Module Handbook

Bachelor‘s Degree Programme

Mechatronics

Technical University of Applied Sciences Würzburg-Schweinfurt

Bachelor‘s Degree Programme Mechatronics

Ignaz-Schön-Str. 11

97421 Schweinfurt

Basis: Study and Examination Regulations for the Mechatronics Bachelor's degree programme (SPO IMC) in the version dated 26th May 2021.

Contents

Study Plan

Study plan of the Bachelor’s Degree Programme Mechatronics

Structure and modular organisation of the programme in ECTS-Credit Points

<table>
<tr><th></th><th colspan="30">Creditpoints (CP)</th></tr>
<tr><th></th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th><th>11</th><th>12</th><th>13</th><th>14</th><th>15</th><th>16</th><th>17</th><th>18</th><th>19</th><th>20</th><th>21</th><th>22</th><th>23</th><th>24</th><th>25</th><th>26</th><th>27</th><th>28</th><th>29</th><th>30</th></tr>
<tr><td>1</td><td colspan="5">Engineering Mathematics 1 (1)</td><td colspan="5">Engineering Mathematics 2 (2)</td><td colspan="5">Physics (3)</td><td colspan="5">Programming 1 (4)</td><td colspan="5">Fundamentals of Electrical Engineering (5)</td><td colspan="5">Fundamentals of Mechanical Design with 3D-CAD (6)</td></tr>
<tr><td>2</td><td colspan="5">Engineering Mathematics 3 (7)</td><td colspan="5">Engineering Mathematics 4 (8)</td><td colspan="5">Microcomputer Systems 1 (9)</td><td colspan="5">Programming 2 (10)</td><td colspan="5">Electrical Engineering 1 (11)</td><td colspan="5">Engineering Mechanics 1 (12)</td></tr>
<tr><td>3</td><td colspan="5">General Electiv (GE) (13)</td><td colspan="5">Engineering Mechanics 2 and Machine Elements (14)</td><td colspan="5">Microcomputer Systems 2 (14)</td><td colspan="5">System Modeling 1 & System Theory (16)</td><td colspan="5">Electrical Engineering 2 (17)</td><td colspan="5">Engineering Mechanics 3 (18)</td></tr>
<tr><td>4</td><td colspan="5">Measuring Techniques (19)</td><td colspan="5">Actuators (20)</td><td colspan="5">Mechatronics Lab (21)</td><td colspan="5">Control Systems 1 (22)</td><td colspan="5">Logical Control and Software Engineering (23)</td><td colspan="5">Embedded Systems and Fieldbuses (24)</td></tr>
<tr><td>5</td><td colspan="5">System Modeling 2 (25)</td><td colspan="5">Control Systems 2 (26)</td><td colspan="5">Specialization A, Module A1 (27)</td><td colspan="5">Specialization A, Module A2 (28)</td><td colspan="5">Specialization B, Module B1 (29)</td><td colspan="5">Specialization B, Module B2 (30)</td></tr>
<tr><td>6</td><td colspan="24">Internship (31)</td><td colspan="6">Engineering Seminar (32)</td></tr>
<tr><td>7</td><td colspan="5">General Engineering Lab (33)</td><td colspan="8">Industrial Project (34)</td><td colspan="11">Bachelor's Thesis (35)</td><td colspan="6">Costing and Ethics for Engineers (36)</td></tr>
</table>

2 First Part of Studies, 1st to 3rd Semester

Subject Area: Mathematics

Responsible for subject area: Prof. Dr. rer. nat. H.-J. Meier

Module No. (according to appendix 2 to the SPO)**: 1**			
Engineering Mathematics 1			
Module length	**Frequency**	**Workload**	**ECTS Credit Points**
1 semester	Winter semester	Total: 150 hrs 60 hrs attendance time (4 SWS) 60 hrs self-directed study time 30 hrs time for exam preparation	5
Responsible for module: Prof. Dr. S. Mark			
Lecturer(s):			
Prof. Dr. S. Mark, Prof. Dr. M. Bier, Prof. Dr. K. Diethelm, Prof. Dr. H. Walter, Prof. Dr. G. Wimmer, Prof. Dr. C. Zirkelbach			
Associated course(s)		**Teaching and learning format**	**Language of instruction**
Engineering Mathematics 1		Seminar-like lectures, Exercise course	English
Applicability and semester of study (according to Appendix 2 to the SPO):			
Bachelor programme Mechatronics (mandatory module, 1st semester)			
Provides basis for module(s): Builds upon module(s):	Engineering Mathematics 3 and 4 (7,8)		
Mandatory participation requirements (according to appendix 2 of the SPO)			
none			
Recommended prerequisites and previous knowledge			
School knowledge in mathematics			
Examination type / requirement for the award of credit points	**Examination length**	**Examination language**	
written exam	90 min	English	
The concrete definition of the duration of the examination, the scope of the examination and further examination conditions (e.g. permitted aids) is made in the examination conditions. These are published on the intranet at the beginning of each semester.			

Learning outcomes (after successful completion of the module)

The students

- name the most important terms, especially in linear algebra and elementary math such as vectors matrices, complex numbers and partial fraction
- use vectors for calculations
- use matrices for calculations
- use complex numbers for calculations
- apply the Gauss algorithm
- solve systems of linear equations
- calculate eigenvalues and eigenvectors
- express rational function due to its partial fraction
- apply mathematics for solving elementary engineering problems.

Content

- Complex numbers
- Vectors calculations in space
- Matrices and vectors
- Systems of linear equations
- Partial fraction

Literature and other learning opportunities

- J. Stewart, *Calculus (Early transcendentals)*, 8th edition. Boston: Cengage Learning, 2016.
- K. A. Stroud, *Engineering Mathematics*, 7th edition. London: Palgrave Macmillan, 2013.
- Lecture notes and exercise sheet on eLearning of THWS.

Special notes

Module No. (according to appendix 2 to the SPO): **2**			
Engineering Mathematics 2			
Module length	**Frequency**	**Workload**	**ECTS Credit Points**
1 semester	Winter semester	Total: 150 hrs 60 hrs attendance time (4 SWS) 60 hrs self-directed study time 30 hrs time for exam preparation	5
Responsible for module: Prof. Dr. S. Mark			
Lecturer(s):			
Prof. Dr. S. Mark, Prof. Dr. M. Bier, Prof. Dr. K. Diethelm, Prof. Dr. H. Walter, Prof. Dr. G. Wimmer, Prof. Dr. C. Zirkelbach			
Associated course(s)		**Teaching and learning format**	**Language of instruction**
Engineering Mathematics 2		Seminar-like lectures, Exercise course	English
Applicability and semester of study (according to Appendix 2 to the SPO):			
Bachelor programme Mechatronics (mandatory module, 1st semester)			
Provides basis for module(s): Builds upon module(s):	Engineering Mathematics 3 and 4 (7, 8)		
Mandatory participation requirements (according to appendix 2 of the SPO)			
none			
Recommended prerequisites and previous knowledge			
School knowledge in mathematics			
Examination type / requirement for the award of credit points	**Examination length**	**Examination language**	
written exam	90 min	English	
The concrete definition of the duration of the examination, the scope of the examination and further examination conditions (e.g. permitted aids) is made in the examination conditions. These are published on the intranet at the beginning of each semester.			
Learning outcomes (after successful completion of the module)			
The students • name the most important terms, especially in analysis such as functions, limits, differential and integral calculus of one variable and functions of several variables • use elementary functions • calculate limits • calculate derivatives and linearize functions • calculate areas • use differential calculus for optimizing • calculate critical points in one and multidimensional problems • apply mathematics for solving elementary engineering problems.			

Content
• Functions • Limits • Differential calculus of one variable • Integral calculus • Functions of several variables
Literature and other learning opportunities
• J. Stewart, *Calculus (Early transcendentals)*, 8th edition. Boston: Cengage Learning, 2016. • K. A. Stroud, *Engineering Mathematics*, 7th edition. London: Palgrave Macmillan, 2013. • Lecture notes and exercise sheet on eLearning of THWS.
Special notes

Module No. (according to appendix 2 to the SPO): 7

Engineering Mathematics 3

Module length	Frequency	Workload	ECTS Credit Points
1 semester	Summer semester	Total: 150 hrs 60 hrs attendance time (4 SWS) 60 hrs self-directed study time 30 hrs time for exam preparation	5

Responsible for module: Prof. Dr. S. Mark

Lecturer(s):

Prof. Dr. S. Mark, Prof. Dr. M. Bier, Prof. Dr. K. Diethelm, Prof. Dr. H. Walter, Prof. Dr. G. Wimmer, Prof. Dr. C. Zirkelbach

Associated course(s)	Teaching and learning format	Language of instruction
Engineering Mathematics 3	Seminar-like lectures, Exercise course	English

Applicability and semester of study (according to Appendix 2 to the SPO):

Bachelor programme Mechatronics (mandatory module, 2nd semester)

Provides basis for module(s):	Contents are used in advanced engineering courses, especially in the modules System Modelling 1 & System Theory and Control Systems 1 (16,22).
Builds upon module(s):	Engineering mathematics 1 and 2 (1,2)

Mandatory participation requirements (according to appendix 2 of the SPO)

none

Recommended prerequisites and previous knowledge

Examination type / requirement for the award of credit points	Examination length	Examination language
written exam	90 min	English

The concrete definition of the duration of the examination, the scope of the examination and further examination conditions (e.g. permitted aids) is made in the examination conditions. These are published on the intranet at the beginning of each semester.

Learning outcomes (after successful completion of the module)

The students

- name the most important terms, especially in advanced mathematical analysis and applied engineering mathematics: double integrals, differential equations, Fourier series, Laplace transform and Fourier transform
- give examples of double integrals in physics and engineering applications
- distinguish between ordinary and partial differential equations
- solve certain types of ordinary differential equations
- calculate the Fourier series of periodic functions
- solve linear ordinary differential equations (as well as systems) with the help of Laplace transform
- apply the Fourier transform
- apply mathematics for solving elementary engineering problems.

Content
• Double integrals • Differential equations • Laplace transform • Fourier series • Fourier transform
Literature and other learning opportunities
• J. Stewart, *Calculus (Early transcendentals)*, 8th edition. Boston: Cengage Learning, 2016. • K. A. Stroud, *Engineering Mathematics*, 7th edition. London: Palgrave Macmillan, 2013. • Lecture notes and exercise sheet on eLearning of THWS.
Special notes

Module No. (according to appendix 2 to the SPO): 8

Engineering Mathematics 4

Module length	Frequency	Workload	ECTS Credit Points
1 semester	Summer semester	Total: 150 hrs 60 hrs attendance time (4 SWS) 60 hrs self-directed study time 30 hrs time for exam preparation	5

Responsible for module: Prof. Dr. H. Walter

Lecturer(s):

Prof. Dr. M. Bodewig, Prof. Dr. K. Diethelm, Prof. Dr. S. Mark, Prof. Dr. H. Walter, Prof. Dr. G. Wimmer

Associated course(s)	Teaching and learning format	Language of instruction
Engineering Mathematics 4	Seminar-like lectures, Exercise course	English

Applicability and semester of study (according to Appendix 2 to the SPO):

Bachelor programme Mechatronics (mandatory module, 2nd semester)

Provides basis for module(s):	System Modeling 1 & System Theory, Measuring Techniques, Control Systems 1, System Modeling 2 (16, 19, 22, 25)
Builds upon module(s):	Engineering Mathematics 1 and Engineering Mathematics 2 (1,2)

Mandatory participation requirements (according to appendix 2 of the SPO)

none

Recommended prerequisites and previous knowledge

Examination type / requirement for the award of credit points	Examination length	Examination language
written exam	90 min	English

The concrete definition of the duration of the examination, the scope of the examination and further examination conditions (e.g. permitted aids) is made in the examination conditions. These are published on the intranet at the beginning of each semester.

Learning outcomes (after successful completion of the module)

The students

- name the basic types of errors and compute the propagation of errors
- recall the representation of numbers in computers
- solve systems of linear equations with the help of adequate direct and iterative approaches
- interpolate measured data by means of polynomials and cubic splines
- apply the least-squares-method to large data sets
- approximate functions by the use of Taylor polynomials
- differentiate numerically
- calculate an approximate solution of definite integrals with the help of suitable quadrature formulas
- discretise ordinary differential equations and apply one-step procedures for their solution
- solve non-linear equations with appropriate iteration methods
- implement numerical approaches using an adequate programming language.

Content

- Error calculation and machine numbers
- Numerical procedures for the solution of systems of linear equations
- Interpolation, regression and approximation
- Numerical differentiation and integration
- Numerical approaches for the solution of ordinary differential equations
- Iterative solution methods for non-linear equations

Programming using a mathematical software

Literature and other learning opportunities

- J. Stoer, R. Bulirsch, *Introduction to Numerical Analysis (Texts in Applied Mathematics)*, 3rd edition. New York: Springer, 2010.
- R.L. Burden, J.D. Faires, *Numerical Analysis*, 9th edition. Boston: Brooks Cole, 2010.
- F. B. Hildebrand, *Introduction to Numerical Analysis*, 2nd edition. New York: Dover Publications, 1987.
- Jeffery J. Leader, *Numerical Analysis and Scientific Computation*, 1st edition. Boston: Addison Wesley, 2004.
- Erwin Kreyszig, *Advanced Engineering Mathematics*, 10th edition. Hoboken: John Wiley & Sons, 2011.
- P. Deuflhard, A. Hohmann, *Numerical Analysis in Modern Scientific Computing*, 2nd Edition. Berlin: Springer, 2003.
- G.M. Phillips, P.J. Taylor, *Theory and Applications of Numerical Analysis*, 2nd edition. London: Academic Press, 1996.
- C.P. Lopez, *MATLAB Programming for Numerical Analysis.* New York: Springer Science+Business Media, 2014.
- Lecture notes in the THWS eLearning system, Schweinfurt: 2021.

Special notes

Subject Area: Programming

Responsible for subject area: Prof. Dr. Ph.D. N. Strobel

Module No. (according to appendix 2 to the SPO): 4

Programming 1

Module length	Frequency	Workload	ECTS Credit Points
1 semester	Winter semester	Total: 150 hrs 60 hrs attendance time (4 SWS) 60 hrs self-directed study time 30 hrs time for exam preparation	5

Responsible for module: Prof. Dr. Ph.D. Strobel

Lecturer(s):
Prof. Dr. Ph.D. Strobel

Associated course(s)	Teaching and learning format	Language of instruction
Programming 1	Seminar-like lectures, Exercise course	English

Applicability and semester of study (according to Appendix 2 to the SPO):
Bachelor programme Mechatronics (mandatory module, 1st semester)

Provides basis for module(s):	Programming 2 (10)
Builds upon module(s):	

Mandatory participation requirements (according to appendix 2 of the SPO)
none

Recommended prerequisites and previous knowledge
Experience with some first programming language, e.g. Java, JavaScript, Arduino C++, or similar.

Examination type / requirement for the award of credit points	Examination length	Examination language
written exam	90 min	English

The concrete definition of the duration of the examination, the scope of the examination and further examination conditions (e.g. permitted aids) is made in the examination conditions. These are published on the intranet at the beginning of each semester.

Learning outcomes (after successful completion of the module)
The students
- name the essential C/C++ data types, control structures, and abstraction mechanisms
- review procedural C++ programs, understand their behavior, and eliminate programming errors
- develop designs for small procedural programs based on written requirements
- implement procedural C++ programs to solve given problems

Content
- variables, data types, namespaces, expressions, operators, operands, assignments
- control structures, functions, C-arrays and pointers, C++ arrays, vectors, strings

Literature and other learning opportunities
• P.J. Deitel, H. Deitel, *C++ How to Program (Global Ed.)*, 10th Edition. Harlow, England: Pearson, 2017.
Special notes
Conducting independent studies to solve programming exercises on the computer is central to learning C++.

Module No. (according to appendix 2 to the SPO): 10

Programming 2

Module length	Frequency	Workload	ECTS Credit Points
1 semester	Summer semester	Total: 150 hrs 60 hrs attendance time (4 SWS) 60 hrs self-directed study time 30 hrs time for exam preparation	5

Responsible for module: Prof. Dr. Ph.D. Strobel

Lecturer(s):

Prof. Dr. Ph.D. Strobel

Associated course(s)	Teaching and learning format	Language of instruction
Programming 2	Seminar-like lectures, Exercise course	English

Applicability and semester of study (according to Appendix 2 to the SPO):

Bachelor programme Mechatronics (mandatory module, 2nd semester)

Provides basis for module(s):	Microcomputer Systems, Logical Control and Software Engineering, Embedded Systems and Fieldbuses (9,23,24)
Builds upon module(s):	Programming 1 (4)

Mandatory participation requirements (according to appendix 2 of the SPO)

none

Recommended prerequisites and previous knowledge

Good knowledge of procedural programming with C++.

