Hochschule Karlsruhe
University of
Applied Sciences

Fakultät für
Elektro- und
Informationstechnik

Module Handbook
Sensor Systems Technology – SSTM

Degree: Master of Science (M.Sc.)

Date: 18.10.2021
SPO Version 5

Index

Abbreviations:

- ECTS European Credit Transfer and Accumulation System
- CP Credit Points, ECTS-Points
- h hours
- SWS semester periods per week
- SoSe Summer semester
- WiSe Winter semester
- SPO examination regulations
- HsKA Hochschule Karlsruhe – Technik und Wirtschaft
- PH Pädagogische Hochschule Karlsruhe
- SSTM Master study program Sensor Systems Technology

Explanations:

Module: Combination of several courses to form a unit with a common learning objective.

Workload: Information on the workload includes the attendance times and the preparation times before and after the actual course. The workload is measured in hours (h), which result from the credits (ECTS): in the form of performance points, so-called credit points (see below).

ECTS: is credit points defined in the European Credit Transfer System (30 Credit points per ½ year).
Each credit point is equivalent to 30 hours total workload

Table of content

1 Semester 1

- Advanced Physics
- Analogue Signal Processing
- Digital Signal Processing
- Advanced Chemistry
- Management

1.1 Advanced Physics

Module title: Advanced Physics

Module summary
Module code: STM110
Module coordinator: Prof. Dr. Roland Görlich
Credits (ECTS): 6
Semester: 1
Pre-requisites with regard to content: Basic knowledge in mathematics and physics (Bachelor level)
Pre-requisites according to the examination regulations: --
Competencies: After successful completion of the module • Students understand the causes and effects of electromagnetic interactions. They know the phenomena of classical electrodynamics and understand their general mathematical descriptions (Maxwell laws) as well as their applications • Students have an understanding of the quantized form of electromagnetic waves (photons) and their interaction with matter • Students have knowledge of the description of quantum mechanical systems • Students will be able to understand and analyze sensor principles based on theoretical models, giving them a deeper understanding of the underlying physical mechanisms • Students are able to network different phenomena with the help of theoretical models and thus structure the field of knowledge • Students are also qualified for more ambitious tasks in the development of sensors • In the course of exercises, students are enabled to present and transport topics from the lecture, to realize and discuss problems and to solve them methodically. In addition, they also acquire social skills in the environment of learning situations.
Assessment: Written examination 120 minutes with mark

Course: Physics
Module code: STM112
Lecturer: Dr. Peter Weidler
Contact hours: 2 lecture hours per week
Semester of delivery: yearly in summer semester
Type/mode: lecture including tutorial
Language of instruction: English
– Content: – Vector Analysis / scalar and vector potentials – Electrostatics / Electromagnetic Fields – Maxwell Equations / Solution of Maxwell Equations
– Recommended reading: – Feynman, Leighton, Sands: Lectures on Physics Electromagnetism and Matter, Vol. II, Part I, Addison Wesley, R. Oldenbourg Verlag – Serway, Jewett: Physics for Scientists and Engineers, Brooks/Cole Thomson – Griffiths: Introduction to Electrodynamics (4th ed.) Pearson Cambridge University Press, 2017 – Shadowitz, Albert: The electromagnetic field, Dover Publications, 1975
Comments: The lecture requires good knowledge in mathematics: calculus and basics in analytical geometry

Course: Solid State Physics
Module code: STM113
Lecturer: Prof. Dr. Roland Görlich
Contact hours: 2 lecture hours per week
Semester of delivery: yearly in summer semester
Type/mode: lecture and exercise / optional
Language of instruction: English
Content: – Aspects of "Modern Physics" (Quantum Theory) – Photons and optical sensors, LASER – Principles of solid-state theory, especially in the field of semiconductors – Diffusion theory based on master equations
Recommended reading: – Lecture notes and exercise sheets – Feynman, Richard Phillips: The Feynman Lectures on Physics, 3 Vols.*, Addison-Wesley – Sternheim, Morton M.: General physics, New York, John Wiley, 1991 – Kittel, Charles: Introduction to Solid State Physics, John Wiley & Sons, Inc., 2005 – Kittel, Charles; Kroemer, Herbert: Thermal Physics, W.H. Freeman and Company New York, – Ashcroft, Neil W.; Mermin, N. David: Solid State Physics, Harcourt Brace College Publisher – Coleman, Charles C.: Modern Physics for Semiconductor Science, WILEY-VCH – Sze, S.M.: Semiconductor devices, Wiley, 2002 – Bird, R. Byron; Stewart, Warren E.; Lightfood, Edwin N.: Transport Phenomena, John Wiley & Sons, Inc.
Comments:

1.2 Analogue Signal Processing

Analogue Signal Processing

Module summary
Module code: STM120
Module coordinator: Prof. Dr. Frieder Keller
Credits (ECTS): 6
Semester: 1
Pre-requisites with regard to content: Lab: 4 ECTS Electrical Engineering at university level. Lecture: 4 ECTS Mathematics at university level, profound knowledge in differential equations
Pre-requisites according to the examination regulations: ---
Competences: The student is able to understand electronic circuits and to work with operational amplifiers. With this module the participants learn use mathematical transformations, have an understanding of dynamic processes, can judge stability of systems and tune controller parameters.
Assessment: Lecture: Written examination 60 minutes with mark; Laboratory passed or failed.

