TUHH
Technische Universität Hamburg-Harburg

Module Manual

Master of Science

Mechatronics

Cohort: Winter Term 2016

Updated: 19th May 2016

Table of Contents

Program description

Content

The consecutive international master program "Mechatronics" extends the education in engineering, mathematics and natural science of the bachelor studies. It provides systematic, scientific and autonomous problem solving capabilities needed in industry and research.

The program covers the methods of computation, design and implementation of mechatronic systems.Students specialize in one out of two concentrations and develop the ability to work in the interfaces of the interconnected sub-disciplines. Based on personal interest, students are able to adapt their study programs within a broad catalogue of elective courses.

Career prospects

The consecutive international Master course "Mechatronics" prepares graduates for a wide range of job profiles in mechatronics engineering.

Graduates can work directly in their specialization area: System Design and Intelligent Systems and Robotics.

Additionally graduates have a multifaceted knowledge of methods for interdisciplinary topics.

Graduates may decide for direct entry into companies or to take up academic careers, e.g. Ph.D. studies, in universities or other research institutions. In companies they can take up jobs as specialists or subsequently qualify for demanding management tasks in the technical area (e.g. project, group, or team leader; R&D director).

The program is designed to be universal and allows graduates to work in a variety of different industrial sectors and with different projects.

Learning target

Graduates of the program are able to transfer the individually acquired specialized knowledge to new, unknown topics, to comprehend, to analyze and to scientifically solve complex problems of their discipline. They can find missing information and plan as well as execute theoretical and experimental studies. They are able to judge, evaluate and question scientific engineering results critically as well as making decisions based on this foundation and draw further conclusions. They are able to act methodically, to organize smaller projects, to select new technologies and scientific methods and to advance these further, if necessary.

Graduates can develop and document new ideas and solutions, independently or in teams. They are capable of presenting and discussing results to and with professionals. They can estimate their own strengths and weaknesses as well as possible consequences of their actions. They are capable of familiarizing themselves with complex tasks, defining new tasks and developing the necessary knowledge to solve them using systematically applied, appropriate means.

System Design

In the system design specialization, graduates learn how to work systematically and methodically on challenging design tasks.

They have broad knowledge of new development methods, are able to select appropriate solution strategies and use these autonomously to develop new products. They are qualified to use the approaches of integrated system development, such as simulation or modern testing procedures.

Intelligent Systems and Robotics

In the intelligent systems and robotics specialization, graduates learn how to work systematically and methodically on challenging tasks.

They have broad knowledge of automation and simulation and are able to select appropriate solution strategies and use these autonomously to develop intelligent systems.

Program structure

The course is designed modularly and is based on the university-wide standardized course structure with uniform module sizes (multiples of six credit points (CP)).

The program combines the disciplines of mechanical and electrical engineering and supports concentration in interdisciplinary fields of system design and system implementation.

All modules in the first semester are mandatory. This helps especially students from abroad to familiarize themselves with the university and culture.

Afterwards the students can broadly personalize their studies due to the high number and variety of elective courses.

In the common core skills, students take the following modules:

- Finite element analysis and Vibration theory (12 CP)
- Theory and design of control systems and Design and implementation of software systems
- Robotics and Mechatronic system
- Complementary courses business and management (catalogue) (6 CP)
- Nontechnical elective complementary courses (catalogue) (6 CP).

Students specialize by selecting one of the following areas, each covering 30 credit points:

- System design
- Intelligent systems and robotics.

Within each area of specialization 30 credits can be chosen form a module catalog containing modules with a size of six credits. Instead, open modules can be attend to the maximum extent of twelve credit points, in which smaller specialized courses can be combined, individually.

Students write a master thesis and one additional scientific project work.

- Project work (12 CP)
- Master thesis (30 CP)

Core qualification

Module M0523: Business & Management	
Module Responsible	Prof. Matthias Meyer
Admission Requirements	None
Recommended Previous Knowledge	None
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students are able to find their way around selected special areas of management within the scope of business management. • Students are able to explain basic theories, categories, and models in selected special areas of business management. • Students are able to interrelate technical and management knowledge.
Skills	• Students are able to apply basic methods in selected areas of business management. • Students are able to explain and give reasons for decision proposals on practical issues in areas of business management.
Personal Competence	
Social Competence	
Autonomy	• Students are capable of acquiring necessary knowledge independently by means of research and preparation of material.
Workload in Hours	Depends on choice of courses
Credit points	6

Courses
Information regarding lectures and courses can be found in the corresponding module handbook published separately.

Module M0524: Nontechnical Elective Complementary Courses for Master

Module Responsible	Dagmar Richter
Admission Requirements	None
Recommended Previous Knowledge	None
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	**The Non-technical Elective Study Area** imparts skills that, in view of the TUHH's training profile, professional engineering studies require but are not able to cover fully. Self-reliance, self-management, collaboration and professional and personnel management competences. The department implements these training objectives in its **teaching architecture**, in its **teaching and learning arrangements**, in **teaching areas** and by means of teaching offerings in which students can qualify by opting for **specific competences** and a **competence level** at the Bachelor's or Master's level. The teaching offerings are pooled in two different catalogues for nontechnical complementary courses. **The Learning Architecture** consists of a cross-disciplinarily study offering. The centrally designed teaching offering ensures that courses in the "non-technical department" follow the specific profiling of TUHH degree courses. The learning architecture demands and trains independent educational planning as regards the individual development of competences. It also provides orientation knowledge in the form of "profiles". The subjects that can be studied in parallel throughout the student's entire study program - if need be, it can be studied in one to two semesters. In view of the adaptation problems that individuals commonly face in their first semesters after making the transition from school to university and in order to encourage individually planned semesters abroad, there is no obligation to study these subjects in one or two specific semesters during the course of studies. **Teaching and Learning Arrangements** provide for students, separated into B.Sc. and M.Sc., to learn with and from each other across semesters. The challenge of dealing with interdisciplinarity and a variety of stages of learning in courses are part of the learning architecture and are deliberately encouraged in specific courses. **Fields of Teaching** are based on research findings from the academic disciplines cultural studies, social studies, arts, historical studies, communication studies and sustainability research, and from engineering didactics. In addition, from the winter semester 2014/15 students on all Bachelor's courses will have the opportunity to learn about business management and start-ups in a goal-oriented way. The fields of teaching are augmented by soft skills offers and a foreign language offer. Here, the focus is on encouraging goal-oriented communication skills, e.g. the skills required by outgoing engineers in international and intercultural situations. **The Competence Level** of the courses offered in this area is different as regards the basic training objective in the Bachelor's and Master's fields. These differences are reflected in the practical examples used, in content topics that refer to different professional application contexts, and in the higher scientific and theoretical level of abstraction in the B.Sc. This is also reflected in the different quality of soft skills, which relate to the different team positions and different group leadership functions of Bachelor's and Master's graduates in their future working life. **Specialized Competence (Knowledge)** Students can • explain specialized areas in context of the relevant non-technical disciplines, • outline basic theories, categories, terminology, models, concepts or artistic techniques in the disciplines represented in the learning area, • different specialist disciplines relate to their own discipline and differentiate it as well as make connections, • sketch the basic outlines of how scientific disciplines, paradigms, models, instruments, methods and forms of representation in the specialized sciences are subject to individual and socio-cultural interpretation and historicity, • Can communicate in a foreign language in a manner appropriate to the subject.
Skills	**Professional Competence (Skills)** In selected sub-areas students can • apply basic and specific methods of the said scientific disciplines, • aquestion a specific technical phenomena, models, theories from the viewpoint of another, aforementioned specialist discipline, • to handle simple and advanced questions in aforementioned scientific disciplines in a sucsessful manner, • justify their decisions on forms of organization and application in practical questions in contexts that go beyond the technical relationship to the subject.
Personal Competence	

Social Competence	**Personal Competences (Social Skills)** Students will be able • to learn to collaborate in different manner, • to present and analyze problems in the abovementioned fields in a partner or group situation in a manner appropriate to the addressees, • to express themselves competently, in a culturally appropriate and gender-sensitive manner in the language of the country (as far as this study-focus would be chosen), • to explain nontechnical items to auditorium with technical background knowledge.
Autonomy	**Personal Competences (Self-reliance)** Students are able in selected areas • to reflect on their own profession and professionalism in the context of real-life fields of application • to organize themselves and their own learning processes • to reflect and decide questions in front of a broad education background • to communicate a nontechnical item in a competent way in writen form or verbaly • to organize themselves as an entrepreneurial subject country (as far as this study-focus would be chosen)
Workload in Hours	Depends on choice of courses
Credit points	6

Courses
Information regarding lectures and courses can be found in the corresponding module handbook published separately.

Module M0563: Robotics

Courses

Title	Typ	Hrs/wk	CP
Robotics: Modelling and Control (L0168)	Lecture	3	3
Robotics: Modelling and Control (L1305)	Recitation Section (small)	2	3

Module Responsible	Prof. Uwe Weltin
Admission Requirements	
Recommended Previous Knowledge	Fundamentals of electrical engineering Broad knowledge of mechanics Fundamentals of control theory
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to describe fundamental properties of robots and solution approaches for multiple problems in robotics.
Skills	Students are able to derive and solve equations of motion for various manipulators. Students can generate trajectories in various coordinate systems. Students can design linear and partially nonlinear controllers for robotic manipulators.
Personal Competence	
Social Competence	Students are able to work goal-oriented in small mixed groups.
Autonomy	Students are able to recognize and improve knowledge deficits independently. With instructor assistance, students are able to evaluate their own knowledge level and define a further course of study.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory International Production Management: Specialisation Production Technology: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory Mechanical Engineering and Management: Core qualification: Compulsory Mechatronics: Core qualification: Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Product Development and Production: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L0168: Robotics: Modelling and Control

Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Uwe Weltin
Language	EN
Cycle	WiSe
Content	Fundamental kinematics of rigid body systems Newton-Euler equations for manipulators Trajectory generation Linear and nonlinear control of robots
Literature	Craig, John J.: Introduction to Robotics Mechanics and Control, Third Edition, Prentice Hall. ISBN 0201-54361-3 Spong, Mark W.; Hutchinson, Seth; Vidyasagar, M. : Robot Modeling and Control. WILEY. ISBN 0-471-64990-2

Course L1305: Robotics: Modelling and Control	
Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Uwe Weltin
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0808: Finite Elements Methods

Courses

Title	Typ	Hrs/wk	CP
Finite Element Methods (L0291)	Lecture	2	3
Finite Element Methods (L0804)	Recitation Section (large)	2	3

Module Responsible	Prof. Otto von Estorff
Admission Requirements	none
Recommended Previous Knowledge	Mechanics I (Statics, Mechanics of Materials) and Mechanics II (Hydrostatics, Kinematics, Dynamics) Mathematics I, II, III (in particular differential equations)
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students possess an in-depth knowledge regarding the derivation of the finite element method and are able to give an overview of the theoretical and methodical basis of the method.
Skills	The students are capable to handle engineering problems by formulating suitable finite elements, assembling the corresponding system matrices, and solving the resulting system of equations.
Personal Competence	
Social Competence	-
Autonomy	The students are able to independently solve challenging computational problems and develop own finite element routines. Problems can be identified and the results are critically scrutinized.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	Civil Engineering: Core qualification: Compulsory Energy Systems: Core qualification: Elective Compulsory Aircraft Systems Engineering: Specialisation Aircraft Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Air Transportation Systems: Elective Compulsory Computational Science and Engineering: Specialisation Scientific Computing: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory Mechatronics: Core qualification: Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Product Development, Materials and Production: Core qualification: Compulsory Technomathematics: Specialisation III. Engineering Science: Elective Compulsory Technomathematics: Core qualification: Elective Compulsory Theoretical Mechanical Engineering: Core qualification: Compulsory

Course L0291: Finite Element Methods	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Otto von Estorff
Language	EN
Cycle	WiSe
Content	- General overview on modern engineering - Displacement method - Hybrid formulation - Isoparametric elements - Numerical integration - Solving systems of equations (statics, dynamics) - Eigenvalue problems - Non-linear systems - Applications - Programming of elements (Matlab, hands-on sessions) - Applications
Literature	Bathe, K.-J. (2000): Finite-Elemente-Methoden. Springer Verlag, Berlin

Course L0804: Finite Element Methods	
Typ	Recitation Section (large)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Otto von Estorff
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0846: Control Systems Theory and Design

Courses

Title	Typ	Hrs/wk	CP
Control Systems Theory and Design (L0656)	Lecture	2	4
Control Systems Theory and Design (L0657)	Recitation Section (small)	2	2

Module Responsible	Prof. Herbert Werner
Admission Requirements	None
Recommended Previous Knowledge	Introduction to Control Systems
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain how linear dynamic systems are represented as state space models; they can interpret the system response to initial states or external excitation as trajectories in state space • They can explain the system properties controllability and observability, and their relationship to state feedback and state estimation, respectively • They can explain the significance of a minimal realisation • They can explain observer-based state feedback and how it can be used to achieve tracking and disturbance rejection • They can extend all of the above to multi-input multi-output systems • They can explain the z-transform and its relationship with the Laplace Transform • They can explain state space models and transfer function models of discrete-time systems • They can explain the experimental identification of ARX models of dynamic systems, and how the identification problem can be solved by solving a normal equation • They can explain how a state space model can be constructed from a discrete-time impulse response
Skills	• Students can transform transfer function models into state space models and vice versa • They can assess controllability and observability and construct minimal realisations • They can design LQG controllers for multivariable plants • They can carry out a controller design both in continuous-time and discrete-time domain, and decide which is appropriate for a given sampling rate • They can identify transfer function models and state space models of dynamic systems from experimental data • They can carry out all these tasks using standard software tools (Matlab Control Toolbox, System Identification Toolbox, Simulink)
Personal Competence	
Social Competence	Students can work in small groups on specific problems to arrive at joint solutions.
Autonomy	Students can obtain information from provided sources (lecture notes, software documentation, experiment guides) and use it when solving given problems. They can assess their knowledge in weekly on-line tests and thereby control their learning progress.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Electrical Engineering: Core qualification: Compulsory Energy Systems: Core qualification: Elective Compulsory Aircraft Systems Engineering: Specialisation Aircraft Systems: Compulsory Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory International Management and Engineering: Specialisation II. Electrical Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory Mechatronics: Core qualification: Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Product Development, Materials and Production: Core qualification: Elective Compulsory Theoretical Mechanical Engineering: Core qualification: Compulsory

Course L0656: Control Systems Theory and Design	
Typ	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Lecturer	Prof. Herbert Werner
Language	EN
Cycle	WiSe
Content	State space methods (single-input single-output) • State space models and transfer functions, state feedback • Coordinate basis, similarity transformations • Solutions of state equations, matrix exponentials, Caley-Hamilton Theorem • Controllability and pole placement • State estimation, observability, Kalman decomposition • Observer-based state feedback control, reference tracking • Transmission zeros • Optimal pole placement, symmetric root locus Multi-input multi-output systems • Transfer function matrices, state space models of multivariable systems, Gilbert realization • Poles and zeros of multivariable systems, minimal realization • Closed-loop stability • Pole placement for multivariable systems, LQR design, Kalman filter Digital Control • Discrete-time systems: difference equations and z-transform • Discrete-time state space models, sampled data systems, poles and zeros • Frequency response of sampled data systems, choice of sampling rate System identification and model order reduction • Least squares estimation, ARX models, persistent excitation • Identification of state space models, subspace identification • Balanced realization and model order reduction Case study • Modelling and multivariable control of a process evaporator using Matlab and Simulink Software tools • Matlab/Simulink
Literature	• Werner, H., Lecture Notes „Control Systems Theory and Design“ • T. Kailath "Linear Systems", Prentice Hall, 1980 • K.J. Astrom, B. Wittenmark "Computer Controlled Systems" Prentice Hall, 1997 • L. Ljung "System Identification - Theory for the User", Prentice Hall, 1999

Course L0657: Control Systems Theory and Design	
Typ	Recitation Section (small)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Herbert Werner
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M1106: Vibration Theory (GES)

Courses

Title	Typ	Hrs/wk	CP
Vibration Theory (GES) (L1423)	Lecture	2	3
Vibration Theory (GES) (L1433)	Recitation Section (large)	1	3

Module Responsible	Prof. Radoslaw Iwankiewicz
Admission Requirements	Linear algebra, calculus, engineering/applied mechanics (especially kinematics and kinetics)
Recommended Previous Knowledge	
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The primary purpose of the study of Vibration Theory is to develop the capacity to understand vibrations and the capacity to analyse, measure, predict and control vibrations, which is needed by the engineers involved in the analysis and design of machines and their supporting structures, vehicles, aircraft, etc.The particular objectives of this course are to: 1. Analyse mechanical structures taking into account the effects of dynamic loads. 1. Appreciate the importance of vibration in structures and mechanical devices. 2. Formulate and solve the equations of motion of mechanical systems. Determine the natural frequencies and normal modes of complex mechanical systems.
Skills	At the end of this course the student should be able to: 1. Develop simple mathematical models for vibration analysis of complex systems; formulate and solve the equation of motion to determine the dynamic response. 2. Carry out the linearization of equations of motion. 1. Determine natural frequencies and normal modes of multi-degree-of-freedom and continuous systems (rods, shafts, taut strings, beams). 2. Carry out modal analysis to predict the dynamic response of linear mechanical systems to external excitations. 3. Analyse, in terms of eigenvalues, stability of time-invariant linear dynamic systems.
Personal Competence	
Social Competence	Students can work in small groups and report on the findings.
Autonomy	Students are able to solve the problems independently.
Workload in Hours	Independent Study Time 138, Study Time in Lecture 42
Credit points	6
Examination	Written exam
Examination duration and scale	2 hours: 2. MDOF systems: Newton- Euler and Lagrange's equations of motion. Linear systems: eigenvalue problem, general solution and stability. Linear MDOF systems: free and forced vibrations. Continuous systems. Energy methods or random vibrations.
Assignment for the Following Curricula	Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory Mechatronics: Core qualification: Compulsory Technomathematics: Specialisation III. Engineering Science: Elective Compulsory Technomathematics: Core qualification: Elective Compulsory

Course L1423: Vibration Theory (GES)	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Radoslaw Iwankiewicz
Language	EN
Cycle	WiSe
Content	SYSTEMS WITH FINITE NUMBER OF DEGREES OF FREEDOM (MULTI- DEGREE-OF-FREEDOM SYSTEMS) 1. Revision of the theory of single-degree-of -freedom systems. 2. Equations of motion of a single rigid body and of multi-body systems: 2.1. Newton- Euler equations 2.2. Lagrange's equations. 3.Linearization of equations of motion. 4.Linear equations of motion in a state-space form. Transformation of coordinates. 5.Linear systems: eigenvalue problem (eigenvalues and eigenvectors). 6. General solution for time-invariant linear systems and stability of those systems. 7. Linear systems: eigenvalue problem, free vibrations, natural frequencies, normal modes (mode shapes). 8. Forced vibrations of linear systems. LINEAR CONTINUOUS SYSTEMS: 9. Longitudinal vibrations of a rod and torsional vibrations of a shaft: 9.1. Eigenvalue problem, free vibrations, natural frequencies, normal modes (mode shapes). 9.2. Forced vibrations. 10. Transverse vibrations of a beam and of a taut string: 10.1. Eigenvalue problem, free vibrations, natural frequencies, normal modes (mode shapes). 10.2. Forced vibrations.
Literature	1. S.S. Rao, Mechanical Vibrations, Addison-Wesley, 3rd edition, 1995. 2. C.F. Beards, Engineering Vibration Analysis with Application to Control Systems, Edward Arnold, 1995. 3. M. Geradin, D.Rixen, Mechanical Vibrations. Theory and Application to Structural Dynamics, J. Wiley, 1994. 4. K. Klotter, Technische Schwingungslehre I, II, Springer Verlag, 1981.

Course L1433: Vibration Theory (GES)	
Typ	Recitation Section (large)
Hrs/wk	1
CP	3
Workload in Hours	Independent Study Time 76, Study Time in Lecture 14
Lecturer	Prof. Radoslaw Iwankiewicz
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M1222: Design and Implementation of Software Systems

Courses

Title	Typ	Hrs/wk	CP
Design and Implementation of Software Systems (L1657)	Lecture	2	3
Design and Implementation of Software Systems (L1658)	Laboratory Course	2	3

Module Responsible	Dr. Sandro Schulze
Admission Requirements	None
Recommended Previous Knowledge	- Imperativ programming languages (C, Pascal, Fortran or similar) - Simple data types (integer, double, char, boolean), arrays, if-then-else, for, while, procedure and function calls
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to describe mechatronic systems and define requirements.
Skills	Students are able to design and implement mechatronic systems. They are able to argue the combination of Hard- and Software and the interfaces.
Personal Competence	
Social Competence	Students are able to work goal-oriented in small mixed groups, learning and broadening teamwork abilities and define task within the team.
Autonomy	Students are able to solve individually exercises related to this lecture with instructional direction. Students are able to plan, execute and summarize a mechatronic experiment.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Examination	Written exam
Examination duration and scale	
Assignment for the Following Curricula	Mechatronics: Core qualification: Compulsory

Course L1657: Design and Implementation of Software Systems

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr. Sandro Schulze
Language	EN
Cycle	WiSe
Content	This course covers software design and implementation of mechatronic systems, tools for automation in Java. Content: • Introduction to software techniques • Procedural Programming • Object oriented software design • Java • Event based programming • Formal methods
Literature	• “The Pragmatic Programmer: From Journeyman to Master”Andrew Hunt, David Thomas, Ward Cunningham • “Core LEGO MINDSTORMS Programming: Unleash the Power of the Java Platform” Brian Bagnall Prentice Hall PTR, 1st edition (March, 2002) ISBN 0130093645 • “Objects First with Java: A Practical Introduction using BlueJ” David J. Barnes & Michael Kölling Prentice Hall/ Pearson Education; 2003, ISBN 0-13-044929-6

Course L1658: Design and Implementation of Software Systems

Typ	Laboratory Course
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr. Sandro Schulze
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0565: Mechatronic Systems

Courses

Title	Typ	Hrs/wk	CP
Electro- and Contromechanics (L0174)	Lecture	2	2
Electro- and Contromechanics (L1300)	Recitation Section (small)	1	2
Mechatronics Laboratory (L0196)	Laboratory	2	2

Module Responsible	Prof. Uwe Weltin
Admission Requirements	none
Recommended Previous Knowledge	Fundamentals of mechanics, electromechanics and control theory
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to describe methods and calculations to design, model, simulate and optimize mechatronic systems and can repeat methods to verify and validate models.
Skills	Students are able to plan and execute mechatronic experiments. Students are able to model mechatronic systems and derive simulations and optimizations.
Personal Competence	
Social Competence	Students are able to work goal-oriented in small mixed groups, learning and broadening teamwork abilities and define task within the team.
Autonomy	Students are able to solve individually exercises related to this lecture with instructional direction. Students are able to plan, execute and summarize a mechatronic experiment.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Examination	Written exam
Examination duration and scale	90 min.
Assignment for the Following Curricula	Aircraft Systems Engineering: Specialisation Aircraft Systems: Elective Compulsory Mechatronics: Core qualification: Compulsory

Course L0174: Electro- and Contromechanics

Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Uwe Weltin
Language	EN
Cycle	SoSe
Content	Introduction to methodical design of mechatronic systems: • Modelling • System identification • Simulation • Optimization
Literature	Denny Miu: Mechatronics, Springer 1992 Rolf Isermann: Mechatronic systems : fundamentals, Springer 2003

Course L1300: Electro- and Contromechanics

Typ	Recitation Section (small)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Uwe Weltin
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Course L0196: Mechatronics Laboratory	
Typ	Laboratory
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Uwe Weltin
Language	DE/EN
Cycle	SoSe
Content	Modeling in MATLAB® und Simulink® Controller Design (Linear, Nonlinear, Observer) Parameter identification Control of a real system with a realtimeboard and Simulink® RTW
Literature	- Abhängig vom Versuchsaufbau - Depends on the experiment

Module M1211: Research Project Mechatronics

Courses

Title	Typ	Hrs/wk	CP

Module Responsible	Prof. Uwe Weltin
Admission Requirements	none
Recommended Previous Knowledge	Subjects of the program of studies.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students are able to demonstrate their detailed knowledge in the field of mechatronics engineering. They can exemplify the state of technology and application and discuss critically in the context of actual problems and general conditions of science and society. The students can develop solving strategies and approaches for fundamental and practical problems in mechatronics engineering. They may apply theory based procedures and integrate safety-related, ecological, ethical, and economic view points of science and society. Scientific work techniques that are used can be described and critically reviewed.
Skills	The students are able to independently select methods for the project work and to justify this choice. They can explain how these methods relate to the field of work and how the context of application has to be adjusted. General findings and further developments may essentially be outlined.
Personal Competence	
Social Competence	The students are able to condense the relevance and the structure of the project work, the work steps and the sub-problems for the presentation and discussion in front of a bigger group. They can lead the discussion and give a feedback on the project to their colleagues.
Autonomy	The students are capable of independently planning and documenting the work steps and procedures while considering the given deadlines. This includes the ability to accurately procure the newest scientific information. Furthermore, they can obtain feedback from experts with regard to the progress of the work, and to accomplish results on the state of the art in science and technology.
Workload in Hours	Independent Study Time 360, Study Time in Lecture 0
Credit points	12
Examination	Project (accord. to Subject Specific Regulations)
Examination duration and scale	lt. FSPO
Assignment for the Following Curricula	Mechatronics: Core qualification: Compulsory

Specialization Intelligent Systems and Robotics

In the intelligent systems and robotics specialization, graduates learn how to work systematically and methodically on challenging tasks.

They have broad knowledge of automation and simulation and are able to select appropriate solution strategies and use these autonomously to develop intelligent systems.