Examination type / requirement for the award of credit points	Examination length	Examination language
written exam	90 min	English

The concrete definition of the duration of the examination, the scope of the examination and further examination conditions (e.g. permitted aids) is made in the examination conditions. These are published on the intranet at the beginning of each semester.

Learning outcomes (after successful completion of the module)

The students

- name basic object-oriented concepts, e.g., encapsulation, separation of concerns, classes, inheritance, polymorphism
- analyze given C++ programs and examine their behavior
- apply object-oriented programming principles to solve selected programming tasks
- compose object-oriented C++ programs using the C++ standard library.

Content

- classes, inheritance, operator overloading, polymorphism
- stream input/output, error handling (exceptions), templates

Literature and other learning opportunities

- P.J. Deitel, H. Deitel, *C++ How to Program (Global Ed.)*, 10th Edition. Harlow, England: Pearson, 2017.

Special notes
Programming skills can only be acquired through practice. This requires time and effort.

Module No. (according to appendix 2 to the SPO): 9			
Microcomputer Systems 1			
Module length	**Frequency**	**Workload**	**ECTS Credit Points**
1 semester	Summer semester	Total: 150 hrs 60 hrs attendance time (4 SWS) 60 hrs self-directed study time 30 hrs time for exam preparation	5
Responsible for module: Prof. Dr.rer.-nat. Mathes			
Lecturer(s):			
Prof. Dr.rer.-nat. Mathes			
Associated course(s)		**Teaching and learning format**	**Language of instruction**
Microcomputer Systems 1		Seminar-like lectures, Exercise course	English
Applicability and semester of study (according to Appendix 2 to the SPO):			
Bachelor programme Mechatronics (mandatory module, 2nd semester)			
Provides basis for module(s):			
Builds upon module(s):	Programming 1, Engineering Mathematics 1 (4,1)		
Mandatory participation requirements (according to appendix 2 of the SPO)			
none			
Recommended prerequisites and previous knowledge			
Fundamental knowledge in programming and mathematics			

Examination type / requirement for the award of credit points	**Examination length**	**Examination language**
written exam	90 min	English

The concrete definition of the duration of the examination, the scope of the examination and further examination conditions (e.g. permitted aids) is made in the examination conditions. These are published on the intranet at the beginning of each semester.

Learning outcomes (after successful completion of the module)

The students

- apply various number systems
- analyze, synthesize and optimize digital circuits
- develop and analyze time-dependent digital circuits and finite-state machines.

Content

- binary and hexadecimal number representation
- addition, subtraction and multiplication in the binary system
- calculation rules of boolean algebra
- digital circuit design and basic circuits
- classification and use of bi-stable flip-flops

Literature and other learning opportunities
• Michael Collier, Svetlana Bebova, Wendy Weu, *Digital Circuit Design: Principles and Practice*, 1st edition. North Charleston: CreateSpace, 2014. • Anil K. Maini, *Digital Electronics: Principles, Devices and Applications*, 1st edition. West Sussex: John Wiley & Sons Ltd., 2007. • Neil Weste, David M. Harris, *CMOS VLSI Design: A Ciruits and Systems Perspective*, 4th edition. London: Pearson Education Inc., 2010.
Special notes

Module No. (according to appendix 2 to the SPO): **15**

Microcomputer Systems 2

Module length	**Frequency**	**Workload**	**ECTS Credit Points**
1 semester	winter semester	Total: 150 hrs 60 hrs attendance time (4 SWS) 60 hrs self-directed study time 30 hrs time for exam preparation	5

Responsible for module: Prof. Dr.rer.-nat. Mathes

Lecturer(s):

Prof. Dr.rer.-nat. Mathes

Associated course(s)	**Teaching and learning format**	**Language of instruction**
Microcomputer Systems 2	Seminar-like lectures, Exercise course	English

Applicability and semester of study (according to Appendix 2 to the SPO):

Bachelor programme Mechatronics (mandatory module, 3rd semester)

Provides basis for module(s):	
Builds upon module(s):	Microcomputer Systems 1 (9)

Mandatory participation requirements (according to appendix 2 of the SPO)

none

Recommended prerequisites and previous knowledge

Fundamental knowledge in programming and mathematics

Examination type / requirement for the award of credit points	**Examination length**	**Examination language**
written exam	90 min	English

The concrete definition of the duration of the examination, the scope of the examination and further examination conditions (e.g. permitted aids) is made in the examination conditions. These are published on the intranet at the beginning of each semester.

Learning outcomes (after successful completion of the module)

The students

- explain the correlation between CPU, memory, periphery and bus system
- implement software in machine language on microcontrollers
- code / decode information using different encoding schemes
- apply methods for error detection and error correction.

Content

- overview of different processor and microcontroller architectures
- fundamental elements of a microcomputer and microcontroller
- representation of data using different encodings
- modern computer architectures

Literature and other learning opportunities
• Michael Collier, Svetlana Bebova, Wendy Weu, *Digital Circuit Design: Principles and Practice*, 1st edition. North Charleston: CreateSpace, 2014. • Anil K. Maini, *Digital Electronics: Principles, Devices and Applications*, 1st edition. West Sussex: John Wiley & Sons Ltd., 2007. • Neil Weste, David M. Harris, *CMOS VLSI Design: A Ciruits and Systems Perspective*, 4th edition. London: Pearson Education Inc., 2010.
Special notes

Subject Area: Electrical Engineering

Responsible for subject area: Prof. Dr. rer. nat. H. Endres

Module No. (according to appendix 2 to the SPO): 5

Fundamentals of Electrical Engineering

Module length	Frequency	Workload	ECTS Credit Points
1 semester	Winter semester	Total: 150 hrs 60 hrs attendance time (4 SWS) 30 hrs self-directed study time 30 hrs time for exam preparation	5

Responsible for module: Prof. Dr.-Ing. Hansmann

Lecturer(s):

Prof. Dr.-Ing. Hansmann

Associated course(s)	Teaching and learning format	Language of instruction
Fundamentals of Electrical Engineering	Seminar-like lectures, Exercise course	English

Applicability and semester of study (according to Appendix 2 to the SPO):

Bachelor programme Mechatronics (mandatory module, 1st semester)

Provides basis for module(s):	Electrical Engineering 1 (11)
Builds upon module(s):	

Mandatory participation requirements (according to appendix 2 of the SPO)

none

Recommended prerequisites and previous knowledge

Attending "Engineering Mathematics 1+2" in parallel.

Examination type / requirement for the award of credit points	Examination length	Examination language
written exam	90 min	English

The concrete definition of the duration of the examination, the scope of the examination and further examination conditions (e.g. permitted aids) is made in the examination conditions. These are published on the intranet at the beginning of each semester.

Learning outcomes (after successful completion of the module)

The students

- comprehend basic definitions of electrical engineering and the physics of current and voltage
- name different methods for analyzing linear electric networks and apply these methods accordingly
- apply complex numbers to describe sinusoidal currents and voltages in single- and multi-phase circuits
- interpret the dynamics of passive components, and design frequency-responsive circuits to filter a signal.

Content
• Basics of Direct Current circuits (resistance, current, voltage, power) • Kirchhoff laws and circuit transformation • Systematic analysis of linear circuits • Basics of alternating current circuits • Phasor diagrams to describe sinusoidal currents and voltages • Frequency-responsive behavior of passive electric networks • Analog filters • Three-phase circuits
Literature and other learning opportunities
• J.W. Nilsson, S.A. Riedel, *Electric Circuits*, 11th edition. London: Pearson, 2019. • J.D. Irwin, R.M. Nelms, *Engineering Circuit Analysis*, 10th edition. Hoboken: Wiley, 2011. • T.L. Floyd, *Principles of Electric Circuits*, 9th edition. London: Pearson, 2009. • C.K. Alexander, M.N.O. Sadiku, *Fundamentals of Electric Circuits*, 6th edition. New York City: McGraw-Hill Education, 2016. • J. Hansmann, *slides and additional material (e-learning)*, Schweinfurt, 2021.
Special notes

Module No. (according to appendix 2 to the SPO)**: 11**

Electrical Engineering 1

Module length	**Frequency**	**Workload**	**ECTS Credit Points**
1 semester	Summer semester	Total: 150 hrs 60 hrs attendance time (4 SWS) 60 hrs self-directed study time 30 hrs time for exam preparation	5

Responsible for module: Prof. Dr.-Ing. Hansmann

Lecturer(s):

Prof. Dr.-Ing. Hansmann

Associated course(s)	**Teaching and learning format**	**Language of instruction**
Electrical Engineering 1	Seminar-like lectures, Exercise course	English

Applicability and semester of study (according to Appendix 2 to the SPO):

Bachelor programme Mechatronics (mandatory module, 2nd semester)

Provides basis for module(s):	Electrical Engineering 2 (17)
Builds upon module(s):	Fundamentals of Electrical Engineering (5)

Mandatory participation requirements (according to appendix 2 of the SPO)

none

Recommended prerequisites and previous knowledge

Circuit analysis in Direct Current and Alternating Current circuits.

Examination type / requirement for the award of credit points	**Examination length**	**Examination language**
written exam	90 min	English

The concrete definition of the duration of the examination, the scope of the examination and further examination conditions (e.g. permitted aids) is made in the examination conditions. These are published on the intranet at the beginning of each semester.

Learning outcomes (after successful completion of the module)

The students

- describe the transient response of a dynamic electric circuit
- construct, calculate and draw the physics of electric and magnetic fields
- name relevant components of electronics
- design circuits based on passive and active components.

Content

- Dynamic electric circuits
- Electric and magnetic fields
- Induction
- Passive components
- Active components
- Semi-conductors
- Circuit design

Literature and other learning opportunities
• R.C. Dorf, *The Engineering Handbook*, 2nd edition. Raton: CRC Press Inc., 2004. • S.N. Makarov, R. Ludwig, S.J. Bitar, *Practical Electrical Engineering*, 2nd edition. Berlin: Springer, 2019. • J. Hansmann, *slides and additional material (eLearning)*, Schweinfurt: 2021.
Special notes

Module No. (according to appendix 2 to the SPO): **17**			
Electrical Engineering 2			
Module length	**Frequency**	**Workload**	**ECTS Credit Points**
1 semester	Winter semester	Total: 150 hrs 60 hrs attendance time (4 SWS) 60 hrs self-directed study time 30 hrs time for exam preparation	5
Responsible for module: Prof. Dr. Tobias Kaupp			
Lecturer(s):			
Prof. Dr. Kaupp			
Associated course(s)		**Teaching and learning format**	**Language of instruction**
Electrical Engineering 2		Seminar-like lectures, Exercise course	English
Applicability and semester of study (according to Appendix 2 to the SPO):			
Bachelor programme Mechatronics (mandatory module, 3rd semester)			
Provides basis for module(s):	Control Systems 1 (22)		
Builds upon module(s):	Fundamentals of Electrical Engineering, Electrical Engineering 1 (5,11), Engineering Mathematics 1-4 (1,2,7,8)		
Mandatory participation requirements (according to appendix 2 of the SPO)			
none			
Recommended prerequisites and previous knowledge			

Examination type / requirement for the award of credit points	**Examination length**	**Examination language**
written exam	90 min	English

The concrete definition of the duration of the examination, the scope of the examination and further examination conditions (e.g. permitted aids) is made in the examination conditions. These are published on the intranet at the beginning of each semester.

Learning outcomes (after successful completion of the module)

The students

- analyse and calculate operating parameters of elementary four-pole networks and interconnections of those
- explain the transient behaviour of electrical circuits
- determine a mathematical description of a linear dynamic system in form of a differential equation
- calculate solutions to 2nd order differential equations with constant coefficients
- explain the purpose and application of transfer functions to analyse electrical systems
- determine the output signals of a system described by a transfer function given different types of input signals
- apply the abovementioned methods to technical systems, including non-electrical systems.

Content
• Four-pole equations, elementary four-pole networks, combining elementary four-pole networks, calculating operating parameters. • Determining differential equations for systems with one or two energy storage components, finding solutions in the time and Laplace domain, significance and determination of initial conditions. • Determination of a system's transfer function, finding the step/impulse response and frequency response, making statements about stability.
Literature and other learning opportunities
• T. Kaupp and G. Schormann, Lecture notes and exercises provided on the THWS eLearning platform, Schweinfurt: 2021. • Van Valkenburg, M. E, *Network Analysis,* 3rd edition. New Delhi, India: PHI, Pearson Education, 2002. • Paul J. Nahin, *Transients for Electrical Engineers*, Springer International Publishing, 2018.
Special notes

Subject Area: Mechanical Engineering

Responsible for subject area: Prof. Dr.-Ing. R. Schlachter

Module No. (according to appendix 2 to the SPO): 6

Fundamentals of Mechanical Design with 3D-CAD

Module length	Frequency	Workload	ECTS Credit Points
1 semester	Winter semester	Total: 150 hrs 60 hrs attendance time (4 SWS) 60 hrs self-directed study time 30 hrs time for exam preparation	5

Responsible for module: Prof. Dr.-Ing. Hofmann

Lecturer(s):

Prof. Dr.-Ing. D. Jung, Prof. Dr.-Ing. A. Hofmann, Prof. Dr.-Ing. Ch. Bunsen, Prof. Dr.-Ing. J. Meyer, Prof. Dr.-Ing. T. Felsner

Associated course(s)	Teaching and learning format	Language of instruction
3D-CAD Lab (CADLab; 1 SWS)	Lab course	English
Fundamentals of Mechanical Design (MD; 4 SWS)	Seminar-like lectures, Exercise course	English

Applicability and semester of study (according to Appendix 2 to the SPO):

Bachelor programme Mechatronics (mandatory module, 1st semester)

Provides basis for module(s):	Engineering Mechanics 1 (12), Engineering Mechanics 2 and Machine Elements (14), Industrial Project (34), Bachelor's Thesis (35)
Builds upon module(s):	

Mandatory participation requirements (according to appendix 2 of the SPO)

none

Recommended prerequisites and previous knowledge

Examination type / requirement for the award of credit points	Examination length	Examination language
(MD) written exam	90 min	English
(CADLab) other examination performance	Practical examination	English

The concrete definition of the duration of the examination, the scope of the examination and further examination conditions (e.g. permitted aids) is made in the examination conditions. These are published on the intranet at the beginning of each semester.

