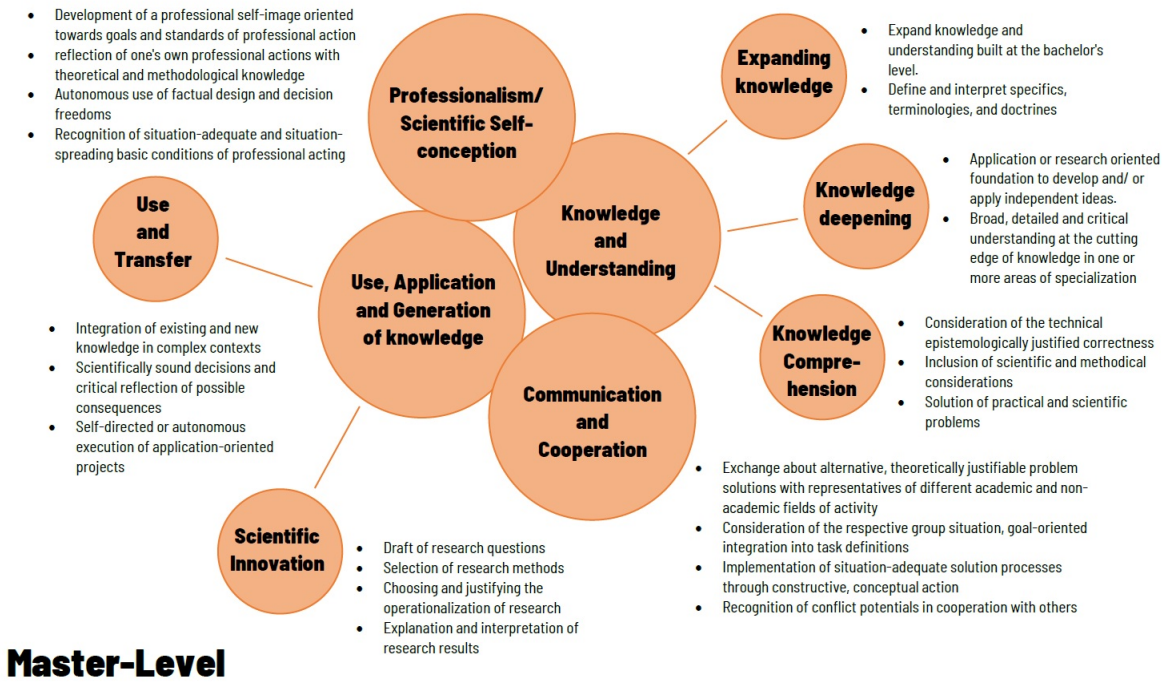
Hochschule Ravensburg-Weingarten Postfach 30 22, 88216 Weingarten

Module Manual Mechatronics (Master)

When designing a study program, in addition to study and examination regulations, a module handbook is created that contains a description of the content of the modules and the competencies to be acquired. Modules can be compulsory or part of the elective range. Each module is concluded with a final module examination and is assigned a certain number of credit points. Study programs and thus also modules are consistently designed from the qualification goals (learning outcomes) to be achieved. In the fields of

- Knowledge and Understanding,
- Use, application and generation of knowledge,
- Scientific self-conception/professionalism and
- Communication and Cooperation

competencies are acquired during the course of study in the respective subject-specific context. Not all competencies or their characteristics are acquired in every module; what is relevant is that at the end of the program students have acquired all competencies.
The basis for this is the Qualifications Framework for German Higher Education Qualifications (Qualifikationsrahmen für Deutsche Hochschulabschlüsse, HQR) and the model legal regulation in accordance with Article 4 Paragraphs 1 - 4 of the State Treaty on Study Accreditation of the Conference of Ministers of Education and Cultural Affairs.



Program Objectives

The integration of as many nations as possible of students with different technical fields of origin requires the positioning as a non-consecutive study program in English. The content of the program should enable students, after successful completion of their studies, to become qualified. After successful completion of their studies, the students should be able to act as qualified interdisciplinary dialogue partners in practice. The professional level should be high in order to be able to face the competition in the university landscape. The intercultural teams of the students in project work enable them to contribute their specialist knowledge and to design interdisciplinary systems, as is required in the disciplines of method review and model building. The level should enable the students to pursue a further scientific path (e.g. doctorate). In the area of social skills, students should have acquired systematic thinking, the ability to think abstractly and the ability to communicate in order to be able to take on leadership tasks, for example.