Module M0630: Robotics and Navigation in Medicine

Courses

Title	Typ	Hrs/wk	CP
Robotics and Navigation in Medicine (L0335)	Lecture	2	3
Robotics and Navigation in Medicine (L0338)	Project Seminar	2	2
Robotics and Navigation in Medicine (L0336)	Recitation Section (small)	1	1

Module Responsible	Prof. Alexander Schlaefer
Admission Requirements	None
Recommended Previous Knowledge	• principles of math (algebra, analysis/calculus) • principles of programming, e.g., in Java or C++ • solid R or Matlab skills
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students can explain kinematics and tracking systems in clinical contexts and illustrate systems and their components in details. Systems can be evaluated with respect to collision detection and safety and regulations. Students can assess typical systems regarding design and limitations.
Skills	The students are able to design and evaluate navigation systems and robotic systems for medical applications.
Personal Competence	
Social Competence	The students discuss the results of other groups, provide helpful feedback and can incoorporate feedback into their work.
Autonomy	The students can reflect their knowledge and document the results of their work. They can present the results in an appropriate manner.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Examination	Written exam
Examination duration and scale	90 minutes
Assignment for the Following Curricula	Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Electrical Engineering: Specialisation Medical Technology: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory International Management and Engineering: Specialisation II. Electrical Engineering: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Bio- and Medical Technology: Elective Compulsory

Course L0335: Robotics and Navigation in Medicine	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Alexander Schlaefer
Language	EN
Cycle	SoSe
Content	- kinematics - calibration - tracking systems - navigation and image guidance - motion compensation The seminar extends and complements the contents of the lecture with respect to recent research results.
Literature	Spong et al.: Robot Modeling and Control, 2005 Troccaz: Medical Robotics, 2012 Further literature will be given in the lecture.

Course L0338: Robotics and Navigation in Medicine	
Typ	Project Seminar
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Alexander Schlaefer
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Course L0336: Robotics and Navigation in Medicine	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Alexander Schlaefer
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0692: Approximation and Stability

Courses

Title	Typ	Hrs/wk	CP
Approximation and Stability (L0487)	Lecture	2	3
Approximation and Stability (L0489)	Seminar	1	2
Approximation and Stability (L0488)	Recitation Section (small)	1	1

Module Responsible	Prof. Marko Lindner
Admission Requirements	None
Recommended Previous Knowledge	• Linear Algebra: systems of linear equations, least squares problems, eigenvalues, singular values • Analysis: sequences, series, differentiation, integration
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to • sketch and interrelate basic concepts of functional analysis (Hilbert space, operators), • name and understand concrete approximation methods, • name and explain basic stability theorems, • discuss spectral quantities, conditions numbers and methods of regularisation
Skills	Students are able to • apply basic results from functional analysis, • apply approximation methods, • apply stability theorems, • compute spectral quantities, • apply regularisation methods.
Personal Competence	
Social Competence	Students are able to solve specific problems in groups and to present their results appropriately (e.g. as a seminar presentation).
Autonomy	• Students are capable of checking their understanding of complex concepts on their own. They can specify open questions precisely and know where to get help in solving them. • Students have developed sufficient persistence to be able to work for longer periods in a goal-oriented manner on hard problems.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Examination	Oral exam
Examination duration and scale	30
Assignment for the Following Curricula	Electrical Engineering: Specialisation Control and Power Systems: Elective Compulsory Electrical Engineering: Specialisation Modeling and Simulation: Elective Compulsory Computational Science and Engineering: Specialisation Scientific Computing: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Technomathematics: Specialisation I. Mathematics: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Numerics and Computer Science: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L0487: Approximation and Stability	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Marko Lindner
Language	DE/EN
Cycle	SoSe
Content	This course is about solving the following basic problems of Linear Algebra, • systems of linear equations, • least squares problems, • eigenvalue problems but now in function spaces (i.e. vector spaces of infinite dimension) by a stable approximation of the problem in a space of finite dimension. **Contents:** • crash course on Hilbert spaces: metric, norm, scalar product, completeness • crash course on operators: boundedness, norm, compactness, projections • uniform vs. strong convergence, approximation methods • applicability and stability of approximation methods, Polski's theorem • Galerkin methods, collocation, spline interpolation, truncation • convolution and Toeplitz operators • crash course on C*-algebras • convergence of condition numbers • convergence of spectral quantities: spectrum, eigen values, singular values, pseudospectra • regularisation methods (truncated SVD, Tichonov)
Literature	• R. Hagen, S. Roch, B. Silbermann: C*-Algebras in Numerical Analysis • H. W. Alt: Lineare Funktionalanalysis • M. Lindner: Infinite matrices and their finite sections

Course L0489: Approximation and Stability	
Typ	Seminar
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Marko Lindner
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Course L0488: Approximation and Stability	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Marko Lindner
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0752: Nonlinear Dynamics

Courses

Title	Typ	Hrs/wk	CP
Nonlinear Dynamics (L0702)	Lecture	4	6

Module Responsible	Prof. Norbert Hoffmann
Admission Requirements	None
Recommended Previous Knowledge	• Calculus • Linear Algebra • Engineering Mechanics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to reflect existing terms and concepts in Nonlinear Dynamics and to develop and research new terms and concepts.
Skills	Students are able to apply existing methods and procesures of Nonlinear Dynamics and to develop novel methods and procedures.
Personal Competence	
Social Competence	Students can reach working results also in groups.
Autonomy	Students are able to approach given research tasks individually and to identify and follow up novel research tasks by themselves.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Examination	Written exam
Examination duration and scale	2 Hours
Assignment for the Following Curricula	Aircraft Systems Engineering: Specialisation Aircraft Systems: Elective Compulsory Computational Science and Engineering: Specialisation Scientific Computing: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Product Development, Materials and Production: Core qualification: Elective Compulsory Theoretical Mechanical Engineering: Core qualification: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L0702: Nonlinear Dynamics

Typ	Lecture
Hrs/wk	4
CP	6
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Lecturer	Prof. Norbert Hoffmann
Language	DE/EN
Cycle	SoSe
Content	Fundamentals of Nonlinear Dynamics.
Literature	S. Strogatz: Nonlinear Dynamics and Chaos. Perseus, 2013.

Module M0714: Numerical Treatment of Ordinary Differential Equations

Courses

Title	Typ	Hrs/wk	CP
Numerical Treatment of Ordinary Differential Equations (L0576)	Lecture	2	3
Numerical Treatment of Ordinary Differential Equations (L0582)	Recitation Section (small)	2	3

Module Responsible	Prof. Blanca Ayuso Dios
Admission Requirements	None
Recommended Previous Knowledge	• Mathematik I, II, III für Ingenieurstudierende (deutsch oder englisch) oder Analysis & Lineare Algebra I + II sowie Analysis III für Technomathematiker • Basic MATLAB knowledge
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to • list numerical methods for the solution of ordinary differential equations and explain their core ideas, • repeat convergence statements for the treated numerical methods (including the prerequisites tied to the underlying problem), • explain aspects regarding the practical execution of a method.
Skills	Students are able to • implement (MATLAB), apply and compare numerical methods for the solution of ordinary differential equations, • to justify the convergence behaviour of numerical methods with respect to the posed problem and selected algorithm, • for a given problem, develop a suitable solution approach, if necessary by the composition of several algorithms, to execute this approach and to critically evaluate the results.
Personal Competence	
Social Competence	Students are able to • work together in heterogeneously composed teams (i.e., teams from different study programs and background knowledge), explain theoretical foundations and support each other with practical aspects regarding the implementation of algorithms.
Autonomy	Students are capable • to assess whether the supporting theoretical and practical excercises are better solved individually or in a team, • to assess their individual progess and, if necessary, to ask questions and seek help.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Examination	Written exam
Examination duration and scale	180 min
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems: Elective Compulsory Electrical Engineering: Specialisation Modeling and Simulation: Elective Compulsory Energy Systems: Core qualification: Elective Compulsory Computational Science and Engineering: Specialisation Scientific Computing: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Technomathematics: Specialisation I. Mathematics: Elective Compulsory Theoretical Mechanical Engineering: Core qualification: Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory

Course L0576: Numerical Treatment of Ordinary Differential Equations	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Blanca Ayuso Dios
Language	DE/EN
Cycle	SoSe
Content	Numerical methods for Initial Value Problems • single step methods • multistep methods • stiff problems • differential algebraic equations (DAE) of index 1 Numerical methods for Boundary Value Problems • initial value methods • multiple shooting method • difference methods • variational methods
Literature	• E. Hairer, S. Noersett, G. Wanner: Solving Ordinary Differential Equations I: Nonstiff Problems • E. Hairer, G. Wanner: Solving Ordinary Differential Equations II: Stiff and Differential-Algebraic Problems

Course L0582: Numerical Treatment of Ordinary Differential Equations	
Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Blanca Ayuso Dios
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0840: Optimal and Robust Control

Courses

Title	Typ	Hrs/wk	CP
Optimal and Robust Control (L0658)	Lecture	2	3
Optimal and Robust Control (L0659)	Recitation Section (small)	2	3

Module Responsible	Prof. Herbert Werner
Admission Requirements	Control Systems Theory and Design
Recommended Previous Knowledge	• Classical control (frequency response, root locus) • State space methods • Linear algebra, singular value decomposition
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain the significance of the matrix Riccati equation for the solution of LQ problems. • They can explain the duality between optimal state feedback and optimal state estimation. • They can explain how the H2 and H-infinity norms are used to represent stability and performance constraints. • They can explain how an LQG design problem can be formulated as special case of an H2 design problem. • They can explain how model uncertainty can be represented in a way that lends itself to robust controller design • They can explain how - based on the small gain theorem - a robust controller can guarantee stability and performance for an uncertain plant. • They understand how analysis and synthesis conditions on feedback loops can be represented as linear matrix inequalities.
Skills	• Students are capable of designing and tuning LQG controllers for multivariable plant models. • They are capable of representing a H2 or H-infinity design problem in the form of a generalized plant, and of using standard software tools for solving it. • They are capable of translating time and frequency domain specifications for control loops into constraints on closed-loop sensitivity functions, and of carrying out a mixed-sensitivity design. • They are capable of constructing an LFT uncertainty model for an uncertain system, and of designing a mixed-objective robust controller. • They are capable of formulating analysis and synthesis conditions as linear matrix inequalities (LMI), and of using standard LMI-solvers for solving them. • They can carry out all of the above using standard software tools (Matlab robust control toolbox).
Personal Competence	
Social Competence	Students can work in small groups on specific problems to arrive at joint solutions.
Autonomy	Students are able to find required information in sources provided (lecture notes, literature, software documentation) and use it to solve given problems.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems: Elective Compulsory Energy Systems: Core qualification: Elective Compulsory Aircraft Systems Engineering: Specialisation Aircraft Systems: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Theoretical Mechanical Engineering: Core qualification: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L0658: Optimal and Robust Control	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Herbert Werner
Language	EN
Cycle	SoSe
Content	• Optimal regulator problem with finite time horizon, Riccati differential equation • Time-varying and steady state solutions, algebraic Riccati equation, Hamiltonian system • Kalman's identity, phase margin of LQR controllers, spectral factorization • Optimal state estimation, Kalman filter, LQG control • Generalized plant, review of LQG control • Signal and system norms, computing H2 and H∞ norms • Singular value plots, input and output directions • Mixed sensitivity design, H∞ loop shaping, choice of weighting filters • Case study: design example flight control • Linear matrix inequalities, design specifications as LMI constraints (H2, H∞ and pole region) • Controller synthesis by solving LMI problems, multi-objective design • Robust control of uncertain systems, small gain theorem, representation of parameter uncertainty
Literature	• Werner, H., Lecture Notes: "Optimale und Robuste Regelung" • Boyd, S., L. El Ghaoui, E. Feron and V. Balakrishnan "Linear Matrix Inequalities in Systems and Control", SIAM, Philadelphia, PA, 1994 • Skogestad, S. and I. Postlewhaite "Multivariable Feedback Control", John Wiley, Chichester, England, 1996 • Strang, G. "Linear Algebra and its Applications", Harcourt Brace Jovanovic, Orlando, FA, 1988 • Zhou, K. and J. Doyle "Essentials of Robust Control", Prentice Hall International, Upper Saddle River, NJ, 1998

Course L0659: Optimal and Robust Control	
Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Herbert Werner
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0803: Embedded Systems

Courses

Title	Typ	Hrs/wk	CP
Embedded Systems (L0805)	Lecture	3	4
Embedded Systems (L0806)	Recitation Section (small)	1	2

Module Responsible	Prof. Heiko Falk
Admission Requirements	None
Recommended Previous Knowledge	Computer Engineering
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Embedded systems can be defined as information processing systems embedded into enclosing products. This course teaches the foundations of such systems. In particular, it deals with an introduction into these systems (notions, common characteristics) and their specification languages (models of computation, hierarchical automata, specification of distributed systems, task graphs, specification of real-time applications, translations between different models). Another part covers the hardware of embedded systems: Sonsors, A/D and D/A converters, real-time capable communication hardware, embedded processors, memories, energy dissipation, reconfigurable logic and actuators. The course also features an introduction into real-time operating systems, middleware and real-time scheduling. Finally, the implementation of embedded systems using hardware/software co-design (hardware/software partitioning, high-level transformations of specifications, energy-efficient realizations, compilers for embedded processors) is covered.
Skills	After having attended the course, students shall be able to realize simple embedded systems. The students shall realize which relevant parts of technological competences to use in order to obtain a functional embedded systems. In particular, they shall be able to compare different models of computations and feasible techniques for system-level design. They shall be able to judge in which areas of embedded system design specific risks exist.
Personal Competence	
Social Competence	Students are able to solve similar problems alone or in a group and to present the results accordingly.
Autonomy	Students are able to acquire new knowledge from specific literature and to associate this knowledge with other classes.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Examination	Written exam
Examination duration and scale	90 minutes, contents of course and labs
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Specialisation Computer Science: Elective Compulsory Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory Electrical Engineering: Core qualification: Elective Compulsory General Engineering Science (English program, 7 semester): Specialisation Computer Science: Elective Compulsory Computational Science and Engineering: Core qualification: Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory

Course L0805: Embedded Systems

Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Heiko Falk
Language	DE/EN
Cycle	SoSe
Content	• Introduction • Specifications and Modeling • Embedded/Cyber-Physical Systems Hardware • System Software • Evaluation and Validation • Mapping of Applications to Execution Platforms • Optimization
Literature	• Peter Marwedel. Embedded System Design - Embedded Systems Foundations of Cyber-Physical Systems. 2nd Edition, Springer, 2012., Springer, 2012.

Course L0806: Embedded Systems	
Typ	Recitation Section (small)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Heiko Falk
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M1145: Automation and Simulation

Courses

Title	Typ	Hrs/wk	CP
Automation and Simulation (L1525)	Lecture	3	3
Automation and Simulation (L1527)	Recitation Section (large)	2	3

Module Responsible	Prof. Günter Ackermann
Admission Requirements	none
Recommended Previous Knowledge	**BSc Mechanical Engineering or similar**
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can describe the structure an the function of process computers, the corresponding components, the data transfer via bus systems an programmable logic computers . They can describe the basich principle of a numeric simulation and the corresponding parameters. Thy can explain the usual method to simulate the dynamic behaviour of three-phase machines.
Skills	Students can describe and design simple controllers using established methodes. They are able to assess the basic characterisitcs of a given automation system and to evaluate, if it is adequate for a given plant. They can modell and simulate technical systems with respect to their dynamical behaviour and can use Matlab/Simulink for the simulation. They are able to applay established methods for the caclulation of the dynamical behaviour of three-phase machines.
Personal Competence	
Social Competence	Teamwork in small teams.
Autonomy	Students are able to identify the need of methocic analysises in the field of automation systems, to do these analysisis in an adequate manner und to evaluate the results critically.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Examination	Oral exam
Examination duration and scale	Vorzugsweise in Dreier-Gruppen, etwa 1 Stunde
Assignment for the Following Curricula	Energy Systems: Core qualification: Elective Compulsory Aircraft Systems Engineering: Specialisation Cabin Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Aircraft Systems: Elective Compulsory International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Aviation Systems: Elective Compulsory International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory

Course L1525: Automation and Simulation	
Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Günter Ackermann
Language	DE
Cycle	SoSe
Content	Structure of automation systsems Aufbau von Automationseinrichtungen Structure and function of process computers and corresponding componentes Data transfer via bus systems Programmable Logic Computers Methods to describe logic sequences Prionciples of the modelling and the simulation of continous technical systems Practical work with an established simulation program (Matlab/Simulink) Simulation of the dynamic behaviour of a three-phase maschine, simulation of a mixed continous/discrete system on base of tansistion flow diagrams.
Literature	U. Tietze, Ch. Schenk: Halbleiter-Schaltungstechnik; Springer Verlag R. Lauber, P. Göhner: Prozessautomatisierung 2, Springer Verlag Färber: Prozessrechentechnik (Grundlagen, Hardware, Echtzeitverhalten), Springer Verlag Einführung/Tutorial Matlab/Simulink - verschiedene Autoren

Course L1527: Automation and Simulation	
Typ	Recitation Section (large)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Günter Ackermann
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M1156: Systems Engineering

Courses

Title	Typ	Hrs/wk	CP
Systems Engineering (L1547)	Lecture	3	4
Systems Engineering (L1548)	Recitation Section (large)	1	2

Module Responsible	Prof. Ralf God
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge in: • Mathematics • Mechanics • Thermodynamics • Electrical Engineering • Control Systems Previous knowledge in: • Aircraft Cabin Systems
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to: • understand systems engineering process models, methods and tools for the development of complex Systems • describe innovation processes and the need for technology Management • explain the aircraft development process and the process of type certification for aircraft • explain the system development process, including requirements for systems reliability • identify environmental conditions and test procedures for airborne Equipment • value the methodology of requirements-based engineering (RBE) and model-based requirements engineering (MBRE)
Skills	Students are able to: • plan the process for the development of complex Systems • organize the development phases and development Tasks • assign required business activities and technical Tasks • apply systems engineering methods and tools
Personal Competence	
Social Competence	Students are able to: • understand their responsibilities within a development team and integrate themselves with their role in the overall process
Autonomy	Students are able to: • interact and communicate in a development team which has distributed tasks
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Examination	Written exam
Examination duration and scale	120 Minutes
Assignment for the Following Curricula	Aircraft Systems Engineering: Core qualification: Compulsory International Management and Engineering: Specialisation II. Aviation Systems: Elective Compulsory International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory

Course L1547: Systems Engineering	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Ralf God
Language	DE
Cycle	SoSe
Content	The objective of the lecture with the corresponding exercise is to accomplish the prerequisites for the development and integration of complex systems using the example of commercial aircraft and cabin systems. Competences in the systems engineering process, tools and methods is to be achieved. Regulations, guidelines and certification issues will be known. Key aspects of the course are processes for innovation and technology management, system design, system integration and certification as well as tools and methods for systems engineering: • Innovation processes • IP-protection • Technology management • Systems engineering • Aircraft program • Certification issues • Systems development • Safety objectives and fault tolerance • Environmental and operating conditions • Tools for systems engineering • Requirements-based engineering (RBE) • Model-based requirements engineering (MBRE)
Literature	- Skript zur Vorlesung - diverse Normen und Richtlinien (EASA, FAA, RTCA, SAE) - Hauschildt, J., Salomo, S.: Innovationsmanagement. Vahlen, 5. Auflage, 2010 - NASA Systems Engineering Handbook, National Aeronautics and Space Administration, 2007 - Hinsch, M.: Industrielles Luftfahrtmanagement: Technik und Organisation luftfahrttechnischer Betriebe. Springer, 2010 - De Florio, P.: Airworthiness: An Introduction to Aircraft Certification. Elsevier Ltd., 2010 - Pohl, K.: Requirements Engineering. Grundlagen, Prinzipien, Techniken. 2. korrigierte Auflage, dpunkt.Verlag, 2008

Course L1548: Systems Engineering	
Typ	Recitation Section (large)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Ralf God
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M1212: Technical Complementary Course for IMPMEC (according to Subject Specific Regulations)

Courses

Title	Typ	Hrs/wk	CP

Module Responsible	Prof. Uwe Weltin
Admission Requirements	None
Recommended Previous Knowledge	See selected module according to FSPO
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	see selected module according to FSPO
Skills	see selected module according to FSPO
Personal Competence	
Social Competence	see selected module according to FSPO
Autonomy	see selected module according to FSPO
Workload in Hours	Independent Study Time 180, Study Time in Lecture 0
Credit points	6
Examination	according to Subject Specific Regulations
Examination duration and scale	lt. FSPO
Assignment for the Following Curricula	Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory

Module M1223: Selected Topics of Mechatronics (Alternative A: 12 LP)

Courses

Title	Typ	Hrs/wk	CP
Introduction to Electromagnetic Waveguides and Antennas (L1669)	Lecture	2	2
Development Management for Mechatronics (L1512)	Lecture	2	3
Fatigue & Damage Tolerance (L0310)	Lecture	2	3
Microcontroller Circuits: Implementation in Hardware and Software (L0087)	Seminar	2	2
Microsystems Technology (L0724)	Lecture	2	4
Model-Based Systems Engineering (MBSE) with SysML/UML (L1551)	Problem-based Learning	3	3
Process Measurement Engineering (L1077)	Lecture	2	3
Process Measurement Engineering (L1083)	Recitation Section (large)	1	1
Feedback Control in Medical Technology (L0664)	Lecture	2	3
Six Sigma (L1130)	Lecture	2	3
Reliability in Engineering Dynamics (L0176)	Lecture	2	2
Reliability in Engineering Dynamics (L1303)	Recitation Section (small)	1	2

Module Responsible	Prof. Uwe Weltin
Admission Requirements	Only one of the modules "Selected Topics of Mechatronics (Alternative A: 12 LP) or "Selected Topics of Mechatronics (Alternative B: 6 LP)" can be selected.
Recommended Previous Knowledge	None
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students are able to express their extended knowledge and discuss the connection of different special fields or application areas of mechatronics • Students are qualified to connect different special fields with each other
Skills	• Students can apply specialized solution strategies and new scientific methods in selected areas • Students are able to transfer learned skills to new and unknown problems and can develop own solution approaches
Personal Competence	
Social Competence	
Autonomy	• Students are able to develop their knowledge and skills by autonomous election of courses.
Workload in Hours	Depends on choice of courses
Credit points	12
Assignment for the Following Curricula	Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory

Course L1669: Introduction to Electromagnetic Waveguides and Antennas	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	30 min
Lecturer	Prof. Christian Schuster
Language	DE/EN
Cycle	WiSe
Content	This course is intended as an introduction into the topics of electromagnetic wave propagation, guiding, sending, and receiving for graduate engineering students that do not have a specific background in electrical engineering. It will be useful for engineers that face the technical challenge of transmitting high frequency / high bandwidth data in e.g. medical, automotive, or avionic applications. Both circuit and field concepts of electromagnetic wave propagation will be introduced and discussed. Topics: - Fundamental properties and phenomena of electrical circuits - Steady-state sinusoidal analysis of electrical circuits - Fundamental properties and phenomena of electromagnetic fields and waves - Steady-state sinusoidal description of electromagnetic fields and waves - Useful microwave network parameters - Transmission lines and basic results from transmission line theory - Plane wave propagation, superposition, reflection and refraction - General theory of waveguides - Most important types of waveguides and their properties - Radiation and basic antenna parameters - Most important types of antennas and their properties - Numerical techniques and CAD tools for waveguide and antenna design
Literature	- Zinke, Brunswig, "Hochfrequenztechnik 1", Springer (1999) - J. Detlefsen, U. Siart, "Grundlagen der Hochfrequenztechnik", Oldenbourg (2012) - D. M. Pozar, "Microwave Engineering", Wiley (2011) - Y. Huang, K. Boyle, "Antenna: From Theory to Practice", Wiley (2008)

Course L1512: Development Management for Mechatronics	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	30 Minuten
Lecturer	Dr. Daniel Steffen
Language	DE
Cycle	SoSe

Content	• Processes and methods of product development - from idea to market launch
	  ◦ identification of market and technology potentials
	  ◦ development of a common product architecture
	  ◦ Synchronized product development across all engineering disciplines
	  ◦ product validation incl. customer view
	• Steering and optimization of product development
	  ◦ Design of processes for product development
	  ◦ IT systems for product development
	  ◦ Establishment of management standards
	  ◦ Typical types of organization

Literature	• Bender: Embedded Systems - qualitätsorientierte Entwicklung • Ehrlenspiel: Integrierte Produktentwicklung: Denkabläufe, Methodeneinsatz, Zusammenarbeit • Gausemeier/Ebbesmeyer/Kallmeyer: Produktinnovation - Strategische Planung und Entwicklung der Produkte von morgen • Haberfellner/de Weck/Fricke/Vössner: Systems Engineering: Grundlagen und Anwendung • Lindemann: Methodische Entwicklung technischer Produkte: Methoden flexibel und situationsgerecht anwenden • Pahl/Beitz: Konstruktionslehre: Grundlagen erfolgreicher Produktentwicklung. Methoden und Anwendung • VDI-Richtlinie 2206: Entwicklungsmethodik für mechatronische Systeme

Course L0310: Fatigue & Damage Tolerance	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	45 min
Lecturer	Dr. Martin Flamm
Language	EN
Cycle	WiSe
Content	Design principles, fatigue strength, crack initiation and crack growth, damage calculation, counting methods, methods to improve fatigue strength, environmental influences
Literature	Jaap Schijve, Fatigue of Structures and Materials. Kluver Academic Puplisher, Dordrecht, 2001 E. Haibach. Betriebsfestigkeit Verfahren und Daten zur Bauteilberechnung. VDI-Verlag, Düsseldorf, 1989