Learning outcomes (after successful completion of the module)
The students • efficiently apply technical standards in an industrial development process • explain material basics and assess various materials suitability for specific applications • interpret general phase diagrams in order to derive a materials behaviour in manufacturing and application • assess properties of a specific steel based on the interpretation of its iron-carbon diagram • preselect non-ferrous or non-metallic engineering materials in a product development project • draw and interpret technical drawings as part of technical communication • handle a CAD-system in order to create simple technical drawings and assembly models • derive tolerances from functional requirements and interpret them in a technical drawing • assess function and suitability of selected machine elements with regard to a specific application in an expert talk • assess the suitability of various manufacturing processes with regard to a given application • structure a development process and work on its sub tasks using established development methods.
Content
see description of the individual courses
Literature and other learning opportunities
• K.H. Grote et. al., *Springer Handbook of Mechanical Engineering*. New York: Springer, 2009. • J. Bartenschlager, *Metal Engineering Textbook*, 1st english edition. Haan-Gruiten: Europa-Lehrmittel, 2016. • P. Childs, *Mechanical design engineering handbook*. Amsterdam: Elsevier Butterworth-Heinemann, 2014. • K.H. Grote et. al., *Taschenbuch für den Maschinenbau*, 25. Auflage. Berlin: Springer Vieweg, 2018. • H. Hoischen, T*echnisches Zeichnen: Grundlagen, Normen, Beispiele, Darstellende Geometrie*, 37. Auflage. Berlin: Cornelsen, 2020 • H.-J. Bargel, G. Schulze, *Werkstoffkunde*, 12. Auflage. Berlin: Springer Vieweg, 2018 • W. Callister, *Materials Science and Engineering - An Introduction*, 10th edition. Hoboken: Wiley, 2020. • G. Pahl, W. Beitz, *Engineering Design – A Systematic Approach*, 3rd edition. London: Springer 2007. • Lectures notes in the THWS eLearning system
Special notes
see description of the individual courses

Course
3D-CAD Lab
Lecturer(s):
Prof. Dr.-Ing. Bunsen, Mr. B. Helbig, visiting lecturers
Content
• Basic handling of 3D-CAD systems • Volume-based modelling of bodies • Basics of creating an assembly model
Special notes

Course
Fundamentals of Mechanical Design
Lecturers(s):
Prof. Dr.-Ing. D. Jung, Prof. Dr.-Ing. A. Hofmann, Prof. Dr.-Ing. Ch. Bunsen, Prof. Dr.-Ing. J. Meyer, Prof. Dr.-Ing. T. Felsner
Content
• Technical standards and their application • Fundamentals of creating and reading technical drawings based on specific machine elements • Engineering tolerances (fits, form-, position- and surface tolerances) • Fundamentals of material science • Composition, structure and properties of steel and other engineering materials • Selected manufacturing processes according to DIN 8580: Primary shaping, Forming, Machining, Welding • Design methodology according to VDI2221/2222: Planning - Conception - Design - Development
Special notes

<table>
<tr><td colspan="4">Module No. (according to appendix 2 to the SPO): 12</td></tr>
<tr><td colspan="4">Engineering Mechanics 1</td></tr>
<tr><td>Module length</td><td>Frequency</td><td>Workload</td><td>ECTS Credit Points</td></tr>
<tr><td>1 semester</td><td>Summer semester</td><td>Total: 150 hrs
60 hrs attendance time (4 SWS)
60 hrs self-directed study time
30 hrs time for exam preparation</td><td>5</td></tr>
<tr><td colspan="4">Responsible for module: Prof. Dr.-Ing. Christel</td></tr>
<tr><td colspan="4">Lecturer(s):</td></tr>
<tr><td colspan="4">Prof. Dr.-Ing. Felsner, Prof. Dr.-Ing. Meyer</td></tr>
<tr><td colspan="2">Associated course(s)</td><td>Teaching and learning format</td><td>Language of instruction</td></tr>
<tr><td colspan="2"></td><td>Seminar-like lectures,
Exercise course</td><td>English</td></tr>
<tr><td colspan="4">Applicability and semester of study (according to Appendix 2 to the SPO):</td></tr>
<tr><td colspan="4">Bachelor programmes
Mechatronics (mandatory module, 2nd semester)
Mechanical Engineering (mandatory module, 1st semester)
Logistics (mandatory module, 3rd semester)
Business and Engineering (mandatory module, 2nd semester)</td></tr>
<tr><td colspan="2">Provides basis for module(s):

Builds upon module(s):</td><td colspan="2">Engineering Mechanics 2 and Machine Elements (14), Engineering Mechanics 3 (18)</td></tr>
<tr><td colspan="4">Mandatory participation requirements (according to appendix 2 of the SPO)</td></tr>
<tr><td colspan="4">none</td></tr>
<tr><td colspan="4">Recommended prerequisites and previous knowledge</td></tr>
<tr><td colspan="4">Solving equations / inequalities, trigonometry, linear systems of equations</td></tr>
<tr><td>Examination type / requirement for the award of credit points</td><td colspan="2">Examination length</td><td>Examination language</td></tr>
<tr><td>written exam</td><td colspan="2">90 min</td><td>English</td></tr>
<tr><td colspan="4">The concrete definition of the duration of the examination, the scope of the examination and further examination conditions (e.g. permitted aids) is made in the examination conditions. These are published on the intranet at the beginning of each semester.</td></tr>
</table>

Learning outcomes (after successful completion of the module)
The students • decompose forces and moments into their components and determine the resultant of sysstems of forces acting on rigid bodies • list the essential components of a mechanical model (beam, rod, supports, joints, load types, etc.), recognize the symbols in existing mechanical models and, for example, correctly assign the support reactions or stress resultants • find the position of the center of gravity by calculation and, for example, consider the weight force of a body correctly in the mechanical model • name the terms statical and kinematical determinacy, describe the meaning and analyze simple mechanical systems in this regard • safely apply the free cutting procedure and draw suitable free body diagrams for a given problem • formulate the conditions of equilibrium for a free body diagram and solve the system of equations for the unknowns (e. g. support / joint reactions, stress resultants, rod or contact forces) • evaluate various possibilities of how a free-body diagram and the associated conditions of equilibrium can be formulated and filter out the most suitable method for the various problems • analyze the internal loads of technical components, check the plausibility of the results and recommend suitable optimization measures • describe the difference between static friction (adhere) and kinetic friction (slide), calculate the contact forces using Coulomb`s theory of friction and enumerate the factors influencing the coefficient of friction • calculate the ratio of the rope forces in case of belt friction • use the correct technical terminology in group discussions as well as for questions and assess each other regarding the correct use of the technical terminology.
Content
• Addition and equilibrium of forces in central and general systems of forces • Characteristic features of selected joints and supports • Calculation of the center of gravity • Method of sections, Newton's laws • Calculation of support reactions and stress resultants • Spatial systems of forces and systems of rigid bodies. Statical determinacy. • Static friction, kinetic friction, belt friction

Literature and other learning opportunities
• D. Gross, W. Hauger, J. Schröder und W. Wall, N. Rajapakse, *Engineering Mechanics 1* (Statics), 2nd edition. Berlin, Heidelberg: Springe, 2013. • D. Gross, W. Ehlers, P. Wriggers, J. Schröder und R. Müller, *Formeln und Aufgaben zur Technische Mechanik 1 (Statik)*, 11., überarbeitete Auflage. Berlin, Heidelberg: Springer Vieweg, 2013. • C. Eller, Holzmann/Meyer/Schumpic, *Technische Mechanik Statik*, 14., überarbeitete Auflage. Wiesbaden: Springer Vieweg, 2015. • U. Gabbert und I. Raecke, *Technische Mechanik für Wirtschaftsingenieure*, 7., aktualisierte Auflage. München: Carl Hanser, 2013. • M. Mayr, *Technische Mechanik*, 8. Auflage. München, Wien: Carl Hanser Verlag, 2015. • O. Romberg und N. Hinrichs, *Keine Panik vor Mechanik*, 9. Auflage. Wiesbaden: Springer Vieweg, 2020. • Lecture notes, video tutorials and online tests in the university's eLearning system. • Interactive simulations on the topics of "equilibrium", "force and motion" and "vector addition" on the PhET website, e. g. https://phet.colorado.edu/en/simulation/forces-and-motion-basics .
Special notes

Module No. (according to appendix 2 to the SPO): 14

Engineering Mechanics 2 and Machine Elements

Module length	Frequency	Workload	ECTS Credit Points
1 semester	Winter semester	Total: 150 hrs 60 hrs attendance time (4 SWS) 60 hrs self-directed study time 30 hrs time for exam preparation	5

Responsible for module: Prof. Dr.-Ing. Bunsen

Lecturer(s):
Prof. Dr.-Ing. Bunsen, Prof. Dr.-Ing Lenz

Associated course(s)	Teaching and learning format	Language of instruction
Engineering Mechanics 2 and Machine Elements	Seminar-like lectures, Exercise course	English

Applicability and semester of study (according to Appendix 2 to the SPO):

Bachelor programme Mechatronics (mandatory module, 3rd semester)

Provides basis for module(s):	Engineering Mechanics 3 (18)
Builds upon module(s):	Engineering Mechanics 1 (12)

Mandatory participation requirements (according to appendix 2 of the SPO)

none

Recommended prerequisites and previous knowledge

Examination type / requirement for the award of credit points	Examination length	Examination language
written exam	90 min	English

The concrete definition of the duration of the examination, the scope of the examination and further examination conditions (e.g. permitted aids) is made in the examination conditions. These are published on the intranet at the beginning of each semester.

Learning outcomes (after successful completion of the module)

The students

- describe different types of mechanical stress
- calculate component deformations taking into account material properties
- calculate normal and shear stresses according to the existing mechanical loads
- calculate equivalent stresses
- carry out mechanical design calculations for components
- carry out dimensioning for dynamically stressed components
- select suitable construction elements for a construction
- dimension screw connections.

Content
• Mechanical stress types and resulting stresses. • Calculation of normal and shear stress due to normal force, torsion and bending. • Calculation of equivalent stresses. • Mechanical material parameters. • Calculation of deformations due to normal force, torsion and bending (bending lines). • Proof of strength and structural strength. • Machine elements and their structure, selection and calculation. • Screws and screw connections.
Literature and other learning opportunities
• R. K. A., Bansal, *Textbook of Strength of Materials*, 6th edition. New Delhi: Laxmi, 2011. • R. Hibbeler, *Statics and Mechanics of Materials*, 5th edition. München: Pearson, 2016. • T. Burns, *Applied Statics and Strength of Materials*, 2nd edition. Hampshire: Cengage, 2009. • R. Mott, E. Vavrek, J. Wang, *Machine Elements in Mechanical Design*, 6th edition. München: Pearson, 2017.
Special notes

Module No. (according to appendix 2 to the SPO): 18

Engineering Mechanics 3

Module length	Frequency	Workload	ECTS Credit Points
1 semester	Winter semester	Total: 150 hrs 60 hrs attendance time (4 SWS) 60 hrs self-directed study time 30 hrs time for exam preparation	5

Responsible for module: Prof. Dr.-Ing. Retka

Lecturer(s):

Prof. Dr.-Ing. Retka, u.a.

Associated course(s)	Teaching and learning format	Language of instruction
Engineering Mechanics 3	Seminar-like lectures, Exercise course	English

Applicability and semester of study (according to Appendix 2 to the SPO):

Bachelor programme Mechatronics (mandatory module, 3rd semester)

Provides basis for module(s):	
Builds upon module(s):	Engineering Mechanics 1 (12)

Mandatory participation requirements (according to appendix 2 of the SPO)

none

Recommended prerequisites and previous knowledge

School knowledge of mathematics and physics

Examination type / requirement for the award of credit points	Examination length	Examination language
written exam	90 min	English

The concrete definition of the duration of the examination, the scope of the examination and further examination conditions (e.g. permitted aids) is made in the examination conditions. These are published on the intranet at the beginning of each semester.

Learning outcomes (after successful completion of the module)

The students

- name different ways of describing the movement of point masses and rigid bodies.
- establish the relationship between the load and the movement for a point mass as well as for systems of rigid bodies.
- compute simple dynamic tasks in mechanical engineering.
- define the terms work, energy, power and efficiency, establish the energy conservation law for various simple systems and analyse it with regard to the quantities it contains.
- apply the conservation of linear momentum.
- analyse the tasks, show different possible solutions and judge which is most effective for solving the dynamic problem.
- check the results, assess the influences on these results and show the limits of the models.

Content
• kinematics of point masses and rigid bodies (Euler's equations, relative motion) • work and energy, power, efficiency • kinetics of point masses and rigid bodies in two dimensions (d'Alembert's principle, Newton's laws of motion, energy and work theorems) • mass moments of inertia • central and eccentrical impact, principle of linear and angular momentum
Literature and other learning opportunities
• D. Gross, W. Hauger, J. Schröder, W. A. Wall, S. Govindjee, *Engineering Mechanics 3: Dynamics*, 2nd edition. Berlin: Springer, 2014. • O. Romberg, N. Hinrichs, *Don’t Panic with Mechanics!*, 1. Auflage. Wiesbaden: Vieweg+Teubner Verlag, Springer Fachmedien Wiesbaden GmbH, 2006. • course documentation in the eLearning system of THWS
Special notes

Further basic modules from the first three semesters

Module No. (according to appendix 2 to the SPO): **3**			
Physics			
Module length	**Frequency**	**Workload**	**ECTS Credit Points**
1 semester	Winter semester	Total: 150 hrs 60 hrs attendance time (4 SWS) 60 hrs self-directed study time 30 hrs time for exam preparation	5
Responsible for module: Prof. Dr. Mark			
Lecturer(s):			
Prof. Dr. Mark, Prof. Dr. Motzek, Prof. Dr. Seufert, Prof. Dr. Walter, Dr. Davidson			
Associated course(s)		**Teaching and learning format**	**Language of instruction**
Physics		Seminar-like lectures, Exercise course, Lab course	English
Applicability and semester of study (according to Appendix 2 to the SPO):			
Bachelor programme Mechatronics (mandatory module, 1st semester)			
Provides basis for module(s):			
Builds upon module(s):			
Mandatory participation requirements (according to appendix 2 of the SPO)			
none			
Recommended prerequisites and previous knowledge			
School knowledge physics (Kinematics, Dynamics, Work, Energy, Power) and mathematics (e.g. Differential calculus)			
Examination type / requirement for the award of credit points	**Examination length**	**Examination language**	
written exam	90 min	English	
The concrete definition of the duration of the examination, the scope of the examination and further examination conditions (e.g. permitted aids) is made in the examination conditions. These are published on the intranet at the beginning of each semester.			
Learning outcomes (after successful completion of the module)			
The students • recognize the fundamental terms of the topics „Waves“, „Quantum Physics“ and „Thermodynamics“ • review the base equation of the named topics • perform calculations based on these equations • apply the quantitative relationships expressed by the equations to technical systems • explain the meaning of the basic terms and equations using sample applications.			

Content
• Simple harmonic motion SHM • Waves in 1D, 2D and 3D • Huygens-Fresnel principle: reflection, refraction, diffraction • Standing waves • Doppler effect • Sound waves and sound levels • Electromagnetic waves and polarization effects • Particle-wave-dualism (particle properties of light and wave properties of particles) • Bohr model of the atom • Basic thermodynamics (Temperature, thermal expansion, ideal gas law and heat) • First law of thermodynamics • Thermodynamic cycles
Literature and other learning opportunities
• D. Halliday, R. Resnick, J. Walker, *Principles of Physics*, 10th edition. Oxford: WILEY, 2014. • P. A. Tipler, *Physics for Scientists and Engineers*, 6th edition. London: Palgrave Macmillan, 2007. • Lecture notes and exercise sheet on eLearning of THWS
Special notes

Module No. (according to appendix 2 to the SPO)**: 13**

General Electives (GE)

Module length	Frequency	Workload	ECTS Credit Points
1 semester	Winter semester and Summer semester	Total: 150 hrs 60 hrs attendance time (4 SWS) 60 hrs self-directed study time 30 hrs time for exam preparation	5

Responsible for module: Dean of the Faculty of Applied Natural Sciences and Humanities

Lecturer(s):

Lecturers of the Faculty of Applied Natural Sciences and Humanities or lecturers appointed by the faculty.

Associated course(s)	Teaching and learning format	Language of instruction
Selection of two general electives (GE) (2 x 2 SWS) or one GE (1 x 4 SWS) from the range of subjects offered by the Faculty of Applied Sciences and Humanities (FANG).	Definition and publication by the Faculty of Applied Natural Sciences and Humanities.	Definition and publication by the Faculty of Applied Natural Sciences and Humanities.

Applicability and semester of study (according to Appendix 2 to the SPO):

Bachelor programme Mechatronics (mandatory module, 3rd semester)

The module serves to build up interdisciplinary competences ("studium generale") and is therefore not directly related to other modules of this degree programme.
It can be used in all other bachelor's degree programmes, provided that there is no restriction for this degree programme.

Provides basis for module(s):	
Builds upon module(s):	

Mandatory participation requirements (according to appendix 2 of the SPO)

none

Recommended prerequisites and previous knowledge

usually none; exceptions are defined and published by the Faculty of Applied Sciences and Humanities.

Examination type / requirement for the award of credit points	Examination length	Examination language
see below	see below	see below

Each GE is completed with an examination.

Definition of the type of examinations as well as their publication are carried out by the Faculty of Applied Sciences and Humanities.

