MODULHANDBUCH

für den Studiengang der
Fakultät Mobilität und Technik

Automotive Systems (Master) – SPO 2.0

Fassung 1.0
Stand 25.01.2023

Gültig ab Wintersemester 2023/2024

Änderungsverzeichnis

Datum	Version	Beschreibung der Änderung	Bearbeiter
25.01.2023	1.0	Modulbeschreibungen	Oberhauser

Hinweis zur Gültigkeit

Dieses Modulhandbuch gilt für Studierende, die das Studium im Studiengang

- Automotive Systems SPO 2.0

der Studien- und Prüfungsordnung der Hochschule Esslingen ab dem WS23/24 aufgenommen haben.

Sonstige Anmerkungen

Der Workload pro Creditpoint beträgt in diesen Studiengängen (§8 (1) MRVO):

Credits	Workload in Stunden
1	30

Freigabe

Dieses Dokument ist freigegeben.

gez. Prof. Mathias Oberhauser

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Studiengangstrukturen und Modulübersichten

Studiengangstruktur

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Modul-nummer ASM	Modulname	Teil-Creditpunkte	Teilgebiet	Lehrumfang SWS je Semester 1	2	3	Studien-Leistung	Prüfungs-Leistung	Credits
3901	Mathematical Methods in Engineering			8				KL 120	8
3902	System Design			8				KL 120	8
3903	Simulation and Control			8				KL 120	8
Ergänzungsmodule. Zu studieren ist Modul 3904 **oder** 3905 je nach Vorkenntnissen; siehe Absatz **Fehler! Verweisquelle konnte nicht gefunden werden.**.									
3904	Vehicle Systems Fundamentals							KL 120	6
3905	IT Fundamentals			6				KL 120	6
Summen 1. Semester				**30**					**30**
3906	Autonomous Systems				8			KL 120	8
3907	Team Project		Project Seminar		1			PA	8
Zwei Spezialisierungs-Module je Studienschwerpunkt									
Nur Studierende mit dem Schwerpunkt **Automotive IT**									
3908	Automotive Communications				7			KL 120	7
3909	Usability and Dependability				7			KL 120	7
Nur Studierende mit dem Schwerpunkt **Vehicle Systems**									
3910	Ride and Handling				8			KL 120	8
3911	Propulsion Systems				6			KL 120	6
Summen 2. Semester					**23**				**30**
3914	Softskills	2	Global Engineering			2		KL 120	7
		2	Project Management			2			
		3	International Negotiations			3			
3915	Master Thesis	21	Master Thesis Project					BE (7)	23
		2	Presentation and Defence					MP 30 (1)	
Summen gesamtes Studium									**90**

Bemerkung: Die Modulnummern sind vorläufig.

Überblick Änderungen Modulhandbuch ASM Stupo 2.0 zu 1.0

Nr.	Modul	Credits	Anmerkungen
3901	Mathematical Methods	8 (+1)	Bereich Stochastik als theoretische Grundlage des autonomen Fahrens neu. Stoff im Teilgebiet Numerical Differential Equations reduziert.
3902	System Design	8	unverändert
3903	Simulation and Control	8	Teilgebiet Microcontroller aus 3809 übernommen, Fuzzy Logik gestrichen da technisch nicht mehr relevant.
3904	Vehicle System Fundamentals	6 (-1)	Modulname geändert (früher Vehicle Technology) Weniger Grundlagen Verbrennungs-motoren zugunsten Grundlagen alternative Antriebe (Batterie-fahrzeug, Brennstoffzelle).
3905	IT Fundamentals	6(-1)	Ersetzt das Modul Electronics, Sensors, and Measurement Techniques da künftig stärkere Ausrichtung in Richtung Software und Algorithmen.
3906	Autonomous Systems	8 (+1)	Ersetzt Simulation and Control 2 Kenntnisse in autonomen Fahren werden für Absolventen sehr wichtig.
3907	Team Project	7(+1)	Inhalt gleichgeblieben. Etwas mehr Zeit für Projektarbeit
3908	Automotive Communications	7 (-1)	Teilgebiete Safety and Security und MMI zwischen 3908 und 3909 getauscht.
3909	Usability and Dependability	7 (-1)	Modulname geändert (früher Reliable Embedded Systems) Teilgebiet Reliable Embedded Systems teils in 3903 verlagert Teilgebiete Safety and Security und MMI zwischen 3908 und 3909 getauscht. Teilgebiet Safety and Security etwas reduziert da z.T. in 3906 verlagert
3910	Ride and Handling	8	unverändert
3911	Propulsion Systems	6 (-2)	Synergie mit dem Modul Antriebsentwicklung (6h) im Masterstudiengang Fahrzeugtechnik (Unterricht auf Englisch). Stärkere Ausrichtung auf Betriebsstrategie hybrider Antriebe. Weniger konventioneller Antrieb (Verbrennungsmotor, Vielganggetriebe). Gemeinsames Lernen internationaler und deutscher Masterstudenten soll gefördert werden.
3912	*Electric and Electronic Architecture*		Modul entfällt (siehe Begründung Stuporeform)
3913	*Packaging and Integration*		Modul entfällt (siehe Begründung Stuporeform)
3914	Softskills	7	Zahl der Prüfungen verringert
3915	Master Thesis	23	unverändert

Module erstes Semester

Mathematical Methods

1	**Module Number** 3901	**Study Programme** ASM	**Semester** 1	**Offered in** ☒WS ☐SS	**Duration** 1 Semester	**Module Type** compulsory	**Workload (h)** 240	**ECTS Points** 8
2	**Courses**		**Teaching and Learning Forms**		**Contact Time**		**Self-Study Time**	**Language**
					(SWS)	**(h)**	**(h)**	
	a) Numerical Analysis		Lecture		3	45	120	English
	b) Numerical Differential Equations		Lecture		2	30		
	c) Statistics and Kalman Filter		Lecture		3	45		
						[1 SWS = 15h]		

3 **Learning Outcomes and Competences**

Once the module has been successfully completed, the students can...