Course: Control Theory
Module code: STM121
Lecturer: Prof. Dr. Samuel de Lucena, Prof. Dr. Frieder Keller
Contact hours: 30
Semester of delivery: Yearly, summer
Type/mode: Lecture
Language of instruction: English
Content: • Modelling of processes • Linearization, Laplace transformation • Evaluation of the Transfer function and the Frequency Characteristic • Stability and Stability Criteria • Control Loop evaluation • Design of Control Loops • Analogue Controller Techniques • Root Locus Analysis and Frequency Response
Recommended reading: 1. Frederik, Dean / Chow, Joe H. - Feedback control problems using Matlab 2. Nise, Norman S. - Control systems engineering 3. Lindner, Douglas - Introduction to signals and systems
Comments:

Course: Analogue Signal Processing Lab
Module code: STM122
Lecturer: Prof. Dr. Ralf Herwig
Contact hours: 2 lab hours per week

Semester of delivery: yearly (summer)
Type/mode: lab; mode: mandatory
Language of instruction: English
Content: Experiments with Resistors, Capacitors, Inductors, Voltage Sources, Diodes and Transistors, Operational Amplifiers (OP), OP basic Circuits.
Recommended reading: Lab textbooks “Introduction to Electrical Engineering” and “Experiments with operational Amplifiers”. Additional e-books given in the lab.
Comments:

1.3 Digital Signal Processing

Digital Signal Processing

Module summary
Module code: STM130
Module coordinator: Prof. Dr. Thorsten Leize
Credits (ECTS): 6
Semester: 1
Pre-requisites with regard to content: Classical programming skills from bachelor's program. Electrical Engineering at university level (roughly equivalent to 4 ECTS)
Pre-requisites according to the examination regulations: --
Competencies: The students know about the object-oriented paradigm and can apply and use it in the programming language C++. They are able to construct object-oriented software designs. Furthermore the students can convert numbers into different representations and understand the principles of A/D and D/A converters as well as microcomputers and can apply these.
Assessment: The lab has to be passed. The mark for the module is given by the mark of the exam in Computer Science, which is an exam of 60 minutes.

Course: Computer Science
Module code: STM131
Lecturer: Prof. Dr. Thorsten Leize
Contact hours: 2 lecture hours each week
Semester of delivery: yearly in summer semester
Type/mode: lecture including lab exercises and homework
Language of instruction: English
Content: • Repetition about basic concepts • Differences between C and C++ • The object oriented programming paradigm • classes, methods, inheritance, operator overloading, polymorphy, UML • Introduction to modern concepts of C++ from new standard versions 11,14 and 20.
Recommended reading: Any modern C++ book.
Comments:

Course: Digital Signal Processing Lab
Module code: STM132
Lecturer: Prof. Dr. Michael Bantel
Contact hours: 2 lab hours per week
Semester of delivery: yearly in summer semester
Type/mode: lab
Language of instruction: English
Content: • Digital Numbers • Logic Gates • Boolean Expressions

• combinatory Logic • sequential Logic • Analog / Digital and Digital / Analog Converters • Programming of Microcomputers
Recommended reading: Kleitz, William - Digital and microprocessor fundamentals - London: Prentice Hall Basic Experiments in Digital technology - Online E-book
Comments:

1.4 Advanced Chemistry

Advanced Chemistry

Module summary
Module code: STM140
Module coordinator: Prof. Dr. Juliane Stölting
Credits (ECTS): 6
Semester: 1
Pre-requisites with regard to content: none
Pre-requisites according to the examination regulations: none
Competencies: After having successfully completed the course the students have knowledge of the working medium of physical and chemical sensors, biosensors.
Assessment: Written exam, 180 minutes
Usability: Sensor system technology

Course: Physical Chemistry
Module code: STM141
Lecturer: Prof. Dr. Juliane Stölting
Contact hours: 4 lecture hours each week
Semester of delivery: yearly in summer semester
Type/mode: lecture including lab exercises and homework
Language of instruction: English
Content: • Spectroscopy • Properties of ideal and real gases • Properties of liquids and solutions • Chemical energetics • Pellistor sensor • 2nd and 3rd law of thermodynamics • Chemical Affinity
Recommended reading: P. Atkins, L. Jones: Chemical Principles, W.H. Freeman and Company, New York, 1998 D.C. Harris: Quantitative Chemical Analysis, W.H. Freeman and Company, New York 1999
Comments:

Course: Chemistry
Module code: STM142
Lecturer: Prof. Dr. Juliane Stölting
Contact hours: 4 lecture hours each week
Semester of delivery: yearly in summer semester
Type/mode: lecture including lab exercises and homework
Language of instruction: English
Content: • Matter and Properties • Chemical Reactions • Materials, • Type of chemical bonds

• Hydrogen bonding • Bonding of models bands • Acids and bases • Buffer • Redox Reactions • Electrochemistry Polymers
Recommended reading: P. Atkins, L. Jones: Chemical Principles, W.H. Freeman and Company, New York, 1998 D.C. Harris: Quantitative Chemical Analysis, W.H. Freeman and Company, New York 1999
Comments:

1.5 Management

Module title: Management

Module Summary
Module code: STM150
Module coordinator: Center of Competence
Credits (ECTS): 6 Points
Semester: 1. Semester
Pre-requisites with regard to content:
Pre-requisites according to the examination regulations: Regarding to the examination regulations no pre-requisites are required.
Competencies: The participants can acquire further qualifications in the area of intercultural communication and management in order to be able to use their personal skills better in the professional life
Assessment: Portfolio, term paper or exam

Course: Intercultural Communication
Module code: STM170
Lecturer: Lectures of the Center of Competence
Contact hours: 2
Semester of delivery: Summer Semester
Type/mode: Exercises, seminar with attendance policy / obligatory
Language of instruction: English
Content: • Language Issues • Culture: Basic Concepts – Cross-Cultural Approaches – The Kulturstandard Method - Multiculturality / Transculturality • German Cultural Standards • Nonverbal Communication • Perception and Stereotypes • Communicative Styles • Intercultural Competence • Conflict Management • Adaptation • Studying and Living in Germany
Recommended reading: Course books or a student reader of printed materials according to the recommendation of the instructor or texts and materials provided on the University's e-learning-platform Ilias.