Learning outcomes (after successful completion of the module)
Subject-specific learning outcomes depend on the particular GE selected. The students • also acquire knowledge and skills that are not subject-specific but may be significant for the desired career goal, such as special knowledge of foreign languages, natural sciences or social sciences • analyze a wide variety of issues • place subject-specific knowledge in an interdisciplinary context • transfer what they have learned to their current training • have expanded their key competencies and, if applicable, foreign language competencies, which supports personality development, also in intercultural terms • are aware of their responsibility in personal, social and ethical terms.
Content
Subjects offered by FANG in the range of • Languages • Cultural studies • Natural sciences and Technology • Politics, Law and Economics • Education, Psychology and Social sciences • Soft Skills • Creativity and Art Excluded from the catalog of courses offered by the FANG are courses whose contents are already components of or directly related to parts of other modules of the degree programme. The corresponding courses are marked with a blocking note in the FANG subject catalog. The contents of the individual GE are published on the Homepage FANG.
Literature and other learning opportunities
depending on the GE selected
Special notes

Module No. (according to appendix 2 to the SPO): **16**			
System Modeling 1 & System Theory			
Module length	**Frequency**	**Workload**	**ECTS Credit Points**
1 semester	Winter semester	Total: 150 hrs 60 hrs attendance time (4 SWS) 60 hrs self-directed study time 30 hrs time for exam preparation	5
Responsible for module: Prof. Dr. Latour			
Lecturer(s):			
Prof. Dr. Latour, Prof. Dr. Kharitonov			
Associated course(s)		**Teaching and learning format**	**Language of instruction**
System Modelling 1 (2 SWS)		Seminar-like lectures, Exercise course	English
System Theory (2 SWS)		Seminar-like lectures, Exercise course	English
Applicability and semester of study (according to Appendix 2 to the SPO):			
Bachelor programme Mechatronics (mandatory module, 3rd semester)			
Provides basis for module(s):	System Modeling 2 (25)		
Builds upon module(s):	Engineering Mathematics 1, 2 ,3 ,4 (1,2,7,8), Physics, Fundamentals of Electrical Engineering, Engineering Mechanics 1 (3,5,12)		
Mandatory participation requirements (according to appendix 2 of the SPO)			
none			
Recommended prerequisites and previous knowledge			

Examination type / requirement for the award of credit points	**Examination length**	**Examination language**
written exam	90 min	English

The concrete definition of the duration of the examination, the scope of the examination and further examination conditions (e.g. permitted aids) is made in the examination conditions. These are published on the intranet at the beginning of each semester.

Learning outcomes (after successful completion of the module)
System Modelling 1: The students • list important terms, physical values and mathematic relationships in the field of energy-, mass- and information-flows of mechatronic systems and define those, especially variables of power and derived variables for the different physical domains (information technology, electrical engineering, mechanics of solid bodies, fluid mechanics, material and thermal transmission) • write down the important analog equations for linear systems (for example according to the flow-effort classification) for the different physical domains • assign the behavior of mechatronic components to different classes of linear functional elements (i.e. capacitors / inductors / resistors or sources / transmitters / converters / storages, drains) • describe the behavior of functional chain based and object oriented 1d simulation programs (for example Matlab-Simulink or comparable programs) and use as well as operate those • form functional chain based simulation models with lumped parameters based on textual or graphical system descriptions by use of standardized procedures (for example “method of energy storages”) • transfer the simulation models to 1d simulation programs, determine suitable parameters of the simulation process (for example numerical step sizes) and define necessary value ranges and data formats for the simulation results • verify the simulation results and models based on quantitative and qualitative methods • use the correct technical terminology of simulation technology within the scope of questions, discussions, exercises and assess each other regarding the proper use of it. System theory: The students • list important elementary signals and describe based on them the signals used in engineering practice • assign the behaviour of dynamical systems to different classes (with lumped/distributed parameters, linear/nonlinear, time-invariant/variant, continuous/discrete) and corresponding mathematical descriptions • derive the differential equations for simple mechanical and electrical systems and indicate the analytical solutions for them • use integral transforms (Laplace, Fourier) and transfer functions for analysis of signals and systems • describe sampling of time-continuous signals in the time and frequency domain and use the sampling theorem to analyse if the original signals can be reconstructed completely.
Content
see description of the individual courses
Literature and other learning opportunities
• L. G. Birta and G. Arbez, *Modelling and Simulation – Exploring dynamic System Behavior*, 2^{nd} edition. London, Heidelberg, New York: Springer Dordrecht, 2013. • R. Isermann, *Mechatronic Systems - Fundamentals*, 2^{nd} edition. London: Springer, 2008. • R. Nollau, *Modellierung und Simulation technischer Systeme*, 1. Auflage. Heidelberg, London, New York: Springer Dordrecht, 2009. • B. Girod, R. Rabenstein and A. Stenger, *Signals and Systems,* Chichester: John Wiley & Sons Ltd, 2001. • M. Werner, *Signale und Systeme*, 3. Auflage. Wiesbaden: Vieweg + Teubner Verlag, 2008.
Special notes
see description of the individual courses

Course
System Modeling 1
Lecturer(s):
Prof. Dr.-Ing. Latour
Content
• explanation of terms of linear mechatronic elements and systems with lumped parameters (1d simulation) and demarcation to 3d simulations • the nature of describing variables of energy flows (one point and two point variables) as a bases for the simulation of mechatronic systems • Analogies across the physical domains (information technology, electrical engineering, mechanics of solid bodies, fluid mechanics, material and thermal transmissions) according to the flow-effort-classification • Equations of time, equations of balance and transfer functions of linear mechatronic elements and systems with information-, mass- and energy-flows • Graphic representations of mechatronic systems (for example technical schematic of effects, symbolic representation with energy flows, multi pole representation, block diagram) • Methods for generation of simulation models • Design, function and limits of use of 1d simulation programs • Examples of modelling of electrical, mechanical, fluid-based and combined mechatronic systems
Special notes

Course
System Theory
Lecturer(s):
Prof. Dr.-Ing. Kharitonov
Content
• elementary signals and their properties, use of elementary signals to build and analyse the signals and systems used in engineering practice • systems and their classification, examples of mechanical and electrical systems and systems with heat and mass transfer • linear time-invariant systems (LTI-systems) and the description of their behaviour by means of excitation with elementary signals, step and impulse response • integral transforms (Laplace, Fourier), their areas of application and properties • transfer functions of LTI-systems, poles and zeros, combining of simple LTI-systems, block diagram and its elementary algebra • sampling of time-continuous signals in the time and frequency domain, sampling theorem, reconstruction of band-limited signals, aliasing
Special notes

3 Second Part of Studies, 4th to 7th Semester

Subject Area: Measuring Techniques and Actuators	
Responsible for subject area:	Prof. Dr.-Ing. Ch. Latour

Module No. (according to appendix 2 to the SPO): 19

Measuring Techniques

Module length	Frequency	Workload	ECTS Credit Points
1 semester	Summer semester	Total: 150 hrs 60 hrs attendance time (4 SWS) 60 hrs self-directed study time 30 hrs time for exam preparation	5

Responsible for module: Prof. Dr.-Ing. Wilke

Lecturer(s):

Prof. Dr.-Ing. Hansmann, Prof. Dr.-Ing. Kharitonov

Associated course(s)	Teaching and learning format	Language of instruction
Measuring Techniques	Seminar-like lectures, Exercise course	English

Applicability and semester of study (according to Appendix 2 to the SPO):

Bachelor program Mechatronics (mandatory module, 4th semester)

Provides basis for module(s):	
Builds upon module(s):	Mathematics (1,2,7,8), Physics (3), Electrical and Mechanical Engineering (5,11,17,6,12,14,18)

Mandatory participation requirements (according to appendix 2 of the SPO)

none

Recommended prerequisites and previous knowledge

Examination type / requirement for the award of credit points	Examination length	Examination language
written exam	90 min	English

The concrete definition of the duration of the examination, the scope of the examination and further examination conditions (e.g. permitted aids) is made in the examination conditions. These are published on the intranet at the beginning of each semester.

Learning outcomes (after successful completion of the module)

The students

- describe the fundamentals of metrology and explain the application in technical systems
- analyse technical systems and develop mathematical description models for abstraction
- represent the solutions of metrological tasks independently of the technical system characteristics
- plan the necessary metrological steps in a targeted manner and carry them out practically
- present their proposals for metrological solutions in technical discussions in an argumentative and comprehensible manner.

Content

- Fundamentals of metrology
- Measuring inaccuracies
- Error calculation
- Measuring system technology
- Data processing
- Fundamentals of sensors
- Current and voltage measurement
- Measuring bridges
- Operational amplifiers

Literature and other learning opportunities

- J. Bentley, *Principles of Measurement Systems*, 4th edition. Harlow: Pearson Education, 2004
- T. Beckwit, R. Marangoni, J.V. Lienhard, *Mechanical Measurements*, Harlow: Pearson Education, 2006
- R. Witte, *Electronic Test Instruments*, 2nd edition. Harlow: Pearson Education, 2002
- H. Czichos, T. Saito and L. Smith (Eds.), Springer, *Handbook of Metrology and Testing*, 2nd edition. Heidelberg, Dordrecht, London, New York: Springer-Verlag, 2011
- DIN 1319-1:1995-01 Fundamentals of metrology - Part 1: Basic terminology
- DIN 1319-2:2005-10 Fundamentals of metrology - Part 2: Terminology related to measuring equipment
- DIN 1319-3:1996-05 Fundamentals of metrology - Part 3: Evaluation of measurements of a single measurand, measurement uncertainty
- JCGM 100:2008: Guide to the Expression of Uncertainty in Measurement (GUM)
- J. Hansmann, A. Kharitonov, *slides and additional materials (eLearning)*, Schweinfurt: 2021

Special notes

Module No. (according to appendix 2 to the SPO): 20

Actuators

Module length	Frequency	Workload	ECTS Credit Points
1 semester	Summer semester	Total: 150 hrs 60 hrs attendance time (4 SWS) 60 hrs self-directed study time 30 hrs time for exam preparation	5

Responsible for module: Prof. Dr.-Ing. B. Müller

Lecturer(s):

Prof. Dr.-Ing. C. Latour, Prof. Dr.-Ing. B. Müller

Associated course(s)	Teaching and learning format	Language of instruction
Fluid-mechatronic Actuators	Seminar-like lectures	English
Electrical Actuators	Seminar-like lectures	English

Applicability and semester of study (according to Appendix 2 to the SPO):

Bachelor program Mechatronics (mandatory module, 4th semester)

Provides basis for module(s):	
Builds upon module(s):	Mathematics (1,2,7,8), Physics (3), Electrical and Mechanical Engineering (5,11,17,6,12,14,18)

Mandatory participation requirements (according to appendix 2 of the SPO)

none

Recommended prerequisites and previous knowledge

Examination type / requirement for the award of credit points	Examination length	Examination language
written exam	90 min	English

The concrete definition of the duration of the examination, the scope of the examination and further examination conditions (e.g. permitted aids) is made in the examination conditions. These are published on the intranet at the beginning of each semester.

Learning outcomes (after successful completion of the module)

The students

- explain the working principles and the design of the most common electrical and fluid-based drives
- apply and derive the mathematical equations for selected drive components and systems
- analyze technical requirements and understand the consequences for the drive system
- use circuit symbols, draw and read circuit diagrams and describe the functions of the components and systems
- use the correct technical terminology of industrial drive technology within the scope of questions, discussions, exercises and assess each other regarding the proper use of it

Content

see description of the individual courses

Literature and other learning opportunities

- A. Hughes, B. Drury, *Electric Motors and Drives – Fundamentals, Types and Applications*, 4th edition. Oxford: Newnes, 2013.
- N. Mohan, T. M. Undeland, W. P. Robbins, *Power Electronics*, 3rd edition. Hoboken: John Wiley & Sons, 2002.
- H. Murrenhoff, *Fundamentals of Fluid Power – Part 1: Hydraulics*, 1st edition. Aachen: Shaker, 2014.
- I. Sivaraman, *Introduction to Hydraulics and Pneumatics*, 3rd edition. Delhi: PHI Learning, 2017.

Special notes

see description of the individual courses

Course
Fluid-mechatronic Actuators
Teacher(s):
Prof. Dr.-Ing. Christoph Latour
Content
• Industrial applications of fluid-mechatronic drive systems • Fundamentals and basic equations of ideal and lossy modules and systems • Classes, applications and requirements of pressure transmission media and means of filtration • Ideal and lossy hydrostatic displacement units (pumps, motors, cylinders) • Resistor based control modules (directional -, pressure -, flow, check - valves) • Energy transport and accumulation • Industrial, hydrostatic drive systems (hydrostatic transmissions and valve controlled cylinder drives)
Special notes

Course
Electrical Actuators
Teacher(s):
Prof. Dr.-Ing. Bernhard Müller
Content

• Fundamentals of electromagnetism
• Design and working principles of electric drives (DC, asynchronous, synchronous, stepper motors)
• DC motors
  o design and types
  o mathematical modeling
  o equivalent circuits
  o operating behavior
• Brushless DC motors
  o design
  o commutation using power electronics

Special notes

Subject Area: Control Systems

Responsible for subject area: Prof. Dr.-Ing. A. Ali

Module No. (according to appendix 2 to the SPO): 22

Control Systems 1

Module length	Frequency	Workload	ECTS Credit Points
1 semester	Summer semester	Total: 150 hrs 60 hrs attendance time (4 SWS) 60 hrs self-directed study time 30 hrs time for exam preparation	5

Responsible for module: Prof. Dr.-Ing. Ali

Lecturer(s):

Prof. Dr.-Ing. Ali

Associated course(s)	Teaching and learning format	Language of instruction
Control Systems 1	Seminar-like lectures, Exercise course	English

Applicability and semester of study (according to Appendix 2 to the SPO):

Bachelor programme Mechatronics (mandatory module, 4th semester)

Provides basis for module(s):	Control Systems 2 (26)
Builds upon module(s):	Engineering Mathematics 1 to 4 (1,2,7,8), System Modeling 1 & System Theory (16)

Mandatory participation requirements (according to appendix 2 of the SPO)

none

Recommended prerequisites and previous knowledge

none

Examination type / requirement for the award of credit points	Examination length	Examination language
written exam	90 min	English

The concrete definition of the duration of the examination, the scope of the examination and further examination conditions (e.g. permitted aids) is made in the examination conditions. These are published on the intranet at the beginning of each semester.

Learning outcomes (after successful completion of the module)
The students • name basic terminology of control engineering and describe mechanism of the feedback control • explain static and dynamic behaviour of control-loop components, describe them in time and frequency domain and identify fundamental characteristics of important systems (P, I, D, first-order lag, second-order-lag etc.) • explain the working principle of the classical PID control, describe characteristic features and properties of each controller component and select a suitable controller for a given application • analyse control systems for stability, oscillations, steady-state accuracy and speed of response using open-loop frequency response and pole-zero maps • build a simulation model for a simple control loop and execute a model-based controller design • use heuristics and empirical methods to select suitable controller structure and adjust its parameters • design a feedback controller for a single-input-single-output system using frequency response and pole-placement techniques.
Content

• Introduction
  ○ Basic terminology, plan of action, feedback control
• Behaviour of control system components
  ○ Deriving system equations
  ○ Description in time and frequency domain
  ○ Transfer function,
  ○ Modelling and simulation
• PID control
• Control loop analysis
  ○ Stability, speed of response, oscillation behaviour, steady-state accuracy
• Controller design
  ○ Empirical design methods
  ○ Model-based control design
  ○ Controller design in frequency domain (loop shaping)
  ○ Pole placement method / root locus.

Literature and other learning opportunities
• K. J. Åström and R. M. Murray, *Feedback systems: an introduction for scientists and engineers*. Princeton, NJ: Princeton University Press, 2009. • K. Ogata, *Modern Control Engineering*, 5th edition. Upper Saddle River, NJ: Pearson Education, 2010. • R. Dorf, R. Bishop, *Modern Control Systems*, 13th edition. Hoboken, NJ: Pearson Education, 2017. • H. Unbehauen, *Regelungstechnik I*, 15th edition. Wiesbaden: Springer Vieweg, 2008. • J. Lunze, *Regelungstechnik 1*, 12th edition. Berlin: Springer-Verlag, 2020.
Special notes

Module No. (according to appendix 2 to the SPO): **26**			
Control Systems 2			
Module length	**Frequency**	**Workload**	**ECTS Credit Points**
1 semester	Winter semester	Total: 150 hrs 60 hrs attendance time (4 SWS) 60 hrs self-directed study time 30 hrs time for exam preparation	5
Responsible for module: Prof. Dr.-Ing. B. Müller			
Lecturer(s):			
Prof. Dr.-Ing. B. Müller			
Associated course(s)		**Teaching and learning format**	**Language of instruction**
Control Systems 2 (3 SWS)		Seminar-like lectures, Exercise course	English
Lab course Control Systems 2 (1 SWS)		Lab course	English
Applicability and semester of study (according to Appendix 2 to the SPO):			
Bachelor programme Mechatronics (mandatory module, 5th semester)			
Provides basis for module(s):			
Builds upon module(s):	System Modeling 1 & System Theory, Control Systems 1 (16,22)		
Mandatory participation requirements (according to appendix 2 of the SPO)			
none			
Recommended prerequisites and previous knowledge			
Fundamentals in Mathematics, Electrical and Mechanical Engineering			

Examination type / requirement for the award of credit points	**Examination length**	**Examination language**
written exam	90 to 120 min	English

The concrete definition of the duration of the examination, the scope of the examination and further examination conditions (e.g. permitted aids) is made in the examination conditions. These are published on the intranet at the beginning of each semester.