Knowledge and Understanding

- ... explain the basic ideas of numerical analysis and understand the relation to the applications
- ... understand the algorithms and their constraints
- ... understand the limitations of the algorithms

Use, Application and Generation of Knowledge

Use and Transfer

- ... apply the algorithms in MATLAB.
- ... analyse the solutions concerning plausibility.
- … recognize and classify connections.
- ... analyse technical problems and derive or develop solutions.
- ... familiarize themselves with new ideas and topics based on their basic knowledge.

Scientific Innovation

- … use methods and tools to gain new insights in the field of numerical analysis.
- ... create new models.
- ... optimize systems.
- ... independently develop approaches for new concepts and assess their suitability.
- ... develop concepts for the optimization of technical applications.

Communication und Cooperation

- ... interpret the results of numerical analysis and draw admissible conclusions.
- ... use the learned knowledge, skills and competences to evaluate the field and interpret them according to other aspects.
- ... communicate and cooperate within the group in order to find adequate solutions for the task at hand.

Scientific Self-Conception/ Professionalism

- ... justify the solution theoretically and methodically.

4	**Contents** Lecture a) • Linear systems • Regression • Numerical differentiation and integration • Nonlinear equations and nonlinear systems Lecture b) • Ordinary differential equations (Runge-Kutta methods, stability and stiffness, shooting methods, applications) • Partial differential equations (finite difference methods, finite element methods, applications) Lecture c) • Descriptive and inferential statistics • Probability theory • Kalman filter Programming in MATLAB as part of the lecture.
5	**Participation Requirements** compulsory: - recommended: Good knowledge of further mathematics
6	**Examination Forms and Prerequisites for Awarding ECTS Points** Written Examination, 120 minutes
7	**Further Use of Module** Applying mathematical methods in other lectures and major fields of automotive engineering
8	**Module Manager and Full-Time Lecturer** Prof. Dr. J. Gaukel, Prof. Dr. M. Stämpfle, Prof. Dr. G. Schaaf
9	**Literature** • Gander W., Gander M.J., Kwok, F., Scientific Computing • Stanoyevitch, Introduction to Numerical Ordinary and Partial Differential Equations Using MATLAB, Wiley • Marchthaler, Dingler: Kalman-Filter: Einführung in die Zustandsschätzung und ihre Anwendung für eingebettete Systeme • Chui, Chen: Kalman Filtering, Springer
10	**Last Updated** 06.10.2022

System Design

1	Module Number	Study Programme	Semester	Offered in	Duration	Module Type	Workload (h)	ECTS Points
	3902	ASM	1	☒WS ☐SS	1 Semester	compulsory	240	8

2	Courses	Teaching and Learning Forms	Contact Time (SWS)	Contact Time (h)	Self-Study Time (h)	Language
	a) Automotive System and Software Architectures	Lecture	4	60	120 [bitte nur Summe eintragen]	English
	b) Automotive Systems Development Process and System Test	Lecture	4	60 [1 SWS = 15h]		

3 **Learning Outcomes and Competences**

Once the module has been successfully completed, the students can...

- … analyze automotive E/E (electronic/electric) architectures and the associated hardware and software architectures
- … develop own solutions in this application domain
- .. . work in a larger interdisciplinary engineering team based on a clear understanding of the required design and development processes necessary.

Knowledge and Understanding

- ... understand the architecture of automotive electric and electronic systems and their development process.
- … know the limits of existing systems, have an idea about future trends in the automotive E/E domain and about the problems to be solved in the future.

Use, Application and Generation of Knowledge

Use and Transfer

- ...understand the complete automotive system development process including system test and application.
- ...see the difference between systems, functions and components and their respective development processes.
- ... analyse the structure of distributed automotive electronic systems, their software architectures and the communication principles and channels.
- ... be able to analyze communication protocols, especially bandwidth and latency.
- ... be able to assess the safety and reliability of systems.
- … compare automotive solutions with solutions and concepts from other technical domains.

Scientific Innovation

- … use methods and tools to gain new insights.
- ... create models for automotive systems and use them for implementation and tests.
- ... optimize automotive E/E architectures with respect to functionality,safety, performance, robustness and cost.
- ... set up and evaluate hypothesis tests and design procedures to verify and validate the E/E design.
- ... independently develop approaches for new systems and assess their suitability, especially transfer related technical concepts and solutions from other technical fields, e.g. aerospace or computer science into the automotive domain.

Communication und Cooperation

- ... communicate actively within an organization and obtain information.
- ... interpret the results of the [field] and draw admissible conclusions.
- ... use the learned knowledge, skills and competences to evaluate E/E concepts and assess their features.
- ... present automotive system design related topics and discuss them.
- ... communicate and cooperate within an engineering team in order to find adequate solutions for the task at hand.

Scientific Self-Conception/ Professionalism

- … analyze the impact of design decisions on the social and economic situation of the society and derive recommendations for decisions from a social and ethical perspective on the basis of the analyses and evaluations made.
- ... justify the solution theoretically and methodically.
- ... reflect and assess one's own abilities in a group comparison and develop strategies to improve them.

4	**Contents** Lecture a): System Development • Typical components and functions of automotive systems. • Typical engine management system and its development process. • Software life cycle including classic V model, agile (Scrum) development and Automotive Spice. • Requirements engineering and requirements management. • SW-documentation and data specification, coding guidelines. • Software and system test. • Application examples of simple functions Lecture b): • Application domains powertrain, chassis, body, advanced driver assistance, infotainment, outlook to automated driving • Basics of distributed systems. ECU hardware requirements and structure, communication relations and communication problems under real-time constraints. • E/E architecture of hybrid and electric powered cars vs. cars with classic combustion engines. Trend towards domain controller and compute-server-architectures. • Automotive bus systems and communication protocols (CAN, LIN, FlexRay, MOST, Automotive Ethernet, V2X). Message based communication vs. service oriented communication. • Diagnosis and diagnostic communication. • Qualitative and quantitative assessment of system safety and reliability. Functional safety including ISO 26262. • ECU software architecture and software standards (AUTOSAR Classic and Adaptive) The lectures will include theory, case studies, literature surveys and presentation of selected topics done by student teams.
5	**Participation Requirements** compulsory: - recommended: Basic knowledge in electronics and computer science. Familiarity with one of the major programming languages, C/C++ preferred. Own experience in self-management of a project, i.e. Bachelor thesis
6	**Examination Forms and Prerequisites for Awarding ECTS Points** Written Examination 120 min
7	**Further Use of Module** Autonomous Systems, Propulsion Systems , Team Project, Master Thesis
8	**Module Manager and Full-Time Lecturer** Prof. Dr. R. Schuler
9	**Literature** • J. Schäuffele, T. Zurawka: Automotive Software Engineering. Springer-Vieweg. • H. Wallentowitz, K. Reif: Handbuch Kraftfahrzeugelektronik. Springer-Vieweg. • R.K. Jurgen. Automotive Electronics Handbook. McGraw-Hill. • W. Zimmermann, R. Schmidgall: Bussysteme in der Fahrzeugtechnik, Springer-Vieweg. • K. Reif (Publisher): Bosch Automotive Handbook Series. Springer-Vieweg.
10	**Last Updated** 2022-10-10