Content Modules

Master studies

Advanced Mathematics
Electrical Drives
Power Electronics
Engineering Design and Materials
Engineering Mechanics
Integration of Mechatronic Systems
Process Interface Equipment
Simulation of Mechatronic Systems
Scientific Project
Advanced Control Systems
Automation
Embedded Computing
Special Module
Optional Module
Master-Thesis
Robotics
Industrial Project
Research Project
Systems Analysis and Simulation with LabView

Module: Advanced Mathematics

Course of study:	Mechatronics (Master)
Degree:	Master of Science (M.Sc.)
Module number:	MM01
Module 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:	benotet
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

Knowledge and understanding

After successfully attending this course the graduates is able to solve mathematical problems arising in typical engineering tasks. Primary focus is on numerically solving on 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.

Focus:

Deepening of individual components of knowledge

Use, application and generation of knowledge/art

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).

Focus:

Use and transfer

Communication and cooperation

Scientific / artistic self-image and professionalism

Module: Electrical Drives

Course of study:	Mechatronics (Master)
Degree:	Master of Science (M.Sc.)
Module number:	MM02
Module title:	Electrical Drives
Module responsible:	Prof. Dr.-Ing. Raphael Ruf
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

Knowledge and understanding

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.

Focus:
Broadening of prior knowledge

Use, application and generation of knowledge/art

Focus:

Communication and cooperation

Scientific / artistic self-image and professionalism

Module: Power Electronics

Course of study:	Mechatronics (Master)
Degree:	Master of Science (M.Sc.)
Module number:	MM03
Module 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:	V
Prerequisites for participation:	Principles of electrical engineering
Applicability of the module:	Mechatronics
Prerequisites allocation ECTS:	K90
ECTS credits:	5
Grading:	benotet
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

Knowledge and understanding

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.

Focus:
Deepening of individual components of knowledge

Use, application and generation of knowledge/art

Focus:

Communication and cooperation

Scientific / artistic self-image and professionalism

Module: Engineering Design and Materials

Course of study:	Mechatronics (Master)
Degree:	Master of Science (M.Sc.)
Module number:	MM04
Module title:	Engineering Design and Materials
Module responsible:	Prof. Dr.-Ing. Michael Niedermeier
Typ of module:	Mandatory module
Module Content:	– product design: mechatronics – selection of materials: steel, light-metals, plastics, ceramics, composites – smart materials and lightweight structures – corrosion – joining technologies – selected machine elements
Courses:	Engineering Design and Materials
Teaching and learning forms:	Lecture/Exercise/Term Paper/Presentations
Prerequisites for participation:	
Applicability of the module:	Mechatronics Electrical Engineering and Embedded Systems Technik-Management & Optimierung
Prerequisites allocation ECTS:	Written examination, 90 minutes.
ECTS credits:	6
Grading:	benotet
Workload:	30h / 1 ECTS
Duration of the module:	one semester
Frequency of offering:	Winter semester only
Literature:	H. Roloff, W. Mattek, Maschinenelemente, Vieweg Verlag Braunschweig, Michael Ashby, Materials Selection in Mechanical Design, Elsevier
Compulsory attendance:	no

Competence dimensions

Knowledge and understanding

Focus:

Use, application and generation of knowledge/art

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.

Focus:

Use and transfer

Communication and cooperation

Scientific / artistic self-image and professionalism

Module: Engineering Mechanics

Course of study:	Mechatronics (Master)
Degree:	Master of Science (M.Sc.)
Module number:	MM05
Module title:	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, kinematics, kinetics, and dynamics are presented in the lecture and are consolidated by means of tutorials in form of team practice. 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. The students should be able, on the one hand, to calculate the rigidity and stiffness even of 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".
Courses:	Engineering Mechanics
Teaching and learning forms:	Lecture
Prerequisites for participation:	Knowledge of mathematics and basics of engineering mechanics
Applicability of the module:	Mechatronics Electrical Engineering and Embedded Systems
Prerequisites allocation ECTS:	Written examination, 90 minutes.
ECTS credits:	6
Grading:	benotet
Workload:	180h
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; 2011. - 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

Knowledge and understanding

This lecture consolidates highly specialized knowledge of engineering mechanics as basis for theoretical and applied research. Special chapters from the areas statics, kinematics, kinetics, and dynamics are presented in the lecture and are consolidated by means of tutorials in form of team practice. 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.