Learning outcomes (after successful completion of the module)

The students

- create mathematical models for dynamic systems in the time domain
- perform simplifications and derive linear and time-invariant (LTI) state-space equations
- analyze basic properties of linear and time-invariant (LTI) state-space models
- calculate the solution of initial value-problems for linear and time-invariant state-space systems
- descripe and apply the structure of basic linear state-space controllers
- design linear state-space controllers
- implement and evaluate linear state-space control systems.

Content
• State space description of linear time-invariant systems • Analysis of linear time-invariant systems • Full-state feedback controller design • Observer-based controller design • Disturbance rejection • Further aspects of modern control systems
Literature and other learning opportunities
• R. C. Dorf, R. H. Bishop, *Modern Control Systems*, 13th edition. Harlow: Pearson, 2017. • N. S. Nise, *Control Systems Engineering - International Student Version,* 6th edition. Hoboken: John Wiley & Sons, 2011. • J. Billingsley, *Essentials of Control Techniques and Theory,* 1st edition. Boca Raton: CRC Press, 2010. • K. Zhou, J. C. Doyle, K. Glover, *Robust and Optimal Control*, 1st edition. Upper Saddle River: Prentice Hall, 1996. • J. Deutscher, *Robust output regulation by observer-based feedforward control*. Int. J. Systems Science 48 (2017), pp. 795-804.
Special notes

Mandatory modules from semesters 4 to 7

<table>
<tr><td colspan="4">Module No. (according to appendix 2 to the SPO): 25</td></tr>
<tr><td colspan="4">System Modeling 2</td></tr>
<tr><td>Module length</td><td>Frequency</td><td>Workload</td><td>ECTS Credit Points</td></tr>
<tr><td>1 semester</td><td>winter semester</td><td>Total: 150 hrs
60 hrs attendance time (4 SWS)
60 hrs self-directed study time
30 hrs time for exam preparation</td><td>5</td></tr>
<tr><td colspan="4">Responsible for module: Prof. Dr. Latour</td></tr>
<tr><td colspan="4">Lecturer(s):</td></tr>
<tr><td colspan="4">Prof. Dr.-Ing. Latour</td></tr>
<tr><td colspan="2">Associated course(s)</td><td>Teaching and learning format</td><td>Language of instruction</td></tr>
<tr><td colspan="2">System Modeling 2</td><td>Seminar-like lectures,
Exercise course</td><td>English</td></tr>
<tr><td colspan="4">Applicability and semester of study (according to Appendix 2 to the SPO):</td></tr>
<tr><td colspan="4">Bachelor programme Mechatronics (mandatory module, 5th semester)</td></tr>
<tr><td>Provides basis for module(s):
Builds upon module(s):</td><td colspan="3">
System Modeling 1 & System Theory (16), Control Systems 1 (22)</td></tr>
<tr><td colspan="4">Mandatory participation requirements (according to appendix 2 of the SPO)</td></tr>
<tr><td colspan="4">none</td></tr>
<tr><td colspan="4">Recommended prerequisites and previous knowledge</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td>Examination type / requirement for the award of credit points</td><td colspan="2">Examination length</td><td>Examination language</td></tr>
<tr><td>written exam</td><td colspan="2">90 to 120 min</td><td>English</td></tr>
<tr><td colspan="4">The concrete definition of the duration of the examination, the scope of the examination and further examination conditions (e.g. permitted aids) is made in the examination conditions. These are published on the intranet at the beginning of each semester.</td></tr>
</table>

Learning outcomes (after successful completion of the module)
The students • specify - based on the knowledge of the simulation of linear mechatronic systems (System Modelling 1) - the describing equations of the most important nonlinearities (for example functions with limited scopes of variables like mechanical stops, functions with multiple input variables at electric and fluid-based resistors and so on) • use the method of experimental modelling of system components by means of predefined measure-ment data or experiments carried out by themselves (for example three dimensional characteristic diagram of a fluid-mechatronic control valve) • work out functional chain based simulation models of linear and nonlinear systems based on textual and graphical system descriptions by use of standardized modelling procedures (for example electrically commutated direct current motor, fluid-mechatronic cylinder drive system) • describe the function of 1d simulation programs, which need a fixed chain with input and output (for example Matlab-Simulink or comparable programs) and use as well as operate those within the scope of exercises and the hands-on training • transfer the worked out simulation models to the 1d simulation programs, define suitable parameters for the simulation process (for example numerical step size) and define the necessary value ranges and data formats for the simulation results • verify the simulations results and the simulation model based on quantitative and qualitative measures • assess the quality of the simulation results by themselves and within the scope of group session at exercises and/or hands-on trainings (for example in the computer room or break out online sessions) • write down the analogous basic equations according to the across-through-classification for system elements of the different physical domains (information technology, electrical engineering, mechanics of solid bodies, fluid mechanics, material and thermal transmissions) as a bases for the object oriented modelling approach • work out analogous circuit diagrams and systems of equations in the time domain according to the across-through-classification for the domains of electrical engineering, solid body and fluid mechanics • describe the function of object oriented 1d simulation programs (for example OpenModelica or comparable programs) and nominate the relevant differences of the classical simulation environments based on a fixed chain of effects • transfer simulation models with a fixed chain of effects into object oriented models and vice versa • use the correct technical terminology of simulation technology within the scope of questions, discussions, exercises, hands-on trainings and assess each other regarding the proper use of it.
Content
• 1-d modelling of linear and nonlinear functional chains of mechatronic systems • important nonlinearities at the classical modelling approach • realistic modelling / grey-box-modelling (physical and theoretical modelling) in theory and practice • analogies between the physical domains (i.e. information technology, electrical engineering, mechanics of solid bodies, fluid mechanics, material and thermal transmissions) according to the across-through-classification • fundamentals of object oriented modelling of mechatronic systems • Design, function and limits of use of 1d simulation programs (both classical and object oriented) • examples for modelling of electric, mechanic, fluid-based and combined mechatronic systems

Literature and other learning opportunities
• L. G. Birta and G. Arbez, *Modelling and Simulation – Exploring dynamic System Behavior*, 2nd edition. London, Heidelberg, New York: Springer Dordrecht, 2013. • R. Isermann, *Mechatronic Systems - Fundamentals*, 2nd edition. London: Springer, 2008. • R. Nollau, *Modellierung und Simulation technischer Systeme*, 1. Auflage. Heidelberg, London, New York: Springer Dordrecht, 2009. • Free simulation software and teaching materials (tutorials, exercises, examples, libraries), object oriented simulation with OpenModelica: https://openmodelica.org/
Special notes

Module No. (according to appendix 2 to the SPO): 23

Logical Control and Software Engineering

Module length	Frequency	Workload	ECTS Credit Points
1 semester	Summer semester	Total: 150 hrs 60 hrs attendance time (4 SWS) 60 hrs self-directed study time 30 hrs time for exam preparation	5

Responsible for module: Prof. Dr. rer. nat. Mathes

Lecturer(s):

Prof. Dr. Kaupp, Prof. Dr. Mathes

Associated course(s)	Teaching and learning format	Language of instruction
Logical Control and Software Engineering	Seminar-like lectures	English

Applicability and semester of study (according to Appendix 2 to the SPO):

Bachelor programme Mechatronics (mandatory module, 4th semester)

Provides basis for module(s):	
Builds upon module(s):	Programming 1, Programming 2, Microcomputer Systems 1 and 2 (4,10,9,15)

Mandatory participation requirements (according to appendix 2 of the SPO)

none

Recommended prerequisites and previous knowledge

Fundamental knowledge of procedural and object-oriented programming, basic algebra knowledge, Boolean logic.

Examination type / requirement for the award of credit points	Examination length	Examination language
written exam	90 min	English

The concrete definition of the duration of the examination, the scope of the examination and further examination conditions (e.g. permitted aids) is made in the examination conditions. These are published on the intranet at the beginning of each semester.

Learning outcomes (after successful completion of the module)

The students

- define and describe the different disciplines of software engineering
- define and describe challenges in big software development projects
- plan software development projects using different process models
- analyze and design complex software
- implement object-oriented software using latest programming languages
- analyze and interpret existing programs
- name the basic terms of a logical control system
- specify the basic hardware and software components of a programmable logic controller (PLC)
- design logical control systems via several design methods such as memory tables, functional block diagrams and step sequences
- implement a logical control system using a PLC programming language.

Content
• process models for software development • success criteria for software development • basic terms of object-orientation and their application • design of logical control systems using memory tables, function block diagrams, and step sequences • implementation of programmable logic controllers (PLCs) • PLC hardware components
Literature and other learning opportunities
• I. Sommerville, *Software Engineering*, Global edition. London: Pearson, 2015. • H. Berger, *Automating with STEP 7 in STL and SCL - SIMATIC S7-300/400 Programmable Controllers*, 6th edition. Erlangen: Publicis Publishing, 2012. • T. Kaupp, B. Müller, M. Ochs, Lecture notes Logical Control, Schweinfurt: 2021.
Special notes

Module No. (according to appendix 2 to the SPO): **24**

Embedded Systems and Fieldbuses

Module length	Frequency	Workload	ECTS Credit Points
1 semester	Summer semester	Total: 150 hrs 60 hrs attendance time (4 SWS) 60 hrs self-directed study time 30 hrs time for exam preparation	5

Responsible for module: Prof. Dr.-Ing. Hansmann

Lecturer(s):

Prof. Dr. rer.nat. Marian Daun

Associated course(s)	Teaching and learning format	Language of instruction
Embedded Systems and Fieldbuses	Seminar-like lectures, Exercise course, Lab course	English

Applicability and semester of study (according to Appendix 2 to the SPO):

Bachelor programme Mechatronics (mandatory module, 4th semester)

Provides basis for module(s):	Internship (31)
Builds upon module(s):	Electrical Engineering 1 and 2 (11,17), Programming 1 and 2 (4,10), Microcomputer systems (9,15)

Mandatory participation requirements (according to appendix 2 of the SPO)

none

Recommended prerequisites and previous knowledge

Mathematics and Electrical Engineering modules.

Examination type / requirement for the award of credit points	Examination length	Examination language
written exam	90 min	English

The concrete definition of the duration of the examination, the scope of the examination and further examination conditions (e.g. permitted aids) is made in the examination conditions. These are published on the intranet at the beginning of each semester.

Learning outcomes (after successful completion of the module)

The students

- name actual embedded systems and microcontroller architectures
- classify and analyze different embedded structures
- select and design suitable embedded systems for a given problem
- list typical error sources on the physical layer
- explain the working principle of the data link layer
- explain advantages and disadvantages of different media access methods
- design bus systems regarding cycle times, number of participants and other bus properties.

Content
• Definitions, requirements, and application fields of embedded systems • Embedded system components: Sensors, information processing, actuators • Architecture of embedded systems: Processor and microcontroller systems, hardware/software co-design • Simultaneous and parallel task processing, definition of real-time processing, real-time systems • Development, test and verification environments and software build process. • Interfaces to peripherals, serial interface. • Polling versus event-driven program processing via interrupts. • Exemplary function group: digital I/O, hardware timer, A/D converter. • Communication on physical layer • Communication on data link layer • Media access control • Overview of different fieldbus systems
Literature and other learning opportunities
• P. Marwedel, *Embedded System Design*, 3rd edition. Cham: Springer, 2021.
Special notes

Module No. **(according to appendix 2 to the SPO): 21**

Mechatronics Lab

Module length	Frequency	Workload	ECTS Credit Points
1 semester	Summer semester	Total: 150 hrs 60 hrs attendance time (4 SWS) 60 hrs self-directed study time 30 hrs time for exam preparation	5

Responsible for module: Prof. Dr.-Ing. Ali

Lecturer(s):

Prof. Dr.-Ing. Ali

Associated course(s)	Teaching and learning format	Language of instruction
Mechatronics Lab	Lab course	English

Applicability and semester of study (according to Appendix 2 to the SPO):

Bachelor programme Mechatronics (mandatory module, 4th semester)

Provides basis for module(s):	
Builds upon module(s):	Measuring Techniques (19), Control Systems 1 (22), Logical Control and Software Engineering (23), Actuators (20), Embedded Systems and Fieldbuses (24)

Mandatory participation requirements (according to appendix 2 of the SPO)

None

Recommended prerequisites and previous knowledge

None

Examination type / requirement for the award of credit points	Examination length	Examination language
other examination performance	Practical examination	English

The concrete definition of the duration of the examination, the scope of the examination and further examination conditions (e.g. permitted aids) is made in the examination conditions. These are published on the intranet at the beginning of each semester.

Learning outcomes (after successful completion of the module)

The students

- identify models of simple dynamic systems from measured data, describe their static and dynamic behaviour, implement the models on a simulator and verify their response
- design a controller using empirical methods, implement the controller on an experimental setup, construct a control loop, measure and interpret the control loop response and optimize controller parameters
- design a controller in frequency domain, analyse control loop for stability and performance and relate controller parameters with control loop response
- select a suitable structure for a controller, adjust its parameters using the pole-placement technique, implement the controller on a real-time computing system, measure and interpret the control-loop response
- record, process and interpret measured data, perform signal conditioning
- implement a logical control assignment on a programmable logic controller (PLC) and put it into operation.

Content

Practical lab assignments from the following core areas of mechatronics:

- Control Systems
- Measuring Techniques
- Actuators
- Logical Control and Software Engineering
- Embedded Systems and Fieldbuses

Literature and other learning opportunities

- Literature is provided in form of lab manuals during the preparation phase of the lab experiments

Special notes

Module No. (according to appendix 2 to the SPO): 33

General Engineering Lab

Module length	Frequency	Workload	ECTS Credit Points
1 semester	Summer and Winter semester	Total: 150 hrs 30 hrs attendance time (2 SWS) 120 hrs self-directed study time	5

Responsible for module: Prof. Dr. Abid Ali

Lecturer(s):

According to the list of practical experiments (eLearning course).

Associated course(s)	Teaching and learning format	Language of instruction
Participation in a total of 15 attempts during the course of study, including a maximum of eight attempts in the first three semesters.	Lab course	English

Applicability and semester of study (according to Appendix 2 to the SPO):

Bachelor programme Mechatronics (mandatory module, nominally assigned to the 7th semester)

Provides basis for module(s):	
Builds upon module(s):	

Mandatory participation requirements (according to appendix 2 of the SPO)

There are no formal requirements. However, the students must have participated in the short course "Occupational safety and machine protection" before they are allowed to perform experiments.

Recommended prerequisites and previous knowledge

The recommended participation requirements and prior knowledge can be found in the descriptions of the individual lab experiments.

Examination type / requirement for the award of credit points	Examination length	Examination language
Other examination performance, form: practical study performance according to §15 SPO	---	English

The concrete definition of the duration of the examination, the scope of the examination and further examination conditions (e.g. permitted aids) is made in the examination conditions. These are published on the intranet at the beginning of each semester.

Learning outcomes (after successful completion of the module)

The students

- apply the knowledge from other modules of the study program in an experiment, identify the knowledge required for a successful execution of the experiment and learned in different modules and link it in an interdisciplinary way
- analyze the processes and methods used in the experiments on a scientific basis
- plan experiments, carry them out and document the results and the procedure in a scientifically correct manner
- interpret experimental results and draw well-founded conclusions.