2 Semester 2

- Sensors A
- Sensor Actor Networks
- Realtime Data Processing
- Focal Subjects A and B
- Language A
- Project A

2.1 Sensors A

Sensors A

Module summary
Module code: STM210
Module coordinator: Prof. Dr. Harald Sehr
Credits (ECTS): 6
Semester: 2
Pre-requisites with regard to content: STM110 Advanced Physics, STM140 Advanced Chemistry
Pre-requisites according to the examination regulations: --
Competencies: Students understand the different working principles of sensors and are able to choose a suitable sensor for a given application. They can design electronic circuits for signal conditioning and evaluate transfer functions and sensor characteristics of resistive and capacitive sensors. They comprehend the fundamentals of chemosensors, their technological implementation, applications and respective challenges of practical measurements. Students understand the physics and technology of modern light sources and optical detectors, and can design advanced optical sensing systems.
Assessment: Written Examination of 180 min duration

Course: Physical Sensors A
Module code: STM211
Lecturer: Prof. Dr. Harald Sehr
Contact hours: 2 SWS
Semester of delivery: Winter Semester
Type/mode: Type: Lecture / Mode: Mandatory
Language of instruction: English
Content: The fundamentals of sensor technology are given, working principles of physical sensors are explained and methods of signal conditioning are discussed. The topics in detail are: Sensor characteristics and transfer function, resistive temperature sensors, strain gauges, resistive force sensors, resistive pressure sensors, signal conditioning, capacitive sensors, inertial sensors.
Recommended reading: Fraden, Handbook of Modern Sensors, AIP Press, Springer; Doebelin, Measurement Systems, McGraw-Hill
Comments: Lecture notes are available on ILIAS.

Course: Optical Sensors
Module code: STM212
Lecturer: Prof. Dr.-Ing. Christian Karnutsch
Contact hours: 2 SWS
Semester of delivery: Winter Semester
Type/mode: Type: Lecture / Mode: Mandatory
Language of instruction: English
Content:

- Light sources for optical sensing
- the detection of optical radiation
- advanced optical sensing systems
- fiberoptic sensors
- interferometric sensors
- modern application examples are discussed.

Recommended reading:
Light-emitting Diodes, EF Schubert, Cambridge University Press
Understanding Fiber Optics, J Hecht, Prentice Hall International
Fiber Optic Sensors: An Introduction for Eng. and Scientists, E Udd, Wiley
Advanced Photonic Structure for Biological and Chemical Detection, X Fan, Springer
Optics, Eugene Hecht, Addison-Wesley

Comments: Lecture notes and all other course materials are available on ILIAS.

Course: Chemical Sensors A
Module code: STM213
Lecturer: Prof. Dr. Markus Graf
Contact hours: 2 SWS
Semester of delivery: Winter Semester
Type/mode: Type: Lecture / Mode: Mandatory
Language of instruction: English
Content: An overview on the immense potential of chemical sensing for a wide range of applications such as environmental monitoring, process automation, human health, comfort and energy efficiency is given. Furthermore, a practical framework for assessing the requirements and performance of chemosensors is introduced. Fundamental chemical concepts are applied to understand typical sensor characteristics. Sensors are described according to their transduction principles with focus on mechanical, thermal and optical chemosensors including the recent trends of miniaturization.
Recommended reading: J. Janata, Principles of Chemical Sensors, Springer P. Gründler, Chemical Sensors, Springer Fundamentals: Brown et. al., Chemistry – The Central Science, Pearson, (SI units) P. Atkins, J. de Paula & J. Keeler, Physical Chemistry, Oxford University Press
Comments: Corresponding lecture notes and complementary materials are available on ILIAS.

2.2 Sensor Actor Networks

Sensor Actor Networks

Module summary
Module code: STM220
Module coordinator: Prof. Dr. Thorsten Leize
Credits (ECTS): 6
Semester: 2
Pre-requisites with regard to content:
Pre-requisites according to the examination regulations: --
Competencies: Students will be able to understand different bus systems and choose an appropriate bus system. Furthermore they know how to design and configure applications of bus systems in sensor systems.
Assessment: Oral (20 minutes) or written exam (60 minutes)

Course: Bus Systems & Local Area Networks
Module code: STM221
Lecturer: Prof. Dr. Thorsten Leize
Contact hours: 2
Semester of delivery: Winter Semester
Type/mode: lecture
Language of instruction: English

Content:
• Signal propagation, signal formatting, error detection
• Bus access types
• ISO/OSI layer model
• Different bus systems for different application areas:
  ○ Ethernet and TCP/IP family
  ○ Field bus systems (serial, HART, Profibus)
  ○ Automotive bus systems, especially CAN
  ○ *I²C as an example of short range bus systems.*

Recommended reading:

Course: Computer Aided Labs A
Module code: STM222
Lecturer: Prof. Dr. Helfried Urban
Contact hours: 4SWS
Semester of delivery: Winter Semester
Type/mode: lab
Language of instruction: English
Content:Students learn and will be able to set experiments and handle the basics of:

- Low pass filtering via RC-Low-Pass, principles of transfer function, Bode-diagram, working with digital oscilloscope, measuring phase angles, input vs. output voltage, cut-off frequency, measurement of the behavior of an operational amplifier at different gains.
- Correlation techniques, fundamental mathematical properties of cross- and autocorrelation, application of correlation techniques by setting up an ultrasonic sensor for liquid level measurement, discussion of the properties of an ultrasonic transmitter / receiver, signal conditioning.
- Damped and forced mechanical oscillations by setting up a model of a multistage building with up to three coupled parallel springs. Mathematical properties of mechanical oscillations, Fourier-formalism and frequency analysis, recognizing possible modes of oscillations (relation of phase
- angles).