Focus:
Deepening of individual components of knowledge

Use, application and generation of knowledge/art

Focus:

Communication and cooperation

Scientific / artistic self-image and professionalism

After finishing the lecture, the graduates are able, on the one hand, to calculate the rigidity and stiffness even of 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".

Module: Integration of Mechatronic Systems

Course of study:	Mechatronics (Master)
Degree:	Master of Science (M.Sc.)
Module number:	MM06
Module title:	Integration of Mechatronic Systems
Module responsible:	Prof. Dr.-Ing. Raphael Ruf
Typ of module:	Mandatory module
Module Content:	This module deals with concepts and methods from the area of statistical experimental planning and the modeling of mechatronic systems: Integration of mechatronic systems: A) Theoretical part: Introduction and overview; Structure of mechatronic systems; Description and modeling of mechatronic systems; Sensors; Actuators; Concepts and methods from the field of modeling mechatronic systems B) Practical part: Automation determines our world. In this laboratory, the students can gain hands-on practical experience with actuators, sensors and controls. Depending on the student's background, the complexity of the task can be adapted accordingly. Beginners learn, for example, simple pneumatic circuits, experiment with different sensors and simulate / control small automation solutions. Experienced students can deepen their knowledge in a complex system with a superior Windows interface and seven Siemens S7 controllers. In the so-called Festo-Lab we use various didactic systems for Mechatronic (manufacturer: Festo didactics): - Pneumatics (actuators, valves, sensors) - various sensors - Simulation software for electronics, pneumatics and mechatronic - small mechatronic solutions for material handling - the large, interlinked playmobil consisting of seven independent modules and a superior control system - Kuka robot with attached image processing
Courses:	Integration of Mechatronic Systems
Teaching and learning forms:	Lecture
Prerequisites for participation:	Mathematics Basic of control theory
Applicability of the module:	Mechatronics
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:	Summer semester only
Literature:	
Compulsory attendance:	no

Competence dimensions

Knowledge and understanding

The graduates will be able to explain the essential elements of mechatronics.

Focus:

Knowledge Comprehension

Use, application and generation of knowledge/art

Graduates can design, build and bring into service a simple mechatronic system. At the end of the semester, each graduate can be proficient at least with MecLab and fluid sim simulation.

Focus:

Use and transfer

Communication and cooperation

Depending on the background of the student we will discuss at the beginning of the semester which stations are to be run individually. Each student should work independently on his / her stations to gain practical experience. Through the modular, individually customizable concept, each student can solve his / her tasks or be supported accordingly. At the end of the semester, each student should be proficient at least with MecLab and fluid sim simulation.

Scientific / artistic self-image and professionalism

Module: Process Interface Equipment

Course of study:	Mechatronics (Master)
Degree:	Master of Science (M.Sc.)
Module number:	MM07
Module 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 -Electrical engineering -Electronics -Measurement technology Participation of the lecture is necessary for the attending the lab.
Applicability of the module:	Mechatronics Electrical Engineering and Embedded Systems
Prerequisites allocation ECTS:	Written examination, 90 minutes.
ECTS credits:	8
Grading:	benotet
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

Knowledge and understanding

Graduates are able to name 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.

Focus:
Deepening of individual components of knowledge

Use, application and generation of knowledge/art

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.

Focus:
Use and transfer

Communication and cooperation

Scientific / artistic self-image and professionalism

Module: Simulation of Mechatronic Systems

Course of study:	Mechatronics (Master)
Degree:	Master of Science (M.Sc.)
Module number:	MM08
Module 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 Basic of control theory
Applicability of the module:	Mechatronics Informatik
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:	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. Eine Sammlung von links auf der Homepage von Prof. Wöllhaf: www.hs-weingarten.de/~woellhaf Links zum Thema Simulation - MATLAB Simulink Programming Free Tutorials - A Partial List of On-Line Matlab Tutorials and Matlab Books - Online Hilfe zu Matlab ... - Eine freundlichen Einführung in Matlab ... - MATLAB/SIMULINK Resources... - An Introdution to Matlab ... - Matlab Quick Reference... - David Gilliam, Matlab (engl.)... - Matlab, Free Clones... - A Collection of Modelling and Simulation Resources on the Internet... - ODE++, a class library for ordinary differential equations ... - Numerische Methoden für Differentialgleichungen... - A Ressource for 3D Programmers
Compulsory attendance:	no

