Mechatronics (Master)

Master of Science

Module Manual

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Valid from: WiSe22/23

RWU

Content Modules

Master studies

Program Objectives

The subject of Mechatronics is composed of the fields electrical-, mechanical engineering and computer science. The aim of the study program Master Mechatronics is to provide graduates with a solid and prevailing education in all three of these fields as well as the links between them. This goal can only be achieved on a satisfactorily level by taking into consideration the beforehand attained knowledge of the students, which is quite a unique feature of this study program.

Due to the versatility of the education, Mechatronic graduates are offered a vast profile of industrial sectors to work within, as well as lots of occupational profiles offered in these sectors. Some prominent examples of these industrial sectors are:
- Plant construction
- Robotics
- Environmental engineering
- Automotive industry: Safety systems; ADAS; Alternative drive systems
- Aerospace industry: Raising efficiency of vessels; Developing new propulsion systems; Increasing safety of air traffic
- Medicine technology: MRI machines; Dialysis machines; Nano technolgy
- Self-employment: Planning services; Counseling service

Due to the ongoing migration of electronic components toward 'classical' areas of engineering, also known as Cyber Physical Systems (CPS), an increasing demand of Mechatronic graduates is to be expected. According to VDI (Verein Deutscher Ingenieure) there are tens of thousands vacant positions in the field, with predicted number of graduates not being able to occupy all of these positions. The following occupational profiles apply to graduates of Master Mechatronics study program:
- Product developer
- Project manager
- Consultant
- Planning engineer
- Servicing engineer

All of these profiles apply to employed as well as self-employed graduates.

The following table shows the relationship of compulsory study modules offered in the course to fields of professional competences:

- Analytic and problem solving competence: Ability to professionally analyze questions of practice and development of proper and valuable solutions.
- Subject and methodical competence: Acquisition of a wide variety of methodic competences required in the field of Mechatronics.
- Self development: Self-reflection and ability to develop own notions regarding personal career.
- Social competence: Acquisition and consolidation of the required abilities which enable or alleviate coping with other people professionally. This includes the ability to chair different groups of interest.

A distinction between major and subsidiary impact of the respective module is made. As can be seen from the table, the majority of modules focuses on 'subject and methodical competence' and 'analytic and problem solving competence', which is to be expected for a technically-oriented study program. However, there are also modules in the study program to foster self development and social competence. The Scientific Project is a good example for such a module. Here, students are intended to work on a well-defined project in international teams with an emphasis on cooperation. This module is completed by a seminar called 'International Sensitization'.

COURSE CONTENTS
MECHATRONICS

SEM	MODULE OVERVIEW						ECTS
1	Mathematics 10	Power Electronics 5	Advanced Engineering Mechanics 5	Process Interface Equipment 5	Simulation of Mechatronic Systems 5		30
2	Electrical Drives 5	Automation 5	Process Interface Equipment 2	Scientific Project 5	Advanced Control Systems 5	Robotics 8	30
3	Engineering Design and Materials 5	Masters Thesis & Colloquium 25					30

Please note that there are different module plans for prior knowledge in the aeeras of mechanical engineering, electrical engineering or computer science (see Study and Examination regulations).

■ Lecture subjects ■ Projects and internship ■ Thesis

Embedded Computing

Course of study:	Mechatronics (Master)
Degree:	Master of Engineering (M.Eng.)
Modul number:	EMM10
Modul title:	Embedded Computing
Module responsible:	Prof. Dr. rer. nat. Markus Pfeil
Typ of module:	Mandatory module
Module Content:	- Embedded Systems in motor management, ABS, medical devices and its increasing programming needs. - Modeling of embedded systems (Cyber-Physical Systems) - Functions of 32-bit micro controllers (ARM), interface functions, its programming under Linux - Implementation of operating systems on microcontrollers
Courses:	Embedded Computing Embedded Computing Lab Embedded Project
Teaching and learning forms:	Lecture and Laboratory / practical course and Project Lecture with integrated applications, development and programming of functions for embedded systems, project management (project idea, realization, presentation)
Prerequisites for participation:	Bachelor knowledge
Applicability of the module:	Electrical Engineering and Embedded Systems Mechatronics
Prerequisites allocation ECTS:	PF
ECTS credits:	10
Grading:	graded
Workload:	10 ECTS Embedded Computing 150 h (60 h Lecture, 90 h Homework) Embedded Computing Lab 60 h (30 h Lecture, 30 h Homework) Embedded Project 90 h (30 Lecture, 60 h Homework)
Duration of the module:	two semester
Frequency of offering:	Every semester
Literature:	B. P. Douglas; "Real-Time UML", Second Edition. Addision Wesley Longman, Inc., 2000. P. Marwedel; "Embedded System Design", Springer Verlag, 2006. D. Abbott; "Linux for Embedded and Real-time Applications", Elsevier Science, 2003
Compulsory attendance:	no

Competence dimensions Embedded Computing

Knowledge and understanding: Knowledge Comprehension

The graduates have broadened their knowledge in the following fields and are capable of reproducing this knowledge:

- Mechatronic and electrical engineering
- Model and simulate mechatronic systems
- Construct electrical and IT components

Use, application and generation of knowledge/art:

Communication and cooperation

With the contents for the module, sustainable work, design and economics will be teached. It will be improved to a level, that it fits to the needs of companies. The intercultural competence of the graduates will be developed by

- international tandem teams
- mixed teams in the labs
- mixed teams for projects and seminars

Scientific / artistic self-image and professionalism

In the course of their study, the graduates have already reached a level of knowledge and understanding that enables them to analyze not only simple but also complex interactions. On this basis, they are capable of independently identifying scientific or practice-related issues in the following fields:

- mechatronic questions
- model and simulate mechatronic systems
- construct electrical and IT components
- present mechatronic projects

Advanced Mathematics

Course of study:	Mechatronics (Master)
Degree:	Master of Engineering (M.Eng.)
Modul number:	MM01
Modul title:	Advanced Mathematics
Module responsible:	Prof. Dr. rer. nat. Wolfgang Ertel
Typ of module:	Mandatory module
Module Content:	1 Linear Algebra (Repetition): - Video Lectures (Gilbert Strang) 2 Computer Algebra: - Gnuplot, a professional Plotting Software; - Short Introduction to GNU Octave / MATLAB, Python 3 Calculus - Selected Topics (Repetition): - Sequences and Convergence; - Series; - Continuity; - Taylor Series; - Differential Calculus in many Variables 4 Statistics and Probability (Repetition): - Statistical Parameters; - Probability Theory; - Distributions; - Random Numbers; - Principal Component Analysis; - Estimators 5 Numerical Mathematics Fundamentals: - Arithmetics on the Computer; - Numerics of Linear Systems of Equations; - Roots of Nonlinear Equations 6 Function Approximation: - Polynomial Interpolation; - Spline interpolation; - Method of Least Squares and Pseudoinverse; - Singular Value Decomposition (SVD) 7 Numerical Integration and Solution of Ordinary Differential Equations: - Numerical Integration; - Numerical Solution of Ordinary Differential Equations; - Linear Differential Equations with Constant Coefficients
Courses:	Advanced Mathematics for Engineers; Advanced Mathematics for Engineers - Lab
Teaching and learning forms:	Lecture/Practical training
Prerequisites for participation:	Undergraduate Mathematics, e.g. Calculus (multidimensional), Linear Algebra, Statistics, Programming
Applicability of the module:	Mechatronics; Electrical Engineering and Embedded Systems; Informatik
Prerequisites allocation ECTS:	Portfolio with 80% weight of the written examination (K90) and 20% weight of the laboratory results (P).
ECTS credits:	10
Grading:	graded
Workload:	30h / 1 ECTS
Duration of the module:	one semester
Frequency of offering:	Winter semester only
Literature:	W. Cheney and D. Kincaid. Numerical mathematics and computing. Thomson Brooks/Cole, 2007. J. Nocedal and S.J. Wright. Numerical optimization. Springer Verlag, 1999. S.M. Ross. Introduction to probability and statistics for engineers and scientists. Academic Press, 2009. G. Strang. Introduction to linear algebra. Wellesley Cambridge Press, 3rd edition, 2003. H. Schwarz: Numerische Mathematik, Teubner Verlag. M. Brill.: Mathematik für Informatiker. Hanser Verlag, 2001. W. Nehrlich: Diskrete Mathematik, Fachbuchverlag Leipzig.
Compulsory attendance:	no

Competence dimensions Advanced Mathematics

Knowledge and understanding: Deepening of individual components of knowledge

After successfully attending this course graduates are able to solve mathematical problems arising in typical engineering tasks. Primary focus is on numerically solving linear problems and on the statistical interpretation of results from measurements. In numerical mathematics, the focus is put on methods for function approximation from data, solution of equations, integration and solution of differential equations. Generation and test of random numbers are essential foundations of simulation and cryptography.

Use, application and generation of knowledge/art: Use and transfer

The graduates have broadened their knowledge in the following fields and are capable of reproducing this knowledge: High level programming languages with built in mathematical functions like Octave or Python will be used for the practical assignments (e.g. programming of algorithms).