Simulation and Control

1	**Module Number** 3903	**Study Programme** ASM	**Semester** 1	**Offered in** ☒WS ☐SS	**Duration** 1 Semester	**Module Type** compulsory	**Workload (h)** 240	**ECTS Points** 8
2	**Courses**		**Teaching and Learning Forms**		**Contact Time**		**Self-Study Time**	**Language**
					(SWS)	**(h)**	**(h)**	
	a) Microcontroller, Modelling and Simulation		Lecture + Lab		2+1	45	120	Englisch
	b) Basic Control		Lecture		2	30		
	c) Advanced Control		Lecture		3	45		
						[1 SWS = 15h]		

3 **Learning Outcomes and Competences**

Once the module has been successfully completed, the students can...

Knowledge and Understanding

- ... understand and know the basic methods of modelling, system simulation and control engineering
- … know how and where to use these methods in the development of automotive systems
- … build up basic control loops using a small Microcontroller (e.g. Arduino)

Use, Application and Generation of Knowledge

Use and Transfer

- ... apply physical laws to derive mathematical system models in different domains (mechanical, electrical, thermal)
- ... apply methods of system simulation and control engineering in automotive applications
- ... analyse and evaluate the behaviour of automotive systems and subsystems by use of simulation results
- … develop small circuits with sensors and actuators and develop programs for Microcontroller, build up, test and calibrate control functions

Scientific Innovation

- … use simulation and control engineering methods and tools to gain new insights into automotive systems or subsystems.
- ... create and optimize the behaviour of automotive systems based on system models
- … get acquainted with practical realization of the simulated problem in a microcontroller environment

Communication und Cooperation

- ... create, communicate and discuss technical information’s in the area of the course subject
- ... communicate actively within an organization and obtain information.

Scientific Self-Conception/ Professionalism

- ... justify the solution theoretically and methodically to improve development methods.
- ... reflect and assess one's own abilities in a group comparison.

4	**Contents** **1. Microcontroller, Modelling and Simulation (2h)** • Systematic System Modelling and Identification in different domains (mechanical, electrical, thermal) • Adding sensors and actuators to the modelled system to get the complete transfer function • Integration of Control loops to manage system control and dynamics • Linearization of sensors / actuators or models (practical example) • Do Simulations using Simulink and Simscape and evaluate results • Build up small control system examples in Hardware and transfer control algorithm to a Real-Time Environment and do AutoCoding (Simulink to Arduino) • Compare pure Simulink/Simscape Simulation with the System realized in Hardware with Microcontroller **2. Basic Control** (2h) • System Representation of SISO Systems (e.g. LDE, Transfer functions, Block diagrams) • Basic principles of open loop and closed loop feedback control • Elements of control loops • Linearization of nonlinear differential equations • Laplacetransformation (definition, rules, examples) • Basic Controllers (PID) • Bode diagramm • Stability, Nyquist criteria, amplitude margin, phase edge • Root locus **3. Advanced Control I** (3h) • Linear and non-linear State Space Representation • State Space Controller Design (Pole Placement) • Observer Design and Separation Theorem • Digital Control / Discrete State Space Design • LQR-Controller Design • Diskretisierung, Matrix Exponentionalfunktion **4. Computer Lab (1h)** • System Representations using Matlab/Simulink, Numerical Simulation • Modelling/Identification and Controller Design of an Electric Drive System • Controller Design of an Electric Drive System
5	**Participation Requirements** compulsory: Mathematics, Physics, Mechanics , Control Engineering Basics recommended: Basics in Matlab/Simulink
6	**Examination Forms and Prerequisites for Awarding ECTS Points** Written Examination, 120 minutes
7	**Further Use of Module** Autonomous Systems, Propulsion Systems, Team project, Master Thesis
8	**Module Manager and Full-Time Lecturer** Prof. Dr.-Ing. Walter Lindermeir , Prof. Mathias Oberhauser, Prof. Georg Mallebrein

9	**Literature** • Lecture Notes and Scripts • Ogata, K.: Modern Control Engineering, Pearson Verlag • Liu, Xiangjie: Systems Control Theory, Science Press Beijing • Palm, W. J.: MATLAB for Engineering Applications, McGraw-Hill • Hanselman D.C., Littlefield B.: Mastering Matlab, Pearson Verlag • Dabney, J.B.; Harman, T.L.: Mastering Simulink • Mohthari: Engineering Applications in Process Control, Fuzzy Control
10	**Last Updated** 18.10.2022

Vehicle System Fundamentals

1	**Module Number** 3904	**Study Programme** ASM	**Semester** 1	**Offered in** ☒WS ☐SS	**Duration** 1 Semester	**Module Type** compulsory	**Workload (h)** 180	**ECTS Points** 6
2	**Courses**		**Teaching and Learning Forms**		**Contact Time**		**Self-Study Time**	**Language**
					(SWS)	**(h)**	**(h)**	
	a) Motor Vehicles		Lecture		3	45	90	Englisch
	b) Introduction to Vehicle Propulsion		Lecture		2	30		
	c) Lab Motor Vehicles		Lab		1	15		

3 **Learning Outcomes and Competences**

Once the module has been successfully completed, the students can...