Course L0087: Microcontroller Circuits: Implementation in Hardware and Software	
Typ	Seminar
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Schriftliche Ausarbeitung
Examination duration and scale	10 min. Vortrag + anschließende Diskussion
Lecturer	Prof. Siegfried Rump
Language	DE
Cycle	WiSe/SoSe
Content	
Literature	

Course L0724: Microsystems Technology	
Typ	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	30 min
Lecturer	Prof. Hoc Khiem Trieu
Language	EN
Cycle	WiSe
Content	• Introduction (historical view, scientific and economic relevance, scaling laws) • Semiconductor Technology Basics, Lithography (wafer fabrication, photolithography, improving resolution, next-generation lithography, nano-imprinting, molecular imprinting) • Deposition Techniques (thermal oxidation, epitaxy, electroplating, PVD techniques: evaporation and sputtering; CVD techniques: APCVD, LPCVD, PECVD and LECVD; screen printing) • Etching and Bulk Micromachining (definitions, wet chemical etching, isotropic etch with HNA, electrochemical etching, anisotropic etching with KOH/TMAH: theory, corner undercutting, measures for compensation and etch-stop techniques; plasma processes, dry etching: back sputtering, plasma etching, RIE, Bosch process, cryo process, XeF2 etching) • Surface Micromachining and alternative Techniques (sacrificial etching, film stress, stiction: theory and counter measures; Origami microstructures, Epi-Poly, porous silicon, SOI, SCREAM process, LIGA, SU8, rapid prototyping) • Thermal and Radiation Sensors (temperature measurement, self-generating sensors: Seebeck effect and thermopile; modulating sensors: thermo resistor, Pt-100, spreading resistance sensor, pn junction, NTC and PTC; thermal anemometer, mass flow sensor, photometry, radiometry, IR sensor: thermopile and bolometer) • Mechanical Sensors (strain based and stress based principle, capacitive readout, piezoresistivity, pressure sensor: piezoresistive, capacitive and fabrication process; accelerometer: piezoresistive, piezoelectric and capacitive; angular rate sensor: operating principle and fabrication process) • Magnetic Sensors (galvanomagnetic sensors: spinning current Hall sensor and magneto-transistor; magnetoresistive sensors: magneto resistance, AMR and GMR, fluxgate magnetometer) • Chemical and Bio Sensors (thermal gas sensors: pellistor and thermal conductivity sensor; metal oxide semiconductor gas sensor, organic semiconductor gas sensor, Lambda probe, MOSFET gas sensor, pH-FET, SAW sensor, principle of biosensor, Clark electrode, enzyme electrode, DNA chip) • Micro Actuators, Microfluidics and TAS (drives: thermal, electrostatic, piezo electric and electromagnetic; light modulators, DMD, adaptive optics, microscanner, microvalves: passive and active, micropumps, valveless micropump, electrokinetic micropumps, micromixer, filter, inkjet printhead, microdispenser, microfluidic switching elements, microreactor, lab-on-a-chip, microanalytics) • MEMS in medical Engineering (wireless energy and data transmission, smart pill, implantable drug delivery system, stimulators: microelectrodes, cochlear and retinal implant; implantable pressure sensors, intelligent osteosynthesis, implant for spinal cord regeneration) • Design, Simulation, Test (development and design flows, bottom-up approach, top-down approach, testability, modelling: multiphysics, FEM and equivalent circuit simulation; reliability test, physics-of-failure, Arrhenius equation, bath-tub relationship) • System Integration (monolithic and hybrid integration, assembly and packaging, dicing, electrical contact: wire bonding, TAB and flip chip bonding; packages, chip-on-board, wafer-level-package, 3D integration, wafer bonding: anodic bonding and silicon fusion bonding; micro electroplating, 3D-MID)
Literature	M. Madou: Fundamentals of Microfabrication, CRC Press, 2002 N. Schwesinger: Lehrbuch Mikrosystemtechnik, Oldenbourg Verlag, 2009 T. M. Adams, R. A. Layton:Introductory MEMS, Springer, 2010 G. Gerlach; W. Dötzel: Introduction to microsystem technology, Wiley, 2008

Course L1551: Model-Based Systems Engineering (MBSE) with SysML/UML	
Typ	Problem-based Learning
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Examination Form	Projektarbeit
Examination duration and scale	ca. 10 Seiten
Lecturer	Prof. Ralf God
Language	DE
Cycle	SoSe
Content	Objectives of the problem-oriented course are the acquisition of knowledge on system design using the formal languages SysML/UML, learning about tools for modeling and finally the implementation of a project with methods and tools of Model-Based Systems Engineering (MBSE) on a realistic hardware platform (e.g. Arduino®, Raspberry Pi®): • What is a model? • What is Systems Engineering? • Survey of MBSE methodologies • The modelling languages SysML /UML • Tools for MBSE • Best practices for MBSE • Requirements specification, functional architecture, specification of a solution • From model to software code • Validation and verification: XiL methods • Accompanying MBSE project
Literature	- Skript zur Vorlesung - Weilkiens, T.: Systems Engineering mit SysML/UML: Modellierung, Analyse, Design. 2. Auflage, dpunkt.Verlag, 2008 - Holt, J., Perry, S.A., Brownsword, M.: Model-Based Requirements Engineering. Institution Engineering & Tech, 2011

Course L1077: Process Measurement Engineering	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	45 Minuten
Lecturer	Prof. Roland Harig
Language	DE/EN
Cycle	SoSe

Content	• Process measurement engineering in the context of process control engineering
	  ◦ Challenges of process measurement engineering
	  ◦ Instrumentation of processes
	  ◦ Classification of pickups
	• Systems theory in process measurement engineering
	  ◦ Generic linear description of pickups
	  ◦ Mathematical description of two-port systems
	  ◦ Fourier and Laplace transformation
	• Correlational measurement
	  ◦ Wide band signals
	  ◦ Auto- and cross-correlation function and their applications
	  ◦ Fault-free operation of correlational methods
	• Transmission of analog and digital measurement signals
	  ◦ Modulation process (amplitude and frequency modulation)
	  ◦ Multiplexing
	  ◦ Analog to digital converter

Literature	- Färber: „Prozeßrechentechnik“, Springer-Verlag 1994 - Kiencke, Kronmüller: „Meßtechnik“, Springer Verlag Berlin Heidelberg, 1995 - A. Ambardar: „Analog and Digital Signal Processing“ (1), PWS Publishing Company, 1995, NTC 339 - A. Papoulis: „Signal Analysis“ (1), McGraw-Hill, 1987, NTC 312 (LB) - M. Schwartz: „Information Transmission, Modulation and Noise“ (3,4), McGraw-Hill, 1980, 2402095 - S. Haykin: „Communication Systems“ (1,3), Wiley&Sons, 1983, 2419072 - H. Sheingold: „Analog-Digital Conversion Handbook“ (5), Prentice-Hall, 1986, 2440072 - J. Fraden: „AIP Handbook of Modern Sensors“ (5,6), American Institute of Physics, 1993, MTB 346

Course L1083: Process Measurement Engineering	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Examination Form	Mündliche Prüfung
Examination duration and scale	
Lecturer	Prof. Roland Harig
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Course L0664: Feedback Control in Medical Technology	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	
Lecturer	Ulf Pilz, Prof. Olaf Simanski
Language	DE
Cycle	SoSe
Content	Taking an engineering point of view, the lecture is structured as follows. • Introduction to the topic with selected examples • Physiology - introduction and overview • Regeneration of functions of the cardiovascular system • Regeneration of the respiratory functions • Closed loop control in anesthesia • regeneration of kidney and liver functions • regeneration of motorize function/ rehabilitation engineering • navigation systems and robotic in medicine The lecture will use knowledge from modeling, simulation and controller design and MATLAB and SIMULINK will be used.
Literature	Silbernagel/Depopoulos: Taschenatlas der Physiologie, Thieme Verlag Stuttgart Werner: Kooperative und autonome Systeme der Medizintechnik, Oldenburg Verlag M.C.K.Khoo:"Physiological Control System", IEEE Press, 2000

Course L1130: Six Sigma	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	90 Minuten
Lecturer	Prof. Claus Emmelmann
Language	DE
Cycle	WiSe
Content	• Introduction and structuring • Basic terms of quality management • Measuring and inspection equipment • Tools of quality management: FMEA, QFD, FTA, etc. • Quality management methodology Six Sigma, DMAIC
Literature	Pfeifer, T.: Qualitätsmanagement : Strategien, Methoden, Techniken, 4. Aufl., München 2008 Pfeifer, T.: Praxishandbuch Qualitätsmanagement, München 1996 Geiger, W., Kotte, W.: Handbuch Qualität : Grundlagen und Elemente des Qualitätsmanagements: Systeme, Perspektiven, 5. Aufl., Wiesbaden 2008

Course L0176: Reliability in Engineering Dynamics	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	90 min.
Lecturer	Prof. Uwe Weltin
Language	EN
Cycle	SoSe
Content	Method for calculation and testing of reliability of dynamic machine systems • Modeling • System identification • Simulation • Processing of measurement data • Damage accumulation • Test planning and execution
Literature	Bertsche, B.: Reliability in Automotive and Mechanical Engineering. Springer, 2008. ISBN: 978-3-540-33969-4 Inman, Daniel J.: Engineering Vibration. Prentice Hall, 3rd Ed., 2007. ISBN-13: 978-0132281737 Dresig, H., Holzweißig, F.: Maschinendynamik, Springer Verlag, 9. Auflage, 2009. ISBN 3540876936. VDA (Hg.): Zuverlässigkeitssicherung bei Automobilherstellern und Lieferanten. Band 3 Teil 2, 3. überarbeitete Auflage, 2004. ISSN 0943-9412

Course L1303: Reliability in Engineering Dynamics	
Typ	Recitation Section (small)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Examination Form	Klausur
Examination duration and scale	90 min
Lecturer	Prof. Uwe Weltin
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M1224: Selected Topics of Mechatronics (Alternative B: 6 LP)

Courses

Title	Typ	Hrs/wk	CP
Introduction to Electromagnetic Waveguides and Antennas (L1669)	Lecture	2	2
Development Management for Mechatronics (L1512)	Lecture	2	3
Fatigue & Damage Tolerance (L0310)	Lecture	2	3
Microcontroller Circuits: Implementation in Hardware and Software (L0087)	Seminar	2	2
Microsystems Technology (L0724)	Lecture	2	4
Model-Based Systems Engineering (MBSE) with SysML/UML (L1551)	Problem-based Learning	3	3
Process Measurement Engineering (L1077)	Lecture	2	3
Process Measurement Engineering (L1083)	Recitation Section (large)	1	1
Feedback Control in Medical Technology (L0664)	Lecture	2	3
Six Sigma (L1130)	Lecture	2	3
Reliability in Engineering Dynamics (L0176)	Lecture	2	2
Reliability in Engineering Dynamics (L1303)	Recitation Section (small)	1	2

Module Responsible	Prof. Uwe Weltin
Admission Requirements	Only one of the modules "Selected Topics of Mechatronics (Alternative A: 12 LP) or "Selected Topics of Mechatronics (Alternative B: 6 LP)" can be selected.
Recommended Previous Knowledge	None
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence *Knowledge*	• Students are able to express their extended knowledge and discuss the connection of different special fields or application areas of mechatronics • Students are qualified to connect different special fields with each other
Skills	• Students can apply specialized solution strategies and new scientific methods in selected areas • Students are able to transfer learned skills to new and unknown problems and can develop own solution approaches
Personal Competence *Social Competence* *Autonomy*	• Students are able to develop their knowledge and skills by autonomous election of courses.
Workload in Hours	Depends on choice of courses
Credit points	6
Assignment for the Following Curricula	Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory

Course L1669: Introduction to Electromagnetic Waveguides and Antennas	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	30 min
Lecturer	Prof. Christian Schuster
Language	DE/EN
Cycle	WiSe
Content	This course is intended as an introduction into the topics of electromagnetic wave propagation, guiding, sending, and receiving for graduate engineering students that do not have a specific background in electrical engineering. It will be useful for engineers that face the technical challenge of transmitting high frequency / high bandwidth data in e.g. medical, automotive, or avionic applications. Both circuit and field concepts of electromagnetic wave propagation will be introduced and discussed. Topics: - Fundamental properties and phenomena of electrical circuits - Steady-state sinusoidal analysis of electrical circuits - Fundamental properties and phenomena of electromagnetic fields and waves - Steady-state sinusoidal description of electromagnetic fields and waves - Useful microwave network parameters - Transmission lines and basic results from transmission line theory - Plane wave propagation, superposition, reflection and refraction - General theory of waveguides - Most important types of waveguides and their properties - Radiation and basic antenna parameters - Most important types of antennas and their properties - Numerical techniques and CAD tools for waveguide and antenna design
Literature	- Zinke, Brunswig, "Hochfrequenztechnik 1", Springer (1999) - J. Detlefsen, U. Siart, "Grundlagen der Hochfrequenztechnik", Oldenbourg (2012) - D. M. Pozar, "Microwave Engineering", Wiley (2011) - Y. Huang, K. Boyle, "Antenna: From Theory to Practice", Wiley (2008)

Course L1512: Development Management for Mechatronics	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	30 Minuten
Lecturer	Dr. Daniel Steffen
Language	DE
Cycle	SoSe

Content	• Processes and methods of product development - from idea to market launch
	  ◦ identification of market and technology potentials
	  ◦ development of a common product architecture
	  ◦ Synchronized product development across all engineering disciplines
	  ◦ product validation incl. customer view
	• Steering and optimization of product development
	  ◦ Design of processes for product development
	  ◦ IT systems for product development
	  ◦ Establishment of management standards
	  ◦ Typical types of organization

Literature	• Bender: Embedded Systems - qualitätsorientierte Entwicklung • Ehrlenspiel: Integrierte Produktentwicklung: Denkabläufe, Methodeneinsatz, Zusammenarbeit • Gausemeier/Ebbesmeyer/Kallmeyer: Produktinnovation - Strategische Planung und Entwicklung der Produkte von morgen • Haberfellner/de Weck/Fricke/Vössner: Systems Engineering: Grundlagen und Anwendung • Lindemann: Methodische Entwicklung technischer Produkte: Methoden flexibel und situationsgerecht anwenden • Pahl/Beitz: Konstruktionslehre: Grundlagen erfolgreicher Produktentwicklung. Methoden und Anwendung • VDI-Richtlinie 2206: Entwicklungsmethodik für mechatronische Systeme

Course L0310: Fatigue & Damage Tolerance	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	45 min
Lecturer	Dr. Martin Flamm
Language	EN
Cycle	WiSe
Content	Design principles, fatigue strength, crack initiation and crack growth, damage calculation, counting methods, methods to improve fatigue strength, environmental influences
Literature	Jaap Schijve, Fatigue of Structures and Materials. Kluver Academic Puplisher, Dordrecht, 2001 E. Haibach. Betriebsfestigkeit Verfahren und Daten zur Bauteilberechnung. VDI-Verlag, Düsseldorf, 1989

Course L0087: Microcontroller Circuits: Implementation in Hardware and Software	
Typ	Seminar
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Schriftliche Ausarbeitung
Examination duration and scale	10 min. Vortrag + anschließende Diskussion
Lecturer	Prof. Siegfried Rump
Language	DE
Cycle	WiSe/SoSe
Content	
Literature	

Course L0724: Microsystems Technology	
Typ	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	30 min
Lecturer	Prof. Hoc Khiem Trieu
Language	EN
Cycle	WiSe
Content	• Introduction (historical view, scientific and economic relevance, scaling laws) • Semiconductor Technology Basics, Lithography (wafer fabrication, photolithography, improving resolution, next-generation lithography, nano-imprinting, molecular imprinting) • Deposition Techniques (thermal oxidation, epitaxy, electroplating, PVD techniques: evaporation and sputtering; CVD techniques: APCVD, LPCVD, PECVD and LECVD; screen printing) • Etching and Bulk Micromachining (definitions, wet chemical etching, isotropic etch with HNA, electrochemical etching, anisotropic etching with KOH/TMAH: theory, corner undercutting, measures for compensation and etch-stop techniques; plasma processes, dry etching: back sputtering, plasma etching, RIE, Bosch process, cryo process, XeF2 etching) • Surface Micromachining and alternative Techniques (sacrificial etching, film stress, stiction: theory and counter measures; Origami microstructures, Epi-Poly, porous silicon, SOI, SCREAM process, LIGA, SU8, rapid prototyping) • Thermal and Radiation Sensors (temperature measurement, self-generating sensors: Seebeck effect and thermopile; modulating sensors: thermo resistor, Pt-100, spreading resistance sensor, pn junction, NTC and PTC; thermal anemometer, mass flow sensor, photometry, radiometry, IR sensor: thermopile and bolometer) • Mechanical Sensors (strain based and stress based principle, capacitive readout, piezoresistivity, pressure sensor: piezoresistive, capacitive and fabrication process; accelerometer: piezoresistive, piezoelectric and capacitive; angular rate sensor: operating principle and fabrication process) • Magnetic Sensors (galvanomagnetic sensors: spinning current Hall sensor and magneto-transistor; magnetoresistive sensors: magneto resistance, AMR and GMR, fluxgate magnetometer) • Chemical and Bio Sensors (thermal gas sensors: pellistor and thermal conductivity sensor; metal oxide semiconductor gas sensor, organic semiconductor gas sensor, Lambda probe, MOSFET gas sensor, pH-FET, SAW sensor, principle of biosensor, Clark electrode, enzyme electrode, DNA chip) • Micro Actuators, Microfluidics and TAS (drives: thermal, electrostatic, piezo electric and electromagnetic; light modulators, DMD, adaptive optics, microscanner, microvalves: passive and active, micropumps, valveless micropump, electrokinetic micropumps, micromixer, filter, inkjet printhead, microdispenser, microfluidic switching elements, microreactor, lab-on-a-chip, microanalytics) • MEMS in medical Engineering (wireless energy and data transmission, smart pill, implantable drug delivery system, stimulators: microelectrodes, cochlear and retinal implant; implantable pressure sensors, intelligent osteosynthesis, implant for spinal cord regeneration) • Design, Simulation, Test (development and design flows, bottom-up approach, top-down approach, testability, modelling: multiphysics, FEM and equivalent circuit simulation; reliability test, physics-of-failure, Arrhenius equation, bath-tub relationship) • System Integration (monolithic and hybrid integration, assembly and packaging, dicing, electrical contact: wire bonding, TAB and flip chip bonding; packages, chip-on-board, wafer-level-package, 3D integration, wafer bonding: anodic bonding and silicon fusion bonding; micro electroplating, 3D-MID)
Literature	M. Madou: Fundamentals of Microfabrication, CRC Press, 2002 N. Schwesinger: Lehrbuch Mikrosystemtechnik, Oldenbourg Verlag, 2009 T. M. Adams, R. A. Layton:Introductory MEMS, Springer, 2010 G. Gerlach; W. Dötzel: Introduction to microsystem technology, Wiley, 2008

Course L1551: Model-Based Systems Engineering (MBSE) with SysML/UML	
Typ	Problem-based Learning
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Examination Form	Projektarbeit
Examination duration and scale	ca. 10 Seiten
Lecturer	Prof. Ralf God
Language	DE
Cycle	SoSe
Content	Objectives of the problem-oriented course are the acquisition of knowledge on system design using the formal languages SysML/UML, learning about tools for modeling and finally the implementation of a project with methods and tools of Model-Based Systems Engineering (MBSE) on a realistic hardware platform (e.g. Arduino®, Raspberry Pi®): • What is a model? • What is Systems Engineering? • Survey of MBSE methodologies • The modelling languages SysML /UML • Tools for MBSE • Best practices for MBSE • Requirements specification, functional architecture, specification of a solution • From model to software code • Validation and verification: XiL methods • Accompanying MBSE project
Literature	- Skript zur Vorlesung - Weilkiens, T.: Systems Engineering mit SysML/UML: Modellierung, Analyse, Design. 2. Auflage, dpunkt.Verlag, 2008 - Holt, J., Perry, S.A., Brownsword, M.: Model-Based Requirements Engineering. Institution Engineering & Tech, 2011

Course L1077: Process Measurement Engineering	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	45 Minuten
Lecturer	Prof. Roland Harig
Language	DE/EN
Cycle	SoSe

Content	• Process measurement engineering in the context of process control engineering
	  ◦ Challenges of process measurement engineering
	  ◦ Instrumentation of processes
	  ◦ Classification of pickups
	• Systems theory in process measurement engineering
	  ◦ Generic linear description of pickups
	  ◦ Mathematical description of two-port systems
	  ◦ Fourier and Laplace transformation
	• Correlational measurement
	  ◦ Wide band signals
	  ◦ Auto- and cross-correlation function and their applications
	  ◦ Fault-free operation of correlational methods
	• Transmission of analog and digital measurement signals
	  ◦ Modulation process (amplitude and frequency modulation)
	  ◦ Multiplexing
	  ◦ Analog to digital converter

Literature	- Färber: „Prozeßrechentechnik“, Springer-Verlag 1994 - Kiencke, Kronmüller: „Meßtechnik“, Springer Verlag Berlin Heidelberg, 1995 - A. Ambardar: „Analog and Digital Signal Processing“ (1), PWS Publishing Company, 1995, NTC 339 - A. Papoulis: „Signal Analysis“ (1), McGraw-Hill, 1987, NTC 312 (LB) - M. Schwartz: „Information Transmission, Modulation and Noise“ (3,4), McGraw-Hill, 1980, 2402095 - S. Haykin: „Communication Systems“ (1,3), Wiley&Sons, 1983, 2419072 - H. Sheingold: „Analog-Digital Conversion Handbook“ (5), Prentice-Hall, 1986, 2440072 - J. Fraden: „AIP Handbook of Modern Sensors“ (5,6), American Institute of Physics, 1993, MTB 346

Course L1083: Process Measurement Engineering	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Examination Form	Mündliche Prüfung
Examination duration and scale	
Lecturer	Prof. Roland Harig
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Course L0664: Feedback Control in Medical Technology	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	
Lecturer	Ulf Pilz, Prof. Olaf Simanski
Language	DE
Cycle	SoSe
Content	Taking an engineering point of view, the lecture is structured as follows. • Introduction to the topic with selected examples • Physiology - introduction and overview • Regeneration of functions of the cardiovascular system • Regeneration of the respiratory functions • Closed loop control in anesthesia • regeneration of kidney and liver functions • regeneration of motorize function/ rehabilitation engineering • navigation systems and robotic in medicine The lecture will use knowledge from modeling, simulation and controller design and MATLAB and SIMULINK will be used.
Literature	Silbernagel/Depopoulos: Taschenatlas der Physiologie, Thieme Verlag Stuttgart Werner: Kooperative und autonome Systeme der Medizintechnik, Oldenburg Verlag M.C.K.Khoo:"Physiological Control System", IEEE Press, 2000

Course L1130: Six Sigma	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	90 Minuten
Lecturer	Prof. Claus Emmelmann
Language	DE
Cycle	WiSe
Content	• Introduction and structuring • Basic terms of quality management • Measuring and inspection equipment • Tools of quality management: FMEA, QFD, FTA, etc. • Quality management methodology Six Sigma, DMAIC
Literature	Pfeifer, T.: Qualitätsmanagement : Strategien, Methoden, Techniken, 4. Aufl., München 2008 Pfeifer, T.: Praxishandbuch Qualitätsmanagement, München 1996 Geiger, W., Kotte, W.: Handbuch Qualität : Grundlagen und Elemente des Qualitätsmanagements: Systeme, Perspektiven, 5. Aufl., Wiesbaden 2008

Course L0176: Reliability in Engineering Dynamics	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	90 min.
Lecturer	Prof. Uwe Weltin
Language	EN
Cycle	SoSe
Content	Method for calculation and testing of reliability of dynamic machine systems • Modeling • System identification • Simulation • Processing of measurement data • Damage accumulation • Test planning and execution
Literature	Bertsche, B.: Reliability in Automotive and Mechanical Engineering. Springer, 2008. ISBN: 978-3-540-33969-4 Inman, Daniel J.: Engineering Vibration. Prentice Hall, 3rd Ed., 2007. ISBN-13: 978-0132281737 Dresig, H., Holzweißig, F.: Maschinendynamik, Springer Verlag, 9. Auflage, 2009. ISBN 3540876936. VDA (Hg.): Zuverlässigkeitssicherung bei Automobilherstellern und Lieferanten. Band 3 Teil 2, 3. überarbeitete Auflage, 2004. ISSN 0943-9412

Course L1303: Reliability in Engineering Dynamics	
Typ	Recitation Section (small)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Examination Form	Klausur
Examination duration and scale	90 min
Lecturer	Prof. Uwe Weltin
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M1269: Lab Cyber-Physical Systems

Courses

Title	Typ	Hrs/wk	CP
Lab Cyber-Physical Systems (L1740)	Problem-based Learning	4	6

Module Responsible	Prof. Heiko Falk
Admission Requirements	None
Recommended Previous Knowledge	Module "Embedded Systems"
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Cyber-Physical Systems (CPS) are tightly integrated with their surrounding environment, via sensors, A/D and D/A converters, and actors. Due to their particular application areas, highly specialized sensors, processors and actors are common. Accordingly, there is a large variety of different specification approaches for CPS - in contrast to classical software engineering approaches. Based on practical experiments using robot kits and computers, the basics of specification and modelling of CPS are taught. The lab introduces into the area (basic notions, characteristical properties) and their specification techniques (models of computation, hierarchical automata, data flow models, petri nets, imperative approaches). Since CPS frequently perform control tasks, the lab's experiments will base on simple control applications. The experiments will use state-of-the-art industrial specification tools (MATLAB/Simulink, LabVIEW, NXC) in order to model cyber-physical models that interact with the environment via sensors and actors.
Skills	After successful attendance of the lab, students are able to develop simple CPS. They understand the interdependencies between a CPS and its surrounding processes which stem from the fact that a CPS interacts with the environment via sensors, A/D converters, digital processors, D/A converters and actors. The lab enables students to compare modelling approaches, to evaluate their advantages and limitations, and to decide which technique to use for a concrete task. They will be able to apply these techniques to practical problems. They obtain first experiences in hardware-related software development, in industry-relevant specification tools and in the area of simple control applications.
Personal Competence	
Social Competence	Students are able to solve similar problems alone or in a group and to present the results accordingly.
Autonomy	Students are able to acquire new knowledge from specific literature and to associate this knowledge with other classes.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Examination	Project
Examination duration and scale	Execution and documentation of all lab experiments
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Specialisation Computer Science: Elective Compulsory Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory General Engineering Science (English program, 7 semester): Specialisation Computer Science: Elective Compulsory Computational Science and Engineering: Specialisation Computer Science: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory

Course L1740: Lab Cyber-Physical Systems

Typ	Problem-based Learning
Hrs/wk	4
CP	6
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Lecturer	Prof. Heiko Falk
Language	DE/EN
Cycle	SoSe
Content	• Experiment 1: Programming in NXC • Experiment 2: Programming the Robot in Matlab/Simulink • Experiment 3: Programming the Robot in LabVIEW
Literature	• Peter Marwedel. Embedded System Design - Embedded System Foundations of Cyber-Physical Systems. 2nd Edition, Springer, 2012. • Begleitende Foliensätze

Module M1302: Applied Humanoid Robotics

Courses

Title	Typ	Hrs/wk	CP
Humanoid Robotics (L1794)	Problem-based Learning	6	6

Module Responsible	Prof. Herbert Werner
Admission Requirements	None
Recommended Previous Knowledge	• Object oriented programming; algorithms and data structures • Introduction to control systems • Control systems theory and design • Mechanics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain humanoid robots. • Students can explain the basic concepts, relationships and methods of forward- and inverse kinematics • Students learn to apply basic control concepts for different tasks in humanoid robotics.
Skills	• Students can implement models for humanoid robotic systems in Matlab and C++, and use these models for robot motion or other tasks. • They are capable of using models in Matlab for simulation and testing these models if necessary with C++ code on the real robot system. • They are capable of selecting methods for solving abstract problems, for which no standard methods are available, and apply it successfully.
Personal Competence	
Social Competence	• Students can develop joint solutions in mixed teams and present these. • They can provide appropriate feedback to others, and constructively handle feedback on their own results
Autonomy	• Students are able to obtain required information from provided literature sources, and to put in into the context of the lecture. • They can independently define tasks and apply the appropriate means to solve them.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Examination	Colloquium
Examination duration and scale	
Assignment for the Following Curricula	Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Bio- and Medical Technology: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L1794: Humanoid Robotics

Typ	Problem-based Learning
Hrs/wk	6
CP	6
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Lecturer	Prof. Herbert Werner
Language	DE/EN
Cycle	SoSe
Content	• Fundamentals of kinematics • Static and dynamic stability of humanoid robotic systems • Combination of different software environments (Matlab, C++, etc.) • Introduction to the necessary software frameworks • Team project • Presentation and Demonstration of intermediate and final results
Literature	• B. Siciliano, O. Khatib. "Handbook of Robotics. Part A: Robotics Foundations", Springer (2008)

Module M1306: Control Lab C

Courses

Title	Typ	Hrs/wk	CP
Control Lab IX (L1836)	Laboratory Course	1	1
Control Lab VII (L1834)	Laboratory Course	1	1
Control Lab VIII (L1835)	Laboratory Course	1	1

Module Responsible	Prof. Herbert Werner
Admission Requirements	None
Recommended Previous Knowledge	• State space methods • LQG control • H2 and H-infinity optimal control • uncertain plant models and robust control • LPV control
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain the difference between validation of a control lop in simulation and experimental validation
Skills	• Students are capable of applying basic system identification tools (Matlab System Identification Toolbox) to identify a dynamic model that can be used for controller synthesis • They are capable of using standard software tools (Matlab Control Toolbox) for the design and implementation of LQG controllers • They are capable of using standard software tools (Matlab Robust Control Toolbox) for the mixed-sensitivity design and the implementation of H-infinity optimal controllers • They are capable of representing model uncertainty, and of designing and implementing a robust controller • They are capable of using standard software tools (Matlab Robust Control Toolbox) for the design and the implementation of LPV gain-scheduled controllers
Personal Competence	
Social Competence	• Students can work in teams to conduct experiments and document the results
Autonomy	• Students can independently carry out simulation studies to design and validate control loops
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Credit points	3
Examination	Colloquium
Examination duration and scale	
Assignment for the Following Curricula	Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory

Course L1836: Control Lab IX

Typ	Laboratory Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Herbert Werner
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
Literature	Experiment Guides

Course L1834: Control Lab VII

Typ	Laboratory Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Herbert Werner
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
Literature	Experiment Guides

Course L1835: Control Lab VIII	
Typ	Laboratory Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Herbert Werner
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
Literature	Experiment Guides

Module M1281: Advanced Topics in Vibration

Courses

Title	Typ	Hrs/wk	CP
Advanced Topics in Vibration (L1743)	Problem-based Learning	4	6

Module Responsible	Prof. Norbert Hoffmann
Admission Requirements	None
Recommended Previous Knowledge	Vibration Theory
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to reflect existing terms and concepts of Advanced Vibrations and to develop and research new terms and concepts.
Skills	Students are able to apply existing methods and procesures of Advanced Vibrations and to develop novel methods and procedures.
Personal Competence	
Social Competence	Students can reach working results also in groups.
Autonomy	Students are able to approach given research tasks individually and to identify and follow up novel research tasks by themselves.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Examination	Written exam
Examination duration and scale	2 Hours
Assignment for the Following Curricula	Computational Science and Engineering: Specialisation Scientific Computing: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Theoretical Mechanical Engineering: Core qualification: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L1743: Advanced Topics in Vibration

Typ	Problem-based Learning
Hrs/wk	4
CP	6
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Lecturer	Prof. Norbert Hoffmann
Language	DE/EN
Cycle	SoSe
Content	Research Topics in Vibrations.
Literature	

Module M0835: Humanoid Robotics

Courses

Title	Typ	Hrs/wk	CP
Humanoid Robotics (L0663)	Seminar	2	2

Module Responsible	Prof. Herbert Werner
Admission Requirements	None
Recommended Previous Knowledge	• Introduction to control systems • Control theory and design
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain humanoid robots. • Students learn to apply basic control concepts for different tasks in humanoid robotics.
Skills	• Students acquire knowledge about selected aspects of humanoid robotics, based on specified literature • Students generalize developed results and present them to the participants • Students practice to prepare and give a presentation
Personal Competence	
Social Competence	• Students are capable of developing solutions in interdisciplinary teams and present them • They are able to provide appropriate feedback and handle constructive criticism of their own results
Autonomy	• Students evaluate advantages and drawbacks of different forms of presentation for specific tasks and select the best solution • Students familiarize themselves with a scientific field, are able of introduce it and follow presentations of other students, such that a scientific discussion develops
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Credit points	2
Examination	Presentation
Examination duration and scale	30 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Control and Power Systems: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Theoretical Mechanical Engineering: Core qualification: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L0663: Humanoid Robotics

Typ	Seminar
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Herbert Werner
Language	DE
Cycle	SoSe
Content	• Grundlagen der Regelungstechnik • Control systems theory and design
Literature	- B. Siciliano, O. Khatib. "Handbook of Robotics. Part A: Robotics Foundations", Springer (2008).

Module M0838: Linear and Nonlinear System Identifikation

Courses

Title	Typ	Hrs/wk	CP
Linear and Nonlinear System Identification (L0660)	Lecture	2	3

Module Responsible	Prof. Herbert Werner
Admission Requirements	Control Systems Theory and Design
Recommended Previous Knowledge	• Classical control (frequency response, root locus) • State space methods • Discrete-time systems • Linear algebra, singular value decomposition • Basic knowledge about stochastic processes
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain the general framework of the prediction error method and its application to a variety of linear and nonlinear model structures • They can explain how multilayer perceptron networks are used to model nonlinear dynamics • They can explain how an approximate predictive control scheme can be based on neural network models • They can explain the idea of subspace identification and its relation to Kalman realisation theory
Skills	• Students are capable of applying the predicition error method to the experimental identification of linear and nonlinear models for dynamic systems • They are capable of implementing a nonlinear predictive control scheme based on a neural network model • They are capable of applying subspace algorithms to the experimental identification of linear models for dynamic systems • They can do the above using standard software tools (including the Matlab System Identification Toolbox)
Personal Competence	
Social Competence	Students can work in mixed groups on specific problems to arrive at joint solutions.
Autonomy	Students are able to find required information in sources provided (lecture notes, literature, software documentation) and use it to solve given problems.
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Credit points	3
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Control and Power Systems: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Theoretical Mechanical Engineering: Core qualification: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L0660: Linear and Nonlinear System Identification

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Herbert Werner
Language	EN
Cycle	SoSe
Content	• Prediction error method • Linear and nonlinear model structures • Nonlinear model structure based on multilayer perceptron network • Approximate predictive control based on multilayer perceptron network model • Subspace identification
Literature	• Lennart Ljung, System Identification - Theory for the User, Prentice Hall 1999 • M. Norgaard, O. Ravn, N.K. Poulsen and L.K. Hansen, Neural Networks for Modeling and Control of Dynamic Systems, Springer Verlag, London 2003 • T. Kailath, A.H. Sayed and B. Hassibi, Linear Estimation, Prentice Hall 2000

Module M0939: Control Lab A

Courses

Title	Typ	Hrs/wk	CP
Control Lab I (L1093)	Laboratory Course	1	1
Control Lab II (L1291)	Laboratory Course	1	1
Control Lab III (L1665)	Laboratory Course	1	1
Control Lab IV (L1666)	Laboratory Course	1	1

Module Responsible	Prof. Herbert Werner
Admission Requirements	•
Recommended Previous Knowledge	• State space methods • LQG control • H2 and H-infinity optimal control • uncertain plant models and robust control • LPV control
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain the difference between validation of a control lop in simulation and experimental validation
Skills	• Students are capable of applying basic system identification tools (Matlab System Identification Toolbox) to identify a dynamic model that can be used for controller synthesis • They are capable of using standard software tools (Matlab Control Toolbox) for the design and implementation of LQG controllers • They are capable of using standard software tools (Matlab Robust Control Toolbox) for the mixed-sensitivity design and the implementation of H-infinity optimal controllers • They are capable of representing model uncertainty, and of designing and implementing a robust controller • They are capable of using standard software tools (Matlab Robust Control Toolbox) for the design and the implementation of LPV gain-scheduled controllers
Personal Competence	
Social Competence	• Students can work in teams to conduct experiments and document the results
Autonomy	• Students can independently carry out simulation studies to design and validate control loops
Workload in Hours	Independent Study Time 64, Study Time in Lecture 56
Credit points	4
Examination	Colloquium
Examination duration and scale	
Assignment for the Following Curricula	Electrical Engineering: Specialisation Control and Power Systems: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Theoretical Mechanical Engineering: Core qualification: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L1093: Control Lab I

Typ	Laboratory Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Herbert Werner
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
Literature	Experiment Guides

Course L1291: Control Lab II	
Typ	Laboratory Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Antonio Mendez Gonzalez
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
Literature	Experiment Guides

Course L1665: Control Lab III	
Typ	Laboratory Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Herbert Werner
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
Literature	Experiment Guides

Course L1666: Control Lab IV	
Typ	Laboratory Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Herbert Werner
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
Literature	Experiment Guides

Module M0550: Digital Image Analysis

Courses

Title	Typ	Hrs/wk	CP
Digital Image Analysis (L0126)	Lecture	4	6

Module Responsible	Prof. Rolf-Rainer Grigat
Admission Requirements	
Recommended Previous Knowledge	System theory of one-dimensional signals (convolution and correlation, sampling theory, interpolation and decimation, Fourier transform, linear time-invariant systems), linear algebra (Eigenvalue decomposition, SVD), basic stochastics and statistics (expectation values, influence of sample size, correlation and covariance, normal distribution and its parameters), basics of Matlab, basics in optics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can • Describe imaging processes • Depict the physics of sensorics • Explain linear and non-linear filtering of signals • Establish interdisciplinary connections in the subject area and arrange them in their context • Interpret effects of the most important classes of imaging sensors and displays using mathematical methods and physical models.
Skills	Students are able to • Use highly sophisticated methods and procedures of the subject area • Identify problems and develop and implement creative solutions. Students can solve simple arithmetical problems relating to the specification and design of image processing and image analysis systems. Students are able to assess different solution approaches in multidimensional decision-making areas. Students can undertake a prototypical analysis of processes in Matlab.
Personal Competence	
Social Competence	
Autonomy	Students can solve image analysis tasks independently using the relevant literature.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Examination	Written exam
Examination duration and scale	60 Minutes, Content of Lecture and materials in StudIP
Assignment for the Following Curricula	Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory Electrical Engineering: Specialisation Medical Technology: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems, Focus Signal Processing: Elective Compulsory Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Software and Signal Processing: Elective Compulsory International Management and Engineering: Specialisation II. Information Technology: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Microelectronics and Microsystems: Specialisation Communication and Signal Processing: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Numerics and Computer Science: Elective Compulsory

Course L0126: Digital Image Analysis	
Typ	Lecture
Hrs/wk	4
CP	6
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Lecturer	Prof. Rolf-Rainer Grigat
Language	EN
Cycle	WiSe
Content	• Image representation, definition of images and volume data sets, illumination, radiometry, multispectral imaging, reflectivities, shape from shading • Perception of luminance and color, color spaces and transforms, color matching functions, human visual system, color appearance models • imaging sensors (CMOS, CCD, HDR, X-ray, IR), sensor characterization(EMVA1288), lenses and optics • spatio-temporal sampling (interpolation, decimation, aliasing, leakage, moiré, flicker, apertures) • features (filters, edge detection, morphology, invariance, statistical features, texture) • optical flow (variational methods, quadratic optimization, Euler-Lagrange equations) • segmentation (distance, region growing, cluster analysis, active contours, level sets, energy minimization and graph cuts) • registration (distance and similarity, variational calculus, iterative closest points)
Literature	Bredies/Lorenz, Mathematische Bildverarbeitung, Vieweg, 2011 Wedel/Cremers, Stereo Scene Flow for 3D Motion Analysis, Springer 2011 Handels, Medizinische Bildverarbeitung, Vieweg, 2000 Pratt, Digital Image Processing, Wiley, 2001 Jain, Fundamentals of Digital Image Processing, Prentice Hall, 1989

Module M0623: Intelligent Systems in Medicine

Courses

Title	Typ	Hrs/wk	CP
Intelligent Systems in Medicine (L0331)	Lecture	2	3
Intelligent Systems in Medicine (L0334)	Project Seminar	2	2
Intelligent Systems in Medicine (L0333)	Recitation Section (small)	1	1

Module Responsible	Prof. Alexander Schlaefer
Admission Requirements	None
Recommended Previous Knowledge	• principles of math (algebra, analysis/calculus) • principles of stochastics • principles of programming, Java/C++ and R/Matlab • advanced programming skills
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students are able to analyze and solve clinical treatment planning and decision support problems using methods for search, optimization, and planning. They are able to explain methods for classification and their respective advantages and disadvantages in clinical contexts. The students can compare different methods for representing medical knowledge. They can evaluate methods in the context of clinical data and explain challenges due to the clinical nature of the data and its acquisition and due to privacy and safety requirements.
Skills	The students can give reasons for selecting and adapting methods for classification, regression, and prediction. They can assess the methods based on actual patient data and evaluate the implemented methods.
Personal Competence	
Social Competence	The students discuss the results of other groups, provide helpful feedback and can incoorporate feedback into their work.
Autonomy	The students can reflect their knowledge and document the results of their work. They can present the results in an appropriate manner.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Examination	Written exam
Examination duration and scale	90 minutes
Assignment for the Following Curricula	Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Electrical Engineering: Specialisation Medical Technology: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Bio- and Medical Technology: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L0331: Intelligent Systems in Medicine

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Alexander Schlaefer
Language	EN
Cycle	WiSe
Content	- methods for search, optimization, planning, classification, regression and prediction in a clinical context - representation of medical knowledge - understanding challenges due to clinical and patient related data and data acquisition The students will work in groups to apply the methods introduced during the lecture using problem based learning.
Literature	Russel & Norvig: Artificial Intelligence: a Modern Approach, 2012 Berner: Clinical Decision Support Systems: Theory and Practice, 2007 Greenes: Clinical Decision Support: The Road Ahead, 2007 Further literature will be given in the lecture

Course L0334: Intelligent Systems in Medicine	
Typ	Project Seminar
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Alexander Schlaefer
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L0333: Intelligent Systems in Medicine	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Alexander Schlaefer
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0552: 3D Computer Vision

Courses

Title	Typ	Hrs/wk	CP
3D Computer Vision (L0129)	Lecture	2	3
3D Computer Vision (L0130)	Recitation Section (small)	2	3

Module Responsible	Prof. Rolf-Rainer Grigat
Admission Requirements	None
Recommended Previous Knowledge	• Knowlege of the modules Digital Image Analysis and Pattern Recognition and Data Compression are used in the practical task • Linear Algebra (including PCA, SVD), nonlinear optimization (Levenberg-Marquardt), basics of stochastics and basics of Matlab are required and cannot be explained in detail during the lecture.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can explain and describe the field of projective geometry.
Skills	Students are capable of • Implementing an exemplary 3D or volumetric analysis task • Using highly sophisticated methods and procedures of the subject area • Identifying problems and • Developing and implementing creative solution suggestions. With assistance from the teacher students are able to link the contents of the three subject areas (modules) • Digital Image Analysis • Pattern Recognition and Data Compression and • 3D Computer Vision in practical assignments.
Personal Competence	
Social Competence	Students can collaborate in a small team on the practical realization and testing of a system to reconstruct a three-dimensional scene or to evaluate volume data sets.
Autonomy	Students are able to solve simple tasks independently with reference to the contents of the lectures and the exercise sets. Students are able to solve detailed problems independently with the aid of the tutorial's programming task.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Examination	Written exam
Examination duration and scale	60 Minutes, Content of Lecture and materials in StudIP
Assignment for the Following Curricula	Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems, Focus Signal Processing: Elective Compulsory Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Software and Signal Processing: Elective Compulsory Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Microelectronics and Microsystems: Specialisation Communication and Signal Processing: Elective Compulsory

Course L0129: 3D Computer Vision	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Rolf-Rainer Grigat
Language	EN
Cycle	WiSe
Content	• Projective Geometry and Transformations in 2D und 3D in homogeneous coordinates • Projection matrix, calibration • Epipolar Geometry, fundamental and essential matrices, weak calibration, 5 point algorithm • Homographies 2D and 3D • Trifocal Tensor • Correspondence search
Literature	• **Skriptum Grigat/Wenzel** • Hartley, Zisserman: Multiple View Geometry in Computer Vision. Cambridge 2003.

Course L0130: 3D Computer Vision	
Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Rolf-Rainer Grigat
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0633: Industrial Process Automation

Courses

Title	Typ	Hrs/wk	CP
Industrial Process Automation (L0344)	Lecture	2	3
Industrial Process Automation (L0345)	Recitation Section (small)	2	3

Module Responsible	Prof. Alexander Schlaefer
Admission Requirements	None
Recommended Previous Knowledge	mathematics and optimization methods principles of automata principles of algorithms and data structures programming skills
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students can evaluate and assess disctrete event systems. They can evaluate properties of processes and explain methods for process analysis. The students can compare methods for process modelling and select an appropriate method for actual problems. They can discuss scheduling methods in the context of actual problems and give a detailed explanation of advantages and disadvantages of different programming methods.
Skills	The students are able to develop and model processes and evaluate them accordingly. This involves taking into account optimal scheduling, understanding algorithmic complexity and implementation using PLCs.
Personal Competence	
Social Competence	The students work in teams to solve problems.
Autonomy	The students can reflect their knowledge and document the results of their work.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Examination	Written exam
Examination duration and scale	90 minutes
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems: Elective Compulsory Computational Science and Engineering: Specialisation Scientific Computing: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory International Production Management: Specialisation Production Technology: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Numerics and Computer Science: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory

Course L0344: Industrial Process Automation	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Alexander Schlaefer
Language	EN
Cycle	WiSe
Content	- foundations of problem solving and system modeling, discrete event systems - properties of processes, modeling using automata and Petri-nets - design considerations for processes (mutex, deadlock avoidance, liveness) - optimal scheduling for processes - optimal decisions when planning manufacturing systems, decisions under uncertainty - software design and software architectures for automation, PLCs
Literature	J. Lunze: „Automatisierungstechnik“, Oldenbourg Verlag, 2012 Reisig: Petrinetze: Modellierungstechnik, Analysemethoden, Fallstudien; Vieweg+Teubner 2010 Hrúz, Zhou: Modeling and Control of Discrete-event Dynamic Systems; Springer 2007 Li, Zhou: Deadlock Resolution in Automated Manufacturing Systems, Springer 2009 Pinedo: Planning and Scheduling in Manufacturing and Services, Springer 2009

Course L0345: Industrial Process Automation	
Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Alexander Schlaefer
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0677: Digital Signal Processing and Digital Filters

Courses

Title	Typ	Hrs/wk	CP
Digital Signal Processing and Digital Filters (L0446)	Lecture	3	4
Digital Signal Processing and Digital Filters (L0447)	Recitation Section (large)	1	2

Module Responsible	Prof. Gerhard Bauch
Admission Requirements	None
Recommended Previous Knowledge	• Mathematics 1-3 • Signals and Systems • Fundamentals of signal and system theory as well as random processes. • Fundamentals of spectral transforms (Fourier series, Fourier transform, Laplace transform)
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students know and understand basic algorithms of digital signal processing. They are familiar with the spectral transforms of discrete-time signals and are able to describe and analyse signals and systems in time and image domain. They know basic structures of digital filters and can identify and assess important properties including stability. They are aware of the effects caused by quantization of filter coefficients and signals. They are familiar with the basics of adaptive filters. They can perform traditional and parametric methods of spectrum estimation, also taking a limited observation window into account.
Skills	The students are able to apply methods of digital signal processing to new problems. They can choose and parameterize suitable filter striuctures. In particular, the can design adaptive filters according to the minimum mean squared error (MMSE) criterion and develop an efficient implementation, e.g. based on the LMS or RLS algorithm. Furthermore, the students are able to apply methods of spectrum estimation and to take the effects of a limited observation window into account.
Personal Competence	
Social Competence	The students can jointly solve specific problems.
Autonomy	The students are able to acquire relevant information from appropriate literature sources. They can control their level of knowledge during the lecture period by solving tutorial problems, software tools, clicker system.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems: Elective Compulsory Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems, Focus Signal Processing: Elective Compulsory Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Microelectronics and Microsystems: Specialisation Microelectronics Complements: Elective Compulsory

Course L0446: Digital Signal Processing and Digital Filters	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Gerhard Bauch
Language	EN
Cycle	WiSe

Content	• Transforms of discrete-time signals:
	  ◦ Discrete-time Fourier Transform (DTFT)
	  ◦ Discrete Fourier-Transform (DFT), Fast Fourier Transform (FFT)
	  ◦ Z-Transform
	• Correspondence of continuous-time and discrete-time signals, sampling, sampling theorem
	• Fast convolution, Overlap-Add-Method, Overlap-Save-Method
	• Fundamental structures and basic types of digital filters
	• Characterization of digital filters using pole-zero plots, important properties of digital filters
	• Quantization effects
	• Design of linear-phase filters
	• Fundamentals of stochastic signal processing and adaptive filters
	  ◦ MMSE criterion
	  ◦ Wiener Filter
	  ◦ LMS- and RLS-algorithm
	• Traditional and parametric methods of spectrum estimation

Literature	K.-D. Kammeyer, K. Kroschel: Digitale Signalverarbeitung. Vieweg Teubner. V. Oppenheim, R. W. Schafer, J. R. Buck: Zeitdiskrete Signalverarbeitung. Pearson StudiumA. V. W. Hess: Digitale Filter. Teubner. Oppenheim, R. W. Schafer: Digital signal processing. Prentice Hall. S. Haykin: Adaptive filter theory. L. B. Jackson: Digital filters and signal processing. Kluwer. T.W. Parks, C.S. Burrus: Digital filter design. Wiley.