Communication and cooperation

Scientific / artistic self-image and professionalism

Electrical Drives

Course of study:	Mechatronics (Master)
Degree:	Master of Engineering (M.Eng.)
Modul number:	MM02
Modul title:	Electrical Drives
Module responsible:	Prof. Dr.-Ing. László Farkas
Typ of module:	Mandatory module
Module Content:	Introduction: -Fundamental equations; -energies, forces, powers. DC machine: -mechanics, equivalent circuit, main equations; - types of machines, variable supply voltage; -application in drives, operating range, risks. AC machine: -Fundamentals of transformer: equations for AC machine; -Electrical machine: equivalence to rotating transformer; -torque, power; -operating range, fundamental understanding. Induction machine: -mechanics, equivalent circuit; -(rotor) resistance, inductances; -heyland circle, Kloss formula; -operation modes, controling; -application in drives, risks, construction. Synchronous machine: -mechanics, equivalent circuit, phasor diagram; -field oriented control, analogon to dc machine. Permanent Magnet Synchronous Machine (PMSM): -mechanics, equations, phasordiagram; -effect of reluctance; -mechanical specialities; -rotordesign. Brushless DC-Motor (BLDC): -application in drives; -advantages/disadvantages in relation to normal synchronous machine. Field of application: -powertrain in hybrids and e-drives; -application for fulldrives or auxiliary drives; -costs versus necessity; -comparison of force densities.
Courses:	Electrical Drives
Teaching and learning forms:	Lecture
Prerequisites for participation:	Principles of electrical engineering
Applicability of the module:	Mechatronics; Electrical Engineering and Embedded Systems
Prerequisites allocation ECTS:	Written examination, 90 minutes.
ECTS credits:	5
Grading:	benotet
Workload:	30h / 1 ECTS
Duration of the module:	one semester
Frequency of offering:	Winter semester only
Literature:	J. Pollefliet: Electronic power control - vol.2: Electronic motor control, Academia press K. Hofer; Elektrische Antriebe in Fahrzeugen W. Leonhard: Control of Electrical Drives, Springer 1997 (dt.: Regelung elektrischer Antriebe, Springer 2000) H. Schäfer, Praxis der elektrischen Antriebe für Hybrid- und Elektrofahrzeuge
Compulsory attendance:	no

Competence dimensions Electrical Drives

Knowledge and understanding: Broadening of prior knowledge

The lecture gives an overview together with formulas of the most important electrical machines in the application for drives. The graduates are able to describe the function of these most used electrical machines and drives together with the necessary control in the drive and give application-hints and examples.

Use, application and generation of knowledge/art:

Communication and cooperation

Scientific / artistic self-image and professionalism

Power Electronics

Course of study:	Mechatronics (Master)
Degree:	Master of Engineering (M.Eng.)
Modul number:	MM03
Modul title:	Power Electronics
Module responsible:	Prof. Dr.-Ing. László Farkas
Typ of module:	Mandatory module
Module Content:	Based on a modern Power Electronics device for electrical drives the main structure and the most important components will be discussed. Especially an introduction to the power semiconductors with their characteristic curves will be given. In the next step the classical circuits are discussed with their main application including the (dis-)advantages: without commutation, commutation by circuit / by network, self commutation. Also an introduction to the possible operation quadrants, their triggering and the harmonics in general is given. Especially the modern vector control (voltage space-vector) will be discussed in detail for the example of the synchronous machine. Finally, a prospect will be given to the most important electrical machines for e-drives with the focus to the used power electronics.
Courses:	Power Electronics
Teaching and learning forms:	Lecture
Prerequisites for participation:	Principles of electrical engineering
Applicability of the module:	Mechatronics
Prerequisites allocation ECTS:	K90
ECTS credits:	5
Grading:	graded
Workload:	30h / 1 ECTS
Duration of the module:	one semester
Frequency of offering:	Winter semester only
Literature:	N. Mohan, T.M. Undeland, W.P. Robbins: Power Electronics - Converters, Applications and Design; Wiley 2003 W. Leonhard: Control of Electrical Drives ; Springer 1997 (dt.: Regelung elektrischer Antriebe, Springer 2000) K. Heumann: Grundlagen der Leistungselektronik, Teubner 2001
Compulsory attendance:	no

Competence dimensions Power Electronics

Knowledge and understanding: Deepening of individual components of knowledge

The students have deepened their existing knowledge in the following areas and are capable of not only reproducing the corresponding contents but also of explaining them. They understand the underlying principles, the whys and wherefores:

-valution of structure of modern power electronics and the interaction of most important components,

-analyze of the used components,

-comparison of concepts.

Use, application and generation of knowledge/art:

Communication and cooperation

Scientific / artistic self-image and professionalism

Engineering Design and Materials

Course of study:	Mechatronics (Master)
Degree:	Master of Engineering (M.Eng.)
Modul number:	MM04
Modul title:	Engineering Design and Materials
Module responsible:	Prof. Dr.-Ing. Michael Niedermeier
Typ of module:	Mandatory module
Module Content:	– design methodology in mechatronical product development – selection of materials: steel, light-metals, plastics, ceramics, composites – smart materials and lightweight structures - corrosion – joining technologies - selected machine elements - compliant mechanisms - life cycle assessment of mechatronical products
Courses:	Engineering Design and Materials
Teaching and learning forms:	V + Ü; lecture/team exercises/student presentations
Prerequisites for participation:	completed bachelor's degree in engineering or natural sciences
Applicability of the module:	Scientific Project; Master Thesis
Prerequisites allocation ECTS:	Written examination, 90 minutes.
ECTS credits:	5
Grading:	graded
Workload:	30h / 1 ECTS
Duration of the module:	one semester
Frequency of offering:	Winter semester only
Literature:	Newest edition in each case: Grote K.-H., Hefazi H., et al., Springer Handbook Mechanical Engineering, chapter Engineering Design, Springer. VDI 2206: Design Methodology for Mechatronic Systems, Beuth Berlin. Roloff H., Mattek W., et al., Maschinenelemente, Springer Vieweg Verlag Braunschweig. Ashby M., Materials Selection in Mechanical Design, Elsevier. Ashby M., Shercliff H., Cebon D., Materials, Elsevier
Compulsory attendance:	no

Competence dimensions Engineering Design and Materials

Knowledge and understanding: Deepening of individual components of knowledge

Graduates discuss current material developments, material combinations in mechatronics. They deepen the systematic approach of mechatronic product development at a high scientific level and expand it in selected areas. Graduates are able to assess a wide range of materials and material effects on the environment (life cycle). They are able to grasp materials science as a complex topic and to combine knowledge from different areas of materials technologies. Graduates can dimension selected machine elements and apply them in mechatronics.