Competence dimensions

Knowledge and understanding

Absolventinnen und Absolventen haben ihr Wissen auf folgenden Gebieten erweitert und können dieses Wissen auch wiedergeben:
- die Herausforderungen in einem Simulationsprojekt
- verschiedene Simulationsmethoden
- die Herausforderungen bei HIL-Simulationen

Focus:
Broadening of prior knowledge

Use, application and generation of knowledge/art

Absolventinnen und Absolventen können das Wissen aus folgenden Themenbereichen praktisch anwenden:
- ein Simulationsprojekt organisieren
- geeignete Simulationsmethoden und Algorithmen auswählen und verwenden
- dynamische Systeme modellieren und diese in expliziten Differentialgleichungen erster Ordnung umwandeln
- Matlab zur Lösung alltäglicher Rechenaufgaben aus der Ingenieurpraxis einsetzen
- ODE-Systeme mit Matlab und Simulink umsetzen und simulieren.

The students should be able, on the one hand, to calculate the rigidity and stiffness even of 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.

Focus:
Use and transfer

Communication and cooperation

Scientific / artistic self-image and professionalism

Module: Scientific Project

Course of study:	Mechatronics (Master)
Degree:	Master of Science (M.Sc.)
Module number:	MM09
Module title:	Scientific Project
Module responsible:	Prof. Dr.-Ing. Raphael Ruf
Typ of module:	Mandatory module
Module Content:	Project of relevance for Mechatronics to be performed 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:	Project
Prerequisites for participation:	
Applicability of the module:	Mechatronics
Prerequisites allocation ECTS:	seminar paper + presentation
ECTS credits:	6
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

Knowledge and understanding

Focus:

Use, application and generation of knowledge/art

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.

Focus:

Scientific innovation

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

Module: Advanced Control Systems

Course of study:	Mechatronics (Master)
Degree:	Master of Science (M.Sc.)
Module number:	MM10
Module 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:	benotet
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

Knowledge and understanding

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.

Focus:
Deepening of individual components of knowledge

Use, application and generation of knowledge/art

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.

Focus:
Scientific innovation

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.

Module: Automation

Course of study:	Mechatronics (Master)
Degree:	Master of Science (M.Sc.)
Module number:	MM11
Module 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
Applicability of the module:	
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

Knowledge and understanding

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.

Focus:

Broadening of prior knowledge

Use, application and generation of knowledge/art

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.

Focus:

Use and transfer

Communication and cooperation

Scientific / artistic self-image and professionalism

Module: Embedded Computing

Course of study:	Mechatronics (Master)
Degree:	Master of Science (M.Sc.)
Module number:	MM12
Module title:	Embedded Computing
Module responsible:	Prof. Dr.-Ing. Raphael Ruf
Typ of module:	Mandatory module
Module Content:	In modern embedded systems, like motor control systems, anti-lock braking systems or medical applications, the computer science part are grown in scale and complexity. This means advanced processors are involved and the programming part are more and more complex. So the developers are looking for software development tools and the support of an operating system. In this lecture an overview about the opportunities of modeling of embedded systems are given. After this first part we continue with an introduction in a typical 32 bit microcontroller (OMAP). The hardware functions and the interfaces of this controller are discussed. The development of programs is done with and without the support of an operating system. As an operating system for microcontrollers we use uCLinux. The last aspects of this lecture deals with operating systems for microcontrollers. We discuss the typical restrictions of microcontroller together with an operating system. Especially the advantages and disadvantages of the use of a virtual memory system are in the focus of this last part of the lecture.
Courses:	Embedded Computing (WS) Embedded Computing Lab (SoSe) Embedded Project (SoSe)
Teaching and learning forms:	Lecture/Lab/Project
Prerequisites for participation:	Bachelor knowledge
Applicability of the module:	Mechatronics Electrical Engineering and Embedded Systems
Prerequisites allocation ECTS:	Portfolio including written examination, 90 minutes.
ECTS credits:	10
Grading:	benotet
Workload:	30h / 1 ECTS
Duration of the module:	one 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

Knowledge and understanding

Absolventinnen und Absolventen sind in der Lage:
- mechatronische Fragestellungen zu analysieren, zu modellieren und das Verhalten zu simulieren,
- elektrische und IT- Komponenten zu erstellen und zu programmieren
- mechatronische Projekte in ihrem interdisziplinären Charakter zu erfassen, zu konzipieren und zu realisieren
- Ergebnisse mechatronischer Projekte auch fachfremden Interessierten zu präsentieren Projektgruppen zu bilden und zu leiten.