Course L0447: Digital Signal Processing and Digital Filters	
Typ	Recitation Section (large)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Gerhard Bauch
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0832: Advanced Topics in Control

Courses

Title	Typ	Hrs/wk	CP
Advanced Topics in Control (L0661)	Lecture	2	3
Advanced Topics in Control (L0662)	Recitation Section (small)	2	3

Module Responsible	Prof. Herbert Werner
Admission Requirements	Optimal and Robust Control
Recommended Previous Knowledge	H-infinity optimal control, mixed-sensitivity design, linear matrix inequalities
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain the advantages and shortcomings of the classical gain scheduling approach • They can explain the representation of nonlinear systems in the form of quasi-LPV systems • They can explain how stability and performance conditions for LPV systems can be formulated as LMI conditions • They can explain how gridding techniques can be used to solve analysis and synthesis problems for LPV systems • They are familiar with polytopic and LFT representations of LPV systems and some of the basic synthesis techniques associated with each of these model structures • Students can explain how graph theoretic concepts are used to represent the communication topology of multiagent systems • They can explain the convergence properties of first order consensus protocols • They can explain analysis and synthesis conditions for formation control loops involving either LTI or LPV agent models • Students can explain the state space representation of spatially invariant distributed systems that are discretized according to an actuator/sensor array • They can explain (in outline) the extension of the bounded real lemma to such distributed systems and the associated synthesis conditions for distributed controllers
Skills	• Students are capable of constructing LPV models of nonlinear plants and carry out a mixed-sensitivity design of gain-scheduled controllers; they can do this using polytopic, LFT or general LPV models • They are able to use standard software tools (Matlab robust control toolbox) for these tasks • Students are able to design distributed formation controllers for groups of agents with either LTI or LPV dynamics, using Matlab tools provided • Students are able to design distributed controllers for spatially interconnected systems, using the Matlab MD-toolbox
Personal Competence	
Social Competence	Students can work in small groups and arrive at joint results.
Autonomy	Students are able to find required information in sources provided (lecture notes, literature, software documentation) and use it to solve given problems.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Aircraft Systems: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Theoretical Mechanical Engineering: Core qualification: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L0661: Advanced Topics in Control	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Herbert Werner
Language	EN
Cycle	WiSe
Content	• Linear Parameter-Varying (LPV) Gain Scheduling - Linearizing gain scheduling, hidden coupling - Jacobian linearization vs. quasi-LPV models - Stability and induced L2 norm of LPV systems - Synthesis of LPV controllers based on the two-sided projection lemma - Simplifications: controller synthesis for polytopic and LFT models - Experimental identification of LPV models - Controller synthesis based on input/output models - Applications: LPV torque vectoring for electric vehicles, LPV control of a robotic manipulator • Control of Multi-Agent Systems - Communication graphs - Spectral properties of the graph Laplacian - First and second order consensus protocols - Formation control, stability and performance - LPV models for agents subject to nonholonomic constraints - Application: formation control for a team of quadrotor helicopters • Control of Spatially Interconnected Systems - Multidimensional signals, l2 and L2 signal norm - Multidimensional systems in Roesser state space form - Extension of real-bounded lemma to spatially interconnected systems - LMI-based synthesis of distributed controllers - Spatial LPV control of spatially varying systems - Applications: control of temperature profiles, vibration damping for an actuated beam
Literature	• Werner, H., Lecture Notes "Advanced Topics in Control" • Selection of relevant research papers made available as pdf documents via StudIP

Course L0662: Advanced Topics in Control	
Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Herbert Werner
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M1173: Applied Statistics

Courses

Title	Typ	Hrs/wk	CP
Applied Statistics (L1584)	Lecture	2	3
Applied Statistics (L1586)	Problem-based Learning	2	2
Applied Statistics (L1585)	Recitation Section (small)	1	1

Module Responsible	Prof. Michael Morlock
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge of statistical methods
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can explain the statistical methods and the conditions of their use.
Skills	Students are able to use the statistics program to solve statistics problems and to interpret and depict the results
Personal Competence	
Social Competence	Team Work, joined presentation of results
Autonomy	To understand and interpret the question and solve
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Examination	Written exam
Examination duration and scale	90 minutes, 28 questions
Assignment for the Following Curricula	Mechanical Engineering and Management: Specialisation Management: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Biomedical Engineering: Core qualification: Compulsory Product Development, Materials and Production: Core qualification: Elective Compulsory

Course L1584: Applied Statistics

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Michael Morlock
Language	DE/EN
Cycle	WiSe
Content	The goal is to introduce students to the basic statistical methods and their application to simple problems. The topics include: • Chi square test • Simple regression and correlation • Multiple regression and correlation • One way analysis of variance • Two way analysis of variance • Discriminant analysis • Analysis of categorial data • Chossing the appropriate statistical method • Determining critical sample sizes
Literature	Applied Regression Analysis and Multivariable Methods, 3rd Edition, David G. Kleinbaum Emory University, Lawrence L. Kupper University of North Carolina at Chapel Hill, Keith E. Muller University of North Carolina at Chapel Hill, Azhar Nizam Emory University, Published by Duxbury Press, CB © 1998, ISBN/ISSN: 0-534-20910-6

Course L1586: Applied Statistics	
Typ	Problem-based Learning
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Michael Morlock
Language	DE/EN
Cycle	WiSe
Content	The students receive a problem task, which they have to solve in small groups (n=5). They do have to collect their own data and work with them. The results have to be presented in an executive summary at the end of the course.
Literature	Selbst zu finden

Course L1585: Applied Statistics	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Michael Morlock
Language	DE/EN
Cycle	WiSe
Content	The different statistical tests are applied for the solution of realistic problems using actual data sets and the most common used commercial statistical software package (SPSS).
Literature	Student Solutions Manual for Kleinbaum/Kupper/Muller/Nizam's Applied Regression Analysis and Multivariable Methods, 3rd Edition, David G. Kleinbaum Emory University Lawrence L. Kupper University of North Carolina at Chapel Hill, Keith E. Muller University of North Carolina at Chapel Hill, Azhar Nizam Emory University, Published by Duxbury Press, Paperbound © 1998, ISBN/ISSN: 0-534-20913-0

Module M1204: Modelling and Optimization in Dynamics

Courses

Title	Typ	Hrs/wk	CP
Flexible Multibody Systems (L1632)	Lecture	2	3
Optimization of dynamical systems (L1633)	Lecture	2	3

Module Responsible	Prof. Robert Seifried
Admission Requirements	None
Recommended Previous Knowledge	• Mathematics I, II, III • Mechanics I, II, III, IV • Simulation of dynamical Systems
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students demonstrate basic knowledge and understanding of modeling, simulation and analysis of complex rigid and flexible multibody systems and methods for optimizing dynamic systems after successful completion of the module.
Skills	Students are able + to think holistically + to independently, securly and critically analyze and optimize basic problems of the dynamics of rigid and flexible multibody systems + to describe dynamics problems mathematically + to optimize dynamics problems
Personal Competence	
Social Competence	Students are able to + solve problems in heterogeneous groups and to document the corresponding results.
Autonomy	Students are able to + assess their knowledge by means of exercises. + acquaint themselves with the necessary knowledge to solve research oriented tasks.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Energy Systems: Core qualification: Elective Compulsory Aircraft Systems Engineering: Specialisation Aircraft Systems: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Product Development, Materials and Production: Core qualification: Elective Compulsory Theoretical Mechanical Engineering: Core qualification: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L1632: Flexible Multibody Systems	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Robert Seifried
Language	DE
Cycle	WiSe
Content	1. Basics of Multibody Systems 2. Basics of Continuum Mechanics 3. Linear finite element modelles and modell reduction 4. Nonlinear finite element Modelles: absolute nodal coordinate formulation 5. Kinematics of an elastic body 6. Kinetics of an elastic body 7. System assembly
Literature	Schwertassek, R. und Wallrapp, O.: Dynamik flexibler Mehrkörpersysteme. Braunschweig, Vieweg, 1999. Seifried, R.: Dynamics of Underactuated Multibody Systems, Springer, 2014. Shabana, A.A.: Dynamics of Multibody Systems. Cambridge Univ. Press, Cambridge, 2004, 3. Auflage.

Course L1633: Optimization of dynamical systems	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Robert Seifried
Language	DE
Cycle	WiSe
Content	1. Formulation and classification of optimization problems 2. Scalar Optimization 3. Sensitivity Analysis 4. Unconstrained Parameter Optimization 5. Constrained Parameter Optimization 6. Stochastic optimization 7. Multicriteria Optimization 8. Topology Optimization
Literature	Bestle, D.: Analyse und Optimierung von Mehrkörpersystemen. Springer, Berlin, 1994. Nocedal, J. , Wright , S.J. : Numerical Optimization. New York: Springer, 2006.

Module M1229: Control Lab B

Courses

Title	Typ	Hrs/wk	CP
Control Lab V (L1667)	Laboratory Course	1	1
Control Lab VI (L1668)	Laboratory Course	1	1

Module Responsible	Prof. Herbert Werner
Admission Requirements	
Recommended Previous Knowledge	• State space methods • LQG control • H2 and H-infinity optimal control • uncertain plant models and robust control • LPV control
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain the difference between validation of a control lop in simulation and experimental validation
Skills	• Students are capable of applying basic system identification tools (Matlab System Identification Toolbox) to identify a dynamic model that can be used for controller synthesis • They are capable of using standard software tools (Matlab Control Toolbox) for the design and implementation of LQG controllers • They are capable of using standard software tools (Matlab Robust Control Toolbox) for the mixed-sensitivity design and the implementation of H-infinity optimal controllers • They are capable of representing model uncertainty, and of designing and implementing a robust controller • They are capable of using standard software tools (Matlab Robust Control Toolbox) for the design and the implementation of LPV gain-scheduled controllers
Personal Competence	
Social Competence	• Students can work in teams to conduct experiments and document the results
Autonomy	• Students can independently carry out simulation studies to design and validate control loops
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Credit points	2
Examination	Colloquium
Examination duration and scale	
Assignment for the Following Curricula	Electrical Engineering: Specialisation Control and Power Systems: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Theoretical Mechanical Engineering: Core qualification: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L1667: Control Lab V

Typ	Laboratory Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Herbert Werner
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
Literature	Experiment Guides

Course L1668: Control Lab VI

Typ	Laboratory Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Herbert Werner
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
Literature	Experiment Guides

Module M1305: Seminar Advanced Topics in Control

Courses

Title	Typ	Hrs/wk	CP
Advanced Topics in Control (L1803)	Seminar	2	2

Module Responsible	Prof. Herbert Werner
Admission Requirements	None
Recommended Previous Knowledge	• Introduction to control systems • Control theory and design • optimal and robust control
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain modern control. • Students learn to apply basic control concepts for different tasks
Skills	• Students acquire knowledge about selected aspects of modern control, based on specified literature • Students generalize developed results and present them to the participants • Students practice to prepare and give a presentation
Personal Competence	
Social Competence	• Students are capable of developing solutions and present them • They are able to provide appropriate feedback and handle constructive criticism of their own results
Autonomy	• Students evaluate advantages and drawbacks of different forms of presentation for specific tasks and select the best solution • Students familiarize themselves with a scientific field, are able of introduce it and follow presentations of other students, such that a scientific discussion develops
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Credit points	2
Examination	Presentation
Examination duration and scale	90 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Control and Power Systems: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory

Course L1803: Advanced Topics in Control

Typ	Seminar
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Herbert Werner
Language	EN
Cycle	WiSe/SoSe
Content	• Seminar on selected topics in modern control
Literature	• To be specified

Specialization System Design

In the system design specialization, graduates learn how to work systematically and methodically on challenging design tasks.

They have broad knowledge of new development methods, are able to select appropriate solution strategies and use these autonomously to develop new products. They are qualified to use the approaches of integrated system development, such as simulation or modern testing procedures.

Module M0752: Nonlinear Dynamics

Courses

Title	Typ	Hrs/wk	CP
Nonlinear Dynamics (L0702)	Lecture	4	6

Module Responsible	Prof. Norbert Hoffmann
Admission Requirements	None
Recommended Previous Knowledge	• Calculus • Linear Algebra • Engineering Mechanics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to reflect existing terms and concepts in Nonlinear Dynamics and to develop and research new terms and concepts.
Skills	Students are able to apply existing methods and procesures of Nonlinear Dynamics and to develop novel methods and procedures.
Personal Competence	
Social Competence	Students can reach working results also in groups.
Autonomy	Students are able to approach given research tasks individually and to identify and follow up novel research tasks by themselves.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Examination	Written exam
Examination duration and scale	2 Hours
Assignment for the Following Curricula	Aircraft Systems Engineering: Specialisation Aircraft Systems: Elective Compulsory Computational Science and Engineering: Specialisation Scientific Computing: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Product Development, Materials and Production: Core qualification: Elective Compulsory Theoretical Mechanical Engineering: Core qualification: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L0702: Nonlinear Dynamics

Typ	Lecture
Hrs/wk	4
CP	6
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Lecturer	Prof. Norbert Hoffmann
Language	DE/EN
Cycle	SoSe
Content	Fundamentals of Nonlinear Dynamics.
Literature	S. Strogatz: Nonlinear Dynamics and Chaos. Perseus, 2013.

Module M0803: Embedded Systems

Courses

Title	Typ	Hrs/wk	CP
Embedded Systems (L0805)	Lecture	3	4
Embedded Systems (L0806)	Recitation Section (small)	1	2

Module Responsible	Prof. Heiko Falk
Admission Requirements	None
Recommended Previous Knowledge	Computer Engineering
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Embedded systems can be defined as information processing systems embedded into enclosing products. This course teaches the foundations of such systems. In particular, it deals with an introduction into these systems (notions, common characteristics) and their specification languages (models of computation, hierarchical automata, specification of distributed systems, task graphs, specification of real-time applications, translations between different models). Another part covers the hardware of embedded systems: Sonsors, A/D and D/A converters, real-time capable communication hardware, embedded processors, memories, energy dissipation, reconfigurable logic and actuators. The course also features an introduction into real-time operating systems, middleware and real-time scheduling. Finally, the implementation of embedded systems using hardware/software co-design (hardware/software partitioning, high-level transformations of specifications, energy-efficient realizations, compilers for embedded processors) is covered.
Skills	After having attended the course, students shall be able to realize simple embedded systems. The students shall realize which relevant parts of technological competences to use in order to obtain a functional embedded systems. In particular, they shall be able to compare different models of computations and feasible techniques for system-level design. They shall be able to judge in which areas of embedded system design specific risks exist.
Personal Competence	
Social Competence	Students are able to solve similar problems alone or in a group and to present the results accordingly.
Autonomy	Students are able to acquire new knowledge from specific literature and to associate this knowledge with other classes.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Examination	Written exam
Examination duration and scale	90 minutes, contents of course and labs
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Specialisation Computer Science: Elective Compulsory Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory Electrical Engineering: Core qualification: Elective Compulsory General Engineering Science (English program, 7 semester): Specialisation Computer Science: Elective Compulsory Computational Science and Engineering: Core qualification: Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory

Course L0805: Embedded Systems

Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Heiko Falk
Language	DE/EN
Cycle	SoSe
Content	• Introduction • Specifications and Modeling • Embedded/Cyber-Physical Systems Hardware • System Software • Evaluation and Validation • Mapping of Applications to Execution Platforms • Optimization
Literature	• Peter Marwedel. Embedded System Design - Embedded Systems Foundations of Cyber-Physical Systems. 2nd Edition, Springer, 2012., Springer, 2012.

Course L0806: Embedded Systems	
Typ	Recitation Section (small)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Heiko Falk
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0805: Technical Acoustics I (Acoustic Waves, Noise Protection, Psycho Acoustics)

Courses

Title	Typ	Hrs/wk	CP
Technical Acoustics I (Acoustic Waves, Noise Protection, Psycho Acoustics) (L0516)	Lecture	2	3
Technical Acoustics I (Acoustic Waves, Noise Protection, Psycho Acoustics) (L0518)	Recitation Section (large)	2	3

Module Responsible	Prof. Otto von Estorff
Admission Requirements	none
Recommended Previous Knowledge	Mechanics I (Statics, Mechanics of Materials) and Mechanics II (Hydrostatics, Kinematics, Dynamics) Mathematics I, II, III (in particular differential equations)
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students possess an in-depth knowledge in acoustics regarding acoustic waves, noise protection, and psycho acoustics and are able to give an overview of the corresponding theoretical and methodical basis.
Skills	The students are capable to handle engineering problems in acoustics by theory-based application of the demanding methodologies and measurement procedures treated within the module.
Personal Competence	
Social Competence	
Autonomy	The students are able to independently solve challenging acoustical problems in the areas treated within the module. Possible conflicting issues and limitations can be identified and the results are critically scrutinized.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Examination	Oral exam
Examination duration and scale	20-30 Minuten
Assignment for the Following Curricula	Energy Systems: Core qualification: Elective Compulsory Aircraft Systems Engineering: Specialisation Cabin Systems: Elective Compulsory International Management and Engineering: Specialisation II. Aviation Systems: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Product Development, Materials and Production: Core qualification: Elective Compulsory Technomathematics: Core qualification: Elective Compulsory Technomathematics: Specialisation III. Engineering Science: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Product Development and Production: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L0516: Technical Acoustics I (Acoustic Waves, Noise Protection, Psycho Acoustics)

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Otto von Estorff
Language	EN
Cycle	SoSe
Content	- Introduction and Motivation - Acoustic quantities - Acoustic waves - Sound sources, sound radiation - Sound engergy and intensity - Sound propagation - Signal processing - Psycho acoustics - Noise - Measurements in acoustics
Literature	Cremer, L.; Heckl, M. (1996): Körperschall. Springer Verlag, Berlin Veit, I. (1988): Technische Akustik. Vogel-Buchverlag, Würzburg Veit, I. (1988): Flüssigkeitsschall. Vogel-Buchverlag, Würzburg

Course L0518: Technical Acoustics I (Acoustic Waves, Noise Protection, Psycho Acoustics)	
Typ	Recitation Section (large)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Otto von Estorff
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0807: Boundary Element Methods

Courses

Title	Typ	Hrs/wk	CP
Boundary Element Methods (L0523)	Lecture	2	3
Boundary Element Methods (L0524)	Recitation Section (large)	2	3

Module Responsible	Prof. Otto von Estorff
Admission Requirements	none
Recommended Previous Knowledge	Mechanics I (Statics, Mechanics of Materials) and Mechanics II (Hydrostatics, Kinematics, Dynamics) Mathematics I, II, III (in particular differential equations)
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students possess an in-depth knowledge regarding the derivation of the boundary element method and are able to give an overview of the theoretical and methodical basis of the method.
Skills	The students are capable to handle engineering problems by formulating suitable boundary elements, assembling the corresponding system matrices, and solving the resulting system of equations.
Personal Competence	
Social Competence	-
Autonomy	The students are able to independently solve challenging computational problems and develop own boundary element routines. Problems can be identified and the results are critically scrutinized.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Civil Engineering: Specialisation Structural Engineering: Elective Compulsory Civil Engineering: Specialisation Geotechnical Engineering: Elective Compulsory Civil Engineering: Specialisation Coastal Engineering: Elective Compulsory Energy Systems: Core qualification: Elective Compulsory Computational Science and Engineering: Specialisation Scientific Computing: Elective Compulsory Mechanical Engineering and Management: Specialisation Product Development and Production: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Product Development, Materials and Production: Core qualification: Elective Compulsory Technomathematics: Specialisation III. Engineering Science: Elective Compulsory Technomathematics: Core qualification: Elective Compulsory Theoretical Mechanical Engineering: Core qualification: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L0523: Boundary Element Methods	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Otto von Estorff
Language	EN
Cycle	SoSe
Content	- Boundary value problems - Integral equations - Fundamental Solutions - Element formulations - Numerical integration - Solving systems of equations (statics, dynamics) - Special BEM formulations - Coupling of FEM and BEM - Hands-on Sessions (programming of BE routines) - Applications
Literature	Gaul, L.; Fiedler, Ch. (1997): Methode der Randelemente in Statik und Dynamik. Vieweg, Braunschweig, Wiesbaden Bathe, K.-J. (2000): Finite-Elemente-Methoden. Springer Verlag, Berlin

Course L0524: Boundary Element Methods	
Typ	Recitation Section (large)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Otto von Estorff
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0840: Optimal and Robust Control

Courses

Title	Typ	Hrs/wk	CP
Optimal and Robust Control (L0658)	Lecture	2	3
Optimal and Robust Control (L0659)	Recitation Section (small)	2	3

Module Responsible	Prof. Herbert Werner
Admission Requirements	Control Systems Theory and Design
Recommended Previous Knowledge	• Classical control (frequency response, root locus) • State space methods • Linear algebra, singular value decomposition
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain the significance of the matrix Riccati equation for the solution of LQ problems. • They can explain the duality between optimal state feedback and optimal state estimation. • They can explain how the H2 and H-infinity norms are used to represent stability and performance constraints. • They can explain how an LQG design problem can be formulated as special case of an H2 design problem. • They can explain how model uncertainty can be represented in a way that lends itself to robust controller design • They can explain how - based on the small gain theorem - a robust controller can guarantee stability and performance for an uncertain plant. • They understand how analysis and synthesis conditions on feedback loops can be represented as linear matrix inequalities.
Skills	• Students are capable of designing and tuning LQG controllers for multivariable plant models. • They are capable of representing a H2 or H-infinity design problem in the form of a generalized plant, and of using standard software tools for solving it. • They are capable of translating time and frequency domain specifications for control loops into constraints on closed-loop sensitivity functions, and of carrying out a mixed-sensitivity design. • They are capable of constructing an LFT uncertainty model for an uncertain system, and of designing a mixed-objective robust controller. • They are capable of formulating analysis and synthesis conditions as linear matrix inequalities (LMI), and of using standard LMI-solvers for solving them. • They can carry out all of the above using standard software tools (Matlab robust control toolbox).
Personal Competence	
Social Competence	Students can work in small groups on specific problems to arrive at joint solutions.
Autonomy	Students are able to find required information in sources provided (lecture notes, literature, software documentation) and use it to solve given problems.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems: Elective Compulsory Energy Systems: Core qualification: Elective Compulsory Aircraft Systems Engineering: Specialisation Aircraft Systems: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Theoretical Mechanical Engineering: Core qualification: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L0658: Optimal and Robust Control	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Herbert Werner
Language	EN
Cycle	SoSe
Content	• Optimal regulator problem with finite time horizon, Riccati differential equation • Time-varying and steady state solutions, algebraic Riccati equation, Hamiltonian system • Kalman's identity, phase margin of LQR controllers, spectral factorization • Optimal state estimation, Kalman filter, LQG control • Generalized plant, review of LQG control • Signal and system norms, computing H2 and H∞ norms • Singular value plots, input and output directions • Mixed sensitivity design, H∞ loop shaping, choice of weighting filters • Case study: design example flight control • Linear matrix inequalities, design specifications as LMI constraints (H2, H∞ and pole region) • Controller synthesis by solving LMI problems, multi-objective design • Robust control of uncertain systems, small gain theorem, representation of parameter uncertainty
Literature	• Werner, H., Lecture Notes: "Optimale und Robuste Regelung" • Boyd, S., L. El Ghaoui, E. Feron and V. Balakrishnan "Linear Matrix Inequalities in Systems and Control", SIAM, Philadelphia, PA, 1994 • Skogestad, S. and I. Postlewhaite "Multivariable Feedback Control", John Wiley, Chichester, England, 1996 • Strang, G. "Linear Algebra and its Applications", Harcourt Brace Jovanovic, Orlando, FA, 1988 • Zhou, K. and J. Doyle "Essentials of Robust Control", Prentice Hall International, Upper Saddle River, NJ, 1998

Course L0659: Optimal and Robust Control	
Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Herbert Werner
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M1143: Mechanical Design Methodology

Courses

Title	Typ	Hrs/wk	CP
Mechanical Design Methodology (L1523)	Lecture	3	4
Mechanical Design Methodology (L1524)	Recitation Section (small)	1	2

Module Responsible	Prof. Josef Schlattmann
Admission Requirements	none
Recommended Previous Knowledge	
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Science-based working on product design considering targeted application of specific product design techniques
Skills	Creative handling of processes used for scientific preparation and formulation of complex product design problems / Application of various product design techniques following theoretical aspects.
Personal Competence	
Social Competence	
Autonomy	
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Examination	Oral exam
Examination duration and scale	
Assignment for the Following Curricula	International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Product Development and Production: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L1523: Mechanical Design Methodology

Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Josef Schlattmann
Language	DE
Cycle	SoSe
Content	• Systematic reflection and analysis of the mechanical design process • Process structuring in sections (task, functions, acting principles, design-elements and total construction) as well as levels (working-, controlling-, and deciding-levels) • Creativity (basics, methods, practical application in mechatronics) • Diverse methods applied as tools (function structure, GALFMOS, AEIOU method, GAMPFT, simulation tools, TRIZ) • Evaluation and selection (technical-economical evaluation, preference matrix) • Value analysis, cost-benefit analysis • Low-noise design of technical products • Project monitoring and leading (leading projects / employees, organisation in product development, creating ideas / responsibility and communication) • Aesthetic product design (industrial design, colouring, specific examples / exercises)
Literature	• Pahl, G.; Beitz, W.; Feldhusen, J.; Grote, K.-H.: Konstruktionslehre: Grundlage erfolgreicher Produktentwicklung, Methoden und Anwendung, 7. Auflage, Springer Verlag, Berlin 2007 • VDI-Richtlinien: 2206; 2221ff

Course L1524: Mechanical Design Methodology	
Typ	Recitation Section (small)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Josef Schlattmann
Language	DE
Cycle	SoSe
Content	• Systematic reflection and analysis of the mechanical design process • Process structuring in sections (task, functions, acting principles, design-elements and total construction) as well as levels (working-, controlling-, and deciding-levels) • Creativity (basics, methods, practical application in mechatronics) • Diverse methods applied as tools (function structure, GALFMOS, AEIOU method, GAMPFT, simulation tools, TRIZ) • Evaluation and selection (technical-economical evaluation, preference matrix) • Value analysis, cost-benefit analysis • Low-noise design of technical products • Project monitoring and leading (leading projects / employees, organisation in product development, creating ideas / responsibility and communication) • Aesthetic product design (industrial design, colouring, specific examples / exercises)
Literature	• Pahl, G.; Beitz, W.; Feldhusen, J.; Grote, K.-H.: Konstruktionslehre: Grundlage erfolgreicher Produktentwicklung, Methoden und Anwendung, 7. Auflage, Springer Verlag, Berlin 2007 • VDI-Richtlinien: 2206; 2221ff

Module M1145: Automation and Simulation

Courses

Title	Typ	Hrs/wk	CP
Automation and Simulation (L1525)	Lecture	3	3
Automation and Simulation (L1527)	Recitation Section (large)	2	3