Content
• The contents can be taken from the descriptions of the individual experiments. The experiments offered are from different areas of mechatronics engineering and are offered by all laboratories of the Faculty of Mechanical Engineering and Faculty of Electrical Engineering. In addition, experiments on the fundamentals of engineering, e.g. physics, chemistry, are offered.
Literature and other learning opportunities
• Experiment instructions, scripts and supplementary documents in the THWS eLearning system.
Special notes

Module No. (according to appendix 2 to the SPO): **34**			
Industrial Project			
Module length	**Frequency**	**Workload**	**ECTS Credit Points**
1 semester	Every semester 2x	Total: 240 hrs 60 hrs attendance time (4 SWS) 180 hrs self-directed study time	8
Responsible for module: Prof. Dr. Jan Hansmann			
Lecturer(s):			
all professors of the bachelor programmes in mechanical engineering and mechatronics and lecturers for the German circumferences			
Associated course(s)		**Teaching and learning format**	**Language of instruction**
Kommunikationsfähigkeiten für Besprechungen, Berichte schreiben		Seminar-like lectures	Deutsch
Project work		Project	English

Applicability and semester of study (according to Appendix 2 to the SPO):	
Bachelor Programmes • Mechanical Engineering (mandatory module, 6th semester) • Mechatronics (mandatory module, 7th semester)	
Provides basis for module(s):	
Builds upon module(s):	all courses from the first to the sixth semester of study
Mandatory participation requirements (according to appendix 2 of the SPO)	
at least 90 CP achieved	
Recommended prerequisites and previous knowledge	
German: Completion of Level A2 according to the Common European Framework of Reference for Languages	

Examination type / requirement for the award of credit points	**Examination length**	**Examination language**
Project	Accompanying studies in the 7th semester	English with german parts
The concrete definition of the duration of the examination, the scope of the examination and further examination conditions (e.g. permitted aids) is made in the examination conditions. These are published on the intranet at the beginning of each semester.		

Learning outcomes (after successful completion of the module)
The students • independently apply the knowledge (specialist knowledge, methods and procedures) acquired in other modules of the bachelor's degree program • use advanced project management methods and apply them to real tasks under supervision • work on the task cooperatively and responsibly in a team • present complex subject-related content clearly and in a manner appropriate to the target group • research and analyze the current state of research and technology • prepare written project documentation in the form of a report • present the main interim and final results to the client • use new project-related and technical vocabulary and phrases in the English-language section • present the main project contents in English • present project content and technical contexts in English • plan and conduct meetings at different language levels in German • use the German language appropriately at different levels in a variety of business situations.
Content
• scientific work • development methodology • communication techniques • Team meetings and communication • presentation techniques • project documentation • German communication and presentations
Literature and other learning opportunities
• Course supervisors, *Scripts Project Management for the Mechanical Engineering Program*, Volume 2. Schweinfurt: THWS, 2021. • Course supervisors, *Script German in Engineering Projects*, Volume 1. Schweinfurt: THWS, 2021. • J. Feldhusen, K.-H. Grote, Pahl/Beitz, *Konstruktionslehre*, 8th edition. Berlin, Heidelberg: Springer-Verlag, 2013. • VDI Guideline 2222, *Design Methodology - Methodical Development of Solution Principles*, Düsseldorf: VDI Society Product and Process Design, 1997. • U. Lindemann, *Methodical development of technical products*, 3rd edition. Berlin, Heidelberg: Springer-Verlag, 2009. • Course supervisors, *Lecture notes*, Volume 1. Schweinfurt: THWS, 2021.
Special notes
As a rule, an excursion to the industrial partner takes place after the interim presentation. During this event, the students present the project results developed up to this point to the industry or research partner under practice-relevant conditions.

Module No. (according to appendix 2 to the SPO): 35

Bachelor's Thesis

Module length	Frequency	Workload	ECTS Credit Points
1 semester	every semester	Total: 360 hrs Attendance at THWS (meetings with supervisor) according to time and effort, approx. 354 h self-directed study time	12

Responsible for module: Dean of Students

Lecturer(s):

Supervisors (examiners) appointed by the examination committee

Associated course(s)	Teaching and learning format	Language of instruction
none	none	none

Applicability and semester of study (according to Appendix 2 to the SPO):

Bachelor programme Mechatronics (mandatory module, 7st semester)

Provides basis for module(s):	
Builds upon module(s):	all modules of the study degree programme

Mandatory participation requirements (according to appendix 2 of the SPO)

a) achieved at least 150 CP
b) passed all modules of the first three study semesters (modules 1 to 18)
c) Module (22) Control Systems 1 successfully passed
d) Internship (31) successfully passed

Recommended prerequisites and previous knowledge

Learning outcomes of all modules of the programme achieved

Examination type / requirement for the award of credit points	Examination length	Examination language
Bachelor’s thesis according to §30 APO (and §8 SPO)	Processing time for continuous exclusive processing usually 10 weeks	English / German

The concretization of the boundary conditions takes place, among other things, via the registration form of the Bachelor`s Thesis. This is published on the intranet of the study programme.

Learning outcomes (after successful completion of the module)
The students • apply their technical and methodological knowledge independently and across disciplines/modules to a problem from the subject area of the degree programme in order to develop an engineering solution on a scientific basis • assess the impact of engineering solutions in the social and ecological environment and act in accordance with professional ethics and standards • critically evaluate their existing knowledge, recognize missing knowledge and expand their existing knowledge on their own responsibility • apply the methods of project management to achieve the desired goals in limited time and with limited resources and budgets • fit into the social environment of e.g. a company • present their results and their approach in writing in a comprehensible manner and in accordance with the principles of scientific work in a technical report.
Content
Independent processing of a problem from the subject area of the course on a academic basis.
Literature and other learning opportunities
• H. Hering, *How to write technical reports: understandable structure, good design, convincing presentation*, 2. Auflage. Berlin, Heidelberg: Springer, 2019. • P. Bock, *Getting it right: R&D Methods for Science and Engineering*, 1. Auflage. San Diego: Academic Press, 2001.
Special notes
With the approval of the examination committee, the Bachelor's thesis may be carried out at an institution outside the university if supervision by the university's examiners is ensured.

Module No. (according to appendix 2 to the SPO): 36

Costing and Ethics for Engineers

Module length	Frequency	Workload	ECTS Credit Points
1 semester	Winter semester	Total: 150 hrs 60 hrs attendance time (4 SWS) 90 hrs self-directed study time	5

Responsible for module: Prof. Dr. Ankenbrand

Lecturer(s):

Prof. Dr. Ankenbrand, Prof Dr. Kraus

Associated course(s)	Teaching and learning format	Language of instruction
Costing (2 SWS)	Lab course	English
Ethics (2 SWS)	Seminar-like lectures, Exercise course	English

Applicability and semester of study (according to Appendix 2 to the SPO):

Bachelor programme Mechatronics (mandatory module, 7th semester)

Provides basis for module(s):	
Builds upon module(s):	

Mandatory participation requirements (according to appendix 2 of the SPO)

none

Recommended prerequisites and previous knowledge

Examination type / requirement for the award of credit points	Examination length	Examination language
Costing: written exam	90 to 120 min	English
Ethics: other examination performance (portfolio audit)		English

The concrete definition of the duration of the examination, the scope of the examination and further examination conditions (e.g. permitted aids) is made in the examination conditions. These are published on the intranet at the beginning of each semester.

Learning outcomes (after successful completion of the module)

The students

- classify cost accounting terms.
- interpret cost trends.
- execute methods of cost accounting.
- describe the basic terms and contents of recognized catalogs of standards.
- explain the factors used to describe responsibility and trust.
- explain the analysis concept for world views and its elements as well as generic examples.
- explain the dual nature of values and their normative core functions in companies.

Content
• Basics and interrelations of controlling • Instruments of controlling • Cost and activity accounting as an information and control system • Cost type, cost center and cost unit accounting • Systems and methods of cost accounting, application possibilities and limits • Ethics, values, morals & norms: Functions and relevance in companies and organizations • Worldview analysis: Philosophical foundations of specific value concepts • Multi-rational management: professional handling of contradictions and dilemmas in companies and organizations
Literature and other learning opportunities
• J. Rich, J. Jones, D. Heitger, M. Mowen, D. Hansen, *Financial and Managerial Accounting. The Cornerstone of Business Decisions*, 2nd edition. Boston: Cengage Learning, 2012. • H. Stolowly, M. Lebas, Y. Ding, *Financial Accounting and Reporting A Global Perspective*, 5th edition. Boston: Cengage Learning, 2017. • J. Weber, U. Schäfer, *Introduction to Controlling*, 1st revised edition. Stuttgart: Schäffer-Poeschel, 2008.
Special notes

4 Second Part of Studies, 6th Semester (Internship Semester)

Subject Area: Internship

Responsible for subject area: Internship coordinator

Module No. (according to appendix 2 to the SPO): 31

Internship

Module length	Frequency	Workload	ECTS Credit Points
1 semester	Winter semester and Summer semester	Total: 720 hrs 700 hrs attendance time (industry, 0 SWS) 20 hrs preparation for the internship	24

Responsible for module: Internship coordinator

Lecturer(s):

Not applicable

Associated course(s)	Teaching and learning format	Language of instruction
Not applicable	Not applicable	Not applicable

Applicability and semester of study (according to Appendix 2 to the SPO):

Bachelor programme Mechatronics (mandatory module, 6th semester)

Provides basis for module(s):	Bachelor`s Thesis (35)
Builds upon module(s):	Preparation and accompaniment through the engineering seminar (32). Technically based on modules from the basic course (1-24).

Mandatory participation requirements (according to appendix 2 of the SPO)

At least 90 ECTS points from the modules 1-30 at the beginning of the internship.
Submission of an internship contract to the Department of Student Affairs (HSST) before the start of the internship.

Recommended prerequisites and previous knowledge

Individual courses (scientific work, presenting and writing) of the engineering seminar (32)

Examination type / requirement for the award of credit points	Examination length	Examination language
Internship certificate		English

The proof of the successful graduation of the practical phase is provided to the HSST by an internship certificate.

Learning outcomes (after successful completion of the module)
The students • analyze the operational processes and (social) structures in corporate practice • transfer the engineering content learned through application in practice • use learned methods and soft sills (e.g. project management, communication skills, problem solving methods) in a targeted manner • develop into a fully fledged academic workforce ("employability").
Content
The required contents of the practical phase are described in detail in the internship guidelines of the degree program. The key features are briefly outlined below: • Getting to know operational practice with adequate support from an engineer in the company • Accompaniment and reflection of the practical phase through the engineering seminar • Independent application of the knowledge and methods acquired in the course of study to real problems from engineering practice
Literature and other learning opportunities
• Depending on the company (internal documentation, processes and standards) and the respective subject area (standard textbooks, scientific publications)
Special notes

<table>
<tr><td colspan="4">Module No. (according to appendix 2 to the SPO): 32</td></tr>
<tr><td colspan="4">Engineering Seminar</td></tr>
<tr><td>Module length</td><td>Frequency</td><td>Workload</td><td>ECTS Credit Points</td></tr>
<tr><td>1 semester</td><td>Winter semester and Summer semester</td><td>Total: 180 hrs
75 hrs attendance time (5 SWS)
105 hrs independent study</td><td>6</td></tr>
<tr><td colspan="4">Responsible for module: Prof. Dr.-Ing. Christel</td></tr>
<tr><td colspan="4">Lecturer(s):</td></tr>
<tr><td colspan="4">Professors of the Faculties, lecturers from Industry</td></tr>
<tr><td colspan="2">Associated course(s)</td><td>Teaching and learning format</td><td>Language of instruction</td></tr>
<tr><td colspan="2">Individual skill seminars, practice exchange seminar, and individual dates with student lectures or guest lectures.</td><td>seminar</td><td>English or German</td></tr>
<tr><td colspan="4">Applicability and semester of study (according to Appendix 2 to the SPO):</td></tr>
<tr><td colspan="4">Bachelor Programmes
Mechanical Engineering (mandatory module, 6th semester)
Mechatronics (mandatory module, 6th semester)</td></tr>
<tr><td colspan="2">Provides basis for module(s):
Builds upon module(s):</td><td colspan="2">Internship (31), Industrial Project (34), Bachelor`s Thesis (35).</td></tr>
<tr><td colspan="4">Mandatory participation requirements (according to appendix 2 of the SPO)</td></tr>
<tr><td colspan="4">none</td></tr>
<tr><td colspan="4">Recommended prerequisites and previous knowledge</td></tr>
<tr><td colspan="4">none</td></tr>
<tr><td>Examination type / requirement for the award of credit points</td><td colspan="2">Examination length</td><td>Examination language</td></tr>
<tr><td>other examination performance: presentation, house work</td><td colspan="2">-</td><td>English / German</td></tr>
<tr><td colspan="4">Special Admission Requirement: Obligation to participate in the seminar dates according to the appendix to the SPO.</td></tr>
</table>

Learning outcomes (after successful completion of the module)
The students • formulate logically coherent structures and research questions for their own work • abstract complex problems, formulate partial goals and plan the work packages (time, content, resources) with the help of IT tools • carry out methodical (literature) research on the state of the art • correctly cite scientific sources in their documentation • solve technical problems using engineering methods, question and evaluate the results. • write scientifically sound reports and present their work results (internship, bachelor`s thesis) in a meaningful and target group-oriented manner • use online communication tools (e.g. video conferencing) in the digital world of work • discuss working methods and results in the group and give constructive feedback • analyze the offered student lectures and assess the procedures, working techniques and presentation techniques with regard to their own thesis / presentation • draw conclusions from the guest lectures of the industry about the state of the art and their own upcoming professional career • reflect on personal behavior and criteria for success in the professional environment • develop their personal and social skills and thus improve, among other things, their ability to create technical reports / presentations on time, to communicate for teamwork or target-oriented and effective communication.
Content
The seminar prepares the internship (31) and accompanies it through the exchange of experiences among the students. The basis of (engineering) scientific work is laid for subsequent projects (34) and the own bachelor's thesis (36). Contents of the seminar: • Scientific work (analysis, hypothesis, synthesis, validation) • Soft skills, such as presentation technique, interviewing, problem-solving methods • Project and self management • Reflection on the practical phase Implementation of the seminar (organization via certificate card): • 4th sem.: Skill seminars "Scientific work" and "Communication & problem solving". Participation in 3 individual dates with student lectures or guest lectures from the industry. • 5th sem.: Skill seminar "Presenting & Writing". Participation in 3 individual dates with student lectures or guest lectures from the industry. • 6th sem.: "Exchange of practice" seminar to accompany the practical phase • 7th sem.: Preparation of an exposé and presentation of the bachelor's thesis

Literature and other learning opportunities
• H. Balzert, *Wissenschaftliches Arbeiten*, 2. Auflage. Herdecke: W3L-Verlag, 2013. • H. Hering, *Technische Berichte: verständlich gliedern, gut gestalten, überzeugend vortragen*, 8., überarbeitete Auflage. Wiesbaden: Springer Vieweg, 2019. • H. Hering, *How to write technical reports: understandable structure, good design, convincing presentation*, 2. Auflage. Berlin, Heidelberg: Springer, 2019. • P. Bock, *Getting it right: R&D Methods for Science and Engineering*, 1. Auflage. San Diego: Academic Press, 2001. • Documents in the university's eLearning system
Special notes
Guest lectures from industry and other universities and research institutions.

5 Second Part of Studies, Specialization A and B (Module No. 27, 28, 29, 30)

5.1 Automation and Robotics

Responsible for subject area: Prof. Dr.-Ing. B. Müller

Module No. (according to appendix 2 to the SPO): 27/28/29/30

Specialization A1, A2 or B1, B2 according to student's choice
Digital Control and Signal Processing

Module length	Frequency	Workload	ECTS Credit Points
1 semester	Winter semester	Total: 150 hrs 60 hrs attendance time (4 SWS) 60 hrs self-directed study time 30 hrs time for exam preparation	5

Responsible for module: Prof. Dr.-Ing. B. Müller

Lecturer(s):
Prof. Dr.-Ing. B. Müller

Associated course(s)	Teaching and learning format	Language of instruction
Digital Control (2 SWS)	Seminar-like lectures, Exercise course	English
Signal Processing (2 SWS)	Seminar-like lectures, Exercise course	English

Applicability and semester of study (according to Appendix 2 to the SPO):
Bachelor programme Mechatronics (mandatory module, 5th semester)

Provides basis for module(s):	
Builds upon module(s):	System Modeling 1 & System Theory, Control Systems 1 (16,22)

Mandatory participation requirements (according to appendix 2 of the SPO)
None

Recommended prerequisites and previous knowledge

Examination type / requirement for the award of credit points	Examination length	Examination language
(MD) written exam	90 min	English

The concrete definition of the duration of the examination, the scope of the examination and further examination conditions (e.g. permitted aids) is made in the examination conditions. These are published on the intranet at the beginning of each semester.

