MicroElectronics Training, Industry and Skills

Work Package WP3

Design Innovative METIS Training

Deliverable D3.1

METIS Curriculum & Training

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RE	Restricted to a group specified by the Consortium (including the Commission Services)	
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1 Introduction

The METIS consortium develops curricula, training content and learning settings in the 4 main areas of microelectronics.

A. Electronic components design for digital, analog or mixed-signal circuits, such as: information processing and storage, RF and microwaves, sensors (imaging, photonics, etc.) and actuators (MEMS etc).

B. Electronic systems design, such as: system-on-chip, system–in-package, hardware/software co-design.

C. Basics of electronics manufacturing, such as: introduction to advanced materials, processing equipment, production process, testing, packaging, predictive/preventive services.

D. Key Competences & Innovative Thinking that will cover the soft skills that are most required by the industry, such as problem solving, critical thinking, entrepreneurial spirit and teamwork.

The named technical areas (design and manufacturing) were identified by the partners during the preparation: They are so interwoven that a comprehensive curriculum for the microelectronics sector would not be possible without understanding the three aspects as a whole. In the present work, modules are structured according to these areas and their main content is linked to learning objectives. In addition, aspects from work package 2 are included and presented separate-ly. This primarily concerns modules that lead to cross-sectoral competencies. For better identification, assignment and further use in all subsequent work steps of this work pack-age, the module contents are linked to the corresponding partner in the consortium. This becomes clear through an additional column in which the abbreviations of the partners are entered. When it comes to structuring the relevant learning content, our approach has a modular structure. The tables below show that we have assigned the corresponding EQF level to each module, named the qualification, if applicable, and assigned it to a learning area. All contents broken down in this way receive a precise description of the competencies, skills and responsibilities from which learning objectives and learning outcomes become clear.

For explanation:

Knowledge means the outcome of the assimilation of information through learning. Knowledge is the body of facts, principles, theories and practices that is related to a field of work or study Skills means the ability to apply knowledge and use know-how to complete tasks and solve problems Competence means the proven ability to use knowledge, skills and personal, social and/or methodological abilities, in work or study situations and in professional and personal development

1.1 Skills Framework

All courses within this curriculum are listed on the Skills Framework (https://drives-compass.eu/). The Skills Framework (formerly DRIVES Framework) was initially developed as one of the outcomes from the Blueprint project DRIVES. The DRIVES project was the Blueprint project for strategic sectoral cooperation on skills between key stakeholders in Automotive sector. Project Number 591988-EPP-1-2017-1-CZ-EPPKA2-SSA-B. The project was co-funded by ERASMUS+ Programme of the European Union. The DRIVES project was composed by 24 partners from

11 European countries and lasted from January 2018 to March 2022. The project partnership set up the sustainability plan where the decision is that the platform is to be further used, maintained and extended by the Automotive Skills Alliance.

In order to exploit synergies, we decided to collaborate with the platform developers and further help to provide inputs and ideas for future development. Some of these ideas are the following:

- A METIS landing page within the Skills Framework, that will comprise all provided courses and the possibility to link results (under development).
- Metrics to gain statistical information on courses such as (under development):
  - Course views,
  - Enrollments,
  - Provider website visits,
  - Ranking of courses by those who finished them.

1.2 Work Based Learning

This section describes the Work Based Learning (WBL) approach in METIS. The digital transformation of all areas of life in general and everything that Industry 4.0 formulates in terms of requirements in particular provide a complex picture of how life is related. This includes, in particular, the way in which learning or knowledge acquisition is changing. The impact on vocational training has been investigated in many studies and is in constant flux with many projects. For the above-mentioned target group, this also means a change in previous working and learning methods. The chosen approach, which is reflected in the learning modules, takes up this changed learning methodology. For this purpose, the learning content itself is didactically reworked and diversified through a variety of media, for example, so that different learning types can also process the content. Probably the most important factor in the context of learning and learning success of the target group is learning support. This is taken up in several respects, so that learning modules are suitable to be used directly in the in-company training context (remix) or to be integrated completely. To this end, we envisage the following methodological/didactic building blocks:

1. The learner receives asynchronous guidance directly in the learning module. This will include a simple explanation of how to keep a learning diary, what it is used for and who can be involved in reflecting on the entries and what this reflection can look like. The learning diary will have standard headings that relate directly to the workplace context (WBL).
2. The content is provided with reflection elements (e.g. quizzes) after certain sections so that interruption and thus re-entry is facilitated. This is an essential aspect when it comes to compatibility with operational tasks and the way learning is evolving in the digital transformation.
3. The learner is given a choice of learning strategies that can be aligned with the reality of the target group's life as well as with company requirements. This creates a superordinate context so that the learner can be put in a position in the first place to complete learning assignments alongside everyday business life and to enable their transfer to business practice.