Module Responsible	Prof. Günter Ackermann
Admission Requirements	none
Recommended Previous Knowledge	**BSc Mechanical Engineering or similar**
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can describe the structure an the function of process computers, the corresponding components, the data transfer via bus systems an programmable logic computers . They can describe the basich principle of a numeric simulation and the corresponding parameters. Thy can explain the usual method to simulate the dynamic behaviour of three-phase machines.
Skills	Students can describe and design simple controllers using established methodes. They are able to assess the basic characterisitcs of a given automation system and to evaluate, if it is adequate for a given plant. They can modell and simulate technical systems with respect to their dynamical behaviour and can use Matlab/Simulink for the simulation. They are able to applay established methods for the caclulation of the dynamical behaviour of three-phase machines.
Personal Competence	
Social Competence	Teamwork in small teams.
Autonomy	Students are able to identify the need of methocic analysises in the field of automation systems, to do these analysisis in an adequate manner und to evaluate the results critically.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Examination	Oral exam
Examination duration and scale	Vorzugsweise in Dreier-Gruppen, etwa 1 Stunde
Assignment for the Following Curricula	Energy Systems: Core qualification: Elective Compulsory Aircraft Systems Engineering: Specialisation Cabin Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Aircraft Systems: Elective Compulsory International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Aviation Systems: Elective Compulsory International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory

Course L1525: Automation and Simulation	
Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Günter Ackermann
Language	DE
Cycle	SoSe
Content	Structure of automation systsems Aufbau von Automationseinrichtungen Structure and function of process computers and corresponding componentes Data transfer via bus systems Programmable Logic Computers Methods to describe logic sequences Prionciples of the modelling and the simulation of continous technical systems Practical work with an established simulation program (Matlab/Simulink) Simulation of the dynamic behaviour of a three-phase maschine, simulation of a mixed continous/discrete system on base of tansistion flow diagrams.
Literature	U. Tietze, Ch. Schenk: Halbleiter-Schaltungstechnik; Springer Verlag R. Lauber, P. Göhner: Prozessautomatisierung 2, Springer Verlag Färber: Prozessrechentechnik (Grundlagen, Hardware, Echtzeitverhalten), Springer Verlag Einführung/Tutorial Matlab/Simulink - verschiedene Autoren

Course L1527: Automation and Simulation	
Typ	Recitation Section (large)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Günter Ackermann
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M1156: Systems Engineering

Courses

Title	Typ	Hrs/wk	CP
Systems Engineering (L1547)	Lecture	3	4
Systems Engineering (L1548)	Recitation Section (large)	1	2

Module Responsible	Prof. Ralf God
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge in: • Mathematics • Mechanics • Thermodynamics • Electrical Engineering • Control Systems Previous knowledge in: • Aircraft Cabin Systems
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to: • understand systems engineering process models, methods and tools for the development of complex Systems • describe innovation processes and the need for technology Management • explain the aircraft development process and the process of type certification for aircraft • explain the system development process, including requirements for systems reliability • identify environmental conditions and test procedures for airborne Equipment • value the methodology of requirements-based engineering (RBE) and model-based requirements engineering (MBRE)
Skills	Students are able to: • plan the process for the development of complex Systems • organize the development phases and development Tasks • assign required business activities and technical Tasks • apply systems engineering methods and tools
Personal Competence	
Social Competence	Students are able to: • understand their responsibilities within a development team and integrate themselves with their role in the overall process
Autonomy	Students are able to: • interact and communicate in a development team which has distributed tasks
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Examination	Written exam
Examination duration and scale	120 Minutes
Assignment for the Following Curricula	Aircraft Systems Engineering: Core qualification: Compulsory International Management and Engineering: Specialisation II. Aviation Systems: Elective Compulsory International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory

Course L1547: Systems Engineering	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Ralf God
Language	DE
Cycle	SoSe
Content	The objective of the lecture with the corresponding exercise is to accomplish the prerequisites for the development and integration of complex systems using the example of commercial aircraft and cabin systems. Competences in the systems engineering process, tools and methods is to be achieved. Regulations, guidelines and certification issues will be known. Key aspects of the course are processes for innovation and technology management, system design, system integration and certification as well as tools and methods for systems engineering: • Innovation processes • IP-protection • Technology management • Systems engineering • Aircraft program • Certification issues • Systems development • Safety objectives and fault tolerance • Environmental and operating conditions • Tools for systems engineering • Requirements-based engineering (RBE) • Model-based requirements engineering (MBRE)
Literature	- Skript zur Vorlesung - diverse Normen und Richtlinien (EASA, FAA, RTCA, SAE) - Hauschildt, J., Salomo, S.: Innovationsmanagement. Vahlen, 5. Auflage, 2010 - NASA Systems Engineering Handbook, National Aeronautics and Space Administration, 2007 - Hinsch, M.: Industrielles Luftfahrtmanagement: Technik und Organisation luftfahrttechnischer Betriebe. Springer, 2010 - De Florio, P.: Airworthiness: An Introduction to Aircraft Certification. Elsevier Ltd., 2010 - Pohl, K.: Requirements Engineering. Grundlagen, Prinzipien, Techniken. 2. korrigierte Auflage, dpunkt.Verlag, 2008

Course L1548: Systems Engineering	
Typ	Recitation Section (large)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Ralf God
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M1212: Technical Complementary Course for IMPMEC (according to Subject Specific Regulations)	
Courses	
Title	**Typ** **Hrs/wk** **CP**
Module Responsible	Prof. Uwe Weltin
Admission Requirements	None
Recommended Previous Knowledge	See selected module according to FSPO
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	see selected module according to FSPO
Skills	see selected module according to FSPO
Personal Competence	
Social Competence	see selected module according to FSPO
Autonomy	see selected module according to FSPO
Workload in Hours	Independent Study Time 180, Study Time in Lecture 0
Credit points	6
Examination	according to Subject Specific Regulations
Examination duration and scale	lt. FSPO
Assignment for the Following Curricula	Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory

Module M1223: Selected Topics of Mechatronics (Alternative A: 12 LP)

Courses

Title	Typ	Hrs/wk	CP
Introduction to Electromagnetic Waveguides and Antennas (L1669)	Lecture	2	2
Development Management for Mechatronics (L1512)	Lecture	2	3
Fatigue & Damage Tolerance (L0310)	Lecture	2	3
Microcontroller Circuits: Implementation in Hardware and Software (L0087)	Seminar	2	2
Microsystems Technology (L0724)	Lecture	2	4
Model-Based Systems Engineering (MBSE) with SysML/UML (L1551)	Problem-based Learning	3	3
Process Measurement Engineering (L1077)	Lecture	2	3
Process Measurement Engineering (L1083)	Recitation Section (large)	1	1
Feedback Control in Medical Technology (L0664)	Lecture	2	3
Six Sigma (L1130)	Lecture	2	3
Reliability in Engineering Dynamics (L0176)	Lecture	2	2
Reliability in Engineering Dynamics (L1303)	Recitation Section (small)	1	2

Module Responsible	Prof. Uwe Weltin
Admission Requirements	Only one of the modules "Selected Topics of Mechatronics (Alternative A: 12 LP) or "Selected Topics of Mechatronics (Alternative B: 6 LP)" can be selected.
Recommended Previous Knowledge	None
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students are able to express their extended knowledge and discuss the connection of different special fields or application areas of mechatronics • Students are qualified to connect different special fields with each other
Skills	• Students can apply specialized solution strategies and new scientific methods in selected areas • Students are able to transfer learned skills to new and unknown problems and can develop own solution approaches
Personal Competence	
Social Competence	
Autonomy	• Students are able to develop their knowledge and skills by autonomous election of courses.
Workload in Hours	Depends on choice of courses
Credit points	12
Assignment for the Following Curricula	Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory

Course L1669: Introduction to Electromagnetic Waveguides and Antennas	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	30 min
Lecturer	Prof. Christian Schuster
Language	DE/EN
Cycle	WiSe
Content	This course is intended as an introduction into the topics of electromagnetic wave propagation, guiding, sending, and receiving for graduate engineering students that do not have a specific background in electrical engineering. It will be useful for engineers that face the technical challenge of transmitting high frequency / high bandwidth data in e.g. medical, automotive, or avionic applications. Both circuit and field concepts of electromagnetic wave propagation will be introduced and discussed. Topics: - Fundamental properties and phenomena of electrical circuits - Steady-state sinusoidal analysis of electrical circuits - Fundamental properties and phenomena of electromagnetic fields and waves - Steady-state sinusoidal description of electromagnetic fields and waves - Useful microwave network parameters - Transmission lines and basic results from transmission line theory - Plane wave propagation, superposition, reflection and refraction - General theory of waveguides - Most important types of waveguides and their properties - Radiation and basic antenna parameters - Most important types of antennas and their properties - Numerical techniques and CAD tools for waveguide and antenna design
Literature	- Zinke, Brunswig, "Hochfrequenztechnik 1", Springer (1999) - J. Detlefsen, U. Siart, "Grundlagen der Hochfrequenztechnik", Oldenbourg (2012) - D. M. Pozar, "Microwave Engineering", Wiley (2011) - Y. Huang, K. Boyle, "Antenna: From Theory to Practice", Wiley (2008)

Course L1512: Development Management for Mechatronics	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	30 Minuten
Lecturer	Dr. Daniel Steffen
Language	DE
Cycle	SoSe

Content	• Processes and methods of product development - from idea to market launch
	  ◦ identification of market and technology potentials
	  ◦ development of a common product architecture
	  ◦ Synchronized product development across all engineering disciplines
	  ◦ product validation incl. customer view
	• Steering and optimization of product development
	  ◦ Design of processes for product development
	  ◦ IT systems for product development
	  ◦ Establishment of management standards
	  ◦ Typical types of organization

Literature	• Bender: Embedded Systems - qualitätsorientierte Entwicklung • Ehrlenspiel: Integrierte Produktentwicklung: Denkabläufe, Methodeneinsatz, Zusammenarbeit • Gausemeier/Ebbesmeyer/Kallmeyer: Produktinnovation - Strategische Planung und Entwicklung der Produkte von morgen • Haberfellner/de Weck/Fricke/Vössner: Systems Engineering: Grundlagen und Anwendung • Lindemann: Methodische Entwicklung technischer Produkte: Methoden flexibel und situationsgerecht anwenden • Pahl/Beitz: Konstruktionslehre: Grundlagen erfolgreicher Produktentwicklung. Methoden und Anwendung • VDI-Richtlinie 2206: Entwicklungsmethodik für mechatronische Systeme

Course L0310: Fatigue & Damage Tolerance	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	45 min
Lecturer	Dr. Martin Flamm
Language	EN
Cycle	WiSe
Content	Design principles, fatigue strength, crack initiation and crack growth, damage calculation, counting methods, methods to improve fatigue strength, environmental influences
Literature	Jaap Schijve, Fatigue of Structures and Materials. Kluver Academic Puplisher, Dordrecht, 2001 E. Haibach. Betriebsfestigkeit Verfahren und Daten zur Bauteilberechnung. VDI-Verlag, Düsseldorf, 1989

Course L0087: Microcontroller Circuits: Implementation in Hardware and Software	
Typ	Seminar
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Schriftliche Ausarbeitung
Examination duration and scale	10 min. Vortrag + anschließende Diskussion
Lecturer	Prof. Siegfried Rump
Language	DE
Cycle	WiSe/SoSe
Content	
Literature	

Course L0724: Microsystems Technology	
Typ	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	30 min
Lecturer	Prof. Hoc Khiem Trieu
Language	EN
Cycle	WiSe
Content	• Introduction (historical view, scientific and economic relevance, scaling laws) • Semiconductor Technology Basics, Lithography (wafer fabrication, photolithography, improving resolution, next-generation lithography, nano-imprinting, molecular imprinting) • Deposition Techniques (thermal oxidation, epitaxy, electroplating, PVD techniques: evaporation and sputtering; CVD techniques: APCVD, LPCVD, PECVD and LECVD; screen printing) • Etching and Bulk Micromachining (definitions, wet chemical etching, isotropic etch with HNA, electrochemical etching, anisotropic etching with KOH/TMAH: theory, corner undercutting, measures for compensation and etch-stop techniques; plasma processes, dry etching: back sputtering, plasma etching, RIE, Bosch process, cryo process, XeF2 etching) • Surface Micromachining and alternative Techniques (sacrificial etching, film stress, stiction: theory and counter measures; Origami microstructures, Epi-Poly, porous silicon, SOI, SCREAM process, LIGA, SU8, rapid prototyping) • Thermal and Radiation Sensors (temperature measurement, self-generating sensors: Seebeck effect and thermopile; modulating sensors: thermo resistor, Pt-100, spreading resistance sensor, pn junction, NTC and PTC; thermal anemometer, mass flow sensor, photometry, radiometry, IR sensor: thermopile and bolometer) • Mechanical Sensors (strain based and stress based principle, capacitive readout, piezoresistivity, pressure sensor: piezoresistive, capacitive and fabrication process; accelerometer: piezoresistive, piezoelectric and capacitive; angular rate sensor: operating principle and fabrication process) • Magnetic Sensors (galvanomagnetic sensors: spinning current Hall sensor and magneto-transistor; magnetoresistive sensors: magneto resistance, AMR and GMR, fluxgate magnetometer) • Chemical and Bio Sensors (thermal gas sensors: pellistor and thermal conductivity sensor; metal oxide semiconductor gas sensor, organic semiconductor gas sensor, Lambda probe, MOSFET gas sensor, pH-FET, SAW sensor, principle of biosensor, Clark electrode, enzyme electrode, DNA chip) • Micro Actuators, Microfluidics and TAS (drives: thermal, electrostatic, piezo electric and electromagnetic; light modulators, DMD, adaptive optics, microscanner, microvalves: passive and active, micropumps, valveless micropump, electrokinetic micropumps, micromixer, filter, inkjet printhead, microdispenser, microfluidic switching elements, microreactor, lab-on-a-chip, microanalytics) • MEMS in medical Engineering (wireless energy and data transmission, smart pill, implantable drug delivery system, stimulators: microelectrodes, cochlear and retinal implant; implantable pressure sensors, intelligent osteosynthesis, implant for spinal cord regeneration) • Design, Simulation, Test (development and design flows, bottom-up approach, top-down approach, testability, modelling: multiphysics, FEM and equivalent circuit simulation; reliability test, physics-of-failure, Arrhenius equation, bath-tub relationship) • System Integration (monolithic and hybrid integration, assembly and packaging, dicing, electrical contact: wire bonding, TAB and flip chip bonding; packages, chip-on-board, wafer-level-package, 3D integration, wafer bonding: anodic bonding and silicon fusion bonding; micro electroplating, 3D-MID)
Literature	M. Madou: Fundamentals of Microfabrication, CRC Press, 2002 N. Schwesinger: Lehrbuch Mikrosystemtechnik, Oldenbourg Verlag, 2009 T. M. Adams, R. A. Layton:Introductory MEMS, Springer, 2010 G. Gerlach; W. Dötzel: Introduction to microsystem technology, Wiley, 2008

Course L1551: Model-Based Systems Engineering (MBSE) with SysML/UML	
Typ	Problem-based Learning
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Examination Form	Projektarbeit
Examination duration and scale	ca. 10 Seiten
Lecturer	Prof. Ralf God
Language	DE
Cycle	SoSe
Content	Objectives of the problem-oriented course are the acquisition of knowledge on system design using the formal languages SysML/UML, learning about tools for modeling and finally the implementation of a project with methods and tools of Model-Based Systems Engineering (MBSE) on a realistic hardware platform (e.g. Arduino®, Raspberry Pi®): • What is a model? • What is Systems Engineering? • Survey of MBSE methodologies • The modelling languages SysML /UML • Tools for MBSE • Best practices for MBSE • Requirements specification, functional architecture, specification of a solution • From model to software code • Validation and verification: XiL methods • Accompanying MBSE project
Literature	- Skript zur Vorlesung - Weilkiens, T.: Systems Engineering mit SysML/UML: Modellierung, Analyse, Design. 2. Auflage, dpunkt.Verlag, 2008 - Holt, J., Perry, S.A., Brownsword, M.: Model-Based Requirements Engineering. Institution Engineering & Tech, 2011

Course L1077: Process Measurement Engineering	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	45 Minuten
Lecturer	Prof. Roland Harig
Language	DE/EN
Cycle	SoSe

Content	• Process measurement engineering in the context of process control engineering
	  ◦ Challenges of process measurement engineering
	  ◦ Instrumentation of processes
	  ◦ Classification of pickups
	• Systems theory in process measurement engineering
	  ◦ Generic linear description of pickups
	  ◦ Mathematical description of two-port systems
	  ◦ Fourier and Laplace transformation
	• Correlational measurement
	  ◦ Wide band signals
	  ◦ Auto- and cross-correlation function and their applications
	  ◦ Fault-free operation of correlational methods
	• Transmission of analog and digital measurement signals
	  ◦ Modulation process (amplitude and frequency modulation)
	  ◦ Multiplexing
	  ◦ Analog to digital converter

Literature	- Färber: „Prozeßrechentechnik“, Springer-Verlag 1994 - Kiencke, Kronmüller: „Meßtechnik“, Springer Verlag Berlin Heidelberg, 1995 - A. Ambardar: „Analog and Digital Signal Processing“ (1), PWS Publishing Company, 1995, NTC 339 - A. Papoulis: „Signal Analysis“ (1), McGraw-Hill, 1987, NTC 312 (LB) - M. Schwartz: „Information Transmission, Modulation and Noise“ (3,4), McGraw-Hill, 1980, 2402095 - S. Haykin: „Communication Systems“ (1,3), Wiley&Sons, 1983, 2419072 - H. Sheingold: „Analog-Digital Conversion Handbook“ (5), Prentice-Hall, 1986, 2440072 - J. Fraden: „AIP Handbook of Modern Sensors“ (5,6), American Institute of Physics, 1993, MTB 346

Course L1083: Process Measurement Engineering	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Examination Form	Mündliche Prüfung
Examination duration and scale	
Lecturer	Prof. Roland Harig
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Course L0664: Feedback Control in Medical Technology	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	
Lecturer	Ulf Pilz, Prof. Olaf Simanski
Language	DE
Cycle	SoSe
Content	Taking an engineering point of view, the lecture is structured as follows. • Introduction to the topic with selected examples • Physiology - introduction and overview • Regeneration of functions of the cardiovascular system • Regeneration of the respiratory functions • Closed loop control in anesthesia • regeneration of kidney and liver functions • regeneration of motorize function/ rehabilitation engineering • navigation systems and robotic in medicine The lecture will use knowledge from modeling, simulation and controller design and MATLAB and SIMULINK will be used.
Literature	Silbernagel/Depopoulos: Taschenatlas der Physiologie, Thieme Verlag Stuttgart Werner: Kooperative und autonome Systeme der Medizintechnik, Oldenburg Verlag M.C.K.Khoo:"Physiological Control System", IEEE Press, 2000

Course L1130: Six Sigma	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	90 Minuten
Lecturer	Prof. Claus Emmelmann
Language	DE
Cycle	WiSe
Content	• Introduction and structuring • Basic terms of quality management • Measuring and inspection equipment • Tools of quality management: FMEA, QFD, FTA, etc. • Quality management methodology Six Sigma, DMAIC
Literature	Pfeifer, T.: Qualitätsmanagement : Strategien, Methoden, Techniken, 4. Aufl., München 2008 Pfeifer, T.: Praxishandbuch Qualitätsmanagement, München 1996 Geiger, W., Kotte, W.: Handbuch Qualität : Grundlagen und Elemente des Qualitätsmanagements: Systeme, Perspektiven, 5. Aufl., Wiesbaden 2008

Course L0176: Reliability in Engineering Dynamics	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	90 min.
Lecturer	Prof. Uwe Weltin
Language	EN
Cycle	SoSe
Content	Method for calculation and testing of reliability of dynamic machine systems • Modeling • System identification • Simulation • Processing of measurement data • Damage accumulation • Test planning and execution
Literature	Bertsche, B.: Reliability in Automotive and Mechanical Engineering. Springer, 2008. ISBN: 978-3-540-33969-4 Inman, Daniel J.: Engineering Vibration. Prentice Hall, 3rd Ed., 2007. ISBN-13: 978-0132281737 Dresig, H., Holzweißig, F.: Maschinendynamik, Springer Verlag, 9. Auflage, 2009. ISBN 3540876936. VDA (Hg.): Zuverlässigkeitssicherung bei Automobilherstellern und Lieferanten. Band 3 Teil 2, 3. überarbeitete Auflage, 2004. ISSN 0943-9412

Course L1303: Reliability in Engineering Dynamics	
Typ	Recitation Section (small)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Examination Form	Klausur
Examination duration and scale	90 min
Lecturer	Prof. Uwe Weltin
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M1224: Selected Topics of Mechatronics (Alternative B: 6 LP)

Courses

Title	Typ	Hrs/wk	CP
Introduction to Electromagnetic Waveguides and Antennas (L1669)	Lecture	2	2
Development Management for Mechatronics (L1512)	Lecture	2	3
Fatigue & Damage Tolerance (L0310)	Lecture	2	3
Microcontroller Circuits: Implementation in Hardware and Software (L0087)	Seminar	2	2
Microsystems Technology (L0724)	Lecture	2	4
Model-Based Systems Engineering (MBSE) with SysML/UML (L1551)	Problem-based Learning	3	3
Process Measurement Engineering (L1077)	Lecture	2	3
Process Measurement Engineering (L1083)	Recitation Section (large)	1	1
Feedback Control in Medical Technology (L0664)	Lecture	2	3
Six Sigma (L1130)	Lecture	2	3
Reliability in Engineering Dynamics (L0176)	Lecture	2	2
Reliability in Engineering Dynamics (L1303)	Recitation Section (small)	1	2

Module Responsible	Prof. Uwe Weltin
Admission Requirements	Only one of the modules "Selected Topics of Mechatronics (Alternative A: 12 LP) or "Selected Topics of Mechatronics (Alternative B: 6 LP)" can be selected.
Recommended Previous Knowledge	None
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students are able to express their extended knowledge and discuss the connection of different special fields or application areas of mechatronics • Students are qualified to connect different special fields with each other
Skills	• Students can apply specialized solution strategies and new scientific methods in selected areas • Students are able to transfer learned skills to new and unknown problems and can develop own solution approaches
Personal Competence	
Social Competence	
Autonomy	• Students are able to develop their knowledge and skills by autonomous election of courses.
Workload in Hours	Depends on choice of courses
Credit points	6
Assignment for the Following Curricula	Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory

Course L1669: Introduction to Electromagnetic Waveguides and Antennas	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	30 min
Lecturer	Prof. Christian Schuster
Language	DE/EN
Cycle	WiSe
Content	This course is intended as an introduction into the topics of electromagnetic wave propagation, guiding, sending, and receiving for graduate engineering students that do not have a specific background in electrical engineering. It will be useful for engineers that face the technical challenge of transmitting high frequency / high bandwidth data in e.g. medical, automotive, or avionic applications. Both circuit and field concepts of electromagnetic wave propagation will be introduced and discussed. Topics: - Fundamental properties and phenomena of electrical circuits - Steady-state sinusoidal analysis of electrical circuits - Fundamental properties and phenomena of electromagnetic fields and waves - Steady-state sinusoidal description of electromagnetic fields and waves - Useful microwave network parameters - Transmission lines and basic results from transmission line theory - Plane wave propagation, superposition, reflection and refraction - General theory of waveguides - Most important types of waveguides and their properties - Radiation and basic antenna parameters - Most important types of antennas and their properties - Numerical techniques and CAD tools for waveguide and antenna design
Literature	- Zinke, Brunswig, "Hochfrequenztechnik 1", Springer (1999) - J. Detlefsen, U. Siart, "Grundlagen der Hochfrequenztechnik", Oldenbourg (2012) - D. M. Pozar, "Microwave Engineering", Wiley (2011) - Y. Huang, K. Boyle, "Antenna: From Theory to Practice", Wiley (2008)

Course L1512: Development Management for Mechatronics	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	30 Minuten
Lecturer	Dr. Daniel Steffen
Language	DE
Cycle	SoSe

Content	• Processes and methods of product development - from idea to market launch
	  ◦ identification of market and technology potentials
	  ◦ development of a common product architecture
	  ◦ Synchronized product development across all engineering disciplines
	  ◦ product validation incl. customer view
	• Steering and optimization of product development
	  ◦ Design of processes for product development
	  ◦ IT systems for product development
	  ◦ Establishment of management standards
	  ◦ Typical types of organization

Literature	• Bender: Embedded Systems - qualitätsorientierte Entwicklung • Ehrlenspiel: Integrierte Produktentwicklung: Denkabläufe, Methodeneinsatz, Zusammenarbeit • Gausemeier/Ebbesmeyer/Kallmeyer: Produktinnovation - Strategische Planung und Entwicklung der Produkte von morgen • Haberfellner/de Weck/Fricke/Vössner: Systems Engineering: Grundlagen und Anwendung • Lindemann: Methodische Entwicklung technischer Produkte: Methoden flexibel und situationsgerecht anwenden • Pahl/Beitz: Konstruktionslehre: Grundlagen erfolgreicher Produktentwicklung. Methoden und Anwendung • VDI-Richtlinie 2206: Entwicklungsmethodik für mechatronische Systeme

Course L0310: Fatigue & Damage Tolerance	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	45 min
Lecturer	Dr. Martin Flamm
Language	EN
Cycle	WiSe
Content	Design principles, fatigue strength, crack initiation and crack growth, damage calculation, counting methods, methods to improve fatigue strength, environmental influences
Literature	Jaap Schijve, Fatigue of Structures and Materials. Kluver Academic Puplisher, Dordrecht, 2001 E. Haibach. Betriebsfestigkeit Verfahren und Daten zur Bauteilberechnung. VDI-Verlag, Düsseldorf, 1989

Course L0087: Microcontroller Circuits: Implementation in Hardware and Software	
Typ	Seminar
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Schriftliche Ausarbeitung
Examination duration and scale	10 min. Vortrag + anschließende Diskussion
Lecturer	Prof. Siegfried Rump
Language	DE
Cycle	WiSe/SoSe
Content	
Literature	