Knowledge and Understanding

- ... explain the basic terms in vehicle technology and internal combustion engine technology as well as in components of electric and hybrid vehicles
- ….describe the different powertrain topologies like conventional, hybrid and battery- as well as fuel cell electric
- ... describe the different vehicle drivetrain configurations like front wheel, rear wheel and 4-wheel-drive
- … explain basic component parts of the chassis and the drive train
- … understand and calculate rolling resistance, aerodynamic drag, climbing and acceleration resistance and their impact on energy consumption
- … gain a first knowledge of transversal vehicle system simulation including torques, powers and energy flows

Use, Application and Generation of Knowledge

Use and Transfer

- … choose the best engine and driveline combination for different types of vehicles.
- ... create testing reports and present test results.
- ... analyze the state of the art wheel suspension systems
- ... understand the physical behaviour of forces between road and tyre for vehicle dynamics simulation
- … familiarize themselves with new ideas and topics in the field of automotive powertrains and suspensions
- … compare different powertrain topologies and their performance and efficiency

Scientific Innovation

- … find new technologies to lower energy consumption .
- ... optimize powertrains for high driving performance
- ... set up new driving test procedures and experience energy flows and driving performance with the help of simulation
- … calibrate tyre models to measurements
- ... independently develop approaches for new suspension and driveline concepts and assess their suitability.

Communication und Cooperation

- ... communicate actively within a research or development team and obtain information.
- ... interpret the results of vehicle testing and draw admissible conclusions.
- ... communicate with powertrain and chassis designers about new solutions

Scientific Self-Conception/ Professionalism

- … derive recommendations for decisions from an environmental and safety perspective on the basis of the analyses and evaluations made.
- ... justify the solution theoretically and methodically

4	**Contents** a) Lecture: Motor Vehicles The course gives a basic knowledge in vehicle technology and their components The power train is mainly focused The aim is to learn the ability to calculate driving resistance and to design the power train with respect to driving performance and fuel consumption b) Introduction to Vehicle Propulsion Internal Combustion Engine (Ice) and Engine Control Fundamentals, including trends of the Ice. Alternative Powertrains: Ice-Hybrid, Battery-Electric Vehicle, Fuel-Cell Electric Vehicle and their specific components (Battery, Fuel-Cell, Electric Motor) Longitudinal vehicle Simulation (Simulink), consumption and performance (torque, power, energy flows) c) Lab: Motor Vehicles Determination of full-load torque and power pattern by using the car test bench Detection of fuel consumption map Determination of a tyre map by using the tyre test bench EUREPA. Analysis of vehicle road tests
5	**Participation Requirements** compulsory: no recommended: Fundamentals of Engineering Mechanics
6	**Examination Forms and Prerequisites for Awarding ECTS Points** Written Examination 120 Minutes
7	**Further Use of Module** Propulsion Systems Team Project
8	**Module Manager and Full-Time Lecturer** Prof. Dr. Holtschulze
9	**Literature** Heywood, J.B. Internal Combustion Engine Fundamentals McGraw-Hill BOSCH Automotive Handbook Distribution SAE
10	**Last Updated** 18.10.2022

IT Fundamentals

1	**Module Number** 3905	**Study Program** ASM	**Semester** 1	**Offered in** X WS SS	**Duration** 1 Semester	**Module Type** compulsory	**Workload (h)** 180	**ECTS Points** 6
2	**Courses**		**Teaching and Learning Forms**		**Contact Time**		**Self-Study Time**	**Language**
					(SWS)	**(h)**	**(h)**	
	a) Data Structures and Algorithms		Lecture		3	45	90	English
	b) Programmable Systems and Networks		Lecture		3	45		
						[1 SWS = 15h]		

3 **Learning Outcomes and Competences**

Once the module has been successfully completed, the students can ...

Knowledge and Understanding

- … explain the architecture and workings of a modern computer
- … understand the representation of items as data in computers
- … explain the working of an operation system
- … explain the challenges and solutions for communication between computers

Use, Application and Generation of Knowledge

Use and Transfer

- … design an algorithm for a specific task
- … implement an algorithm efficiently in an imperative programming language (C, Python)
- … analyse the complexity of an algorithm
- … choose a data structure suitable for a specific task
- … analyse network communication
- … choose types of network communication for a specific task
- … consider the architecture of the computer and the operating system to implement a distributed system

Scientific Innovation

- … use methods and tools to gain new insights in the field
- ... create software solutions to task at hand

Communication and Cooperation

- ... communicate actively within the lectures and obtain information.
- ... present technical contents and simulation results and discuss them with the class and the lecturer.
- ... communicate and cooperate within the group in order to find adequate solutions for the task at hand.

Scientific Self-Conception/ Professionalism

- ... present and justify the solution to given tasks theoretically and methodically
- … take ideas and suggestions from other source into consideration

4 **Contents**

a) Lecture: Data Structures and Algorithms

- Number theory
- Graph theory
- Notation, design and classification of algorithms
- Data structures: arrays, lists, sets
- Complexity, efficiency, computability, O-notation
- Search and sort algorithms
- Programming in C
- Programming in Python

b) Lecture: Programmable Systems and Networks

- Number and character encoding (range, resolution, overflows)
- Architecture of computers
- Architecture of CPU, memory and inputs/ouputs
- Overview of structure and tasks of an operation system
- Types of operation systems
- Processes and threads
- Memory management
- Interprocess communication and synchronisation
- File systems
- Program execution
- Network fundamentals and architectures
- Addressing, media access (Ethernet, WLAN)
- Local networks (IP)
- Routing in networks
- Transport protocols (TCP, UDP)
- Application protocols

5 **Participation Requirements**

Compulsory:

- none

Recommended:

- Discrete mathematics
- Basics of some programming language
- Computer handling

6 **Examination Forms and Prerequisites for awarding ECTS Points**

Written Examination 120 Minutes

7 **Further Use of Module**

Automotive Communication

Usability and Dependability

8 **Module Manager and Full-Time Lecturer**

NN, NN

9	**Literature** - Brian W. Kernighan and Dennis M. Ritchie: The C Programming language, Prentice Hall, 2000 - Randal E. Bryant, David R. O'Hallaron: Computer Systems A Programmer's Perspective, Pearson, 2015 - Andrew S. Tanenbaum and Herbert Bos: Modern Operating Systems, Pearson, 2014 - James Kurose and Keith Ross: Computer Networking, Pearson, 2021
10	**Last Updated** 12.10.2022

Pflichtmodule zweites Semester

Autonomous Systems

1	**Module Number** 3906	**Study Programme** ASM	**Semester** 2	**Offered in** WS XSS	**Duration** 1 Semester	**Module Type** compulsory	**Workload (h)** 240	**ECTS Points** 8
2	**Courses**		**Teaching and Learning Forms**		**Contact Time**		**Self-Study Time**	**Language**
					(SWS)	**(h)**	**(h)**	
	a) Mobile Robotics		Lecture		4	60	120	Englisch
	b) Sensors		Lecture		2	30	[bitte nur Summe eintragen]	
	c) Data Fusion		Lecture		2	30		
						[1 SWS = 15h]		

3 **Learning Outcomes and Competences**

Once the module has been successfully completed, the students will be able to design, implement and evaluate autonomous systems, especially in the fields of mobile robotics and self-driving vehicles.