The aim of the lecture Embedded Computing is to give an overview about specific computing aspects in embedded systems. The first step is the modeling part which gives an opportunity to model the behavior and the restrictions of embedded systems. As next the lecture gives a detailed introduction in a modern 32 bit microcontroller which is used in sophisticated embedded applications. Programming aspects and the use of real time operating systems are discussed.

Focus:
Knowledge Comprehension

Use, application and generation of knowledge/art

Focus:

Communication and cooperation

Scientific / artistic self-image and professionalism

.

Module: Special Module

Course of study:	Mechatronics (Master)
Degree:	Master of Science (M.Sc.)
Module number:	MM13
Module title:	Special Module
Module responsible:	Prof. Dr.-Ing. Raphael Ruf
Typ of module:	Compulsory elective module
Module Content:	
Courses:	§29 SPO Tab. 2
Teaching and learning forms:	
Prerequisites for participation:	
Applicability of the module:	
Prerequisites allocation ECTS:	
ECTS credits:	8
Grading:	
Workload:	
Duration of the module:	one semester
Frequency of offering:	Every semester
Literature:	
Compulsory attendance:	no

Competence dimensions

Knowledge and understanding

Focus:

Use, application and generation of knowledge/art

Focus:

Communication and cooperation

Scientific / artistic self-image and professionalism

Module: Optional Module

Course of study:	Mechatronics (Master)
Degree:	Master of Science (M.Sc.)
Module number:	MM14
Module title:	Optional Module
Module responsible:	Prof. Dr.-Ing. Raphael Ruf
Typ of module:	Elective module
Module Content:	
Courses:	§29 SPO Tab. 3
Teaching and learning forms:	
Prerequisites for participation:	
Applicability of the module:	
Prerequisites allocation ECTS:	
ECTS credits:	
Grading:	
Workload:	
Duration of the module:	one semester
Frequency of offering:	
Literature:	
Compulsory attendance:	no

Competence dimensions

Knowledge and understanding

Focus:

Use, application and generation of knowledge/art

Focus:

Communication and cooperation

Scientific / artistic self-image and professionalism

Module: Master-Thesis

Course of study:	Mechatronics (Master)
Degree:	Master of Science (M.Sc.)
Module number:	MM15
Module title:	Master-Thesis
Module responsible:	Prof. Dr.-Ing. Raphael Ruf
Typ of module:	Mandatory module
Module Content:	The Master thesis is to be written in English language. If the thesis work is performed at one of the partner universities, tutoring and marking are performed by one professor from RWU and one professor from the partner university. After completion, the results of the Master Thesis are to be presented in a public presentation at the RWU.
Courses:	
Teaching and learning forms:	Project
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:	
Prerequisites allocation ECTS:	Master-Thesis and colloquium
ECTS credits:	25
Grading:	graded
Workload:	30h per 1 ECTS
Duration of the module:	one semester
Frequency of offering:	Every semester
Literature:	
Compulsory attendance:	no

Competence dimensions

Knowledge and understanding

Focus:

Use, application and generation of knowledge/art

Focus:

Communication and cooperation

Scientific / artistic self-image and professionalism

The Master-Thesis is an accredited examination which shall prove the candidates 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.

Module: Robotics

Course of study:	Mechatronics (Master)
Degree:	Master of Science (M.Sc.)
Module number:	MM16
Module 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:	benotet
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

Knowledge and understanding

Absolventinnen und Absolventen haben ihr Wissen auf folgenden Gebieten erweitert und können dieses Wissen auch wiedergeben:
- die Einsatzgebiete
- Herausforderungen beim Einsatz von Robotern
- Verschiedene Möglichkeiten der Bahnplanung
- Aufbau von Robotersystemen
- Wie ein Roboter dynamisch simuliert werden kann
- Kuka-Roboter in unterschiedlichen Arten bewegen
- Koordinatensysteme einrichten
- Kuka-Roboter programmieren
- Simulation einer Roboterzelle mit Kuka-SimPro
- Automatisierungsaufgaben mit Hilfe von Industrierobotern lösen
- Einen einfachen mobilen Roboter programmieren

Focus:
Broadening of prior knowledge

Use, application and generation of knowledge/art

Absolventinnen und Absolventen können das Wissen aus folgenden Themenbereichen praktisch anwenden:
- Das inverse Problem für 6-achs-Roboter lösen.
- Mit homogenen Transformationsmatrizen 3D Systeme beschreiben.
- Einfache Automatisierungsaufgaben mit Hilfe eines Roboters lösen.