Recommended reading:
Books / text sources about passive electronic filtering methods, operational amplifiers, mathematics of correlation techniques, principles of mechanical oscillations and mathematics of Fourier formalism / frequency analysis. Also books recommended for the lectures / modules of Sensors A / B of Prof. Sehr.

Comments: lab is splitted into three separate experiments which must be finalized by writing a complete report with discussion of methods and results for each experiment.

2.3 Realtime Data Processing

Realtime Data Processing

Module summary
Module code: STM230
Module coordinator: Prof. Dr.-Ing. Christian Langen
Credits (ECTS): 6
Semester: 2
Pre-requisites with regard to content: Successful completion of “Control Theory” which is part of the module “Analogue Signal Processing”
Pre-requisites according to the examination regulations: --
Competences: Course Aim: To produce students who can design digital signal processing (DSP) and digital control (DC) systems and can create commercially-viable digital signal processing and control applications using high-performance and energy-efficient microprocessors. Specific Learning Outcomes: Students have knowledge and understanding of - DSP and DC basic concepts such as sampling, reconstruction and aliasing. - Fundamental filtering algorithms such as FIR, IIR, FFT and adaptive filters. - Microprocessors as low-power computing platforms. - DSP and DC software programming basics and principles. By the intellectual skills: - Ability to choose between different DSP and DC algorithms for different applications. - Ability to use different design methods to achieve better results. - Ability to evaluate experimental results (e.g. quality, speed, power) and correlate them with the corresponding designing and programming techniques. Practical abilities: On successful completion of this module the student will be able to: - Implement DSP and DC and design methods on microprocessors. - Use commercial hardware and software tools to develop real-time DSP and DC applications.
Assessment: Written exam, 120 minutes

Course: Real-Time Signal Processors with Lab
Module code: STM231
Lecturer: Prof. Dr.-Ing. Christian Langen
Contact hours: *30*
Semester of delivery: *Yearly (winter)*
Type/mode: *Lecture with lab and seminar projects, papers and presentations*
Language of instruction: English
• Content: • Part 1 – Lecture: • Discrete-Time Signals and Systems: Convolution and Correlation • Sampling, Reconstruction and Aliasing   ○ Review of Complex Exponentials and Fourier Analysis

- Time and Frequency Domains
- Z-Transform: Time and Frequency Domains
- FIR Filters: Moving Average Filters, Window Method of Design
- IIR Filters: Impulse Invariant and Bilinear Methods of Design, Simple Design Example
- Fast Fourier Transform: Review if Fourier Transforms, Derivation of Radix-2 FFT Algorithm
- Adaptive Filters: Prediction and System Identifications, Equalisation and Noise Cancellation

Part 2 – Lab Exercises

- Introduction to the Microprocessor Hardware and Development Tool Chain
- Analog Inputs and Outputs, Polling, Interrupts and Direct Memory Access (DMA) for Data Input/
- Output.
- Non-Recursive Systems. Example: Delay
- Recursive Systems. Example: Echo
- Non-Recursive Filters with Finite Impulse Response (FIR)
- Recursive Filters with Infinite Impulse Response (IIR)
- Fast Fourier Transform (FFT)
- 8.) Adaptive Filters. Least Mean Square (LMS) Algorithm

Recommended reading:

1.) Chassaing, Rulph; Reay, Donald: Digital Signal Processing and Applications with the C6713 and C6416 DSK, Wiley 2008.
2.) Reay, Donald: Digital Signal Processing and Applications with the OMAP-L138 eXperimenter. Wiley 2012.
3.) Kuo, Sen M.; Lee, Bob H.; Tian, Wenshun: Real-Time Digital Signal Processing. Fundamentals, Implementations and Applications. Wiley 2013.
4.) Reay, Donald: Digital Signal Processing Usingn the ARM Cortex-M4. Wiley 2016.
5.) Unsalan, Cem; Yücel, M. Erkin; Gürhan, D. Neniz: Digital SIgnal Processing using ARM Cortex-M Based Microcontrollers. ARM Education Media 2018.

Comments: Project, presentation and paper assessment preferred!

Course: Digital Control Systems
Module code: STM232
Lecturer: Prof. Dr.-Ing. Frieder Keller/ Prof. Dr. Samuel de Lucena
Contact hours: 30
Semester of delivery: Yearly (winter)
Type/mode: lecture / mandatory
Language of instruction: English

Contents:

- Digital Control compared to Analogue Control
- z-Transform
- 2.1 Definition of the z-transform
- 2.2 Properties of the z-transform
- The inverse z-transform
- z-transform and difference equations
- Stability of discrete-time systems
- PID control algorithms
- Transformation from analogue to digital
- Simulation of Digital Control Loops
- Parameter Optimization with MATLAB
- Deadbeat control algorithms
- System Identification

Recommended reading:
1. Zilouchian, Ali / Jamshidi, Mo - Intelligent control systems using soft computing methodologies 2. Ogata, Katsuhiko – Discrete-Time Control Systems *3.* Nise, Norman S. - Control systems engineering – New York: Wiley 3rd Ed. 2000
Comments:

2.4 Focal Subjects A and B (1)

Focal Subjects 1

Module summary
Module code: STM240 and STM340
Module coordinator: Prof. Dr. Thorsten Leize
Credits (ECTS): 4 each module
Semester: 2 and 3
Pre-requisites with regard to content: Computer Science (1. Semester)
Pre-requisites according to the examination regulations: --
Competencies: The students get an overview about different modern programming languages and additional programming paradigms. They know and can apply different object-oriented design patterns.
Assessment: Each of the parts of this module are assessed separately because they take place in different semesters Written exam of 1 hour each of the electives