Knowledge and Understanding

The students

- understand sensor principles and sensor signal processing
- understand how to retrieve situation understanding from sensor data
- know the most important components of a mobile autonomous system, their requirements and their mode of operation

Use, Application and Generation of Knowledge

Use and Transfer

- … apply fundamental techniques and algorithms to fuse raw signals of different sensors
- … apply fundamental techniques and algorithms of a mobile robotics software system
- … analyze and develop solutions to real-world problems

Scientific Innovation

- … develop novel approaches using state of the art statistics and filtering methods
- … develop novel approaches using state of the art machine learning methods, e.g. deep neural networks

Communication und Cooperation

- ... communicate actively within a development team with engineers from other disciplines
- ... present technical contents and discuss them

Scientific Self-Conception/ Professionalism

- … design and implement software algorithms as part of a project team
- … evaluate different sensor configurations and autonomous driving system architectures

4	**Contents** Lecture: Mobile Robotics • Introduction to mobile robotics and automated driving • Machine learning and sensor-based environment perception • Mapping and localization • Action and motion planning • Design and architecture of mobile autonomous systems Lecture: Sensors • Sensor Technology (Radar, Lidar, Camera) • Sensor Raw Data • Data Sets Data Fusion • Introduction object tracking • Basics Statistics, Kalman filter (KF) an application for automated driving • From sensor data to tracked objects, e.g. Point cloud data, segmentation and clustering
5	**Participation Requirements** compulsory: no recommended: undergraduate course in physics undergraduate course in computer science, programming in C/C++ or Python module ASM 3901 (Mathematical Methods in Engineering) module ASM 3902 (Simulation and Control)
6	**Examination Forms and Prerequisites for Awarding ECTS Points** Written Examination 120 Min
7	**Further Use of Module** Master Thesis
8	**Module Manager and Full-Time Lecturer** Prof. Dr. Ralf Schuler, Prof. Dr. Markus Enzweiler, Prof. Dr. Clemens Klöck, Prof. Dr. Frank Niewels,?
9	**Literature** Sebastian Thrun et al.: Probabilistic Robotics. MIT Press, 2005. Richard Szeliski.: Computer Vision: Algorithms and Applications, 2022. RaJ, A. (Jun 28, 2002). Euclidean Clustering for Lidar point cloud data. RaJ, A. (Jun 6, 2002). 3D RANSAC Algorithm for Lidar PCD Segmentation. Maybeck, P.S. (1979). Chapter 1, "Introduction" from STOCHASTIC MODELS, ESTIMATION, AND CONTROL, Volume 1. Academic Press, 1979.
10	**Last Updated** 05.10.2022

Team Project

1	**Module Number** 3907	**Study Programme** ASM	**Semester** 2	**Offered in** WS X SS	**Duration** 1 Semester	**Module Type** compulsory	**Workload (h)** 240	**ECTS Points** 8
2	**Courses**		**Teaching and Learning Forms**		**Contact Time**		**Self-Study Time**	**Language**
	Team Project		Project work		**(SWS)** 1	**(h)** 15 [1 SWS = 15h]	**(h)** 225	Englisch

3 **Learning Outcomes and Competences**

Once the module has been successfully completed, the students can...

Knowledge and Understanding

- ... develop a project plan
- ... split complex tasks into subtasks.
- ... apply the knowledge from lectures and labs on a real application.
- ... understand the limitations of project time and human resources.

Use, Application and Generation of Knowledge

Use and Transfer

- ... use methods and tools of project management.
- ... understand the principles of systems engineering.
- … work with state of the art engineering software and measurement equipment.

...

Scientific Innovation

- ... describe interfaces of complex systems.
- ... apply scientific methods to solve industrial problems.
- … discuss pros and cons of new solutions in a group.
- … interpret measurement data and simulation results.

Communication und Cooperation

- ... work together according to a project plan
- ... take into account cultural differences in working style, leadership and communication.
- ... cooperate within the group in order to find adequate solutions for the project task.

Scientific Self-Conception/ Professionalism

- ...work successfully in international development groups in industry.

4 **Contents**

- application of project management
- constitution of hierarchy (project-manager, teams members)
- constitution of project structure (time schedule, work packages
- realisation of given task
- documentation and evaluation of results
- presentation of results
- project feedback

5 **Participation Requirements**

compulsory: -

recommended: Lectures and labs of first semester

6	**Examination Forms and Prerequisites for Awarding ECTS Points** Presentation in a group , 20 minutes Group report
7	**Further Use of Module** Preparation for Master thesis
8	**Module Manager and Full-Time Lecturer** Prof. Mathias Oberhauser
9	**Literature** •
10	**Last Updated** 10.10.2022

Wahlmodule Vertiefung Automotive IT

Automotive Communications

1	**Module Number** 3908	**Study Programme** ASM	**Semester** 2	**Offered in** WS XSS	**Duration** 1 Semester	**Module Type** compulsory	**Workload (h)** 210	**ECTS Points** 7
2	**Courses**		**Teaching and Learning Forms**		**Contact Time**		**Self-Study Time**	**Language**
					(SWS)	**(h)**	**(h)**	
	a) Communication Systems		Lecture		3	45	105	English
	b) Vehicle-to-X (V2X)		Lecture		4	60 [1 SWS = 15h]		

3 **Learning Outcomes and Competences**

Once the module has been successfully completed, the students can...