4. Every learner in the company environment has a mentor - this is particularly true for the EQF 4 target group addressed, who are accompanied by company trainers in GER and AUT. If we in the project are generally aiming at digital transformation and the changes in lifeworld and thus the changing learning strategies, we must, in my view, also ensure that company mentors and/or trainers acquire the corresponding methodological skills in order to successfully design learning support in the aforementioned change. To this, we include a part in each module that is aimed at company mentors and is so comprehensive that the company mentor can acquire knowledge about it and transfer this knowledge to the company context.

The basic approach in all modules is the “remix”. A characteristic of digital transformation in lifelong learning is that the individual decides how deeply to dive into the material, how many transfer steps need to be repeated or which part is taken up in a comparable context and expanded, supplemented or reworked. This is especially true of the part for workplace mentors. We would like to highlight a part of the content in connection with WBL. In this part of the module, the mentor can learn how to align a simple didactic procedure with operational possibilities/tools/facilities. In addition, he/she can learn how to set up a digital learning workshop in order to promote cross-sectional competences (digital skills) of the learners at the same time. Finally, he/she will also get an introduction on how to cooperate and collaborate with learners from other occupational areas/departments in company contexts. This way, soft skills of the learners will be developed and the methodology has the potential to address company developments (product and process).

1.3 Presentation and Dissemination

The curriculum, its modules and courses are presented in this deliverable and online on the METIS website, to boost dissemination. The web pages are therefore also part of this deliverable.

- Curriculum Modules (https://www.metis4skills.eu/curriculum-modules/)
- Curriculum Courses (https://www.metis4skills.eu/curriculum-courses/)

Additionally this document will also be posted on the METIS website.

1.3.1 Module Table

The most important representation of the curriculum is the table containing all modules and the courses according to the modules (similar to section 2). The courses are displayed when clicking on the according module. This table can be filtered by the four main areas of microelectronics. These features are exemplarily shown in Figure 1.

1.3.2 Course Table

The course table summarises all stand-alone courses grouped by partners (similar to Appendix A. Courses by Partner). This table can be filtered and linked on a by-partner-basis.

All Areas | A. Component Design | B. System Design | C. Basics of Manufacturing | D. Key Competences and Innovative Thinking

#	Module Name	LH	EQF	
B1	PCB Production	85.5	4-7	+
B2	Basics of Microelectronics	50.5	5-7	+
B3	Signal Processing	24	4	+
B4	IoT Systems	230	4	+
B5	IoT Solutions	254	4-5	−

ID	Course Name	LH	EQF	Partner	Link
P15.10	IIoT Solutions	182	4	P15	
P15.11	Cloud for IoT	28	5	P15	
P15.12	Protocols for IoT	44	4	P15	

B6	Reliability of ICs	41	6-7	+
B7	Electromagnetic Compatibility	50	7	+
B8	Microcontroller	229	4	+
B9	Advanced Microcontroller Development	100	4-5	+
B10	Design, Prototype Fabrication and Challenging Applications of Silicon Microsystems with Piezoresistive Feedback	75	7	+
B11	System Design for Electronic Modules	60	6-7	+
B12	Analog and Digital Design Flows	42	6-7	+

Figure 1: Screenshot of table on curriculum modules.

2 Modules

The structure of the METIS curriculum follows a modular approach. Each stand-alone module is structured in a "Core Unit" and “Satellite Units”. Each module is a stand-alone block of training that can be delivered to the trainees autonomously.

There are two types of modules available in the curriculum:

- On the one hand more single small courses are be grouped into one module.
- On the other hand large courses are split into subcourses and form their own module.

Every individual course (large or small) is highlighted in bold.

Altogether the METIS curriculum includes 109 courses. These courses are developed within the scope of this project. These are grouped into 41 modules, that can be taken by learners individually on a module-by-module basis.

In the following we provide an overview on the different modules categorised by the four main areas of microelectronics (see Introduction). For every module respectively course, we provide

- the module/course name,
- the number of learning hours (LHs) needed,
- the European Qualification Framework (EQF) level this course is aiming for,
- the partner, that is providing the course,
- a link to the Skills Framework (Active courses are marked with ⧉, courses under development are marked with 🕓) and
- a link to the course syllabus.

2.1 Component Design

In the area of Component Design the METIS curriculum provides 42 individual courses comprising 10 modules, consisting of 10 core units and 44 satellite units.