Course: Numerical Simulation
Module code: STM241
Lecturer: Prof. Dr. Thomas Westermann
Contact hours: 2
Semester of delivery: Winter Semester
Type/mode: *Lecture with lab; mode: focal sublect*
Language of instruction: English
Content: In order to support the design and construction phase of a product as well as the optimization phase, simulation tools were used in many industrial areas. One of the major tools in simulation techniques are the finite difference and finite element methods. This lecture gives an introduction to these techniques and to the application of the finite element program ANSYS on concrete problems.
Recommended reading: Lecture notes of the course available from the webpage of lecturer: lecture notes.pdf

Course: Advanced Programming
Module code: STM341
Lecturer: Prof. Dr. Thorsten Leize
Contact hours: 2
Semester of delivery: Summer Semester
Type/mode: *focal subject*
Language of instruction: English
Content: • Introduction to Java programming language. • Short introduction to Scala programming language and functional paradigm • Futures and concurrency • Object-oriented design pattern
Recommended reading: *See Ilias*

2.5 Focal Subjects A and B (2)

Focal Subject 2

Module summary
Module code: STM240 and STM340
Module coordinator: Prof. Dr. Karsten Pinkwart
Credits (ECTS): 4
Semester: 2 and 3
Pre-requisites with regard to content:
Pre-requisites according to the examination regulations: --
Competencies: After successful completion of this module, the student is able: to carry out a technical and economic analysis of the electrical storage requirements to evaluate technologies for storage in the form of electrical energy, electrochemical energy, material energy, mechanical energy to carry out a comparison of the storage systems to analyse technical and economic parameters to show perspectives to collect the right energy storage and / or conversion system for his application to implement the energy storage and / or conversion system in a exisiting application architecture to differentiate between power and energy optimized systems and applications
Assessment: Written exam of 60 mins in each semester

Course: Electrochemical Storage Systems
Module code: STM247
Lecturer: Prof. Dr. Karsten Pinkwart
Contact hours: 2
Semester of delivery: Winter Semester
Type/mode: lecture and lab
Language of instruction: English
Content: The students will get a comprehensive overview of electrochemical energy and conversion methods, including batteries, redox-flow batteries, fuel cells, supercapacitors, hydrogen generation and storage. The lecture addresses electrochemical processes, materials, components, degradation mechanisms, device assembly and manufacturing, while also discussing the challenges and perspectives for each energy storage device. The students will learn fundamentals of energy storage and conversion. The lecture is concentrated on technology aspects for mobile application.
Recommended reading: Crompton, T.R.; Battery Reference Book; Reed Educational and Professional Publishing Ltd; Oxford 2000 Linden, D.; Reddy, T.b.; Handbook of Batteries; McGraw Hill; New York 2001 Garche, J.; Dyer, C.K.; Moseley, P.T.; Encyclopedia of Electrochemical Power Sources; Elsevier Science; Amsterdam 2009

Course: Renewable Electricity Generation and Storage
Module code: STM347

Lecturer: Prof. Dr. Karsten Pinkwart
Contact hours: 2
Semester of delivery: Summer Semester
Type/mode: lecture
Language of instruction: English
Content: The lectures subject is the technical evaluation of different forms of energy storage. The aim is, to point out the potential as well as the physically and material technical limits of these techniques. Special attention applies to energy densities and energy efficiency. Students will understand the abilities of these techniques due to different applications.
Recommended reading: Patrick T. Moseley Jurgen Garche, Electrochemical Energy Storage for Renewable Sources and Grid Balancing, Elsevier, Amsterdam 2014 Bent Sørensen, Renewable Energy- Physics, Engineering, Environmental Impacts, Economics and Planning, Academic Press, 2017 Pengwei Du Ning Lu, Energy Storage for Smart Grids-Planning and Operation for Renewable and Variable Energy Resources (VERs), Academic Press, 2014 Yasar Demirel, Energy - Production, Conversion, Storage, Conservation, and Coupling, Springer, 2012 Robert A. Huggins, Energy Storage - Fundamentals, Materials and Applications, Springer, 2016
Comments:

2.6 Focal Subjects A and B (3)

Module title: Focal Subject 3

Module summary
Module code: -STM240 and STM340
Module coordinator: Prof. Dr. Jan Hoinkis
Credits (ECTS): 4
Semester: 2 and 3
Pre-requisites with regard to content: chemistry, physics, physical chemistry
Pre-requisites according to the examination regulations: --
Competencies: Participants will be able: • to evaluate and select suitable sensors in wastewater and exhaust gas treatment • to evaluate and design water treatment processes with a focus on membrane technology and sensors • operate analytical measuring instruments under instruction and understand the underlying measuring principles • to solve a complex task in the field of water and exhaust gas treatment together as a team • to plan, carry out and evaluate accompanying analytics for water and exhaust gas treatment processes
Assessment: Written examination of 1 hour each elective

Course: Environmental Process Technology
Module code: STM244
Lecturer: Prof. Dr. Jan Hoinkis
Contact hours: 2
Semester of delivery: Winter Semester
Type/mode: Type: lecture, mode: optional
Language of instruction: English
Content: Ecotoxicology, wastewater contaminants, sewage treatment plants, industrial wastewater treatment, exhaust gas purification for automotives and power plants, solid waste management, production integrated technologies
Recommended reading: P. Atkins, L. Jones, W.H. Freeman, Chemical Principles, Macmillan Learning, D.C. Harris, Quantitative Chemical Analysis, W.H. Freeman, D.W. Connell, Concepts of Environmental Chemistry, CRC Press, M.R. Templeton, D. Butler, Introduction to Wastewater Treatment, bookboon.com, T.K. Sen, Physical, Chemical and Biological Treatment Processes for Water and Wastewater, Nova Science Publishers, R.W. Baker, Membrane Technology and Applications, Wiley
Comments