Learning outcomes (after successful completion of the module)
The students • name and describe the components and the structure of digital control systems • apply the indirect controller design approach to derive digital control algorithms • explain the impacts of the sampling process on the control performance • analyse the closed-loop performance with digital controller using frequency response methods • state the discrete-time state equations for linear and time-invariant systems • calculate exact discrete-time models of linear and time-invariant sampled systems • apply basic state-space controller design methods on discrete-time systems • explain the basics of signal processing in automation systems • apply and evaluate the fundamentals of time-discrete signals such as sampling, aliasing, sampling theorem, etc. • apply a Discrete Fourier Transform (DFT) and interpret the results of a DFT • calculate and implement simple discrete filters • analyse the influence of window functions on the leakage effect.
Content
see description of the individual courses
Literature and other learning opportunities
• C. L. Phillips, H. T. Nagle, A. Chakrabortty, *Digital Control System Analysis and Design*, 4th edition. London: Pearson, 2015. • G. F. Franklin, J. D. Powell, M. Workman, *Digital Control of Dynamic Systems,* 3rd edition. London: Pearson, 1998. • A. V. Oppenheim, R. W. Schafer, *Discrete-time signal processing,* 3rd edition. Upper Saddle River: Prentice Hall, 2010. • P. Dyke, *An Introduction to Laplace Transforms and Fourier Series*, 2nd edition. London: Springer 2014.
Special notes
see description of the individual courses

Course
Digital Control
Lecturer(s):
Prof. Dr.-Ing. B. Müller, S. Iff
Content

• Introduction to digital control (discrete-time control systems)
  ○ Important terms, structures, components
• Indirect controller design approach
  ○ Discretization of continuous-time control laws
  ○ Implementation issues
• Mathematical description and analysis of closed-loop system with digital controller
  ○ Mathematical modelling of sampling process
  ○ Discussion of sampled signals in the frequency domain
  ○ Shannon's sampling theorem
• State space description of discrete-time systems
  ○ General form of linear time-invariant state space equations
  ○ Important properties (stability, controllability, observability)
  ○ Derivation of discrete-time description of sampled system
• Discrete-time state feedback control

Special notes

Course
Signal Processing
Lecturer(s):
S. Iff
Content
• Properties of analog and time-discrete signals and systems • Relationships between Fourier series, Fourier-, Laplace- and Z-transform • Sampling, Aliasing, Sampling theorem • Discrete Fourier Transform (DFT) • Short-time Fourier transform, leakage effect and window functions • Realization and implementation of time-discrete filters
Special notes

Module No. (according to appendix 2 to the SPO): 27/28/29/30

Specialization A1, A2 or B1, B2 according to student's choice
Robotics and Lab Work

Module length	Frequency	Workload	ECTS Credit Points
1 semester	Winter semester	Total: 150 hrs 60 hrs attendance time (4 SWS) 60 hrs self-directed study time 30 hrs time for exam preparation	5

Responsible for module: Prof. Dr.-Ing. F. Mühlfeld

Lecturer(s):
Prof. Dr.-Ing. F. Mühlfeld, M. Löser

Associated course(s)	Teaching and learning format	Language of instruction
Robotics (2 SWS)	Seminar-like lectures, Exercise course	English
Automation Lab (2 SWS)	Lab course	English

Applicability and semester of study (according to Appendix 2 to the SPO):
Bachelor programme Mechatronics (mandatory module, 5th semester)

Provides basis for module(s):	
Builds upon module(s):	Control Systems 1, Actuators, Logical Control and Software Engineering (22,20,23)

Mandatory participation requirements (according to appendix 2 of the SPO)
None

Recommended prerequisites and previous knowledge
- Completion of courses Control Systems 1, Actuators, Logical Control and Software Engineering
- Experience in preparation and documentation of lab exercises

Examination type / requirement for the award of credit points	Examination length	Examination language
(MD) written exam	90 min	English

The concrete definition of the duration of the examination, the scope of the examination and further examination conditions (e.g. permitted aids) is made in the examination conditions. These are published on the intranet at the beginning of each semester.

Learning outcomes (after successful completion of the module)
The students • name, identify and describe different types of robots and robotic systems • explain what kind of robot kinematics are applied to certain automation tasks and why • sketch the different components of an industrial robot and its kinematic chain • derive what kinematic is required to achieve a certain degree of freedom • form rotation matrices and translation vectors from sketches of coordinate systems • transform between Euler angles and rotation matrices • transform vectors from one coordinate system to another using homogenous matrices • apply the Denavit-Hartenberg convention to an arbitrary open kinematic chain • explain the purpose and principles of a forward and inverse kinematic transformation • calculate and draw motion control profiles for given parameters and tasks • apply theoretical concepts in robotics and automation to practical lab tasks on real robots and plants • implement a PLC-Hardware configuration • design a logical control functionality and implement in PLC-development environment • write documentation in preparation and evaluation of lab tasks • coordinate tasks within a group setting for lab experiments.
Content
See description of the individual courses
Literature and other learning opportunities
• T. Kaupp, B. Brandenstein-Köth, M. Ochs, Lecture notes robotics, Schweinfurt: 2021. • T. Kaupp, B. Müller, M. Löser, *Lab instructions for PLC programming and industrial robot experiments*, Schweinfurt 2020. • John J. Craig, *Introduction to Robotics – Mechanics and Control*, 3rd edition. Upper Saddle River, NY: Pearson Prentice Hall, 2004. • W. Weber, *Industrieroboter: Methoden der Steuerung und Regelung*, 4. Auflage. München: Carl Hanser Verlag, 2019.
Special notes
see description of the individual courses

Course
Robotics
Lecturer(s):
M. Löser
Content
• Overview of robotics: history and classification (industrial, service, mobile, humanoid etc.) • Typical applications for industrial robots • Introduction to collaborative robots • Components of an industrial robot • Open kinematic chains and degrees of freedom • Kinematics of common industrial robots, e.g. articulated, SCARA, gantry robots • Fundamentals of kinematics: coordinate systems, rotation matrices, Euler angles, homogeneous matrices • Kinematics of industrial robots: forward and inverse transformation, Denavit-Hartenberg convention • Motion control of industrial robots: interpolation methods (point-to-point and continuous path)
Special notes

Course
Automation Lab
Lecturer(s):
Prof. Dr.-Ing. F. Mühlfeld; M. Löser
Content
• Experiments with programmable logic controllers (PLCs): basic and advanced • Design of a PLC program in simulation; verification of the functionality • Operating, teaching and programming an industrial robot
Special notes

5.2 Voice Control (only in WS 2023/24) and Digital Hardware Design

Responsible for subject area: Prof. U. Mann

Module No. (according to appendix 2 to the SPO): 27/28/29/30

Specialization A1, A2 or B1, B2 according to student's choice
Voice Control

Module length	Frequency	Workload	ECTS Credit Points
1 semester	only winter semester 2023/24	Total: 150 hrs 60 hrs attendance time (4 SWS) 60 hrs self-directed study time 30 hrs time for exam preparation	5

Responsible for module: Prof. Dr.-Ing. Martin Spiertz

Lecturer(s):
Prof. Dr.-Ing. Martin Spiertz

Associated course(s)	Teaching and learning format	Language of instruction
Voice Control (4 SWS)	Seminar-like lectures, Exercise course, Lab course	English

Applicability and semester of study (according to Appendix 2 to the SPO):
Bachelor programme Mechatronics (mandatory module, 5th semester)

Provides basis for module(s):	
Builds upon module(s):	Programming 1 and 2, System Theory, Measuring Techniques

Mandatory participation requirements (according to appendix 2 of the SPO)
none

Recommended prerequisites and previous knowledge
Programming 1 and 2, System Theory, Measuring Techniques

Examination type / requirement for the award of credit points	Examination length	Examination language
(MD) written exam	90 min	English

The concrete definition of the duration of the examination, the scope of the examination and further examination conditions (e.g. permitted aids) is made in the examination conditions. These are published on the intranet at the beginning of each semester.

Learning outcomes (after successful completion of the module)
The students
- name methods for processing audio analysis and sensors
- analyse speech features with cepstral analysis and synthesis like mel-filterbank and phase vocoder
- plan dataacquisition and administration for artificial intelligence
- analyse and design neural networks with current software packages
- analyse and interprete existing software packages for voice control
- implement object oriented software in Python
- earn the qualification to analyse problems and work out solutions for audio signal processing and machine learning

Content
• Object oriented programming with Python • Speech signal processing from microphone to the source filter model of voice • Speech synthesis with the vocoder • Classification with artificial neural networks • Real time implementation on low-budget-hardware • Implementation of a keywordspotter under the MIT license
Literature and other learning opportunities
• Goodfellow, I et.al. Deep Learning. mitp, 2018 • Rabiner L. R. et. al.. Theory and Applications of Digital Speech Processing. Financial Times Prentice Hall, 2010
Special notes

Module No. (according to appendix 2 to the SPO): 27/28/29/30

Specialization A1, A2 or B1, B2 according to student's choice
Hardware Description Languages

Module length	Frequency	Workload	ECTS Credit Points
1 semester	Winter semester	Total: 150 hrs 60 hrs attendance time (4 SWS) 60 hrs self-directed study time 30 hrs time for exam preparation	5

Responsible for module: Prof. Dr. Heinz Endres

Lecturer(s):
Prof. Dr. Heinz Endres

Associated course(s)	Teaching and learning format	Language of instruction
Hardware Description Languages (2 SWS)	Seminar-like lectures, Exercise course	English
Lab SystemVerilog Design with FPGAs (2 SWS)	Exercise course, Lab course	English

Applicability and semester of study (according to Appendix 2 to the SPO):
Bachelor program Mechatronics (mandatory module, 5th semester)

Provides basis for module(s):	
Builds upon module(s):	Microcomputer Systems 1+2 (9,15), Programming 1+2 (4,10)

Mandatory participation requirements (according to appendix 2 of the SPO)
none

Recommended prerequisites and previous knowledge
Basic knowledge of mathematics and basic programming knowledge.

Examination type / requirement for the award of credit points	Examination length	Examination language
(MD) written exam	90 min	English

The concrete definition of the duration of the examination, the scope of the examination and further examination conditions (e.g. permitted aids) is made in the examination conditions. These are published on the intranet at the beginning of each semester.

Learning outcomes (after successful completion of the module)
The students
- differentiate between the different concepts of a hardware description language and can apply them to small and medium size projects
- comprehend the difference between an algorithmic approach of a classical programming language and a circuit description in a high-level description language
- describe the structure and architecture of a field programmable gate array (FPGA)
- develop small projects including verifying and debugging FPGA devices
- apply the concept of static timing analysis and can calculate the timing behavior of small circuits.

Content
see description of the individual courses

Literature and other learning opportunities
• Donald Thomas, *Logic Design and Verification Using SystemVerilog*, Revised edition. North Charleston: CreateSpace, 2016. • Stuart Sutherland, *RTL Modeling with SystemVerilog for Simulation and Synthesis: Using SystemVerilog for ASIC and FPGA Design*, 1st edition. Tualatin: Sutherland HDL Inc., 2017. • The Institute of Electrical and Electronics Engineers Inc., IEEE Std 1800-2017, *Standard for System Verilog Unified Hardware Design, Specification, and Verification Language*, New York: IEEE Inc., 2018. • Notes to lecture in the THWS eLearning system
Special notes

Course
Hardware Description Languages
Lecturer(s):
Prof. Dr. Heinz Endres
Content
• Basic elements and structure of SystemVerilog as a hardware design and verification language • Test benches and simulation using SystemVerilog as testbench description language • Description of sequential and combinatorial elements and finite-state machines • Programming of FPGA modules • Principles of static timing analysis and its application • Handling of memories as part of SystemVerilog and FPGA design
Special notes

Course
Lab SystemVerilog Design with FPGAs
Lecturer(s):
Prof. Dr. Heinz Endres
Content
Different own experiments to program Xilinx SoCs, with focus on • SystemVerilog for both design and verification, • hand-on experiments debugging an STA (static timing analysis) environment, • design examples for controlling an HDMI interface, • and the creation of a small video game.
Special notes

5.3 Automated Systems and Human-Machine Interaction

Responsible for subject area: Prof. Dr.-Ing. S. Hofauer

Module No. (according to appendix 2 to the SPO): **27/28/29/30**

Specialization A1, A2 oder B1, B2 according to student's choice
Human-Machine Interaction and Interlinked Production

Module length	Frequency	Workload	ECTS Credit Points
1 semester	Winter semester	Total: 150 hrs 60 hrs attendance time (4 SWS) 60 hrs self-directed study time 30 hrs time for exam preparation	5

Responsible for module: Prof. Dr.-Ing. Sonja Hofauer

Lecturer(s):
Prof. Dr.-Ing. Sonja Hofauer

Associated course(s)	Teaching and learning format	Language of instruction
Human-Machine Interaction (3 SWS)	Seminar-like lectures, Exercise course	English
Interlinked Production (1 SWS)	Seminar-like lectures, Exercise course	English

Applicability and semester of study (according to Appendix 2 to the SPO):
Bachelor programme Mechatronics (mandatory module, 5th semester)

Provides basis for module(s):
Builds upon module(s):

Mandatory participation requirements (according to appendix 2 of the SPO)
none

Recommended prerequisites and previous knowledge
none

Examination type / requirement for the award of credit points	Examination length	Examination language
(MD) written exam	90 min	English

The concrete definition of the duration of the examination, the scope of the examination and further examination conditions (e.g. permitted aids) is made in the examination conditions. These are published on the intranet at the beginning of each semester.

Learning outcomes (after successful completion of the module)
The students • Apply the activities of human-centered development according to DIN EN ISO 9241 • Choose different methods for the human-centered development of user interfaces • Differentiate between different user interface technologies and modalities with regard to their areas of application, name the advantages and disadvantages of different user interface technologies and select suitable user interface technologies for specific applications • Develop experimental user studies with hypotheses, independent and dependent variables to evaluate human-machine interaction. • Develop user interface concepts for different applications • Apply evaluation methods to examine different user interface concepts • Apply Industry 4.0 methods
Content
See descriptions of the individual courses
Literature and other learning opportunities
• B. Preim, R. Dachselt, *Interaktive Systeme*, *Band 2: User Interface Engineering, 3D-Interaktion, Natural User Interfaces*, 2. Auflage. Berlin, Heidelberg: Springer Vieweg, 2015. • A. Butz, A. Krüger, *Mensch-Maschine-Interaktion*, 2. Auflage. Berlin, Bosten: Walter De Gruyter Oldenburg, 2017. • J. J. LaViola, E. Kruijff, R. P. McMahan, D. A. Bowman, I. Poupyrev, *3D User Interfaces, Theory and Practice*, 2. Auflage. Boston: Addison-Wesley, 2017. • G. Meixner, Ch. Müller, *Automotive User Interfaces, Interactive Experiences in the Car*. Cham (CH): Springer International Publishing, 2017. • R. Dörner, W. Broll, P. Grimm, B. Jung, *Virtual und Augmented Reality (VR/AR): Grundlagen und Methoden der virtuellen und augmentierten Realität*. 2. Auflage. Berlin: Springer Vieweg, 2019. • Lecture notes in the FHWS eLearning system.
Special notes

Course
Human-Machine Interaction
Lecturer(s):
Prof. Dr.-Ing. Sonja Hofauer
Content
• Activities of human-centered development according to DIN EN ISO 9241. • Basics of human information processing, motor skills & cognition • User interface technologies and modalities in various application areas (e.g. augmented and virtual reality, language, gestures, touch) • Evaluation methods of user interfaces • Usability and user experience • Challenges of human-machine interaction in increasingly automated systems
Special notes

Course
Interlinked Production
Lecturer(s):
Prof. Dr.-Ing. Sonja Hofauer
Content
• Networking of production machines via communication protocols with central databases within Industry 4.0 • IoT functionalities for machines and individualized products • Human-robot collaboration in production and assembling
Special notes