#	ID	Name	LH	EQF	Partner	Link
A1		Electronics Basics	28	4		
	P11.2	**Electronics Basics In the Field of Semiconductor Manufacturing**	**24**	**4**	**P11**	
	P1.3	**Intro to Semiconductors**	**2**	**4**	**P1**	
	P1.2	**Logic: Gates and Binary Calculations**	**2**	**4**	**P1**	
A2	**P9.1**	**ElectrONiX MOOC - Amplifiers**	**28**	**5-6**	**P9**	
	P9.1.1	Diodes and Transistors	12	5	P9	
	P9.1.2	Transistor Circuits	4	5	P9	
	P9.1.3	Transistor Amplifiers	4	5	P9	
	P9.1.4	Differential Amplifiers	4	5	P9	
	P9.1.5	Operational Amplifiers	4	5	P9	
A3	**P9.2**	**ElectrONiX MOOC - Digital**	**25**	**5-6**	**P9**	
	P9.2.1	CMOS Circuits	5	5	P9	
	P9.2.2	Multivibrators	10	5	P9	
	P9.2.3	Analog-To-Digital Converters	5	5	P9	
	P9.2.4	Digital-To-Analog Converters	5	5	P9	
	P9.2.5	Hardware Interfaces	5	5	P9	
A4	**P9.3**	**ElectrONiX MOOC - Resonance**	**20**	**5-6**	**P9**	
	P9.3.1	Lab Basics	5	6	P9	
	P9.3.2	Passive Filters	5	6	P9	
	P9.3.3	Active Filters	5	6	P9	
	P9.3.4	Resonance Circuits	5	6	P9	
A5	**P9.4**	**ElectrONiX MOOC - Power**	**18**	**5-6**	**P9**	
	P9.4.1	Linear Voltage Regulators	6	6	P9	
	P9.4.2	Switched Mode Power Supplies	6	6	P9	
	P9.4.3	Fundamentals of EMC	6	6	P9	
A6		Sensor Basics	6	6-7		
	P7.1	**Sensors (Basic sensor concepts)**	**1**	**6-7**	**P7**	
	P7.2	**Sensor/Optics**	**1**	**6-7**	**P7**	
	P7.3	**Sensor/Mechanical**	**1**	**6-7**	**P7**	
	P7.4	**Sensor/Temperature**	**1**	**6-7**	**P7**	
	P7.5	**Sensor/Magnetic**	**1**	**6-7**	**P7**	
	P7.6	**Sensor/Gas**	**1**	**6-7**	**P7**	
A7		Semiconductor Sensors	107	5-7		
	P11.12	**Semiconductor Sensors**	**24**	**5-6**	**P11**	
	P7.7	**Sensor System Design**	**1.5**	**6-7**	**P7**	
	P7.8	**Sensor Data Analytics**	**1.5**	**6-7**	**P7**	
	P12.4	**Resistive sensor front-end**	**40**	**7**	**P12**	
	P12.5	**Capacitive sensor front-end**	**40**	**7**	**P12**	
A8		Sensors Advanced	322	6-7		
	P12.6	**Physics of resistivity measurements**	**60**	**7**	**P12**	
	P12.7	**Piezoresistive Si sensors**	**80**	**7**	**P12**	
	P12.9	**Piezoelectric microsensors**	**40**	**6**	**P12**	

#	ID	Name	LH	EQF	Partner	Link
	P12.10	**Capacitive microsensors**	**40**	**6**	**P12**	
	P12.11	**Thermal and radiation sensors**	**60**	**6**	**P12**	
	P2.10	**Magnetic Speed Sensors**	**2**	**6-7**	**P2**	
A9		Silicon Mechanics	160	7		
	P12.1	**Mechanics of Si beam and diaphragm structures**	**80**	**7**	**P12**	
	P12.2	**Viscous damping in microstructures**	**40**	**7**	**P12**	
	P12.3	**Non-viscous damping in microstructures**	**40**	**7**	**P12**	
A10	**P13.1**	**Nanomaterials for Electronics**	**125**	**7**	**P13**	
	P13.1.1	Current trends in nanoelectronics	25	7	P13	
	P13.1.2	Materials for deep-submicron and nanometer CMOS IC, HEMT, Organic Electronics, CArbon nanotubes and Graphene	50	7	P13	
	P13.1.3	Single Electron Transistor (SET), Spintronics, Quantum Electronics	50	7	P13	
A11		Computer Aided Design Tools	500	6-7		
	EP.6	**Cadence: VLSI Fundamentals Education Kit**	**100**	**6**	**EP**	
	EP.7	**Analog Simulation and Layout Education Kit**	**100**	**6**	**EP**	
	EP.8	**Verification Methodologies Education Kit**	**100**	**7**	**EP**	
	EP.9	**Shift-Left Development Education Kit**	**100**	**7**	**EP**	
	EP.10	**Tensilica Processor IP Education Kit**	**100**	**7**	**EP**	

Table 1: Table for Area A.