Course: Environmental Sensorics
Module code: STM344
Lecturer: Prof. Dr. Michael Bantel / Prof. Dr. Ulrich Schönauer
Contact hours: 2
Semester of delivery: Summer Semester
Type/mode: Type: e.g. lecture, lab, seminar; mode: mandatory or optional
Language of instruction: English

Content: • Basics of radioactivity, • measuring radioactivity in environment, • effect on humans, • sensors/detectors for measuring radioactivity
Recommended reading: Script for lecture, Glenn Knoll: “Radiation Detection and Measurement” 4th edition
Comments:

2.7 Focal Subject A and B (4)

Module title: Focal Subject 4

Module summary
Module code: -STM240 and STM340-
Module coordinator: Prof. Dr. Harald Sehr
Credits (ECTS): 4
Semester: 2 and 3
Pre-requisites with regard to content:
Pre-requisites according to the examination regulations: --
Competencies: Students understand the fabrication technologies for silicon microsystems and hybrid integrated electronic circuits. They are able to choose a suitable fabrication sequence for a certain system and can evaluate the advantages and risks of different fabrication approaches.
Assessment: Written examination of 60 min duration each semester

Course: Hybrid Technology
Module code: STM248
Lecturer: Prof. Dr. Ulrich Schönauer
Contact hours: 2
Semester of delivery: Winter semester
Type/mode: *lecture*
Language of instruction: English
Content: • Thick-film and hybrid technology in sensor production • Introduction to thick-film technology • Basic materials, components, manufacturing • Layer systems, Production, quality control • Circuit lay-out, Design rules, Print cycles, • Screen manufacturing, Screen printing, Parameters, • Quality control, Drying and sintering • Comparison: thick- vs. thin-film technology • Structure dimensions, Assembly and packaging • Surface mount technology (SMT) • Active and passive devices (SMD), • Connection technologies, Soldering processes • Adhesive employment, Chip-on-board processes • Die- and wire-bonding, Welding processes, Packaging
Recommended reading: *Gupta, T. K.: Handbook of Thick-Film and Thin-Film Hybrid Microelectronics* *Wiley-Interscience* *Sergent, J. E.: Hybrid Microelectronics Handbook, McGraw Hill*
Comments: Lecture notes are available on ILIAS.

Course: Microsystems
Module code: STM346
Lecturer: Prof. Dr. Markus Graf
Contact hours: 2
Semester of delivery: Summer Semester
Type/mode: lecture
Language of instruction: English
Content: • Introduction • Photolithography • Deposition Technologies • Evaporation, Sputtering, Chemical Vapour Deposition • Properties of Differently Deposited Films • Etching Technologies • Wet Etching • Dry Etching • Deep Reactive Ion Etching • Examples of Fabrication Sequences
Recommended reading: *Madou, Fundamentals of Microfabrication, CRC Press,(2002)* Kovacs, Micromachined Transducers Sourcebook, WCB McGraw-Hill, 1998
Comments: Lecture notes are available on ILIAS.

2.8 Language A

Module title: Language A

Module Summary
Module code: STM250
Module coordinator: : IFS
Credits (ECTS): 4
Semester: 2
Pre-requisites with regard to content:
Pre-requisites according to the examination regulations: Regarding to the examination regulations no pre-requisites are required
Competencies: The competencies result from the module descriptions for the modules German as a Foreign Language, which are offered by the Institute for Foreign Languages (IFS) at the University of Karlsruhe. The module descriptions can be viewed at https://www.h-ka.de/en/study/additional-skills/languages/deutsch
Assessment: The tests are carried out and defined by the IFS.

Course: Deutsch als Fremdsprache
Module code: IFS
Lecturer: Lecturers at the Institute for Foreign Languages
Scope of weekly semester hours (SWS): 4
Semester of delivery: Winter semester
Type/mode: Lecture, Compulsory subject
Language of instruction: German
The content for the courses German as a Foreign Language are offered by the Institute for Foreign Languages (IFS) at the University of Karlsruhe. For details see the website: https://www.h-ka.de/en/study/additional-skills/languages/deutsch
Recommended reading: • see Website IFS • The scripts and books used are announced by the respective lecturers and lecturers at the IFS.

2.10 Project A

Module title: Project A

Module summary
Module code: STM 260
Module coordinator: supervising professors
Credits (ECTS): 4
Semester: 2
Pre-requisites with regard to content:
Pre-requisites according to the examination regulations: ---
Competencies: The participants can independently work on a task individually or in small groups and • understand the task and develop the technical implementation in a solution-oriented manner • implement the project with all technical designs and ideally simulate and test it • learn to work together in the team structure • write the documentation as a scientific paper • present the work and discuss questions in order to be able to work out and implement a task in a team systematically and in a targeted manner in professional practice.
Assessment: Presentation of the project work (20 minutes) and discussion

3 Semester 3

- Sensors B
- Automotive Sensors Applications
- System Integration
- Focal Subjects B
- Language B
- Project B

3.1 Sensors B

Sensors B

Module summary
Module code: STM310
Module coordinator: Prof. Dr. Harald Sehr
Credits (ECTS): 6
Semester: Summer Semester
Pre-requisites with regard to content: STM210 Sensors A
Pre-requisites according to the examination regulations: --
Competencies: Students understand the different working principles of sensors and are able to choose a suitable sensor for a given application. They can design electronic circuits for signal conditioning and evaluate transfer functions and sensor characteristics of magnetic field sensors and inductive sensors. They comprehend the fundamentals, implementation and application of electrochemical and biosensors. Students understand fabrication technologies for optofluidic sensor systems. They are able to assess the potential for miniaturization of advanced and complex analysis systems and can design the microtechnological process route required for the fabrication of lab-on-a-chip devices.
Assessment: Written Examination of 180 min duration

Course: STM311 Physical Sensors B
Module code: STM311
Lecturer: Prof. Dr. Harald Sehr
Contact hours: 2 SWS
Semester of delivery: Summer Semester
Type/mode: Type: Lecture / Mode: Mandatory
Language of instruction: English
Content: Working principles, applications and signal conditioning of physical sensors are discussed. The topics in detail are: Thermocouples, magnetic field sensors, induction sensors, inductance sensors, eddy current sensors, magnetisation sensors.
Recommended reading: Fraden, Handbook of Modern Sensors, AIP Press, Springer Doebelin, Measurement Systems, McGraw-Hill
Comments: Lecture notes are available on ILIAS.