Knowledge and Understanding

- ... know network architectures used in vehicles for onboard and offboard communication.
- … understand wired and wireless technologies, protocols, and standards relevant for vehicular networks.
- … comprehend use cases and applications of automotive communication.

Use, Application and Generation of Knowledge

Use and Transfer

- … design and implement automotive communication technologies.
- ... setup and configure networked devices in a vehicle.

Scientific Innovation

- … evaluate the suitability of different technical solutions.
- … use measurements and/or simulation tools to analyse automotive communication.

Communication and Cooperation

- ... communicate actively within an organization and obtain information.
- ... present technical contents and discuss them.
- ... communicate and cooperate within the group to find adequate solutions for the task at hand.

Scientific Self-Conception/ Professionalism

- … derive recommendations for decisions from a social and ethical perspective based on analysis and evaluation.

4	**Contents** Lecture a): **Communication systems** • Fundamentals of communication networks • Ethernet and TCP/IP basics • On-board communication systems in vehicles • Automotive Ethernet technology • Selected applications (e.g., SOME/IP) Lecture b): **Vehicle-to-X (V2X)** • Fundamentals of radio communication • Radio communication technologies (e.g., 5G, IEEE 802.11p) • Fundamentals of safety • Message encoding (e.g., ASN.1) • Vehicle-to-X (V2X) motivation and use cases • V2X messages • Geo-networking (e.g., addressing, routing) • V2X applications • Simulation tools • Privacy and security for V2X
	Participation Requirements compulsory: - recommended: • Basics of communication systems and computer networks, • Knowledge of a programming language, preferably C/C++ and/or Java
6	**Examination Forms and Prerequisites for Awarding ECTS Points** Written Examination 120 min
7	**Further Use of Module** Master Thesis
8	**Module Manager and Full-Time Lecturer** Prof. Dr.-Ing. M. Scharf, Prof. Dr. D. Schoop, Prof. Dr.-Ing. H. Melcher
9	**Literature** • Andrew S. Tanenbaum, Nick Feamster, David Wetherall, “Computer Networks”, 6th Edition, Pearson, 2021 • James F. Kurose, Keith W. Ross, “Computer Networking: A Top-Down Approach”, 7th edition, Pearson, 2016 • Kirsten Matheus, Thomas Königseder, “Automotive Ethernet”, Cambridge University Press, 2015 • Christoph Sommer, Falko Dressler, “Vehicular Networking”, Cambridge University Press, 2014 • Standards of the European Telecommunications Standards Institute (ETSI), Intelligent Transport Systems (ITS)
10	**Last Updated** 11. Oct.2022

Usability and Dependability

1	**Module Number** 3909	**Study Programme** ASM	**Semester** 2	**Offered in** WS XSS	**Duration** 1 Semester	**Module Type** compulsory	**Workload (h)** ~~240~~ 210	**ECTS Points** ~~8~~ 7
2	**Courses**		**Teaching and Learning Forms**		**Contact Time**		**Self-Study Time**	**Language**
					(SWS)	**(h)**	**(h)**	
	a) Safety and Security		Lecture		3	45	105	Englisch
	b) Automotive Man Machine Interaction (MMI)		Lecture		4	60 [1 SWS = 15h]		

3 **Learning Outcomes and Competences**

Once the module has been successfully completed, the students can...

Knowledge and Understanding

- … understand usability, user experience (UX), and users'/drivers' requirements and project management issues in the development of automotive applications
- ... understand safety and security issues in the development of automotive applications

Use, Application and Generation of Knowledge

Use and Transfer

- … understand and apply requirements analysis, test and documentation
- … understand and evaluate existing navigation systems
- … implement and test a prototype navigation system
- … understand usability and UX management according to ISO 9241
- … give presentations of project results

- ... understand the main concepts: safety, functional safety, security, information security.
- … understand the main concepts in security
- ... be aware of security threats in the automotive domain
- ... understand security risk management
- … understand the main concepts in safety
- … understand safety management according to ISO 26262

Scientific Innovation

- … use methods and tools to gain new insights in the field of usable and dependable automotive systems

Communication und Cooperation

- ... communicate actively within an organization and obtain information
- ... present technical contents and discuss them regularly
- ... communicate and cooperate within the group to find adequate solutions for the task at hand

Scientific Self-Conception/ Professionalism

- … derive recommendations for decisions from a social and ethical perspective based on the analyses and evaluations made

4 **Contents**

Lecture a): **Safety and Security**

- Main concepts: safety, functional safety, security, information security
- Main concepts in security
- Security threats in the automotive domain, e.g.
  - Insecure bus systems
  - Chip manipulation
  - Component theft
  - Evading access controls
- Counter measures based on cryptography
- Security risk management
- Safety and Security in vehicular ad hoc networks (VANETs)
- Main concepts in safety
- Safety management according to ISO 26262

Lecture b): **Automotive Man Machine Interaction (MMI)**

- Basics terms and concepts of man machine interaction, requirements of graphical user interfaces, design requirements (software ergonomics, usability, dialog principles). On-board Pattern Recognition Systems.
  - machine vision systems (e.g. in traffic monitoring and automatic congestion detection, in driver assistance systems, for gesture recognition)
  - speech communication: speech recognition and understanding systems, speech dialogs: speech synthesis and language generation (Human-Machine Interface).
  - usability engineering, testing and evaluation of recognition systems

Driver Assistance Systems

- concepts for programming of driver assistance systems in automobiles: environment models, interpretation and fusion of sensor data, piloting functions, cooperative concepts.
- implementation of important concepts in laboratory – user-centered design

Human Factors Engineering

- human factors, such as vision, cognition
- driver attention and distraction
- usability, user-centered design, UX
- multimodal Interfaces Lab (programming exercises and presentations, simulation)

Project

- selected tasks and semester project (group work)

Participation Requirements

compulsory: -

recommended:

- C/C++ programming
- computer networks basics
- object oriented modelling (UML)
- software engineering

