

11	<p>Literature</p> <p>Grisby: "Electric Power Engineering Handbook – Volume I (Power Systems)"; CRC Press; ISBN 0-8493-9288-8</p> <p>Sallam & Malik: "Electric Distribution Systems"; Willey; ISBN 9780470276822</p> <p>Sivanagaraju & Satyanarayana: "Electric Power Transmission and Distribution"; Pearson Education; ISBN 978-81-317-0791-3</p> <p>National and international standards EN 50160, IEC 61000 series, VDE AR 4105, VDE 4100, VDE 4110</p> <p>The following literature material will be provided:</p> <ul style="list-style-type: none">- Slides
-----------	-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

MPWp07 Embedded Programming & Design of Real-Time Control Systems

1	Module Name Embedded Programming & Design of Real-Time Control Systems
1.1	Module Identifier MPWp07
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 <ul style="list-style-type: none"> - 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.

	<ul style="list-style-type: none"> - 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. <p>Embedded Signal Processing Systems - Lab</p> <p>The lab focuses on teaching practical skills related to programming of embedded systems using C:</p> <ul style="list-style-type: none"> - 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	<p>Learning Outcome / Competencies</p> <p>to understand:</p> <ul style="list-style-type: none"> - 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. <p>to apply:</p> <ul style="list-style-type: none"> - 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. <p>to transfer:</p> <ul style="list-style-type: none"> - 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	<p>Course Organization and Structure</p> <p>lecture (V) / laboratory (L)</p>
5	<p>Credits and Workload</p> <p>5 CP / 150 hours in total, including 56 hours classroom teaching and lab. 2 SWS V / 2 SWS L</p>

6	<p>Examination Modalities</p> <p>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:</p> <ul style="list-style-type: none"> ▪ Lab Attendance ▪ Lab Progress <p>25% of the module grade is obtained by the laboratory.</p> <p>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.</p> <p>Examination Duration: 90 minutes</p>
7	<p>Necessary Prerequisites</p> <p>None</p>
8	<p>Recommended Prerequisites</p> <p>None</p>
9	<p>Duration and Frequency of Course</p> <p>see module description of Elective 1 to 3 (MWP01, MWP02, MWP03)</p>
10	<p>Applicability /Utilization</p> <p>This module is applicable for the major Power Engineering. See appendix 2 BBPO (Compulsory options catalogues) for its suitability for other majors.</p>
11	<p>Literature</p> <p>The following literature material will be provided:</p> <ul style="list-style-type: none"> - Electronic Script - Laboratory Workbook <p>Further literature recommendations will be provided during the lecture.</p>

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 (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 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: <ul style="list-style-type: none"> - 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 <ul style="list-style-type: none"> o different types of diagrams, advantages and disadvantages

	<ul style="list-style-type: none"> ○ methods of data quality assurance, bad data detection and elimination - Introduction of data base software <ul style="list-style-type: none"> ○ limitations of spread sheet software and characteristics of data base applications ○ data base setup and design, data bases queries (SQL) ○ use of data base software for typical engineering tasks - Methods and tools of requirements engineering <ul style="list-style-type: none"> ○ methods of software specification and description, introduction of UML diagrams ○ stakeholder, business process and use case identification, description, verification and management ○ architectural views, structure of big software systems, decomposition and interface design ○ criteria for the evaluation and selection of standard software <p>The topics are introduced in the lecture and practiced in exercises</p>
3	<p>Learning Outcome / Competencies</p> <p>to understand: the participant understands</p> <ul style="list-style-type: none"> - the industrial software engineering processes and development tasks - structure and potential of big data base applications - the requirements engineering and software specification processes <p>to apply: the participant can</p> <ul style="list-style-type: none"> - 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 <p>to transfer: the participant can</p> <ul style="list-style-type: none"> - 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	<p>Course Organization and Structure</p> <p>lecture (V) / laboratory (L)</p>
5	<p>Credits and Workload</p> <p>5 CP / 150 hours in total, including 56 hours classroom teaching and lab. 2 SWS V / 2 SWS L</p>
6	<p>Examination Modalities</p> <p>In order to write the end-of term exam, it is required to successfully present the results of the exercises</p> <p>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:</p> <ul style="list-style-type: none"> - Presentation - Exercises

	<p>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.</p> <p>Examination Duration: 90 minutes</p>
7	<p>Necessary Prerequisites</p> <p>None</p>
8	<p>Recommended Prerequisites</p> <p>None</p>
9	<p>Duration and Frequency of Course</p> <p>see module description of Elective 1 to 3 (MWP01, MWP02, MWP03)</p>
10	<p>Applicability /Utilization</p> <p>This module is applicable for the major Power Engineering. See appendix 2 BBPO (Compulsory options catalogues) for its suitability for other majors.</p>
11	<p>Literature</p> <p>The lecture script and further material is provided in electronic form.</p> <p>Further literature recommendations will be provided during the lecture.</p>

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 (summer term)
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 <p>The module gives an overview of hydrogen technology and fuel cells. Participants will gain experience with these technologies. The course will cover</p> <ul style="list-style-type: none"> - 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 cell 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 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. 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 – electives from other majors

MAwp01 Model-based Real-time Simulation of Mechatronic Systems

MAwp04 Autonomous Mobile Robots

MCwp06 (I)IoT and Cloud Networking

MCwp07 Smart Home

MC04 Advanced Software Design and Development

MMwp02 Safety in Embedded Control Systems

MMwp04 Advanced Software Design Techniques