Use, application and generation of knowledge/art: Use and transfer

The most important materials can be selected and used to design a mechatronical product. The graduates are able to calculate and design the mechanical parts of a mechatronical product. To gain a practice related understanding on the subject of corrosion, tribology and surface technology together with user related know how on important types of metals.

Communication and cooperation

The students discuss justifiable solutions to problems with the lecturer in a subject-related manner.

Scientific / artistic self-image and professionalism

Students recognise the framework conditions of professional action and reflect responsibly on decisions in mechatronics product development.

Advanced Engineering Mechanics

Course of study:	Mechatronics (Master)
Degree:	Master of Engineering (M.Eng.)
Modul number:	MM05
Modul title:	Advanced Engineering Mechanics
Module responsible:	Prof. Dr.-Ing. Ralf Stetter
Typ of module:	Mandatory module
Module Content:	This lecture consolidates highly specialized knowledge of engineering mechanics as basis for theoretical and applied research. Special chapters from the areas statics, mechanics of materials, kinematics, kinetics, and dynamics are presented in the lecture and are consolidated by means of tutorials in form of exercises. Through this specialized problem solving qualifications for the development of new calculation methods are acquired. The subject matter taught additionally serves as a basis for the application of the finite element method.
Courses:	Advanced Engineering Mechanics
Teaching and learning forms:	Variant A) Lecture; Variant B) E-Learning with accompanying shortened lecture
Prerequisites for participation:	Knowledge of mathematics
Applicability of the module:	Mechatronics; Electrical Engineering and Embedded Systems
Prerequisites allocation ECTS:	Written examination, 90 minutes.
ECTS credits:	5
Grading:	graded
Workload:	Variant A) Lecture: 45 h presence; 105 h self-study Variant B) E-Learning with accompanying shortened lecture: 22,5 h presence; 127,5 h self-study
Duration of the module:	one semester
Frequency of offering:	Winter semester only
Literature:	-Dankert&Dankert: Technische Mechanik: Statik, Festigkeitslehre, Kinematik/Kinetik. Vieweg Teubner Verlag; 2013. -Hibbeler: Statics&Dynamics. MACMILLAN. - Gross, D.; Hauger, W.; Schröder, J.; Wall, W.A.; Rajapakse, N.: Engineering Mechanics 1 – Statics; Springer; 2013. - Gross, D.; Hauger, W.; Schröder, J.; Wall, W.A.; Bonet, J.: Engineering Mechanics 2 – Mechanics of Materials; Springer; 2018. - Gross, D.; Ehlers, W.; Wriggers, P.; Schröder, J.; Müller, R.: Statics – Formulas and Problems. Springer; 2017. - Gross, D.; Ehlers, W.; Wriggers, P.; Schröder, J.; Müller, R.: Mechanics of Materials – Formulas and Problems. Springer; 2017.
Compulsory attendance:	no

Competence dimensions Advanced Engineering Mechanics

Knowledge and understanding: Broadening of prior knowledge

The graduates can explain the basics of engineering mechanics (statics, kinematics, kinetics, and dynamics) which are also the basis for theoretical and applied research. The graduates can explicate the fundamental equations of engineering mechanics which also serve as a basis für the application of the finite element method.

Use, application and generation of knowledge/art: Use and transfer

The graduates can solve problems in the context of statics, mechanics of materials and dynamics. They are be able, on the one hand, to calculate the rigidity, stiffness, stresses and so on of even complicated components and to analyze even complex mechanisms dynamically, on the other hand also to play an active role in the advancement of the research field "mechanics".