6	**Examination Forms and Prerequisites for Awarding ECTS Points** Written Examination 120 min
7	**Further Use of Module** Master Thesis
8	**Module Manager and Full-Time Lecturer** Prof. A. Beck, Prof. Dr. D. Schoop,
9	**Literature** • *Shiho Kim, Rakesh Shrestha, Automotive Cyber Security Introduction, Challenges, and Standardization, Springer, 2020* • *Christof Paar, Embedded Security in Cars, 2005* • *Hans-Leo Ross, Safety for Future Transport and Mobility, Springer, 2021* • *ISO 26262 („Road vehicles – Functional safety“)* • *DIN EN ISO 9241 („Ergonomics of human-system interaction”)*
10	**Last Updated** 16 Oct 2022

Wahlmodule Vertiefung Vehicle Systems

Ride and Handling

1	**Module Number** 3910	**Study Programme** ASM	**Semester** 2	**Offered in** WS XSS	**Duration** 1 Semester	**Module Type** compulsory	**Workload (h)** 240	**ECTS Points** 8
2	**Courses**		**Teaching and Learning Forms**		**Contact Time**		**Self-Study Time**	**Language**
					(SWS)	**(h)**	**(h)**	
	a) Handling		Lecture		4	60	120	Englisch
	b) Suspension Modeling		Lecture		4	60 [1 SWS = 15h]	[bitte nur Summe eintragen]	

3 **Learning Outcomes and Competences**

Once the module has been successfully completed, the students can...

Knowledge and Understanding

- ... develop an understanding of theory and methods in vehicle dynamics, with the focus on ride and handling properties
- ... estimate the effect of changing model parameters on ride and handling criteria

Use, Application and Generation of Knowledge

Use and Transfer

- ... analyze the performance characteristics for ride and handling

Scientific Innovation

- … apply scientific tools to the development of computer simulation models

Communication und Cooperation

- ... work together with electronic and software experts in the field of chassis control
- ... discuss new solutions for suspension systems with design engineers
- ... present technical contents in the field of suspension and handling technology and discuss them.

Scientific Self-Conception/ Professionalism

- *... justify the solution theoretically and methodically.*

4	**Contents** a) Lecture Handling terminology of vehicle handling, control loop ”driver-vehicle-environment”, demands on vehicle handling, planar kinematics of vehicle motion, linear (bicycle) model, under- and oversteer, steady state and transient test procedures, handling characteristics under normal driving conditions, analysis and discussion of vehicle dynamics and vehicle handling including a des- cription of the tire, nonlinear model, yaw velocity damping characteristics, effects of design parameters and the road/tire friction coefficient on handling performance b) Lecture Suspension Modeling terminology in multibody dynamics, kinematics of free bodies, force and tor- que elements, play and friction, Newton-Euler equations, constraint functi- ons, joints and linkages, flexible bodies, structure and functionality of multi- body codes, types of analysis, introduction into MSC.ADAMS, application in suspension modeling and simulation for ride, handling on uneven roads, and load case generation for durability Lab projects: development of a simple multibody simulation blockset in Si- mulink, modeling and analysis of double wishbone and McPhersion suspen- sions in MSC.ADAMS, full vehicle simulations in MSC.ADSAMS/Car
5	Participation Requirements compulsory: no recommended: undergraduate course in mechanics (especially planar kinematics and kinetics of rigid bodies) fundamentals of automotive engineering including principles of chassis de- sign linear algebra including fundamental matrix calculus and eigenvalues Modul 103 Simulation and Control 1
6	**Examination Forms and Prerequisites for Awarding ECTS Points** Written Examination 120 Minutes
7	**Further Use of Module** Master Thesis
8	**Module Manager and Full-Time Lecturer** Prof. Thomas Schirle
9	**Literature** Schindler, E.: Fahrdynamik – Grundlagen des Lenkverhaltens und ihre Anwendung für Fahrzeugregelsysteme. expert verlag, 2007 Gillespie, T.D.: Fundamentals of Vehicle Dynamics. SAE Wong: Theory of Ground Vehicles. SAE Nikravesh, P. E.: Computer-Aided Analysis of Mechanical Systems. Prentice Hall 1988 MSC: ADAMS Documentaion and Tutorials
10	**Last Updated** 15.06.2019

Propulsion Systems

1	Module Number	Study Programme	Semester	Offered in	Duration	Module Type	Workload	ECTS
	3911	ASM	2	☐ WS ☒SS	1 Semester	compulsory	180 h	6

2	Courses	Teaching and Learning Forms	Contact Time		Self-Study Time	Language
			(SWS)	(h)	(h)	
	a) Control of electrical and electrified Powertrains (Comb. Eng./EM/Hybrid)	Lecture / Exercise	3	45	90	English
	b) Operating Strategies of electrical and electrified Powertrains	Lecture / Exercise	2	30		
	c) Seminar Powertrain Simulation	Seminar	1	15		

3 **Learning Outcomes and Competences**

Once the module has been successfully completed, the students can...

Knowledge and Understanding

a) Control of electrical and electrified powertrains
- …understand the function and construction of modern combustion engine control systems
- …know about torque based system structure, air-, fuel- and ignition paths
- …know and understand the possibilities of distribution of torque/power in hybrid powertrains
- …understand and explain the scope of functions for recuperation in electrified powertrains
- …understand the functionality of power electronic actuators

b) Operating strategies of electrical and electrified powertrains
- …identify and explain operating modes of hybrid vehicles
- …know and present operating modes of various powertrains
- …understand and evaluate operating strategies of electric- and hybrid vehicles in detail
- …understand the interaction of components in the powertrain system to optimize consumption and emissions

c) Seminar powertrain simulation
- …understand structure and functionality of powertrain simulation models

Use, Application and Generation of Knowledge

Use and Transfer

a) Control of electrical and electrified powertrains
- … design control of e-drives for electric and hybrid vehicles
- … evaluate concepts of electric drives
- … compare fuel consumption with different loads, speeds, ignition timings
- … calculate resulting speeds, torques, and powers for different powertrain types
- … based on the basic knowledge of common drive components, evaluate new drive structures in terms of evaluate essential properties such as performance, smoothness, package or costs

b) Operating strategies of electrical and electrified powertrains
- …design and optimize operating strategies for different hybrid structures
- …recognize concept-related restrictions and evaluate operating quality
- …compare different operating strategies and evaluate them with regard to consumption, emissions, efficiency and range

c) Seminar powertrain simulation
- … make use of simulation tools to represent and evaluate interactions in drive systems

	Scientific Innovation a) Control of electrical and electrified powertrains • … create some software, functions for drives and discuss how they work

Pflichtmodule drittes Semester

Softskills

1	**Module Number** 3914	**Study Programme** ASM	**Semester** 1	**Offered in** WS	**Duration** 1 Semester	**Module Type** compulsory	**Workload (h)** 210	**ECTS Points** 7
2	**Courses**		**Teaching and Learning Forms**		**Contact Time**		**Self-Study Time**	**Language**
	a) Global Engineering b) Project Management c) International Negotiations		Lecture Lecture Lecture		**(SWS)** 2 2 2	**(h)** 45 45 45 [1 SWS = 15h]	**(h)** 105	Englisch

3 **Learning Outcomes and Competences**

Once the module has been successfully completed, the students can...