2.2 System Design

In the area of System Design the METIS curriculum provides 31 individual courses comprising 12 modules, consisting of 12 core units and 34 satellite units.

#	ID	Name	LH	EQF	Partner	Link
B1		PCB Production	85.5	4-7		
	P14.4	**Printed Circuit Design**	**60**	**6-7**	**P14**	
	P11.10	**PCB Production**	**24**	**4-5**	**P11**	
	P2.12	**Chip-Package-PCB Co-Design Methodology**	**1.5**	**6**	**P2**	
B2		Basics of Microelectronics	50.5	5-7		
	P9.6	**Basics of Microelectronics**	**25**	**6-7**	**P9**	
	P11.3	**Integrated Circuits**	**24**	**5-6**	**P11**	
	P2.14	**A/D and D/A Converters Fundamental Considerations and Definitions**	**1.5**	**5-6**	**P2**	
B3	**P11.13**	**Signal Processing**	**24**	**4**	**P11**	
B4		IoT Systems	230	4		
	P15.8	**Basic IIoT Systems**	**66**	**4**	**P15**	
	P15.9	**Advanced IIoT systems**	**164**	**4**	**P15**	
B5		IoT Solutions	254	4-5		
	P15.10	**IIoT Solutions**	**182**	**4**	**P15**	
	P15.11	**Cloud for IoT**	**28**	**5**	**P15**	
	P15.12	**Protocols for IoT**	**44**	**4**	**P15**	
B6		Reliability of ICs	41	6-7		
	P9.5	**Reliable ICs in Design and Application**	**25**	**7**	**P9**	
	P2.9.1	**Probabilistic System Architecture - Definition and Verification - Part 1 of 4**	**4**	**6-7**	**P2**	
	P2.9.2	**Probabilistic System Architecture - Definition and Verification - Part 2 of 4**	**4**	**6-7**	**P2**	
	P2.9.3	**Probabilistic System Architecture - Definition and Verification - Part 3 of 4**	**4**	**6-7**	**P2**	
	P2.9.4	**Probabilistic System Architecture - Definition and Verification - Part 4 of 4**	**4**	**6-7**	**P2**	
B7		Electromagnetic Compatibility	50	7		
	P9.7	**Electromagnetic Compatibility Essentials**	**25**	**7**	**P9**	
	P9.8	**Electromagnetic Compatibility of Integrated Circuits**	**25**	**7**	**P9**	
B8		Microcontroller	229	4		
	P15.3	**Design of microcontroller devices to project specification**	**87**	**4**	**P15**	
	P15.4	**Embedded development**	**44**	**4**	**P15**	
	P15.5	**Firmware development**	**98**	**4**	**P15**	
B9		Advanced Microcontroller Development	100	4-5		
	P15.6	**OPC - Open Platforms Communication**	**42**	**5**	**P15**	
	P15.7	**Sensor assessment applicable to the project**	**58**	**4**	**P15**	
B10	**P13.2**	**Design, Prototype Fabrication and Challenging Applications of Silicon Microsystems with Piezoresistive Feedback**	**75**	**7**	**P13**	

#	ID	Name	LH	EQF	Partner	Link
	P13.2.1	Principle of Microsystems with Piezoresistive Feedback	15	7	P13	
	P13.2.2	Process and Technology Integration	20	7	P13	
	P13.2.3	Design of Microdevices with Piezoresisitive Feedback	20	7	P13	
	P13.2.4	Sensors with Piezoresistive Feedback	20	7	P13	
B11	**P14.7**	**System Design for Electronic Modules**	**60**	**6-7**	**P14**	
	P14.7.1	Module circuits and constructions	30	6-7	P14	
	P14.7.2	System design	30	6-7	P14	
B12		Analog and Digital Design Flows	42	6-7		
	P2.5.1	**Integrated Circuits design flow and transfer of digital / analog macros into system on chip (SoC) - Part 1**	**3**	**6-7**	**P2**	
	P2.5.2	**Integrated Circuits design flow and transfer of digital / analog macros into system on chip (SoC) - Part 2**	**3**	**6-7**	**P2**	
	P2.5.3	**Integrated Circuits design flow and transfer of digital / analog macros into system on chip (SoC) - Part 3**	**3**	**6-7**	**P2**	
	P2.5.4	**Integrated Circuits design flow and transfer of digital / analog macros into system on chip (SoC) - Part 4**	**3**	**6-7**	**P2**	
	P10.3	**VHDL language and design flow**	**30**	**7**	**P10**	

Table 2: Table for Area B.

2.3 Basics of Manufacturing

In the area of Basics of Manufacturing the METIS curriculum provides 27 individual courses comprising 11 modules, consisting of 11 core units and 36 satellite units.