Communication and cooperation

Scientific / artistic self-image and professionalism

Process Interface Equipment

Course of study:	Mechatronics (Master)
Degree:	Master of Engineering (M.Eng.)
Modul number:	MM07
Modul title:	Process Interface Equipment
Module responsible:	Prof. Dr.-Ing. Raphael Ruf
Typ of module:	Mandatory module
Module Content:	- Introduction and overview of industrial automation systems; - System interfaces to field elements (binary, digital, analog and signal adaption); - Sensor principles and example devices; - Actuators; - Operational amplifiers; - ADC- and DAC converters; - Linearisation Lab tests: - Intelligent contactor turning on / off Ohmic inductive load (Identification of R, L, and C of load, non-linear behaviour of L, over Voltage protection) - Temperature measurement by TC, RTD and and pyroelectric sensor (Identify type of sensor, Parameter Identification of dynamic model Pt1-Tt, Limits of linear behaviour of different type of measurement amplifiers) - Characteristics of intelligent position sensors (Limit switches, inductive sensor, capacitive sensor, 2/3 wire interface, switching distance) - Position control of pneumatic platform (kinematics of platform, acceleration sensor, pwm signal smoothing, behaviour of pneumatic cylinders and valves) - AC drive unit coupled to a PLC (signal adaptation to analogue input:: Resistor, Tacho generator, Current (Hall) sensor, loop powered current level detector, proximity switches for detection of rotation)
Courses:	Process Interface Equipment; Laboratory on Process Interface Equipment
Teaching and learning forms:	Lecture + Practical training
Prerequisites for participation:	-Basic mathematical knowledge; -Basic physical knowledge; -Basic electrical engineering knowledge; -Participation of the lecture is necessary for attending the lab.
Applicability of the module:	Master Mechatronics
Prerequisites allocation ECTS:	Written examination, 90 minutes.
ECTS credits:	5 lecture, 3 lab
Grading:	graded
Workload:	30h / 1 ECTS
Duration of the module:	one semester

Frequency of offering:	Winter semester only
Literature:	Gussow, M.: Basic Electricity Schrüfer, E.: Elektrische Messtechnik Alciatore, D.: Introduction to Mechatronics Webster, J.: The Measurement, Instrumentation and Sensors Handbook Fischer, R.: Elektrotechnik für Maschinenbauer
Compulsory attendance:	no

Competence dimensions Process Interface Equipment

Knowledge and understanding: Deepening of individual components of knowledge

Graduates are able to name and explain components of an automation system which are closely related to the respective technical process. Focus is on sensors as well as actuators and their interfacing to the automation system.

Graduates are capable of designing and simulating measurement amplifiers using operational amplifiers.

Graduates have a solid knowledge of the most common wiring techniques found in automation systems.

Use, application and generation of knowledge/art: Use and transfer

Graduates are capable of applying the knowledge they have acquired in the following fields:

- Wiring of up-to-date process components to the respective automation computer.
- Theoretical and practical experience concerning intelligent sensors and actuators of industrial process interface equipment.
- Desiging of measurement amplifiers and signal adaption units.

Communication and cooperation

Scientific / artistic self-image and professionalism

Simulation of Mechatronic Systems

Course of study:	Mechatronics (Master)
Degree:	Master of Engineering (M.Eng.)
Modul number:	MM08
Modul title:	Simulation of Mechatronic Systems
Module responsible:	Prof. Dr.-Ing. Konrad Wöllhaf
Typ of module:	Mandatory module
Module Content:	• Introduction; • Model Forms; • Simulation Algorithms; • Simulation in Practice; • Applications; • Component Models; • HIL / Co-Simulation
Courses:	Simulation of Mechatronic Systems
Teaching and learning forms:	Lecture
Prerequisites for participation:	-Mathematics; -Basics of control theory
Applicability of the module:	Mechatronics; Computer science
Prerequisites allocation ECTS:	Written examination, 90 minutes.
ECTS credits:	5
Grading:	graded
Workload:	30h / 1 ECTS
Duration of the module:	one semester
Frequency of offering:	Winter semester only
Literature:	Angermann, A.; Beuschel, M.; Rau, M. & Wohlfarth, U. MATLAB – Simulink – Stateflow De Gruyter Oldenbourg, 2021 Angermann, A.; Beuschel, M.; Rau, M. & Wohlfarth, U. (2002), Matlab-Simulink-Stateflow, Oldenbourg. Atkinson, L.V. & Harley, P.J. (1983), An Introduction to Numerical Methods with Pascal, Addison-Wesley. Cellier, F.E. (1992), Continuous system modeling, Springer. Karnopp, D.C.; Margolis, D.L. & Rosenbert, R.C. (2000), System Dynamics, John Wiley & Sons, New York. Lyshevski, S.E. (1999), Electromechanical Systems, Electric Machines, and Applied Mechatron-ics, CRC Press. Mathews, J.H. (1992), Numerical Methods, Prentice-Hall. Tiller, M. (2001), Introduction to Physical Modeling with Modelica, Kluwer Academic Publishers Group. www.hs-weingarten.de/~woellhaf
Compulsory attendance:	no

Competence dimensions Simulation of Mechatronic Systems

Knowledge and understanding: Deepening of individual components of knowledge

Graduates have deepened and widened their knowledge in the following areas and may reflect that knowledge:

-Challenges of a simulation project

-Different simulation methods

-Challenges arising with HIL-simulations

Use, application and generation of knowledge/art: Use and transfer

Knowledge of the following fields can be practically applied by graduates:

-Organizing a simulation project

-Choosing and applying suitable simulation methods and algorithms

-Modeling dynamic systems and describing them with explicit differential equations of first order

-Applying Matlab to solve everyday calculation tasks in engineering practice

-Implementing and simulating ODE-systems with Matlab and Simulink

Gradates are be able, on the one hand, to calculate the rigidity and stiffness even of complicated components and to analyze complex mechanisms dynamically, on the other hand also to play an active role in the advancement of the research field.