Course L0724: Microsystems Technology	
Typ	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	30 min
Lecturer	Prof. Hoc Khiem Trieu
Language	EN
Cycle	WiSe
Content	• Introduction (historical view, scientific and economic relevance, scaling laws) • Semiconductor Technology Basics, Lithography (wafer fabrication, photolithography, improving resolution, next-generation lithography, nano-imprinting, molecular imprinting) • Deposition Techniques (thermal oxidation, epitaxy, electroplating, PVD techniques: evaporation and sputtering; CVD techniques: APCVD, LPCVD, PECVD and LECVD; screen printing) • Etching and Bulk Micromachining (definitions, wet chemical etching, isotropic etch with HNA, electrochemical etching, anisotropic etching with KOH/TMAH: theory, corner undercutting, measures for compensation and etch-stop techniques; plasma processes, dry etching: back sputtering, plasma etching, RIE, Bosch process, cryo process, XeF2 etching) • Surface Micromachining and alternative Techniques (sacrificial etching, film stress, stiction: theory and counter measures; Origami microstructures, Epi-Poly, porous silicon, SOI, SCREAM process, LIGA, SU8, rapid prototyping) • Thermal and Radiation Sensors (temperature measurement, self-generating sensors: Seebeck effect and thermopile; modulating sensors: thermo resistor, Pt-100, spreading resistance sensor, pn junction, NTC and PTC; thermal anemometer, mass flow sensor, photometry, radiometry, IR sensor: thermopile and bolometer) • Mechanical Sensors (strain based and stress based principle, capacitive readout, piezoresistivity, pressure sensor: piezoresistive, capacitive and fabrication process; accelerometer: piezoresistive, piezoelectric and capacitive; angular rate sensor: operating principle and fabrication process) • Magnetic Sensors (galvanomagnetic sensors: spinning current Hall sensor and magneto-transistor; magnetoresistive sensors: magneto resistance, AMR and GMR, fluxgate magnetometer) • Chemical and Bio Sensors (thermal gas sensors: pellistor and thermal conductivity sensor; metal oxide semiconductor gas sensor, organic semiconductor gas sensor, Lambda probe, MOSFET gas sensor, pH-FET, SAW sensor, principle of biosensor, Clark electrode, enzyme electrode, DNA chip) • Micro Actuators, Microfluidics and TAS (drives: thermal, electrostatic, piezo electric and electromagnetic; light modulators, DMD, adaptive optics, microscanner, microvalves: passive and active, micropumps, valveless micropump, electrokinetic micropumps, micromixer, filter, inkjet printhead, microdispenser, microfluidic switching elements, microreactor, lab-on-a-chip, microanalytics) • MEMS in medical Engineering (wireless energy and data transmission, smart pill, implantable drug delivery system, stimulators: microelectrodes, cochlear and retinal implant; implantable pressure sensors, intelligent osteosynthesis, implant for spinal cord regeneration) • Design, Simulation, Test (development and design flows, bottom-up approach, top-down approach, testability, modelling: multiphysics, FEM and equivalent circuit simulation; reliability test, physics-of-failure, Arrhenius equation, bath-tub relationship) • System Integration (monolithic and hybrid integration, assembly and packaging, dicing, electrical contact: wire bonding, TAB and flip chip bonding; packages, chip-on-board, wafer-level-package, 3D integration, wafer bonding: anodic bonding and silicon fusion bonding; micro electroplating, 3D-MID)
Literature	M. Madou: Fundamentals of Microfabrication, CRC Press, 2002 N. Schwesinger: Lehrbuch Mikrosystemtechnik, Oldenbourg Verlag, 2009 T. M. Adams, R. A. Layton:Introductory MEMS, Springer, 2010 G. Gerlach; W. Dötzel: Introduction to microsystem technology, Wiley, 2008

Course L1551: Model-Based Systems Engineering (MBSE) with SysML/UML	
Typ	Problem-based Learning
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Examination Form	Projektarbeit
Examination duration and scale	ca. 10 Seiten
Lecturer	Prof. Ralf God
Language	DE
Cycle	SoSe
Content	Objectives of the problem-oriented course are the acquisition of knowledge on system design using the formal languages SysML/UML, learning about tools for modeling and finally the implementation of a project with methods and tools of Model-Based Systems Engineering (MBSE) on a realistic hardware platform (e.g. Arduino®, Raspberry Pi®): • What is a model? • What is Systems Engineering? • Survey of MBSE methodologies • The modelling languages SysML /UML • Tools for MBSE • Best practices for MBSE • Requirements specification, functional architecture, specification of a solution • From model to software code • Validation and verification: XiL methods • Accompanying MBSE project
Literature	- Skript zur Vorlesung - Weilkiens, T.: Systems Engineering mit SysML/UML: Modellierung, Analyse, Design. 2. Auflage, dpunkt.Verlag, 2008 - Holt, J., Perry, S.A., Brownsword, M.: Model-Based Requirements Engineering. Institution Engineering & Tech, 2011

Course L1077: Process Measurement Engineering	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	45 Minuten
Lecturer	Prof. Roland Harig
Language	DE/EN
Cycle	SoSe

Content	• Process measurement engineering in the context of process control engineering
	  ◦ Challenges of process measurement engineering
	  ◦ Instrumentation of processes
	  ◦ Classification of pickups
	• Systems theory in process measurement engineering
	  ◦ Generic linear description of pickups
	  ◦ Mathematical description of two-port systems
	  ◦ Fourier and Laplace transformation
	• Correlational measurement
	  ◦ Wide band signals
	  ◦ Auto- and cross-correlation function and their applications
	  ◦ Fault-free operation of correlational methods
	• Transmission of analog and digital measurement signals
	  ◦ Modulation process (amplitude and frequency modulation)
	  ◦ Multiplexing
	  ◦ Analog to digital converter

Literature	- Färber: „Prozeßrechentechnik“, Springer-Verlag 1994 - Kiencke, Kronmüller: „Meßtechnik“, Springer Verlag Berlin Heidelberg, 1995 - A. Ambardar: „Analog and Digital Signal Processing“ (1), PWS Publishing Company, 1995, NTC 339 - A. Papoulis: „Signal Analysis“ (1), McGraw-Hill, 1987, NTC 312 (LB) - M. Schwartz: „Information Transmission, Modulation and Noise“ (3,4), McGraw-Hill, 1980, 2402095 - S. Haykin: „Communication Systems“ (1,3), Wiley&Sons, 1983, 2419072 - H. Sheingold: „Analog-Digital Conversion Handbook“ (5), Prentice-Hall, 1986, 2440072 - J. Fraden: „AIP Handbook of Modern Sensors“ (5,6), American Institute of Physics, 1993, MTB 346

Course L1083: Process Measurement Engineering	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Examination Form	Mündliche Prüfung
Examination duration and scale	
Lecturer	Prof. Roland Harig
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Course L0664: Feedback Control in Medical Technology	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	
Lecturer	Ulf Pilz, Prof. Olaf Simanski
Language	DE
Cycle	SoSe
Content	Taking an engineering point of view, the lecture is structured as follows. • Introduction to the topic with selected examples • Physiology - introduction and overview • Regeneration of functions of the cardiovascular system • Regeneration of the respiratory functions • Closed loop control in anesthesia • regeneration of kidney and liver functions • regeneration of motorize function/ rehabilitation engineering • navigation systems and robotic in medicine The lecture will use knowledge from modeling, simulation and controller design and MATLAB and SIMULINK will be used.
Literature	Silbernagel/Depopoulos: Taschenatlas der Physiologie, Thieme Verlag Stuttgart Werner: Kooperative und autonome Systeme der Medizintechnik, Oldenburg Verlag M.C.K.Khoo:"Physiological Control System", IEEE Press, 2000

Course L1130: Six Sigma	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	90 Minuten
Lecturer	Prof. Claus Emmelmann
Language	DE
Cycle	WiSe
Content	• Introduction and structuring • Basic terms of quality management • Measuring and inspection equipment • Tools of quality management: FMEA, QFD, FTA, etc. • Quality management methodology Six Sigma, DMAIC
Literature	Pfeifer, T.: Qualitätsmanagement : Strategien, Methoden, Techniken, 4. Aufl., München 2008 Pfeifer, T.: Praxishandbuch Qualitätsmanagement, München 1996 Geiger, W., Kotte, W.: Handbuch Qualität : Grundlagen und Elemente des Qualitätsmanagements: Systeme, Perspektiven, 5. Aufl., Wiesbaden 2008

Course L0176: Reliability in Engineering Dynamics	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	90 min.
Lecturer	Prof. Uwe Weltin
Language	EN
Cycle	SoSe
Content	Method for calculation and testing of reliability of dynamic machine systems • Modeling • System identification • Simulation • Processing of measurement data • Damage accumulation • Test planning and execution
Literature	Bertsche, B.: Reliability in Automotive and Mechanical Engineering. Springer, 2008. ISBN: 978-3-540-33969-4 Inman, Daniel J.: Engineering Vibration. Prentice Hall, 3rd Ed., 2007. ISBN-13: 978-0132281737 Dresig, H., Holzweißig, F.: Maschinendynamik, Springer Verlag, 9. Auflage, 2009. ISBN 3540876936. VDA (Hg.): Zuverlässigkeitssicherung bei Automobilherstellern und Lieferanten. Band 3 Teil 2, 3. überarbeitete Auflage, 2004. ISSN 0943-9412

Course L1303: Reliability in Engineering Dynamics	
Typ	Recitation Section (small)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Examination Form	Klausur
Examination duration and scale	90 min
Lecturer	Prof. Uwe Weltin
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M1269: Lab Cyber-Physical Systems

Courses

Title	Typ	Hrs/wk	CP
Lab Cyber-Physical Systems (L1740)	Problem-based Learning	4	6

Module Responsible	Prof. Heiko Falk
Admission Requirements	None
Recommended Previous Knowledge	Module "Embedded Systems"
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Cyber-Physical Systems (CPS) are tightly integrated with their surrounding environment, via sensors, A/D and D/A converters, and actors. Due to their particular application areas, highly specialized sensors, processors and actors are common. Accordingly, there is a large variety of different specification approaches for CPS - in contrast to classical software engineering approaches. Based on practical experiments using robot kits and computers, the basics of specification and modelling of CPS are taught. The lab introduces into the area (basic notions, characteristical properties) and their specification techniques (models of computation, hierarchical automata, data flow models, petri nets, imperative approaches). Since CPS frequently perform control tasks, the lab's experiments will base on simple control applications. The experiments will use state-of-the-art industrial specification tools (MATLAB/Simulink, LabVIEW, NXC) in order to model cyber-physical models that interact with the environment via sensors and actors.
Skills	After successful attendance of the lab, students are able to develop simple CPS. They understand the interdependencies between a CPS and its surrounding processes which stem from the fact that a CPS interacts with the environment via sensors, A/D converters, digital processors, D/A converters and actors. The lab enables students to compare modelling approaches, to evaluate their advantages and limitations, and to decide which technique to use for a concrete task. They will be able to apply these techniques to practical problems. They obtain first experiences in hardware-related software development, in industry-relevant specification tools and in the area of simple control applications.
Personal Competence	
Social Competence	Students are able to solve similar problems alone or in a group and to present the results accordingly.
Autonomy	Students are able to acquire new knowledge from specific literature and to associate this knowledge with other classes.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Examination	Project
Examination duration and scale	Execution and documentation of all lab experiments
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Specialisation Computer Science: Elective Compulsory Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory General Engineering Science (English program, 7 semester): Specialisation Computer Science: Elective Compulsory Computational Science and Engineering: Specialisation Computer Science: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory

Course L1740: Lab Cyber-Physical Systems

Typ	Problem-based Learning
Hrs/wk	4
CP	6
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Lecturer	Prof. Heiko Falk
Language	DE/EN
Cycle	SoSe
Content	• Experiment 1: Programming in NXC • Experiment 2: Programming the Robot in Matlab/Simulink • Experiment 3: Programming the Robot in LabVIEW
Literature	• Peter Marwedel. Embedded System Design - Embedded System Foundations of Cyber-Physical Systems. 2nd Edition, Springer, 2012. • Begleitende Foliensätze

Module M1306: Control Lab C

Courses

Title	Typ	Hrs/wk	CP
Control Lab IX (L1836)	Laboratory Course	1	1
Control Lab VII (L1834)	Laboratory Course	1	1
Control Lab VIII (L1835)	Laboratory Course	1	1

Module Responsible	Prof. Herbert Werner
Admission Requirements	None
Recommended Previous Knowledge	• State space methods • LQG control • H2 and H-infinity optimal control • uncertain plant models and robust control • LPV control
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain the difference between validation of a control lop in simulation and experimental validation
Skills	• Students are capable of applying basic system identification tools (Matlab System Identification Toolbox) to identify a dynamic model that can be used for controller synthesis • They are capable of using standard software tools (Matlab Control Toolbox) for the design and implementation of LQG controllers • They are capable of using standard software tools (Matlab Robust Control Toolbox) for the mixed-sensitivity design and the implementation of H-infinity optimal controllers • They are capable of representing model uncertainty, and of designing and implementing a robust controller • They are capable of using standard software tools (Matlab Robust Control Toolbox) for the design and the implementation of LPV gain-scheduled controllers
Personal Competence	
Social Competence	• Students can work in teams to conduct experiments and document the results
Autonomy	• Students can independently carry out simulation studies to design and validate control loops
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Credit points	3
Examination	Colloquium
Examination duration and scale	
Assignment for the Following Curricula	Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory

Course L1836: Control Lab IX

Typ	Laboratory Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Herbert Werner
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
Literature	Experiment Guides

Course L1834: Control Lab VII

Typ	Laboratory Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Herbert Werner
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
Literature	Experiment Guides

Course L1835: Control Lab VIII	
Typ	Laboratory Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Herbert Werner
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
Literature	Experiment Guides

Module M1281: Advanced Topics in Vibration

Courses

Title	Typ	Hrs/wk	CP
Advanced Topics in Vibration (L1743)	Problem-based Learning	4	6

Module Responsible	Prof. Norbert Hoffmann
Admission Requirements	None
Recommended Previous Knowledge	Vibration Theory
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to reflect existing terms and concepts of Advanced Vibrations and to develop and research new terms and concepts.
Skills	Students are able to apply existing methods and procesures of Advanced Vibrations and to develop novel methods and procedures.
Personal Competence	
Social Competence	Students can reach working results also in groups.
Autonomy	Students are able to approach given research tasks individually and to identify and follow up novel research tasks by themselves.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Examination	Written exam
Examination duration and scale	2 Hours
Assignment for the Following Curricula	Computational Science and Engineering: Specialisation Scientific Computing: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Theoretical Mechanical Engineering: Core qualification: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L1743: Advanced Topics in Vibration

Typ	Problem-based Learning
Hrs/wk	4
CP	6
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Lecturer	Prof. Norbert Hoffmann
Language	DE/EN
Cycle	SoSe
Content	Research Topics in Vibrations.
Literature	

Module M0835: Humanoid Robotics

Courses

Title	Typ	Hrs/wk	CP
Humanoid Robotics (L0663)	Seminar	2	2

Module Responsible	Prof. Herbert Werner
Admission Requirements	None
Recommended Previous Knowledge	• Introduction to control systems • Control theory and design
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain humanoid robots. • Students learn to apply basic control concepts for different tasks in humanoid robotics.
Skills	• Students acquire knowledge about selected aspects of humanoid robotics, based on specified literature • Students generalize developed results and present them to the participants • Students practice to prepare and give a presentation
Personal Competence	
Social Competence	• Students are capable of developing solutions in interdisciplinary teams and present them • They are able to provide appropriate feedback and handle constructive criticism of their own results
Autonomy	• Students evaluate advantages and drawbacks of different forms of presentation for specific tasks and select the best solution • Students familiarize themselves with a scientific field, are able of introduce it and follow presentations of other students, such that a scientific discussion develops
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Credit points	2
Examination	Presentation
Examination duration and scale	30 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Control and Power Systems: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Theoretical Mechanical Engineering: Core qualification: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L0663: Humanoid Robotics

Typ	Seminar
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Herbert Werner
Language	DE
Cycle	SoSe
Content	• Grundlagen der Regelungstechnik • Control systems theory and design
Literature	- B. Siciliano, O. Khatib. "Handbook of Robotics. Part A: Robotics Foundations", Springer (2008).

Module M0838: Linear and Nonlinear System Identifikation

Courses

Title	Typ	Hrs/wk	CP
Linear and Nonlinear System Identification (L0660)	Lecture	2	3

Module Responsible	Prof. Herbert Werner
Admission Requirements	Control Systems Theory and Design
Recommended Previous Knowledge	• Classical control (frequency response, root locus) • State space methods • Discrete-time systems • Linear algebra, singular value decomposition • Basic knowledge about stochastic processes
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain the general framework of the prediction error method and its application to a variety of linear and nonlinear model structures • They can explain how multilayer perceptron networks are used to model nonlinear dynamics • They can explain how an approximate predictive control scheme can be based on neural network models • They can explain the idea of subspace identification and its relation to Kalman realisation theory
Skills	• Students are capable of applying the predicition error method to the experimental identification of linear and nonlinear models for dynamic systems • They are capable of implementing a nonlinear predictive control scheme based on a neural network model • They are capable of applying subspace algorithms to the experimental identification of linear models for dynamic systems • They can do the above using standard software tools (including the Matlab System Identification Toolbox)
Personal Competence	
Social Competence	Students can work in mixed groups on specific problems to arrive at joint solutions.
Autonomy	Students are able to find required information in sources provided (lecture notes, literature, software documentation) and use it to solve given problems.
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Credit points	3
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Control and Power Systems: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Theoretical Mechanical Engineering: Core qualification: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L0660: Linear and Nonlinear System Identification

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Herbert Werner
Language	EN
Cycle	SoSe
Content	• Prediction error method • Linear and nonlinear model structures • Nonlinear model structure based on multilayer perceptron network • Approximate predictive control based on multilayer perceptron network model • Subspace identification
Literature	• Lennart Ljung, System Identification - Theory for the User, Prentice Hall 1999 • M. Norgaard, O. Ravn, N.K. Poulsen and L.K. Hansen, Neural Networks for Modeling and Control of Dynamic Systems, Springer Verlag, London 2003 • T. Kailath, A.H. Sayed and B. Hassibi, Linear Estimation, Prentice Hall 2000

Module M0939: Control Lab A

Courses

Title	Typ	Hrs/wk	CP
Control Lab I (L1093)	Laboratory Course	1	1
Control Lab II (L1291)	Laboratory Course	1	1
Control Lab III (L1665)	Laboratory Course	1	1
Control Lab IV (L1666)	Laboratory Course	1	1

Module Responsible	Prof. Herbert Werner
Admission Requirements	•
Recommended Previous Knowledge	• State space methods • LQG control • H2 and H-infinity optimal control • uncertain plant models and robust control • LPV control
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain the difference between validation of a control lop in simulation and experimental validation
Skills	• Students are capable of applying basic system identification tools (Matlab System Identification Toolbox) to identify a dynamic model that can be used for controller synthesis • They are capable of using standard software tools (Matlab Control Toolbox) for the design and implementation of LQG controllers • They are capable of using standard software tools (Matlab Robust Control Toolbox) for the mixed-sensitivity design and the implementation of H-infinity optimal controllers • They are capable of representing model uncertainty, and of designing and implementing a robust controller • They are capable of using standard software tools (Matlab Robust Control Toolbox) for the design and the implementation of LPV gain-scheduled controllers
Personal Competence	
Social Competence	• Students can work in teams to conduct experiments and document the results
Autonomy	• Students can independently carry out simulation studies to design and validate control loops
Workload in Hours	Independent Study Time 64, Study Time in Lecture 56
Credit points	4
Examination	Colloquium
Examination duration and scale	
Assignment for the Following Curricula	Electrical Engineering: Specialisation Control and Power Systems: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Theoretical Mechanical Engineering: Core qualification: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L1093: Control Lab I

Typ	Laboratory Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Herbert Werner
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
Literature	Experiment Guides

Course L1291: Control Lab II	
Typ	Laboratory Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Antonio Mendez Gonzalez
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
Literature	Experiment Guides

Course L1665: Control Lab III	
Typ	Laboratory Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Herbert Werner
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
Literature	Experiment Guides

Course L1666: Control Lab IV	
Typ	Laboratory Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Herbert Werner
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
Literature	Experiment Guides

Module M0603: Nonlinear Structural Analysis

Courses

Title	Typ	Hrs/wk	CP
Nonlinear Structural Analysis (L0277)	Lecture	3	4
Nonlinear Structural Analysis (L0279)	Recitation Section (small)	1	2

Module Responsible	Prof. Alexander Düster
Admission Requirements	None
Recommended Previous Knowledge	Mathematics I, II, III, Mechanics I, II, III, IV Differential Equations 2 (Partial Differential Equations)
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to + give an overview of the different nonlinear phenomena in structural mechanics. + explain the mechanical background of nonlinear phenomena in structural mechanics. + to specify problems of nonlinear structural analysis, to identify them in a given situation and to explain their mathematical and mechanical background.
Skills	Students are able to + model nonlinear structural problems. + select for a given nonlinear structural problem a suitable computational procedure. + apply finite element procedures for nonlinear structural analysis. + critically verify and judge results of nonlinear finite elements. + to transfer their knowledge of nonlinear solution procedures to new problems.
Personal Competence	
Social Competence	Students are able to + solve problems in heterogeneous groups and to document the corresponding results. + share new knowledge with group members.
Autonomy	Students are able to + assess their knowledge by means of exercises and E-Learning.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	Civil Engineering: Specialisation Structural Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Civil Engineering: Elective Compulsory Materials Science: Specialisation Modelling: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Product Development, Materials and Production: Core qualification: Elective Compulsory Naval Architecture and Ocean Engineering: Core qualification: Elective Compulsory Ship and Offshore Technology: Core qualification: Elective Compulsory Theoretical Mechanical Engineering: Core qualification: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L0277: Nonlinear Structural Analysis	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Alexander Düster
Language	DE/EN
Cycle	WiSe
Content	1. Introduction 2. Nonlinear phenomena 3. Mathematical preliminaries 4. Basic equations of continuum mechanics 5. Spatial discretization with finite elements 6. Solution of nonlinear systems of equations 7. Solution of elastoplastic problems 8. Stability problems 9. Contact problems
Literature	[1] Alexander Düster, Nonlinear Structrual Analysis, Lecture Notes, Technische Universität Hamburg-Harburg, 2014. [2] Peter Wriggers, Nonlinear Finite Element Methods, Springer 2008. [3] Peter Wriggers, Nichtlineare Finite-Elemente-Methoden, Springer 2001. [4] Javier Bonet and Richard D. Wood, Nonlinear Continuum Mechanics for Finite Element Analysis, Cambridge University Press, 2008.