<table>
<tr><td colspan="4">Module No. (according to appendix 2 to the SPO): 27/28/29/30</td></tr>
<tr><td colspan="4">Specialization A1, A2 oder B1, B2 according to student's choice
Automated and Connected Mobility</td></tr>
<tr><td>Module length</td><td>Frequency</td><td>Workload</td><td>ECTS Credit Points</td></tr>
<tr><td>1 semester</td><td>Winter semester</td><td>Total: 150 hrs
60 hrs attendance time (4 SWS)
60 hrs self-directed study time
30 hrs time for exam preparation</td><td>5</td></tr>
<tr><td colspan="4">Responsible for module: Prof. Dr.-Ing. Sonja Hofauer</td></tr>
<tr><td colspan="4">Lecturer(s):</td></tr>
<tr><td colspan="4">Prof. Dr.-Ing. Sonja Hofauer</td></tr>
<tr><td colspan="2">Associated course(s)</td><td>Teaching and learning format</td><td>Language of instruction</td></tr>
<tr><td colspan="2">Automated and Connected Mobility (2 SWS)</td><td>Seminar-like lectures,
Exercise course</td><td>English</td></tr>
<tr><td colspan="2">Internet of Things Lab (2 SWS)</td><td>Supervised Lab course</td><td>English</td></tr>
<tr><td colspan="4">Applicability and semester of study (according to Appendix 2 to the SPO):</td></tr>
<tr><td colspan="4">Bachelor programme Mechatronics (mandatory module, 5th semester)</td></tr>
<tr><td colspan="2">Provides basis for module(s):
Builds upon module(s):</td><td colspan="2"></td></tr>
<tr><td colspan="4">Mandatory participation requirements (according to appendix 2 of the SPO)</td></tr>
<tr><td colspan="4">none</td></tr>
<tr><td colspan="4">Recommended prerequisites and previous knowledge</td></tr>
<tr><td colspan="4">Basic programming skills</td></tr>
<tr><td>Examination type / requirement for the award of credit points</td><td colspan="2">Examination length</td><td>Examination language</td></tr>
<tr><td>(MD) written exam</td><td colspan="2">90 min</td><td>English</td></tr>
<tr><td colspan="4">The concrete definition of the duration of the examination, the scope of the examination and further examination conditions (e.g. permitted aids) is made in the examination conditions. These are published on the intranet at the beginning of each semester.</td></tr>
<tr><td colspan="4">Learning outcomes (after successful completion of the module)</td></tr>
<tr><td colspan="4">The students
Discuss different levels of automated driving according to SAE J3016
Describe central components of driver assistance systems and analyze them with respect to the degree of automation
Identify the division of tasks between human drivers and vehicle systems depending on the degree of automation
Examine technical and ethical challenges of automated and connected driving
Differentiate V2X fields of application of connected mobility to increase traffic safety and efficiency
Examine sustainable mobility concepts
Develop applications in Node Red using Raspberry Pi with sensors, MQTT and Machine Learning for Image Classification.</td></tr>
</table>

Content
See descriptions of the individual courses
Literature and other learning opportunities
• H. Winner, S.Hakuli, Lotz, F. Singer, C., *Handbook of Driver Assistance Systems- Basic Information, Components and Systems for Active Safety and Comfort*. Cham (CH): Springer International Publishing, 2016. • A. Eskandarian, *Handbook of Intelligent Vehicles,* London: Springer, 2012. • D. P. F. Möller und R. E. Haas, *Guide to Automotive Connectivity and Cybersecurity: Trends, Technologies, Innovations and Applications*, Cham (CH): Springer International Publishing, 2019. • A. Sciarretta, A. Vahidi, *Energy-Efficient Driving of Road Vehicles, Toward Cooperative, Connected, and Automated Mobility*. Cham (CH): Springer International Publishing, 2020. • F. Firouzi, K. Chakrabarty, S. Nassif, Intelligent Internet of Things. Springer Cham 2020. • Lecture notes in the FHWS eLearning system.
Special notes

Course
Automated & Connected Mobility
Lecturer(s):
Prof. Dr.-Ing. Sonja Hofauer
Content
• Levels automated driving according to SAE J3016 • Advanced Driver Assistance Systems • Computer Vision and Deep Learning • Vehicle-to-Vehicle and Vehicle-to-Infrastructure communication and its applications • Future and sustainable mobility concepts
Special notes

Course
Internet of Things Lab
Lecturer(s):
Prof. Dr.-Ing. Sonja Hofauer
Content
• Developing Node Red Applications using Raspberry Pi and Sensors • MQTT Broker for data transmission • Human Machine Interface • Computer Vision for image classification on a Raspberry Pi
Special notes

5.4 Applied Machine Learning and Design of Experiments

Responsible for subject area: Prof. Dr.-Ing. S. Schreiber

Module No. (according to appendix 2 to the SPO): **27/28/29/30**			
Specialization A1, A2 or B1, B2 according to student's choice **Applied Machine Learning**			
Module length	**Frequency**	**Workload**	**ECTS Credit Points**
1 semester	Winter semester	Total: 150 hrs 60 hrs attendance time (4 SWS) 60 hrs self-directed study time 30 hrs time for exam preparation	5
Responsible for module: Prof. Dr.-Ing. Schiffler			
Lecturer(s):			
Prof. Dr.-Ing. Schiffler			
Associated course(s)		**Teaching and learning format**	**Language of instruction**
Applied Machine Learning, AML (3 SWS) Practical Laboratory Exercise (1 SWS)		Seminar-like lectures, Exercise course, Lab course self-paced-learning on PC with supervision	English English
Applicability and semester of study (according to Appendix 2 to the SPO):			
Bachelor programme Mechatronics (mandatory module, 5th semester)			
Provides basis for module(s):	none		
Builds upon module(s):	Engineering Mathematics 1-4 (1,2 7,8), Programming 1+2 (4,10), Measuring Techniques (19)		
Mandatory participation requirements (according to appendix 2 of the SPO)			
none			
Recommended prerequisites and previous knowledge			
Successful completion of the underlying modules			
Examination type / requirement for the award of credit points	**Examination length**	**Examination language**	
(MD) written exam	90 min	English	
The concrete definition of the duration of the examination, the scope of the examination and further examination conditions (e.g. permitted aids) is made in the examination conditions. These are published on the intranet at the beginning of each semester.			
Learning outcomes (after successful completion of the module)			
The students • explain the basic principles in machine learning algorithms • apply the learned basics to solve simple tasks by the use of a PC and software • apply state of the art software libraries for solving engineering tasks by machine learning algorithms and interpret the results • explain different approaches for the training and interference of neuronal networks			

Content
see description of the individual courses
Literature and other learning opportunities
• David Forsyth: *Applied Machine Learning*, Springer Link: https://link.springer.com/book/10.1007/978-3-030-18114-7 • Aurélien Géron: *Hands-On Machine Learning with Scikit-Learn and TensorFlow: Concepts, Tools, and Techniques*, https://ebookcentral.proquest.com/lib/fhws/detail.action?docID=5892320 • A. Schiffler, Notes to lectures in the THWS eLearning system. Schweinfurt, 2021.
Special notes

Course
Applied Machine Learning, AML (3 SWS)
Lecturer(s):
Prof. Dr.-Ing. Schiffler
Content
• Introduction and context • Basic Math: Multi variant linear regression, Logistic regression, Regularization, Neuronal Network representation • Application of the basics in different software tools/languages: Matlab, Python, JavaScript • Solving simplified real world problems with basic machine learning algorithms • Computer vision and neuronal networks (deep learning) • Introduction to high level machine learning software libraries • Implementation concepts on automation, embedded or mobile devices
Special notes

Course
Practical Laboratory Exercise (1 SWS)
Lecturer(s):
Prof. Dr.-Ing. Schiffler
Content
Exercise course on PC • Working with Matlab, Python and JavaScript • Solve small tasks on base of the lectures every week • Work in groups or individual
Special notes

<table>
<tr><td colspan="4">Module No. (according to appendix 2 to the SPO): 27/28/29/30</td></tr>
<tr><td colspan="4">Specialization A1, A2 or B1, B2 according to student's choice
Design of Experiments</td></tr>
<tr><td>Module length</td><td>Frequency</td><td>Workload</td><td>ECTS Credit Points</td></tr>
<tr><td>1 semester</td><td>Winter semester</td><td>Total: 150 hrs
60 hrs attendance time (4 SWS)
60 hrs self-directed study time
30 hrs time for exam preparation</td><td>5</td></tr>
<tr><td colspan="4">Responsible for module: Prof. Dr.-Ing. Schreiber</td></tr>
<tr><td colspan="4">Lecturer(s):</td></tr>
<tr><td colspan="4">Prof. Dr.-Ing. Schreiber</td></tr>
<tr><td colspan="2">Associated course(s)</td><td>Teaching and learning format</td><td>Language of instruction</td></tr>
<tr><td colspan="2">Design of Experiments, DOE (3 SWS)</td><td>Seminar-like lectures,
Exercise course</td><td>English</td></tr>
<tr><td colspan="2">Practical (Laboratory) Exercise (1 SWS)</td><td>Lab course with supervision</td><td>English</td></tr>
<tr><td colspan="4">Applicability and semester of study (according to Appendix 2 to the SPO):</td></tr>
<tr><td colspan="4">Bachelor programme Mechatronics (mandatory module, 5th semester)</td></tr>
<tr><td>Provides basis for module(s):
Builds upon module(s):</td><td colspan="3">
Engineering Mathematics 1-4 (1,2,7,8), Programming 1+2 (4,10), Measuring Techniques (19)</td></tr>
<tr><td colspan="4">Mandatory participation requirements (according to appendix 2 of the SPO)</td></tr>
<tr><td colspan="4">none</td></tr>
<tr><td colspan="4">Recommended prerequisites and previous knowledge</td></tr>
<tr><td colspan="4">Successful completion of the underlying modules</td></tr>
<tr><td>Examination type / requirement for the award of credit points</td><td colspan="2">Examination length</td><td>Examination language</td></tr>
<tr><td>(MD) written exam</td><td colspan="2">90 min</td><td>English</td></tr>
<tr><td colspan="4">The concrete definition of the duration of the examination, the scope of the examination and further examination conditions (e.g. permitted aids) is made in the examination conditions. These are published on the intranet at the beginning of each semester.</td></tr>
<tr><td colspan="4">Learning outcomes (after successful completion of the module)</td></tr>
<tr><td colspan="4">The students
explain the benefits of systematically planned experiments
reproduce design methods for simulations and lab experiments
operate a designated software package to set up state of the art experimental designs
analyse experimental results employing basic statistics and regression
interpret the outcome of the planned experiments
apply this knowledge to conceive concepts of self-optimizing test-rigs or other industrial applications</td></tr>
</table>

Content
see description of the individual courses
Literature and other learning opportunities
• NIST/SEMATECH, *e-Handbook of Statistical Methods* (chapter 5), http://www.itl.nist.gov/div898/handbook/ • A. Jiju, *Design of Experiments for Engineers and Scientists*, Oxford: Butterworth-Heinemann, 2003. • W. Kleppmann, *Versuchsplanung - Produkte und Prozesse optimieren* (German), 10. revised edition. München: Carl Hanser Verlag, 2020. • S. Schreiber, Notes to lectures in the THWS eLearning system. Schweinfurt, 2021.
Special notes

Course
Design of Experiments, DOE
Lecturer(s):
Prof. Dr.-Ing. Schreiber
Content
• Basic Math: Elementary statistics, Design space, Multi variate linear regression • Process modelling: Definition of Factors, Responses, Constraints • Design strategies: Screening designs, Response-Surface-Model (RSM) designs, Classical (full / fractional factorial) designs, Optimal designs, Space filling designs • Analysis and interpretation of experimental results • Introduction to dedicated software tools: Cornerstone, Excel, Matlab, …
Special notes

Course
Practical Laboratory Exercise
Lecturer(s):
Prof. Dr.-Ing. Schreiber
Content
• Practical exercises in class-room, lab or PC-pool • Planning, performing and evaluating experiments and simulations along with the lecture • Application of dedicated software tools: Cornerstone, Excel, Matlab, … • Work individually or in groups
Special notes

5.5 Robotics and Production

Responsible for subject area: Prof. Dr.-Ing. Christian Ziegler

Module No. (according to appendix 2 to the SPO): 27/28/29/30

Specialization A1, A2 or B1, B2 according to student's choice

Manufacturing Automation and Production Engineering

Module length	Frequency	Workload	ECTS Credit Points
1 semester	Winter semester	Total: 150 hrs 60 hrs attendance time (4 SWS) 60 hrs self-directed study time 30 hrs time for exam preparation	5

Responsible for module: Prof. Dr.-Ing. Christian Ziegler

Lecturer(s):

Prof. Dr.-Ing. Christian Ziegler

Associated class(es)	Teaching and learning format	Language of instruction
Manufacturing Automation and Production Engineering (4 SWS)	Seminar-like lectures, Exercise course	English

Applicability and semester of study (according to Appendix 2 to the SPO):

Bachelor program Mechatronics (mandatory module, 5th semester)

Mandatory participation requirements (according to appendix 2 of the SPO)

none

Recommended prerequisites and previous knowledge

Basic knowledge of mathematics and the fundamentals of mechatronics

Examination type / requirement for the award of credit points	Examination length	Examination language
(MD) written exam	90 min	English

The concrete definition of the duration of the examination, the scope of the examination and further examination conditions (e.g. permitted aids) is made in the examination conditions. These are published on the intranet at the beginning of each semester.

Learning outcomes (after successful completion of the module)

The students

- describe basic assembly technologies
- describe elements of automation technology
- select handling device based on application
- select components for simple automated production processes
- select gripper technology and calculate design-relevant parameters of grippers
- describe major industrial control and communication technology concepts
- describe production planning and optimization concept

Content
see description of the individual courses
Literature and other learning opportunities
• FELDMANN, Klaus; SCHÖPPNER, Volker; SPUR, Günther. Handbuch Fügen, Handhaben und Montieren. Carl Hanser Verlag GmbH, 2014 • LAMB, Frank. Industrial Automation: Hands-On. McGraw-Hill Education, 2021 • HESSE, Stefan. Fertigungsautomatisierung. Friedr. Vieweg & Sohn Verlagsgesellschaft mbH, 2000
Special notes
see description of the individual courses

Course
Manufacturing Automation and Production Engineering
Teacher(s):
Prof. Dr.-Ing. Christian Ziegler
Content
• Elements of production automation • Handling, assembly, and processing with industrial robots • Gripping technologies, selection and calculation of grippers • Basics of control and communication technologies • Material logistics and feeding technologies • Planning and optimization of manufacturing systems
Special notes

Modul No. (according to appendix 2 to the SPO): 27/28/29/30

Specialization A1, A2 or B1, B2 according to student's choice
Robot Programming

Module length	**Frequency**	**Workload**	**ECTS Credit Points**
1 semester	Winter semester	Total: 150 hrs 60 hrs attendance time (4 SWS) 60 hrs self-directed study time 30 hrs time for exam preparation	5

Responsible for module: Dr. rer. nat. Dorit Borrmann

Lecturer(s):
Prof. Dr. Dorit Borrmann

Associated class(es)	**Teaching and learning format**	**Language of instruction**
Robot Programming (4 SWS)	Seminar-like lectures, Exercise course, Lab course	English

Applicability and semester of study (according to Appendix 2 to the SPO):
Bachelor program Mechatronics (mandatory module, 5th semester)

Provides basis for module(s):	None.
Builds upon module(s):	Programming 1 (4),Programming 2 (10)

Mandatory participation requirements (according to appendix 2 of the SPO)
none

Recommended prerequisites and previous knowledge
Basic knowledge of mathematics; basic programming knowledge, as provided in "Programming 1" and "Programming 2"

Examination type / requirement for the award of credit points	**Examination length**	**Examination language**
(MD) written exam	90 min	English

The concrete definition of the duration of the examination, the scope of the examination and further examination conditions (e.g. permitted aids) is made in the examination conditions. These are published on the intranet at the beginning of each semester.

Learning outcomes (after successful completion of the module)
The students

- describe the basic components of every ROS system like ROS nodes, topics, workspaces, and packages
- list relevant tools and libraries for use in ROS
- describe and develop packages using the ROS build system
- describe the information processing and communication in ROS
- develop simple programs for stationary arm-type and mobile robots
- describe the procedure for developing simulations in Gazebo
- name the application possibilities of ROS-Industrial and list application examples

Content
see description of the individual courses
Literature and other learning opportunities
• QUIGLEY, Morgan; GERKEY, Brian; SMART, William D. Programming Robots with ROS: a practical introduction to the Robot Operating System. " O'Reilly Media, Inc.", 2015. • MAHTANI, Anil, et al. Effective robotics programming with ROS. Packt Publishing Ltd, 2016. • HERTZBERG, J.; LINGEMANN, K.; NÜCHTER, A., Mobile Roboter - Eine Einführung aus Sicht der Informatik. Springer, 2012. • THRUN, S.; Burgard, W.; Fox, D., Probabilistic Robotics, MIT Press, 2005
Special notes
see description of the individual courses

Course
Robot Programming
Lecturer(s):
Prof. Dr. Dorit Borrmann
Content
Programming of mobile and manipulation robots using the Robot Operating System (ROS): • Architecture and working environment • ROS build system • ROS communication middleware • Robot software architectures • Relevant tools and libraries • Integration and utilization of sensor data • Basics of localization and mapping • Basics of path planning and control • ROS-Industrial • Simulation in Gazebo and application examples
Special notes