Communication and cooperation

Scientific / artistic self-image and professionalism

Scientific Project

Course of study:	Mechatronics (Master)
Degree:	Master of Engineering (M.Eng.)
Modul number:	MM09
Modul title:	Scientific Project
Module responsible:	Prof. Dr.-Ing. Raphael Ruf
Typ of module:	Mandatory module
Module Content:	- Project in the field of Mechatronics to be conducted at the RWU. - Providing the essential tools necessary to understand different cultures. - Training participants' usage of the given tools in various cross cultural scenarios and teams. - Finding a common understanding of what a team comprises of, which is shared by all participants. - Being aware of communication und language problems within the participants. - Clarifying the goals and rules of the project teams for effective co-operation. - Finding constructive and neutral ways of dealing with conflict. - Understanding functions, targets, roles and expectations of each team member. - Integrating a permanent intercultural learning process for the future.
Courses:	Working in international scientific project teams seminar Scientific Project
Teaching and learning forms:	Seminar and Project
Prerequisites for participation:	None
Applicability of the module:	Mechatronics
Prerequisites allocation ECTS:	-Scientific project report -Scientific project presentation -Seminar paper
ECTS credits:	Scientific Project: 5 Working in international scientific project teams seminar: 1
Grading:	graded
Workload:	30h per 1 ECTS
Duration of the module:	one semester
Frequency of offering:	Every semester
Literature:	Depends on the chosen project.
Compulsory attendance:	no

Competence dimensions Scientific Project

Knowledge and understanding:

Use, application and generation of knowledge/art: Scientific innovation

In the course of their study, the graduates have already reached a level of knowledge and understanding that enables them to analyze not only simple but also complex interactions. On this basis, they are capable of independently identifying scientific or practice-related issues. They can also develop solutions to problems for the following complex issues and thus make a contribution to the further development of science/society/practice: Independent working on the field of mechatronics.

Communication and cooperation

The graduates are capable of communicating effectively. By attending the module, they have improved their communicative skills in the following fields (technical/general/foreign language): To develop a process of learning that encourages intercultural understanding and tolerance amongst the participants. To effectively work in teams by enhancing each team member's contribution in successfully completing a scientific project.

Scientific / artistic self-image and professionalism

Advanced Control Systems

Course of study:	Mechatronics (Master)
Degree:	Master of Engineering (M.Eng.)
Modul number:	MM10
Modul title:	Advanced Control Systems
Module responsible:	Prof. Dr.-Ing. Lothar Berger
Typ of module:	Mandatory module
Module Content:	Attendees are first given an introduction to analysis and modeling of dynamic systems - electrical, mechanical, and thermal. Then, design and optimization of single and multiple stage digital PID control is presented, as well as single-input and multi-input state control - without and with observer, optimal control, and model-predictive control. Finally, adaptive control methods are illustrated; based upon recursive parameter estimation, and neural nets. Within the complementary lab, attendees are educated to choose and implement suitable digital control methods for given dynamic systems - like mixer tank setup and balanced beam setup - utilizing computer-based tools like MATLAB/Simulink; as C programmed algorithms.
Courses:	Digital Control Digital Control Lab
Teaching and learning forms:	Lecture; Lab - or - E-Learning: Lessons, Exercises; Homework: Practical work
Prerequisites for participation:	Advanced Mathematics
Applicability of the module:	Simulation of Mechatronic Systems, Integration of Mechatronic Systems, Robotics, Embedded Control, Scientific Project, Master Thesis
Prerequisites allocation ECTS:	K60: Written examination; 60 minutes
ECTS credits:	5
Grading:	graded
Workload:	Presence: 60h, Self-study: 90h - or - Online: 36h, Self-study: 90h, Homework: 24h
Duration of the module:	one semester
Frequency of offering:	Summer semester only
Literature:	Script - or - lessons, exercises, and sample solutions; and complementary: Burns, R.S., Advanced Control Engineering, Butterworth-Heinemann Macia, N. F., Thaler, G. J.: Modeling and Control of Dynamic Systems, Cengage Learning Moudgalya, K. M.: Digital Control, Wiley Press, W. H., Teukolsky, S. A., Numerical Recipes in C, Cambridge
Compulsory attendance:	no

Competence dimensions Advanced Control Systems

Knowledge and understanding: Deepening of individual components of knowledge

Attendees learned about models of dynamic systems - electrical, mechanical, and thermal - and both classical control methods, like digital PID control, and advanced control methods, like state control without/with observer, model-predictive control, and adaptive control.

Use, application and generation of knowledge/art: Scientific innovation

Attendees learned to characterize, model, and simulate dynamic systems - electrical, mechanical, and thermal - and choose and implement suitable digital control methods, from both established methods, like digital PID control, and advanced methods, like state control without/with observer, optimal control, model-predictive control, and adaptive control. Attendees learned to assess these digital control methods, regarding effort, safety, and cost-effectiveness; and how to implement these, utilizing computer-based tools like MATLAB/Simulink; as C programmed algorithms. Through the complementary lab, attendees learned to choose and implement suitable digital control methods for given dynamical systems; like mixer tank setup and balanced beam setup.