#	ID	Name	LH	EQF	Partner	Link
C1		Clean Room Basics	48	4-6		
	P11.1	**Clean Room Technology/Clean Room Behaviour**	**24**	**4-6**	**P11**	
	P11.14	**Vaccuum Technology**	**24**	**4-6**	**P11**	
C2		Materials in Microelectronics	100	6-7		
	P14.1	**Materials in Microelectronics**	**40**	**6-7**	**P14**	
	P14.2	**Nanomaterials in Microelectronics**	**40**	**6-7**	**P14**	
	P14.3	**Nanotechnology in Microelectronics**	**20**	**6-7**	**P14**	
C3		Manufacturing Process Flows	101	4-5		
	P10.1	**Introduction to nanoscale CMOS Technology: Process flow and process modules**	**17**	**7**	**P10**	
	P11.4	**Manufacturing and Assembly Processes**	**24**	**4-5**	**P11**	
	P14.6	**Smart manufacturing in microelectronics**	**60**	**6-7**	**P14**	
C4		Quality Management	25	4-7		
	P11.11	**Quality Managment**	**24**	**4-6**	**P11**	
	P14.5	**Quality assurance techniques in microelectronics**	**20**	**6-7**	**P14**	
	P2.6	**Process Control Monitoring - measurement in wafer manufacturing**	**1**	**6**	**P2**	
C5	**P11.9**	**Preventive Maintenance**	**24**	**4-6**	**P11**	
C6		Power Semiconductors	4	5-7		
	P2.11	**Power Semiconductors Overview**	**1**	**5**	**P2**	
	P2.7	**Introduction to power MOSFETs**	**1**	**6-7**	**P2**	
	P2.13	**Basics of GaN power devices: material, design and reliability challenges**	**2**	**6-7**	**P2**	
	P10.8	**GaN-IC platform for power electronics Training**	**16**	**7**	**P10**	
C7		Introduction to Manufacturing Processes	14	6-7		
	P2.2	**Introduction to Plasmaetching**	**2**	**5-7**	**P2**	
	P2.8.1	**Introduction to Lithography Part 1**	**6**	**6-7**	**P2**	
	P2.8.2	**Introduction to Lithography Part 2**	**6**	**6-7**	**P2**	
	P1.6	**Microchips and Solar Chips**	**2**	**4**	**P1**	
C8		Advanced Manufacturing Processes	40	6-7		
	P2.3	**Semiconductor Carrier Technology**	**2**	**6-7**	**P2**	
	P2.16	**Ion Implantation for Semiconductor Industry**	**1**	**6-7**	**P2**	
	P10.4	**Advanced Cleaning and surface preparation in advanced CMOS Technologies**	**19**	**7**	**P10**	
	P10.7	**Photonics Integrated Circuit training**	**18**	**7**	**P10**	
C9		Design for Test	7	6		
	P2.1	**Introduction to Test Engineering for IC Development**	**2**	**6**	**P2**	

#	ID	Name	LH	EQF	Partner	Link
	P2.15	**Selected Topics on Chip Assembly for Chip Designers**	**5**	**6**	**P2**	
C10		Production Process	1	5-7		
	P2.4	**OptiGEN - Scheduling and Optimization**	**1**	**5-7**	**P2**	

Table 3: Table for Area C.

2.4 Key Competences & Innovative Thinking

In the area of Key Competences & Innovative Thinking the METIS curriculum provides 19 individual courses comprising 8 modules, consisting of 8 core units and 18 satellite units.

#	ID	Name	LH	EQF	Partner	Link
D1		Programming	35	4		
	P1.1	**Creative Computing—Introduction to Scratch Programming**	**2**	**4**	**P1**	
	EP.1	**Learning to code: Programming with Pocket Code**	**15**	**4**	**EP**	
	EP.2	**Informatik-Fit**	**18**	**4**	**EP**	
D2		Programmable Logic Controller	96	4-6		
	P11.7	**Programmable Logic Controller (PLC) - Basics**	**24**	**4-6**	**P11**	
	P11.5	**PLC - Advanced**	**24**	**4-6**	**P11**	
	P11.8	**PLC - Controlling and Networking**	**24**	**4-6**	**P11**	
	P11.6	**PLC - Visualtisation with WinCC flex**	**24**	**4-6**	**P11**	
D3	**P15.1**	**Basic Project management**	**64**	**4**	**P15**	
D4		Advanced Project Management	65.5	5-7		
	P15.2	**Advanced Project management**	**64**	**5**	**P15**	
	P7.9	**Agile Project Management**	**1.5**	**6-7**	**P7**	
D5		Design Thinking	3.5	4-7		
	P1.5	**Engineering Design Process**	**2**	**4**	**P1**	
	P7.10	**Design Thinking**	**1.5**	**6-7**	**P7**	
D6		Trends in Microelectronics	24.5	4		
	P1.4	**Education and Career Paths**	**2**	**4**	**P1**	
	P10.5	**Frontier and trends of IC Industry Technology, overview of nanoscale technology and recent and emerging applications leveraging on nanoelectronics**	**23.5**	**7**	**P10**	
D7		Machine Learning	12	7		
	P10.2	**Hardware-efficient machine learning: Designing across the algorithm-architecture circuit stack**	**12**	**7**	**P10**	
D8		Collaboration and Co-Creation	38	6		
	EP.3	**The Collaboration Roadmap**	**7**	**6**	**EP**	
	EP.4	**Collaboration and Co-Creation for Engineers**	**21**	**6**	**EP**	
	EP.5	**Entrepreneurship and Technology: From Idea to Market**	**10**	**6**	**EP**	