Course: Optofluidic Sensor Systems
Module code: STM312
Lecturer: Prof. Dr.-Ing. Christian Karnutsch
Contact hours: 2 SWS
Semester of delivery: Summer Semester
Type/mode: Type: Lecture / Mode: Mandatory
Language of instruction: English
Content: Micro- and nanofabrication technologies for optofluidic sensors and instruments for micro- and nanomeasurements are discussed. Subsequently, applications of Optofluidics (some of them under active research) in the fields of biology, medicine and chemical detection systems are introduced by studying selected analysis systems and their miniaturization.
Recommended reading:

[1] Fabrication Engineering at the Micro- and Nanoscale; Stephen A. Campbell; Oxford University Press [2] MEMS and Microsystems: Design, Manufacture, and Nanoscale Engineering; Tai-Ran Hsu; John Wiley & Sons [3] Optofluidics: Fundamentals, Devices, and Applications; Yeshaiahu Fainman, Luke Lee, Demetri Psaltis, Changhuei Yang; McGraw Hill Professional [4] Scanning Electron Microscopy and X-Ray Microanalysis; Joseph Goldstein, Dale Newbury, David Joy, Charles Lyman, Patrick Echlin, Eric Lifshin, Linda Sawyer, and Joseph Michael; Springer
Comments: Lecture notes and all other course materials are available on ILIAS.

Course: Chemical and Bio Sensors
Module code: STM313
Lecturer: Prof. Dr. Markus Graf
Contact hours: 2 SWS
Semester of delivery: Summer Semester
Type/mode: Type: Lecture / Mode: Mandatory
Language of instruction: English
Content: The chemosensor portfolio is further extended by the electrochemical transduction principle including potentiometric, amperometric and conductometric sensor types. Subsequently, the particularities of biosensors and their implementation according to transduction principles are devised and respective applications are presented. Current trends such as miniaturization by micro- and nanotechnology and sensor system aspects are discussed.
Recommended reading: J. Janata, Principles of Chemical Sensors, Springer P. Gründler, Chemical Sensors, Springer F.-G. Banica, Chemical Sensors and Biosensors, Wiley Fundamentals: Brown et. al., Chemistry – The Central Science, Pearson, (SI units) J. Berg et al., “Biochemistry”, Freeman
Comments: Corresponding lecture notes and complementary materials are available on ILIAS

3.2 Automotive Sensors Applications

Automotive Sensors Applications

Module summary
Module code: STM320
Module coordinator: Prof. Dr. Frieder Keller
Credits (ECTS): 6
Semester: 3
Pre-requisites with regard to content: Programming knowledge in C/C++, Basic knowledge in the field of “Combustion Engines”, “Powertrain” and “Electronically Controlled Braking Systems” Knowledge of “Theory of Probabilities”
Pre-requisites according to the examination regulations: --
Competencies: The students know the special requirements for electronic technology in modern vehicles and the sensors and actuators applicable under mobile conditions. They understand the interaction of the components in the system, are able to analyze weak points in the system’s security and safety and can apply concepts how to avoid them. The students are able to apply advanced software to evaluate information from laboratory measurement systems.
Assessment: Written exam, 60 minutes; Lab: passed or failed

Course: Automotive Sensors
Module code: STM321
Lecturer: Prof. Dr. Frieder Keller
Contact hours: 15
Semester of delivery: yearly, summer
Type/mode: lecture / mandatory
Language of instruction: English
Content: • Electronics in Automobiles - An Overview • Sensorics in Drive Train Control • Safety Systems • Comfort Systems • Sensors for Position, Speed, Acceleration, Angular Speed, Force, Torque, Temperature and Pressure, Oxygen Concentration • System Design
Recommended reading: 1) Automotive Handbook, Robert Bosch GmbH 2) Automotive Electronics Handbook, Ronald K. Jurgen 3) Automobile Electronics, Eric Chonwanietz, Butterworth-Heinemann Ltd
Comments:

Course: Computer Aided Labs B
Module code: STM322
Lecturer: Prof. Dr. Helfried Urban
Contact hours: 30
Semester of delivery: yearly, summer semester
Type/mode: Lab, mandatory
Language of instruction: English
Content: Laboratory experiments set-up with modern measurement tools and computer control. Application of software tools for sensor signal evaluation.
Recommended reading: 1) Stonick, Virginia L / Bradly, Kevin, Labs for signals and systems using MATLAB 2) Doeblin, Ernest O, Measurement Systems
Comments:

3.3 System Integration

System Integration

Module Summary
Module code: STM330
Module coordinator: Prof. Dr. Thorsten Leize
Credits (ECTS): 6 Points
Semester: 3. Semester
Pre-requisites with regard to content: Bus Systems & LAN
Pre-requisites according to the examination regulations: none
Competencies: Students know the design and working principals of data exchange in internet and about the display and presentation of sensor data. They can organise, structure and store the data in different formats
Assessment: written exam 120 minutes
Usability:

Course: Efficient Video Coding
Module code: STM331
Lecturer: Prof. Dr. Christian Langen
Contact hours: 2 hours per week
Semester of delivery: summer semester
Type/mode: Experimental lecture
Language of instruction: English
Content: • Wavelets and Filter Banks – Analogy to Fourier Series • The Haar Wavelet with Corresponding Filter Bank • Description of Filters by Impulse Response, Z Transform and Matrices • Multirate and Polyphase Discrete-Times Systems • Two-Channel Filter Bank – Conditions for Perfect Reconstruction • Quality Criteria of Filter Banks • The Lifting Scheme • Deslauriers-Dubuc Interpolating Filters • Edge Detection, Smoothing, Denoising and Image/Video Compression • The VC-2 Codec: Implementation of the Theoretical Concepts
Recommended reading: • Addison, Paul S.: The Illustrated Wavelet Handbook. Introductory Theory and Applications in • Science, Engineering and Finance. Taylor & Francis, 2002 • Burrus, G. S.; Gopinath, R. A.; Guo, H.: Introduction to Wavelets and Wavelet Transforms. A • Primer. Prentice-Hall, 1998. • Jensen, A.; la Cour-Harbo, A.: Ripples in Mathematics. The Discrete Wavelet Transform. • Springer, 2001. • Mallat, S.: A Wavelet Tour of Signal Processing. The Sparse Way. Academic Press, 2008. • Stark, H.-G.: Wavelets and Signal Processing. An Application-Based Introduction. Springer, 2005.

- Vetterli, M.; Kovancevic, J.: Wavelets and Subband Coding. Prentice Hall, 1995.
- Borer, T.: The VC-2 Low-Delay Video Codec. BBC Research & Development White Paper WH 238,
- August 2013.

Course: Communication and Visualisation
Module code: STM332
Lecturer: Prof. Dr. Thorsten Leize
Scope of weekly semester hours (SWS): 2
Semester of delivery: Summer semester
Type/mode: lecture with lab and assignments
Language of instruction: English
Content: • HTTP transport • HTML description language • Javasript • Graphics • Perl scripts on the server for dynamic web pages • Other languages for the backend • Storage of date in text files, json, xml • Relational databases
Recommended reading: see Ilias • We work with assignments

3.4 Focal subjects B

Focal B Subjects

See details in combination with Focal subjects A

3.5 Language B

Language B

Module Summary
Module code: STM350
Module coordinator: : IFS
Credits (ECTS): 4
Semester: 2
Pre-requisites with regard to content:
Pre-requisites according to the examination regulations: Regarding to the examination regulations no pre-requisites are required
Competencies: The competencies result from the module descriptions for the modules German as a Foreign Language, which are offered by the Institute for Foreign Languages (IFS) at the University of Karlsruhe. The module descriptions can be viewed at https://www.h-ka.de/en/study/additional-skills/languages/deutsch
Assessment: The tests are carried out and defined by the IFS.

Course: Deutsch als Fremdsprache
Module code: IFS
Lecturer: Lecturers at the Institute for Foreign Languages
Scope of weekly semester hours (SWS): 4
Semester of delivery: Winter semester
Type/mode: Lecture, Compulsory subject
Language of instruction: German
The content for the courses German as a Foreign Language are offered by the Institute for Foreign Languages (IFS) at the University of Karlsruhe. For details see the website: https://www.h-ka.de/en/study/additional-skills/languages/deutsch
Recommended reading: • see Website IFS • The scripts and books used are announced by the respective lecturers and lecturers at the IFS.

3.6 Project B

Project B

Module summary
Module code: STM360
Module coordinator: Supervising professor
Credits (ECTS): 4
Semester: 3
Pre-requisites with regard to content:
Pre-requisites according to the examination regulations:
Competencies: The participants can independently work on a task in small groups and • understand the task and develop the technical implementation in a solution-oriented manner • implement the project with all technical designs and ideally simulate and test it • learn to work together in the team structure • write the documentation as a scientific paper • present the work and discuss questions in order to be able to work out and implement a task in a team systematically and in a targeted manner in professional practice.
Assessment: Presentation of the project work (20 minutes) and discussion

4 Semester 4

- Thesis
- Final Examination

4.1 Master Thesis

Master Thesis

Module Summary
Module code: STM410
Module coordinator: Supervising professors
Credits (ECTS): 27 Points
Semester: 4
Pre-requisites with regard to content: Knowledge of the modules of semesters 1-3
Pre-requisites according to the examination regulations: The project work has to be completed.
Competencies: The students can work on an engineering topic in a given time frame independently, result-oriented and appropriately according to scientific criteria by • analyze and structure information given by literature, independently acquire the relevant specialist and methodological knowledge, • select scientific methods and procedures and use and solve the question of the master thesis, • interpret, evaluate and critically reflect on the results obtained, • formulate the content of the master thesis in a clearly structured manner according to scientific procedures using the specialist terminology in order to be able to work on topics independently in professional practice and write reports.
Assessment: Written thesis (duration: 6 months)
Usability:

4.2 Final Examination

Final Examination

Module Summary
Module code: STM420
Module coordinator: Supervising professors
Credits (ECTS): 3
Semester: 4. Semester
Pre-requisites with regard to content: Knowledge of the modules of the semesters 1-3
Pre-requisites according to the examination regulations: all exams of the 1st semester with the exception of the Management module, 6 ECTS may be left from 2nd semester, 6 ECTS may be left from 3rd semester. Both projects have to be passed successfully.
Competencies: The participants can independently prepare a presentation and present the questions and the work of the thesis by • give a short introduction to the topic and present the main questions and tasks • present the solutions and technical developments • discuss possible solutions and results in order to be able to present, discuss and answer questions in later professional practice.
Assessment: Oral examination (duration: 60 minutes)