Communication and cooperation

Attendees learned about presenting and applying advanced digital control methods as a systems science; aimed at interdisciplinary projects; operated within a team of scientists, engineers, designers, and economists.

Scientific / artistic self-image and professionalism

Attendees learned about economical and ecological considerations in choosing, implementing, and optimizing advanced digital control methods for industrial processes.

Automation

Course of study:	Mechatronics (Master)
Degree:	Master of Engineering (M.Eng.)
Modul number:	MM11
Modul title:	Automation
Module responsible:	Prof. Dr.-Ing. Raphael Ruf
Typ of module:	Mandatory module
Module Content:	- Fields of automation - Microcontroller characteristics - ARM Cortex M4 architecture by example of STM32 devices - Basic programming of STM32 MCUs - Software patterns for programming embedded systems
Courses:	Automation
Teaching and learning forms:	Lecture with programming exercises. Every participant receives his own evaluation board and extension board for the duration of the lecture.
Prerequisites for participation:	Knowledge in basic electrical engineering. Basic knowledge of C or any other programming language.
Applicability of the module:	Mechatronics Electrical Engineering
Prerequisites allocation ECTS:	Klausur 90 Minuten
ECTS credits:	5
Grading:	graded
Workload:	30h per 1 ECTS
Duration of the module:	one semester
Frequency of offering:	Summer semester only
Literature:	Noviello, C.: Mastering STM32 Mazidi, M.: STM32 Arm Programming for Embedded Systems Amos, B.: Hands-on RTOS with Microcontrollers Yiu, J.: The Definite Guide to Cortex M3 and M4 Processors Gannsle, J.: The Art of Designing Embedded Systems Pont, M.: Patterns for Time-Triggered Embedded Systems Prinz, P.: C in a Nutshell
Compulsory attendance:	no

Competence dimensions Automation

Knowledge and understanding: Broadening of prior knowledge

Graduates can give an overview over the different fields of automation and are able to judge which automation computer is suitable respectively. They have knowledge about the most important microcontroller characteristics and a solid up-to-date market overview.
Graduates have a solid understanding of the ARM Cortex M4 architecture and further microcontroller peripheral features using the example of STM microcontrollers.
Graduates know about fundamental software patterns used in product automation. They are able to match a suitable pattern to requirements.

Use, application and generation of knowledge/art: Use and transfer

Due to up-to-date market overview obtained from attending the module, graduates can choose the most appropriate microcontroller for their actual task at hand. This serves economic as well as ecological (reduced energy consumption and or battery operation) purposes.
With the software patterns learned in this module, graduates may lay the successful foundation of developing electronic embedded products. Thanks to using proven patterns, chances of entering a dead-end in the developing cycle are reduced to a minimum.

Communication and cooperation

Scientific / artistic self-image and professionalism

Special Module

Course of study:	Mechatronics (Master)
Degree:	Master of Engineering (M.Eng.)
Modul number:	MM13
Modul title:	Special Module
Module responsible:	Prof. Dr.-Ing. Raphael Ruf
Typ of module:	Compulsory elective module
Module Content:	dependent on chosen module
Courses:	Module(s) may be chosen according to table 2 of the SPO. Then, the respective module records of said module(s) in the module handbook will apply.
Teaching and learning forms:	dependent on chosen module
Prerequisites for participation:	dependent on chosen module
Applicability of the module:	dependent on chosen module
Prerequisites allocation ECTS:	dependent on chosen module
ECTS credits:	dependent on chosen module
Grading:	dependent on chosen module
Workload:	dependent on chosen module
Duration of the module:	one semester
Frequency of offering:	Every semester
Literature:	dependent on chosen module
Compulsory attendance:	no

Competence dimensions Special Module

Knowledge and understanding:

dependent on chosen module

Use, application and generation of knowledge/art:

dependent on chosen module

Communication and cooperation

dependent on chosen module

Scientific / artistic self-image and professionalism

dependent on chosen module

Master-Thesis

Course of study:	Mechatronics (Master)
Degree:	Master of Engineering (M.Eng.)
Modul number:	MM15
Modul title:	Master-Thesis
Module responsible:	Prof. Dr.-Ing. Raphael Ruf
Typ of module:	Mandatory module
Module Content:	Students should prove their knowledge gained from theoretical and practical lectures on an engineering project or a research transaction. Working methodology shall be tailored to the needs of the employer, including sustainability, design and economic aspects.
Courses:	-Master Thesis activity -Master Thesis report -Master Thesis colloquium
Teaching and learning forms:	Engineering and/or research experience
Prerequisites for participation:	In order to be entitled to begin the Master Thesis, candidates need to have gained at least 55 ECTS from the modules of semesters MM1 and MM2.
Applicability of the module:	Mechatronics
Prerequisites allocation ECTS:	-Delivery of Master Thesis report -Presentation of the results in a colloquium public to all members of the university.
ECTS credits:	25
Grading:	The Master Thesis shall have a duration of 6 months. It will be assessed and graded by two professors one of whom is lecturing at the Hochschule Ravensburg-Weingarten – University of Applied Sciences.
Workload:	30h per 1 ECTS
Duration of the module:	one semester
Frequency of offering:	Every semester
Literature:	Largely subject dependent.
Compulsory attendance:	no

Competence dimensions Master-Thesis

Knowledge and understanding:

Students are able to define, work on, evaluate and explain scientific topics.