Table 4: Table for Area D.

Appendix A. Courses by Partner

This appendix comprises the syllabi of all courses that are provided in the METIS curriculum and training. The courses are grouped by partners.

The following partners participated in course creation:

- Semi Europe (P1)
- Infineon (P2)
- Arcelik (P7)
- TU Graz (P9)
- Imec (P10)
- Dresden Chip Academy (P11)
- USN (P12)
- TU Sofia (P13)
- BME (P14)
- IAL-FVG (P15)

Detailed descriptions for every single course can be found in Appendix B. Syllabi, where we list the syllabi of all courses.

A.1 Semi Europe (P1)

Semi Europe (P1) provides the following courses:

ID	Course Name	LH	EQF	Link
P1.1	Creative Computing—Introduction to Scratch Programming	2	4	
P1.2	Logic: Gates and Binary Calculations	2	4	
P1.3	Intro to Semiconductors	2	4	
P1.4	Education and Career Paths	2	4	
P1.5	Engineering Design Process	2	4	
P1.6	Microchips and Solar Chips	2	4	

Table 5: Courses provided by Semi Europe (P1).

A.2 Infineon (P2)

Infineon (P2) provides the following courses.

ID	Course Name	LH	EQF	Link
P2.1	Introduction to Test Engineering for IC Development	2	6	
P2.2	Introduction to Plasmaetching	2	5-7	
P2.3	Semiconductor Carrier Technology	2	6-7	
P2.4	OptiGEN - Scheduling and Optimization	1	5-7	
P2.5.1	Integrated Circuits design flow and transfer of digital / analog macros into system on chip (SoC) - Part 1	3	6-7	
P2.5.2	Integrated Circuits design flow and transfer of digital / analog macros into system on chip (SoC) - Part 2	3	6-7	
P2.5.3	Integrated Circuits design flow and transfer of digital / analog macros into system on chip (SoC) - Part 3	3	6-7	
P2.5.4	Integrated Circuits design flow and transfer of digital / analog macros into system on chip (SoC) - Part 4	3	6-7	
P2.6	Process Control Monitoring - measurement in wafer manufacturing	1	6	
P2.7	Introduction to power MOSFETs	1	6-7	
P2.8.1	Introduction to Lithography Part 1	6	6-7	
P2.8.2	Introduction to Lithography Part 2	6	6-7	
P2.9.1	Probabilistic System Architecture - Definition and Verification - Part 1 of 4	4	6-7	
P2.9.2	Probabilistic System Architecture - Definition and Verification - Part 2 of 4	4	6-7	
P2.9.3	Probabilistic System Architecture - Definition and Verification - Part 3 of 4	4	6-7	
P2.9.4	Probabilistic System Architecture - Definition and Verification - Part 4 of 4	4	6-7	
P2.10	Magnetic Speed Sensors	2	6-7	
P2.11	Power Semiconductors Overview	1	5	
P2.12	Chip-Package-PCB Co-Design Methodology	1.5	6	
P2.13	Basics of GaN power devices: material, design and reliability challenges	2	6-7	
P2.14	A/D and D/A Converters Fundamental Considerations and Definitions	1.5	5-6	
P2.15	Selected Topics on Chip Assembly for Chip Designers	5	6	
P2.16	Ion Implantation for Semiconductor Industry	1	6-7	

Table 6: Courses provided by Infineon (P2).

A.3 Arcelik (P7)

Arcelik (P7) provides the following courses.

ID	Course Name	LH	EQF	Link
P7.1	Sensors (Basic sensor concepts)	1	6-7	
P7.2	Sensor/Optics	1	6-7	
P7.3	Sensor/Mechanical	1	6-7	
P7.4	Sensor/Temperature	1	6-7	
P7.5	Sensor/Magnetic	1	6-7	
P7.6	Sensor/Gas	1	6-7	
P7.7	Sensor System Design	1.5	6-7	
P7.8	Sensor Data Analytics	1.5	6-7	
P7.9	Agile Project Management	1.5	6-7	
P7.10	Design Thinking	1.5	6-7	

Table 7: Courses provided by Arcelik (P7).