Course L0279: Nonlinear Structural Analysis	
Typ	Recitation Section (small)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Alexander Düster
Language	DE/EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0746: Microsystem Engineering

Courses

Title	Typ	Hrs/wk	CP
Microsystem Engineering (L0680)	Lecture	2	4
Microsystem Engineering (L0682)	Problem-based Learning	1	1
Microsystem Engineering (L0681)	Recitation Section (small)	1	1

Module Responsible	Prof. Manfred Kasper
Admission Requirements	
Recommended Previous Knowledge	Electrical Engineering Fundamentals
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students know about the most important technologies and materials of MEMS as well as their applications in sensors and actuators.
Skills	Students are able to analyze and describe the functional behaviour of MEMS components and to evaluate the potential of microsystems.
Personal Competence	
Social Competence	Students are able to solve specific problems alone or in a group and to present the results accordingly.
Autonomy	Students are able to acquire particular knowledge using specialized literature and to integrate and associate this knowledge with other fields.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Examination	Written exam
Examination duration and scale	zweistündig
Assignment for the Following Curricula	Electrical Engineering: Core qualification: Compulsory Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory International Management and Engineering: Specialisation II. Electrical Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Microelectronics and Microsystems: Core qualification: Elective Compulsory

Course L0680: Microsystem Engineering	
Typ	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Lecturer	Prof. Manfred Kasper
Language	EN
Cycle	WiSe
Content	Object and goal of MEMS Scaling Rules Lithography Film deposition Structuring and etching Energy conversion and force generation Electromagnetic Actuators Reluctance motors Piezoelectric actuators, bi-metal-actuator Transducer principles Signal detection and signal processing Mechanical and physical sensors Acceleration sensor, pressure sensor Sensor arrays System integration Yield, test and reliability
Literature	M. Kasper: Mikrosystementwurf, Springer (2000) M. Madou: Fundamentals of Microfabrication, CRC Press (1997)

Course L0682: Microsystem Engineering	
Typ	Problem-based Learning
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Manfred Kasper
Language	EN
Cycle	WiSe
Content	Examples of MEMS components Layout consideration Electric, thermal and mechanical behaviour Design aspects
Literature	Wird in der Veranstaltung bekannt gegeben

Course L0681: Microsystem Engineering	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Manfred Kasper
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0806: Technical Acoustics II (Room Acoustics, Computational Methods)

Courses

Title	Typ	Hrs/wk	CP
Technical Acoustics II (Room Acoustics, Computational Methods) (L0519)	Lecture	2	3
Technical Acoustics II (Room Acoustics, Computational Methods) (L0521)	Recitation Section (large)	2	3

Module Responsible	Prof. Otto von Estorff
Admission Requirements	none
Recommended Previous Knowledge	Technical Acoustics I (Acoustic Waves, Noise Protection, Psycho Acoustics) Mechanics I (Statics, Mechanics of Materials) and Mechanics II (Hydrostatics, Kinematics, Dynamics) Mathematics I, II, III (in particular differential equations)
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students possess an in-depth knowledge in acoustics regarding room acoustics and computational methods and are able to give an overview of the corresponding theoretical and methodical basis.
Skills	The students are capable to handle engineering problems in acoustics by theory-based application of the demanding computational methods and procedures treated within the module.
Personal Competence	
Social Competence	
Autonomy	The students are able to independently solve challenging acoustical problems in the areas treated within the module. Possible conflicting issues and limitations can be identified and the results are critically scrutinized.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Examination	Oral exam
Examination duration and scale	20-30 Minuten
Assignment for the Following Curricula	Aircraft Systems Engineering: Specialisation Cabin Systems: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Product Development, Materials and Production: Core qualification: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Product Development and Production: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L0519: Technical Acoustics II (Room Acoustics, Computational Methods)

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Otto von Estorff
Language	EN
Cycle	WiSe
Content	- Room acoustics - Sound absorber - Standard computations - Statistical Energy Approaches - Finite Element Methods - Boundary Element Methods - Geometrical acoustics - Special formulations - Practical applications - Hands-on Sessions: Programming of elements (Matlab)
Literature	Cremer, L.; Heckl, M. (1996): Körperschall. Springer Verlag, Berlin Veit, I. (1988): Technische Akustik. Vogel-Buchverlag, Würzburg Veit, I. (1988): Flüssigkeitsschall. Vogel-Buchverlag, Würzburg Gaul, L.; Fiedler, Ch. (1997): Methode der Randelemente in Statik und Dynamik. Vieweg, Braunschweig, Wiesbaden Bathe, K.-J. (2000): Finite-Elemente-Methoden. Springer Verlag, Berlin

Course L0521: Technical Acoustics II (Room Acoustics, Computational Methods)	
Typ	Recitation Section (large)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Otto von Estorff
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0832: Advanced Topics in Control

Courses

Title	Typ	Hrs/wk	CP
Advanced Topics in Control (L0661)	Lecture	2	3
Advanced Topics in Control (L0662)	Recitation Section (small)	2	3

Module Responsible	Prof. Herbert Werner
Admission Requirements	Optimal and Robust Control
Recommended Previous Knowledge	H-infinity optimal control, mixed-sensitivity design, linear matrix inequalities
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain the advantages and shortcomings of the classical gain scheduling approach • They can explain the representation of nonlinear systems in the form of quasi-LPV systems • They can explain how stability and performance conditions for LPV systems can be formulated as LMI conditions • They can explain how gridding techniques can be used to solve analysis and synthesis problems for LPV systems • They are familiar with polytopic and LFT representations of LPV systems and some of the basic synthesis techniques associated with each of these model structures • Students can explain how graph theoretic concepts are used to represent the communication topology of multiagent systems • They can explain the convergence properties of first order consensus protocols • They can explain analysis and synthesis conditions for formation control loops involving either LTI or LPV agent models • Students can explain the state space representation of spatially invariant distributed systems that are discretized according to an actuator/sensor array • They can explain (in outline) the extension of the bounded real lemma to such distributed systems and the associated synthesis conditions for distributed controllers
Skills	• Students are capable of constructing LPV models of nonlinear plants and carry out a mixed-sensitivity design of gain-scheduled controllers; they can do this using polytopic, LFT or general LPV models • They are able to use standard software tools (Matlab robust control toolbox) for these tasks • Students are able to design distributed formation controllers for groups of agents with either LTI or LPV dynamics, using Matlab tools provided • Students are able to design distributed controllers for spatially interconnected systems, using the Matlab MD-toolbox
Personal Competence	
Social Competence	Students can work in small groups and arrive at joint results.
Autonomy	Students are able to find required information in sources provided (lecture notes, literature, software documentation) and use it to solve given problems.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Aircraft Systems: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Theoretical Mechanical Engineering: Core qualification: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L0661: Advanced Topics in Control	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Herbert Werner
Language	EN
Cycle	WiSe
Content	• Linear Parameter-Varying (LPV) Gain Scheduling - Linearizing gain scheduling, hidden coupling - Jacobian linearization vs. quasi-LPV models - Stability and induced L2 norm of LPV systems - Synthesis of LPV controllers based on the two-sided projection lemma - Simplifications: controller synthesis for polytopic and LFT models - Experimental identification of LPV models - Controller synthesis based on input/output models - Applications: LPV torque vectoring for electric vehicles, LPV control of a robotic manipulator • Control of Multi-Agent Systems - Communication graphs - Spectral properties of the graph Laplacian - First and second order consensus protocols - Formation control, stability and performance - LPV models for agents subject to nonholonomic constraints - Application: formation control for a team of quadrotor helicopters • Control of Spatially Interconnected Systems - Multidimensional signals, l2 and L2 signal norm - Multidimensional systems in Roesser state space form - Extension of real-bounded lemma to spatially interconnected systems - LMI-based synthesis of distributed controllers - Spatial LPV control of spatially varying systems - Applications: control of temperature profiles, vibration damping for an actuated beam
Literature	• Werner, H., Lecture Notes "Advanced Topics in Control" • Selection of relevant research papers made available as pdf documents via StudIP

Course L0662: Advanced Topics in Control	
Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Herbert Werner
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0919: Laboratory: Analog and Digital Circuit Design

Courses

Title	Typ	Hrs/wk	CP
Laboratory: Analog Circuit Design (L0692)	Laboratory Course	2	3
Laboratory: Digital Circuit Design (L0694)	Laboratory Course	2	3

Module Responsible	Prof. Wolfgang Krautschneider
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge of semiconductor devices and circuit design
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain the structure and philosophy of the software framework for circuit design. • Students can determine all necessary input parameters for circuit simulation. • Students know the basics physics of the analog behavior. • Students are able to explain the functions of the logic gates of their digital design. • Students can explain the algorithms of checking routines. • Students are able to select the appropriate transistor models for fast and accurate simulations.
Skills	• Students can activate and execute all necessary checking routines for verification of proper circuit functionality. • Students are able to run the input desks for definition of their electronic circuits. • Students can define the specifications of the electronic circuits to be designed. • Students can optimize the electronic circuits for low-noise and low-power. • Students can develop analog circuits for mobile medical applications. • Students can define the building blocks of digital systems.
Personal Competence	
Social Competence	• Students are trained to work through complex circuits in teams. • Students are able to share their knowledge for efficient design work. • Students can help each other to understand all the details and options of the design software. • Students are aware of their limitations regarding circuit design, so they do not go ahead, but they involve experts when required. • Students can present their design approaches for easy checking by more experienced experts.
Autonomy	• Students are able to realistically judge the status of their knowledge and to define actions for improvements when necessary. • Students can break down their design work in sub-tasks and can schedule the design work in a realistic way. • Students can handle the complex data structures of their design task and document it in consice but understandable way. • Students are able to judge the amount of work for a major design project.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Examination	Written exam
Examination duration and scale	60 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Nanoelectronics and Microsystems Technology: Elective Compulsory Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Microelectronics and Microsystems: Core qualification: Elective Compulsory

Course L0692: Laboratory: Analog Circuit Design	
Typ	Laboratory Course
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Wolfgang Krautschneider
Language	DE
Cycle	WiSe
Content	• Input desk for circuits • Algorithms for simulation • MOS transistor model • Simulation of analog circuits • Placement and routing • Generation of layouts • Design checking routines • Postlayout simulations
Literature	Handouts to be distributed

Course L0694: Laboratory: Digital Circuit Design	
Typ	Laboratory Course
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Wolfgang Krautschneider
Language	DE
Cycle	SoSe
Content	• Definition of specifications • Architecture studies • Digital simulation flow • Philosophy of standard cells • Placement and routing of standard cells • Layout generation • Design checking routines
Literature	Handouts will be distributed

Module M0913: CMOS Nanoelectronics with Practice

Courses

Title	Typ	Hrs/wk	CP
CMOS Nanoelectronics (L0764)	Lecture	2	3
CMOS Nanoelectronics (L1063)	Laboratory Course	2	2
CMOS Nanoelectronics (L1059)	Recitation Section (small)	1	1

Module Responsible	Prof. Wolfgang Krautschneider
Admission Requirements	None
Recommended Previous Knowledge	Fundamentals of MOS devices and electronic circuits
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain the functionality of very small MOS transistors and explain the problems occurring due to scaling-down the minimum feature size. • Students are able to explain the basic steps of processing of very small MOS devices. • Students can exemplify the functionality of volatile and non-volatile memories und give their specifications. • Students can describe the limitations of advanced MOS technologies. • Students can explain measurement methods for MOS quality control.
Skills	• Students can quantify the current-voltage-behavior of very small MOS transistors and list possible applications. • Students can describe larger electronic systems by their functional blocks. • Students can name the existing options for the specific applications and select the most appropriate ones.
Personal Competence	
Social Competence	• Students can team up with one or several partners who may have different professional backgrounds • Students are able to work by their own or in small groups for solving problems and answer scientific questions.
Autonomy	• Students are able to assess their knowledge in a realistic manner. • The students are able to draw scenarios for estimation of the impact of advanced mobile electronics on the future lifestyle of the society.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory Electrical Engineering: Core qualification: Compulsory Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory International Management and Engineering: Specialisation II. Electrical Engineering: Elective Compulsory Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Microelectronics and Microsystems: Core qualification: Elective Compulsory

Course L0764: CMOS Nanoelectronics	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Wolfgang Krautschneider
Language	EN
Cycle	WiSe
Content	• Ideal and non-ideal MOS devices • Threshold voltage, Parasitic charges, Work function difference • I-V behavior • Scaling-down rules • Details of very small MOS transistors • Basic CMOS process flow • Memory Technology, SRAM, DRAM, embedded DRAM • Gain memory cells • Non-volatile memories, Flash memory circuits • Methods for Quality Control, C(V)-technique, Charge pumping, Uniform injection • Systems with extremely small CMOS transistors
Literature	• S. Deleonibus, Electronic Device Architectures for the Nano-CMOS Era, Pan Stanford Publishing, 2009. • Y. Taur and T.H. Ning, Fundamentals of Modern VLSI Devices, Cambridge University Press, 2nd edition. • R.F. Pierret, Advanced Semiconductor Fundamentals, Prentice Hall, 2003. • F. Schwierz, H. Wong, J. J. Liou, Nanometer CMOS, Pan Stanford Publishing, 2010. • H.-G. Wagemann und T. Schönauer, Silizium-Planartechnologie, Grundprozesse, Physik und Bauelemente Teubner-Verlag, 2003, ISBN 3519004674

Course L1063: CMOS Nanoelectronics	
Typ	Laboratory Course
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Wolfgang Krautschneider
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L1059: CMOS Nanoelectronics	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Wolfgang Krautschneider
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M1024: Methods of Integrated Product Development

Courses

Title	Typ	Hrs/wk	CP
Integrated Product Development II (L1254)	Lecture	3	3
Integrated Product Development II (L1255)	Problem-based Learning	2	3

Module Responsible	Prof. Dieter Krause
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge of Integrated product development and applying CAE systems
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	After passing the module students are able to: • explain technical terms of design methodology, • describe essential elements of construction management, • describe current problems and the current state of research of integrated product development.
Skills	After passing the module students are able to: • select and apply proper construction methods for non-standardized solutions of problems as well as adapt new boundary conditions, • solve product development problems with the assistance of a workshop based approach, • choose and execute appropriate moderation techniques.
Personal Competence	
Social Competence	After passing the module students are able to: • prepare and lead team meetings and moderation processes, • work in teams on complex tasks, • represent problems and solutions and advance ideas.
Autonomy	After passing the module students are able to: • give a structured feedback and accept a critical feedback, • implement the accepted feedback autonomous.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Examination	Oral exam
Examination duration and scale	30 Minuten
Assignment for the Following Curricula	Aircraft Systems Engineering: Specialisation Cabin Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Air Transportation Systems: Elective Compulsory International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Product Development and Production: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L1254: Integrated Product Development II	
Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Dieter Krause
Language	DE
Cycle	WiSe
Content	**Lecture** The lecture extends and enhances the learned content of the module “Integrated Product Development and lightweight design” and is based on the knowledge and skills acquired there. Topics of the course include in particular: • Methods of product development, • Presentation techniques, • Industrial Design, • Design for variety • Modularization methods, • Design catalogs, • Adapted QFD matrix, • Systematic material selection, • Assembly oriented design, Construction management • CE mark, declaration of conformity including risk assessment, • Patents, patent rights, patent monitoring • Project management (cost, time, quality) and escalation principles, • Development management for mechatronics, • Technical Supply Chain Management. **Exercise (PBL)** In the exercise the content presented in the lecture “Integrated Product Development II” and methods of product development and design management will be enhanced. Students learn an independently moderated and workshop based approach through industry related practice examples to solve complex and currently existing issues in product development. They will learn the ability to apply important methods of product development and design management autonomous and acquire further expertise in the field of integrated product development. Besides personal skills, such as teamwork, guiding discussions and representing work results will be acquired through the workshop based structure of the event under its own planning and management.
Literature	• Andreasen, M.M., Design for Assembly, Berlin, Springer 1985. • Ashby, M. F.: Materials Selection in Mechanical Design, München, Spektrum 2007. • Beckmann, H.: Supply Chain Management, Berlin, Springer 2004. • Hartmann, M., Rieger, M., Funk, R., Rath, U.: Zielgerichtet moderieren. Ein Handbuch für Führungskräfte, Berater und Trainer, Weinheim, Beltz 2007. • Pahl, G., Beitz, W.: Konstruktionslehre, Berlin, Springer 2006. • Roth, K.H.: Konstruieren mit Konstruktionskatalogen, Band 1-3, Berlin, Springer 2000. • Simpson, T.W., Siddique, Z., Jiao, R.J.: Product Platform and Product Family Design. Methods and Applications, New York, Springer 2013.

Course L1255: Integrated Product Development II	
Typ	Problem-based Learning
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Dieter Krause
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M1173: Applied Statistics

Courses

Title	Typ	Hrs/wk	CP
Applied Statistics (L1584)	Lecture	2	3
Applied Statistics (L1586)	Problem-based Learning	2	2
Applied Statistics (L1585)	Recitation Section (small)	1	1

Module Responsible	Prof. Michael Morlock
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge of statistical methods
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can explain the statistical methods and the conditions of their use.
Skills	Students are able to use the statistics program to solve statistics problems and to interpret and depict the results
Personal Competence	
Social Competence	Team Work, joined presentation of results
Autonomy	To understand and interpret the question and solve
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Examination	Written exam
Examination duration and scale	90 minutes, 28 questions
Assignment for the Following Curricula	Mechanical Engineering and Management: Specialisation Management: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Biomedical Engineering: Core qualification: Compulsory Product Development, Materials and Production: Core qualification: Elective Compulsory

Course L1584: Applied Statistics

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Michael Morlock
Language	DE/EN
Cycle	WiSe
Content	The goal is to introduce students to the basic statistical methods and their application to simple problems. The topics include: • Chi square test • Simple regression and correlation • Multiple regression and correlation • One way analysis of variance • Two way analysis of variance • Discriminant analysis • Analysis of categorial data • Chossing the appropriate statistical method • Determining critical sample sizes
Literature	Applied Regression Analysis and Multivariable Methods, 3rd Edition, David G. Kleinbaum Emory University, Lawrence L. Kupper University of North Carolina at Chapel Hill, Keith E. Muller University of North Carolina at Chapel Hill, Azhar Nizam Emory University, Published by Duxbury Press, CB © 1998, ISBN/ISSN: 0-534-20910-6

Course L1586: Applied Statistics	
Typ	Problem-based Learning
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Michael Morlock
Language	DE/EN
Cycle	WiSe
Content	The students receive a problem task, which they have to solve in small groups (n=5). They do have to collect their own data and work with them. The results have to be presented in an executive summary at the end of the course.
Literature	Selbst zu finden

Course L1585: Applied Statistics	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Michael Morlock
Language	DE/EN
Cycle	WiSe
Content	The different statistical tests are applied for the solution of realistic problems using actual data sets and the most common used commercial statistical software package (SPSS).
Literature	Student Solutions Manual for Kleinbaum/Kupper/Muller/Nizam's Applied Regression Analysis and Multivariable Methods, 3rd Edition, David G. Kleinbaum Emory University Lawrence L. Kupper University of North Carolina at Chapel Hill, Keith E. Muller University of North Carolina at Chapel Hill, Azhar Nizam Emory University, Published by Duxbury Press, Paperbound © 1998, ISBN/ISSN: 0-534-20913-0

Module M1204: Modelling and Optimization in Dynamics

Courses

Title	Typ	Hrs/wk	CP
Flexible Multibody Systems (L1632)	Lecture	2	3
Optimization of dynamical systems (L1633)	Lecture	2	3

Module Responsible	Prof. Robert Seifried
Admission Requirements	None
Recommended Previous Knowledge	• Mathematics I, II, III • Mechanics I, II, III, IV • Simulation of dynamical Systems
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students demonstrate basic knowledge and understanding of modeling, simulation and analysis of complex rigid and flexible multibody systems and methods for optimizing dynamic systems after successful completion of the module.
Skills	Students are able + to think holistically + to independently, securly and critically analyze and optimize basic problems of the dynamics of rigid and flexible multibody systems + to describe dynamics problems mathematically + to optimize dynamics problems
Personal Competence	
Social Competence	Students are able to + solve problems in heterogeneous groups and to document the corresponding results.
Autonomy	Students are able to + assess their knowledge by means of exercises. + acquaint themselves with the necessary knowledge to solve research oriented tasks.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Energy Systems: Core qualification: Elective Compulsory Aircraft Systems Engineering: Specialisation Aircraft Systems: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Product Development, Materials and Production: Core qualification: Elective Compulsory Theoretical Mechanical Engineering: Core qualification: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L1632: Flexible Multibody Systems	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Robert Seifried
Language	DE
Cycle	WiSe
Content	1. Basics of Multibody Systems 2. Basics of Continuum Mechanics 3. Linear finite element modelles and modell reduction 4. Nonlinear finite element Modelles: absolute nodal coordinate formulation 5. Kinematics of an elastic body 6. Kinetics of an elastic body 7. System assembly
Literature	Schwertassek, R. und Wallrapp, O.: Dynamik flexibler Mehrkörpersysteme. Braunschweig, Vieweg, 1999. Seifried, R.: Dynamics of Underactuated Multibody Systems, Springer, 2014. Shabana, A.A.: Dynamics of Multibody Systems. Cambridge Univ. Press, Cambridge, 2004, 3. Auflage.

Course L1633: Optimization of dynamical systems	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Robert Seifried
Language	DE
Cycle	WiSe
Content	1. Formulation and classification of optimization problems 2. Scalar Optimization 3. Sensitivity Analysis 4. Unconstrained Parameter Optimization 5. Constrained Parameter Optimization 6. Stochastic optimization 7. Multicriteria Optimization 8. Topology Optimization
Literature	Bestle, D.: Analyse und Optimierung von Mehrkörpersystemen. Springer, Berlin, 1994. Nocedal, J. , Wright , S.J. : Numerical Optimization. New York: Springer, 2006.

Module M1268: Linear and Nonlinear Waves

Courses

Title	Typ	Hrs/wk	CP
Linear and Nonlinear Waves (L1737)	Problem-based Learning	4	6

Module Responsible	Prof. Norbert Hoffmann
Admission Requirements	Master-Level
Recommended Previous Knowledge	Good Knowledge in Mathematics, Mechanics and Dynamics.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to reflect existing terms and concepts in Wave Mechanics and to develop and research new terms and concepts.
Skills	Students are able to apply existing methods and procesures of Wave Mechanics and to develop novel methods and procedures.
Personal Competence	
Social Competence	Students can reach working results also in groups.
Autonomy	Students are able to approach given research tasks individually and to identify and follow up novel research tasks by themselves.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Examination	Written exam
Examination duration and scale	2 Hours
Assignment for the Following Curricula	Computational Science and Engineering: Specialisation Scientific Computing: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Naval Architecture and Ocean Engineering: Core qualification: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Maritime Technology: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L1737: Linear and Nonlinear Waves

Typ	Problem-based Learning
Hrs/wk	4
CP	6
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Lecturer	Prof. Norbert Hoffmann
Language	DE/EN
Cycle	WiSe
Content	Introduction into the Dynamics of Linear and Nonlinear Waves.
Literature	G.B. Witham, Linear and Nonlinear Waves. Wiley 1999. C.C. Mei, Theory and Applications of Ocean Surface Waves. World Scientific 2004.

Module M1229: Control Lab B

Courses

Title	Typ	Hrs/wk	CP
Control Lab V (L1667)	Laboratory Course	1	1
Control Lab VI (L1668)	Laboratory Course	1	1

Module Responsible	Prof. Herbert Werner
Admission Requirements	
Recommended Previous Knowledge	• State space methods • LQG control • H2 and H-infinity optimal control • uncertain plant models and robust control • LPV control
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain the difference between validation of a control lop in simulation and experimental validation
Skills	• Students are capable of applying basic system identification tools (Matlab System Identification Toolbox) to identify a dynamic model that can be used for controller synthesis • They are capable of using standard software tools (Matlab Control Toolbox) for the design and implementation of LQG controllers • They are capable of using standard software tools (Matlab Robust Control Toolbox) for the mixed-sensitivity design and the implementation of H-infinity optimal controllers • They are capable of representing model uncertainty, and of designing and implementing a robust controller • They are capable of using standard software tools (Matlab Robust Control Toolbox) for the design and the implementation of LPV gain-scheduled controllers
Personal Competence	
Social Competence	• Students can work in teams to conduct experiments and document the results
Autonomy	• Students can independently carry out simulation studies to design and validate control loops
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Credit points	2
Examination	Colloquium
Examination duration and scale	
Assignment for the Following Curricula	Electrical Engineering: Specialisation Control and Power Systems: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Theoretical Mechanical Engineering: Core qualification: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L1667: Control Lab V

Typ	Laboratory Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Herbert Werner
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
Literature	Experiment Guides

Course L1668: Control Lab VI

Typ	Laboratory Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Herbert Werner
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
Literature	Experiment Guides

Module M1305: Seminar Advanced Topics in Control

Courses

Title	Typ	Hrs/wk	CP
Advanced Topics in Control (L1803)	Seminar	2	2

Module Responsible	Prof. Herbert Werner
Admission Requirements	None
Recommended Previous Knowledge	• Introduction to control systems • Control theory and design • optimal and robust control
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain modern control. • Students learn to apply basic control concepts for different tasks
Skills	• Students acquire knowledge about selected aspects of modern control, based on specified literature • Students generalize developed results and present them to the participants • Students practice to prepare and give a presentation
Personal Competence	
Social Competence	• Students are capable of developing solutions and present them • They are able to provide appropriate feedback and handle constructive criticism of their own results
Autonomy	• Students evaluate advantages and drawbacks of different forms of presentation for specific tasks and select the best solution • Students familiarize themselves with a scientific field, are able of introduce it and follow presentations of other students, such that a scientific discussion develops
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Credit points	2
Examination	Presentation
Examination duration and scale	90 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Control and Power Systems: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory

Course L1803: Advanced Topics in Control

Typ	Seminar
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Herbert Werner
Language	EN
Cycle	WiSe/SoSe
Content	• Seminar on selected topics in modern control
Literature	• To be specified

Thesis

Module M-002: Master Thesis

Courses

Title	Typ	Hrs/wk	CP

Module Responsible	Professoren der TUHH
Admission Requirements	• According to General Regulations §24 (1): At least 126 ECTS credit points have to be achieved in study programme. The examinations board decides on exceptions.
Recommended Previous Knowledge	
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• The students can use specialized knowledge (facts, theories, and methods) of their subject competently on specialized issues. • The students can explain in depth the relevant approaches and terminologies in one or more areas of their subject, describing current developments and taking up a critical position on them. • The students can place a research task in their subject area in its context and describe and critically assess the state of research.
Skills	The students are able: • To select, apply and, if necessary, develop further methods that are suitable for solving the specialized problem in question. • To apply knowledge they have acquired and methods they have learnt in the course of their studies to complex and/or incompletely defined problems in a solution-oriented way. • To develop new scientific findings in their subject area and subject them to a critical assessment.
Personal Competence	
Social Competence	Students can • Both in writing and orally outline a scientific issue for an expert audience accurately, understandably and in a structured way. • Deal with issues competently in an expert discussion and answer them in a manner that is appropriate to the addressees while upholding their own assessments and viewpoints convincingly.
Autonomy	Students are able: • To structure a project of their own in work packages and to work them off accordingly. • To work their way in depth into a largely unknown subject and to access the information required for them to do so. • To apply the techniques of scientific work comprehensively in research of their own.
Workload in Hours	Independent Study Time 900, Study Time in Lecture 0
Credit points	30
Examination	according to Subject Specific Regulations
Examination duration and scale	see FSPO
Assignment for the Following Curricula	Civil Engineering: Thesis: Compulsory Bioprocess Engineering: Thesis: Compulsory Chemical and Bioprocess Engineering: Thesis: Compulsory Computer Science: Thesis: Compulsory Electrical Engineering: Thesis: Compulsory Energy and Environmental Engineering: Thesis: Compulsory Energy Systems: Thesis: Compulsory Environmental Engineering: Thesis: Compulsory Aircraft Systems Engineering: Thesis: Compulsory Global Innovation Management: Thesis: Compulsory Computational Science and Engineering: Thesis: Compulsory Information and Communication Systems: Thesis: Compulsory International Production Management: Thesis: Compulsory International Management and Engineering: Thesis: Compulsory Joint European Master in Environmental Studies - Cities and Sustainability: Thesis: Compulsory Logistics, Infrastructure and Mobility: Thesis: Compulsory Materials Science: Thesis: Compulsory Mechanical Engineering and Management: Thesis: Compulsory Mechatronics: Thesis: Compulsory Biomedical Engineering: Thesis: Compulsory Microelectronics and Microsystems: Thesis: Compulsory Product Development, Materials and Production: Thesis: Compulsory Renewable Energies: Thesis: Compulsory Naval Architecture and Ocean Engineering: Thesis: Compulsory

	Ship and Offshore Technology: Thesis: Compulsory Theoretical Mechanical Engineering: Thesis: Compulsory Process Engineering: Thesis: Compulsory Water and Environmental Engineering: Thesis: Compulsory