Use, application and generation of knowledge/art:

Students are able to define, work on, evaluate and explain scientific topics.

Communication and cooperation

Scientific / artistic self-image and professionalism

The Master Thesis is an accredited examination which shall prove the candidate's ability to solve problems and work on a topic from the subject matter of his major field of study within a specified period of time using adequate methods.

Robotics

Course of study:	Mechatronics (Master)
Degree:	Master of Engineering (M.Eng.)
Modul number:	MM16
Modul title:	Robotics
Module responsible:	Prof. Dr.-Ing. Konrad Wöllhaf
Typ of module:	Mandatory module
Module Content:	The module Robotics will give interested students an introduction to the state of the art in robotics. This includes mobile systems as well as manipulators for indoor and outdoor use. Manipulators: • History, Types of Robots, Applications, Social Impact • Kinematic: Homogeneous Transformation, Euler-Angles, Quaternions, DH-Parameter, Forward-Backward Kinematic • Robot-Movements: Trajectories, Collision Detection • Dynamics: Principle-Virtual Work, Iterative Newton-Euler, Luh-Walker-Paul • Position Control • Programming: Languages, Online/Offline, Control-Panel Mobile Robotics: In this lecture the basics for the definition and handling of mobile robotics will be explained. This includes AUVs, UUVs and UGVs with a focus on UGVs. Beside real world examples the general technologies for the development of mobile systems will be introduced and explained. Therefore the following topics are handled during the lecture: • description of platforms of mobile robots (kinematic and dynamic models) • possible sensors for mobile systems • communication for mobile systems (inter robot communication, local on board communication and communication with the control station) • self localization • automatic generation of maps based on sensor data • algorithms for collision avoidance • algorithms for path planning
Courses:	Robotics Lab on Robotics
Teaching and learning forms:	Lecture / practical training (laboratory)
Prerequisites for participation:	MOBILE ROBOTICS: - knowledge about geometry and matrix operations - basics in physics - control theory basics Robotics Lab: Basics in programming, robotics lecture or adequate previous knowledge.
Applicability of the module:	Mechatronics Electrical Engineering and Embedded Systems Informatik

Prerequisites allocation ECTS:	Written examination, 90 minutes
ECTS credits:	8
Grading:	graded
Workload:	30h / 1 ECTS
Duration of the module:	one semester
Frequency of offering:	Summer semester only
Literature:	MANIPULATORS: - R. Isermann, Mechatronic Systems, Springer 1999 - Schilling, Fundamentals of Robotics, Prentice Hall - Craig, Robotics, Addison Wesley MOBILE ROBOTICS: - Howie Choset, Kevin M. Lynch., Seth Hutchinson, George Kantor, Wolfram Burgard, Lydia E. Kavraki, Sebastian Thrun; Principles of Robot Motion – Theory, Algorithms, and Implementation; MIT Press; 2005 - Sebastian Thrun, Wolfram Burgard, Dieter Fox; Probabilistic Robotics; MIT Press; 2006 - Saeed B. Niku; Introduction to Robotics – Analysis, Systems, Applications; Prentice Hall; 2001 Weber, W. Industrieroboter Hanser-Verlag, 2019 Behrens, R. Biomechanische Grenzwerte für die sichere Mensch-Roboter- Kollaboration Springer Vieweg, 2018 Hesse, S., Greifer-Praxis: Greifer in der Handhabungstechnik Vogel, 1991 DIN EN ISO 10218-2 Industrieroboter - Sicherheitsanforderungen - Teil 2: Robotersysteme und Integration (ISO 10218-2:2011) Beuth Verlag, Betlin, 2012 Hesse, S. & Malisa, V. (Eds.) Taschenbuch Robotik - Montage - Handhabung Carl Hanser Verlag GmbH & Co. KG, 2016 Buxbaum, H.-J. (Ed.) Mensch-Roboter-Kollaboration Springer-Verlag, 2020
Compulsory attendance:	no

Competence dimensions Robotics

Knowledge and understanding: Deepening of individual components of knowledge

Graduates have deepened and widened their knowledge in the following areas and may reflect that knowledge:

-Fields of application

-Challenges with the deployment of robots and different possibilities of path planning

-Composition of robot structures and dynamic simulation of a robot

-Moving Kuka robots in different ways and establishing coordinate systems

-Programming of Kuka robots and simulation of a robot cell with Kuka-SimPro

-Solving automation tasks with the help of industrial robots and programming a simple mobile robot

Use, application and generation of knowledge/art: Use and transfer

Knowledge of the following fields can be practically applied by graduates:

-Solving the inverse problem for a 6-axis robot

-Describing 3D systems with the help of homogenous transformation matrices and solving simple automation tasks with the help of a robot

Communication and cooperation

Scientific / artistic self-image and professionalism

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