A.4 TU Graz (P9)

TU Graz (P9) provides the following courses.

ID	Course Name	LH	EQF	Link
P9.1	ElectrONiX MOOC - Amplifiers	28	5-6	
P9.2	ElectrONiX MOOC - Digital	25	5-6	
P9.3	ElectrONiX MOOC - Resonance	20	5-6	
P9.4	ElectrONiX MOOC - Power	18	5-6	
P9.5	Reliable ICs in Design and Application	25	7	
P9.6	Basics of Microelectronics	25	6-7	
P9.7	Electromagnetic Compatibility Essentials	25	7	
P9.8	Electromagnetic Compatibility of Integrated Circuits	25	7	

Table 8: Courses provided by TU Graz (P9).

A.5 Imec (P10)

Imec (P10) provides the following courses.

ID	Course Name	LH	EQF	Link
P10.1	Introduction to nanoscale CMOS Technology: Process flow and process modules	17	7	
P10.2	Hardware-efficient machine learning: Designing across the algorithm-architecture circuit stack	12	7	
P10.3	VHDL language and design flow	30	7	
P10.4	Advanced Cleaning and surface preparation in advanced CMOS Technologies	19	7	
P10.5	Frontier and trends of IC Industry Technology, overview of nanoscale technology and recent and emerging applications leveraging on nanoelectronics	23.5	7	
P10.7	Photonics Integrated Circuit training	18	7	
P10.8	GaN-IC platform for power electronics Training	16	7	

Table 9: Courses provided by Imec (P10).

A.6 Dresden Chip Academy (P11)

Dresden Chip Academy (P11) provides the following courses.

ID	Course Name	LH	EQF	Link
P11.1	Clean Room Technology/Clean Room Behaviour	24	4-6	
P11.2	Electronics Basics In the Field of Semiconductor Manufacturing	24	4	
P11.3	Integrated Circuits	24	5-6	
P11.4	Manufacturing and Assembly Processes	24	4-5	
P11.5	PLC - Advanced	24	4-6	
P11.6	PLC - Visualtisation with WinCC flex	24	4-6	
P11.7	Programmable Logic Controller (PLC) - Basics	24	4-6	
P11.8	PLC - Controlling and Networking	24	4-6	
P11.9	Preventive Maintenance	24	4-6	
P11.10	PCB Production	24	4-5	
P11.11	Quality Managment	24	4-6	
P11.12	Semiconductor Sensors	24	5-6	
P11.13	Signal Processing	24	4	
P11.14	Vaccuum Technology	24	4-6	

Table 10: Courses provided by Dresden Chip Academy (P11).

A.7 USN (P12)

USN (P12) provides the following courses.

ID	Course Name	LH	EQF	Link
P12.1	Mechanics of Si beam and diaphragm structures	80	7	
P12.2	Viscous damping in microstructures	40	7	
P12.3	Non-viscous damping in microstructures	40	7	
P12.4	Resistive sensor front-end	40	7	
P12.5	Capacitive sensor front-end	40	7	
P12.6	Physics of resistivity measurements	60	7	
P12.7	Piezoresistive Si sensors	80	7	
P12.9	Piezoelectric microsensors	40	6	
P12.10	Capacitive microsensors	40	6	
P12.11	Thermal and radiation sensors	60	6	

Table 11: Courses provided by USN (P12).

A.8 TU Sofia (P13)

TU Sofia (P13) provides the following courses.

ID	Course Name	LH	EQF	Link
P13.1	Nanomaterials for Electronics	125	7	
P13.2	Design, Prototype Fabrication and Challenging Applications of Silicon Microsystems with Piezoresistive Feedback	75	7	

Table 12: Courses provided by TU Sofia (P13).

A.9 BME (P14)

BME (P14) provides the following courses.

ID	Course Name	LH	EQF	Link
P14.1	Materials in Microelectronics	40	6-7	
P14.2	Nanomaterials in Microelectronics	40	6-7	
P14.3	Nanotechnology in Microelectronics	20	6-7	
P14.4	Printed Circuit Design	60	6-7	
P14.5	Quality assurance techniques in microelectronics	20	6-7	
P14.6	Smart manufacturing in microelectronics	60	6-7	
P14.7	System Design for Electronic Modules	60	6-7	

Table 13: Courses provided by BME (P14).

A.10 IAL-FVG (P15)

IAL-FVG (P15) provides the following courses.