Focus:
Use and transfer

Communication and cooperation

Scientific / artistic self-image and professionalism

Module: Industrial Project

Course of study:	Mechatronics (Master)
Degree:	Master of Science (M.Sc.)
Module number:	MM17
Module title:	Industrial Project
Module responsible:	Prof. Dr.-Ing. Raphael Ruf
Typ of module:	Elective module
Module Content:	To be defined by industrial supervisor. To apply theoretical background knowledge from lectures in a project in industrial context.
Courses:	
Teaching and learning forms:	Project
Prerequisites for participation:	
Applicability of the module:	Mechatronics
Prerequisites allocation ECTS:	Practical work
ECTS credits:	5
Grading:	benotet
Workload:	30h / 1 ECTS
Duration of the module:	one semester
Frequency of offering:	
Literature:	
Compulsory attendance:	no

Competence dimensions

Knowledge and understanding

Focus:

Use, application and generation of knowledge/art

Focus:

Communication and cooperation

Scientific / artistic self-image and professionalism

One day per week a project of relevance for mechatronics can be performed in industry to acquire complementary practical experience.

Module: Research Project

Course of study:	Mechatronics (Master)
Degree:	Master of Science (M.Sc.)
Module number:	MM18
Module title:	Research Project
Module responsible:	Prof. Dr.-Ing. Raphael Ruf
Typ of module:	Elective module
Module Content:	To be defined by teaching supervisor or by professor. To apply theoretical background knowledge from lectures in a project in research context.
Courses:	
Teaching and learning forms:	Project
Prerequisites for participation:	
Applicability of the module:	
Prerequisites allocation ECTS:	Project work
ECTS credits:	5
Grading:	benotet
Workload:	30h / 1 ECTS
Duration of the module:	one semester
Frequency of offering:	
Literature:	
Compulsory attendance:	no

Competence dimensions

Knowledge and understanding

Focus:

Use, application and generation of knowledge/art

Focus:

Communication and cooperation

Scientific / artistic self-image and professionalism

In the course of their study, the students 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: One day per week a project of relevance for mechatronics can be performed in a lab to acquire complementary practical experience.

Module: Systems Analysis and Simulation with LabView

Course of study:	Mechatronics (Master)
Degree:	Master of Science (M.Sc.)
Module number:	MM20
Module title:	Systems Analysis and Simulation with LabView
Module responsible:	Prof. Dr.-Ing. Raphael Ruf
Typ of module:	Elective module
Module Content:	LabVIEW is a data driven oriented programming language for measurement acquirement and processing including the visualisation of measuring devices. The course concentrates on basics of LabVIEW and its applications concerning data acquirement and communications by USB (NI DAQ 6251), RIO-Systems with FPGA, CAN-Bus and Ethernet (Internet communication). The actual version is LabVIEW 2012
Courses:	
Teaching and learning forms:	Lecture/Practical training
Prerequisites for participation:	Knowledge of programming languages like C
Applicability of the module:	
Prerequisites allocation ECTS:	Portfolio
ECTS credits:	5
Grading:	benotet
Workload:	30h / 1 ECTS
Duration of the module:	one semester
Frequency of offering:	Every semester
Literature:	
Compulsory attendance:	no

Competence dimensions

Knowledge and understanding

Focus:

Use, application and generation of knowledge/art

After successful participation the students should be able to write simple LabVIEW programs for measurement data acquirement, processing and visualization. They should furthermore be able to pass the (optional) CLAD test, arranged by the company National Instruments on Internet (http://www.ni.com/training/labview_exam.htm). This is a prerequisite for becoming a CLAD (Certified LabVIEW Associate Developer), which can be accomplished in a separated examination.

Focus:

Use and transfer

Communication and cooperation

Scientific / artistic self-image and professionalism

Valid from: SoSe21 (Stichtag 15.02.2021)
SPO: 27.06.2019
Print date: 02.03.2021