Knowledge and Understanding

- ... understand sales & marketing aspects of global engineering projects.
- … understand different approaches towards global engineering projects (waterfall, agile, hybrid project management).
- … develop a project plan, split complex tasks into subtasks.
- ... apply the knowledge from lectures and labs on a real application.
- ... understand the limitations of project time and human resources.
- … know about Intellectual properties and patent topics in engineering
- … know cultural differences.
- … improve language and mimic as a tool of successful interaction
- … understand mechanisms of multilateral business and trade formals

Use, Application and Generation of Knowledge

Use and Transfer

- ... be able to choose the right right engineering approach in relation to the market needs
- … use methods and tools of project management.
- ... understand the principles of Global Engineering.
- … interpret gantt-charts, calculate the time and financial aspects of projects.
- … include and consult IP and patent experts in a professional manner – and know when appropriate
- … use state-of –the-art software support for projects
- … apply the gained knowledge to case-studies.
- … improve cooperation within your own unit / company
- … improve company - customer relationships
- … come to better results with international partners
- … being able to estimate the economic impact of IPR
- … transfer engineering results to production
- ...

Scientific Innovation

- ... describe the dependency of R&D, production, sales & finance of projects.
- ... apply scientific methods to solve engineering tasks.
- … discuss pros and cons of different project management approaches.

Communication und Cooperation

- ... work together according to a project plan
- ... take into account cultural differences in working style, leadership and communication.
- ... cooperate within diverse international groups in order to find adequate solutions for the project task.
- … lead project teams
- … achieve more satisfying business output of international negotiations
- … use the right negotiation options according to the specific (cultural) counterparts
- … handle difficult situations and settle conflicts peacefully

Scientific Self-Conception/ Professionalism

- ...work successfully in international development groups in industry.

4	**Contents** **a) and b) (Global Engineering & Project Management)** • Sales & Marketing Aspects of Engineering Projects - Project lifecycle and analysis - Branding - Key Account Management - Customer Management - Bid management • Intellectual Property and Patents - Basics of Intellectual Property Rights (IPR) - Global Corporate Patent Strategy and Management - Company examples • Classical Project Management - Project Management Processes - Functions and responsibilities of a project manager - Scope, Time, Quality & Risk Management - Communications, HR & Integration Management - Documentation, reporting, presentation, decision making • Agile and Hybrid Project Management - Overview of different agile methods - Scrum - Integration of classical and agile methods • Critical Chain Project Management (CCPM) - Gamification with theoretical inputs - application of project management to a case study • Supporting IT structures - IT Network and Infrastructure - IT Organisation - IT Security - Managing Product Data - From Engineering to Production **c) International Negotiations** • Background teaching of cultural differences • Interactive / international role plays • Exchanging of experiences of business and other cross-cultural transactions and achievements / failures. • Discourse and examples aimed at improving individual skills / arguments. • Win-win situations – learning different methods of negotiations
	Participation Requirements • compulsory: - • recommended: Negotiation English Some basic business experience Basic multicultural skills
6	**Examination Forms and Prerequisites for Awarding ECTS Points** 120 min written exam
7	**Further Use of Module** Module Team Project, Preparation for Master thesis, Preparation for negotiations in job sitatuions
8	**Module Manager and Full-Time Lecturer** Prof. Dr. Siegfried Zürn - plus external experts and lecturers

9	**Literature** • Script and case studies will be provided in electronic format • PMBOK Guide 8th edition, PMI Institute • Larson, E.W.; C.F. Gray (2016): Project Management – The Managerial Process, McGraw-Hill • Mühlen, Alexander (2010): International negotiations, Münster Verlag,2010
10	**Last Updated** 2022-10-10

Master Thesis

1	**Module Number** 3915	**Study Programme** ASM	**Semester** 3	**Offered in** X WS SS	**Duration** 1 Semester	**Module Type** compulsory	**Workload (h)** 690	**ECTS Points** 23
2	**Courses**		**Teaching and Learning Forms**		**Contact Time**		**Self-Study Time**	**Language**
					(SWS)	**(h)**	**(h)**	
	Master Thesis		Thesis		2	30	600	Englisch
	Master Thesis Presentation and Defence		Presentation		1	15	45	
3	**Learning Outcomes and Competences** Once the module has been successfully completed, the students can... **Knowledge and Understanding** • ... handle and solve a problem with scientific methods on their own ..**Use, Application and Generation of Knowledge** *Use and Transfer* • ... do scientific literature research . • … write a scientific report. • … give a presentation about thesis results. • … organize themselves. ... *Scientific Innovation* • ... understand the theories and their limitations in there engineering discipline. • ... find new solutions. ... **Communication und Cooperation** • ... give comprehensive intermediate reports to supervisors. • ... work together with technical staff in industrial labs. • ... cooperate within their own department and other departments and suppliers. **Scientific Self-Conception/ Professionalism** • ...work in R&D departments in industry • … join a PhD program							
4	**Contents** • constitution of project structure (time schedule, work packages) • realisation of given task with scientific methods and within a given timeframe • documentation and evaluation of results • presentation and defense of results							
5	**Participation Requirements** compulsory: - recommended: Lectures and labs of first and second semester, team project							

6	**Examination Forms and Prerequisites for Awarding ECTS Points** Presentation and and oral examination , 30 minutes Thesis report
7	**Further Use of Module** Preparation for Master thesis
8	**Module Manager and Full-Time Lecturer** Prof. Mathias Oberhauser
9	**Literature** •
10	**Last Updated** 23.04.2019