ID	Course Name	LH	EQF	Link
P15.1	Basic Project management	64	4	
P15.2	Advanced Project management	64	5	
P15.3	Design of microcontroller devices to project specification	87	4	
P15.4	Embedded development	44	4	
P15.5	Firmware development	98	4	
P15.6	OPC - Open Platforms Communication	42	5	
P15.7	Sensor assessment applicable to the project	58	4	
P15.8	Basic IIoT Systems	66	4	
P15.9	Advanced IIoT systems	164	4	
P15.10	IIoT Solutions	182	4	
P15.11	Cloud for IoT	28	5	
P15.12	Protocols for IoT	44	4	

Table 14: Courses provided by IAL-FVG (P15).

A.11 External Providers

The METIS curriculum exploits synergies with external course providers, to usefully supplement the curriculum. The following courses are provided by external institutions and will therefore not be validated in Work Package 4.

ID	Course Name	LH	EQF	Link
EP.1	Learning to code: Programming with Pocket Code	15	4	
EP.2	Informatik-Fit	18	4	
EP.3	The Collaboration Roadmap	7	6	
EP.4	Collaboration and Co-Creation for Engineers	21	6	
EP.5	Entrepreneurship and Technology: From Idea to Market	10	6	
EP.6	Cadence: VLSI Fundamentals Education Kit	100	6	
EP.7	Analog Simulation and Layout Education Kit	100	6	
EP.8	Verification Methodologies Education Kit	100	7	
EP.9	Shift-Left Development Education Kit	100	7	
EP.10	Tensilica Processor IP Education Kit	100	7	

Table 15: Courses provided by External providers (EPs).

Appendix B. Syllabi

This appendix includes the syllabi of all courses that are provided by the METIS partners and that are included in the METIS curriculum.

Every syllabus includes the following:

- The name of the course and a brief overview.
- The duration, i.e. the learning hours (LHs).
- Information for which profiles this training is designed and delivered for (example: Engineers, Technicians, etc.).
- Information on what is usual level of education these profiles must have in order to be able to understand the training (high school, bachelor or master diploma, etc.).
- The course responsible and the course lecturers
- Educational prerequisites, explaining what is the requirement for a person to attend this training (in terms of previous knowledge/experience needed to understand it).
- Learning outcomes, describing on what students should be able to do after completion of each course. The learning outcomes are separated into:
  - Knowledge, which means the outcome of the assimilation of information through learning. Knowledge is the body of facts, principles, theories and practices that is related to a field of work or study.
  - Skills, which means the ability to apply knowledge and use know-how to complete tasks and solve problems.
  - Competence, which means the proven ability to use knowledge, skills and personal, social and/or methodological abilities, in work or study situations and in professional and personal development.
- Abstract, including a short description on what is the aim of the training, why it is important and what is it about.
- Detailed content description of the training.
- Teaching methods (for example presentation, practical demonstration, online etc.).
- Assessment defining how learners can show, that they reached the learning outcomes.
- Recommended literature.

This document does not include syllabi for courses provided by external providers, that are summarised in A.11.

Syllabus – Training description –

Creative Computing—Introduction to Scratch Programming

Name of the course:
Creative Computing—Introduction to Scratch Programming

Course topic:
In this course, we are going to learn about Scratch, which is an educational programming language with graphical interface.

Duration:
0.3 hours

Participants of the course:
Highschool students and above who want to learn an easy-to-use programming language with graphical interface.

Educational background:
Highschool students, diploma students, bachelor students, master students, doctorate students, and professionals with knowledge of operating computers.

Course responsible:
Company: SEMI
Department: SEMI University

Course lecturers:
N/A

Educational prerequisites
N/A

Learning outcomes

- ***Skills***
  - *Launch the Scratch canvas to create your project.*
  - *Upload Sprites and background for your project.*
  - *Apply Motion, Events, Looks, and Sound code blocks to your animations.*

Abstract
Scratch is an educational programming language with graphical interface.
It was created as a tool which would make programming easy and intuitively understandable. Its purpose was to allow users without any programming experience to learn the basic principles of imperative and multi-threading programming and hopefully will encourage them to continue in other languages. Naturally, its application is limited to fun and educational projects.
When people learn to code in Scratch, they learn important strategies for solving problems, designing projects and communicating ideas

Content
1. *Getting Starter*
   - *1.1. Course Instructions*
   - *1.2. Time Commitment*
   - *1.3. Course Objectives*

2. *Scratch—Introduction*
    - *2.1. Let's Get Started*
        - *2.1.1. Launch the Scratch Canvas*
    - *2.2. Sprites*
        - *2.2.1. Add New Sprite*
        - *2.2.2. Delete Sprite*
        - *2.2.3. Resize Your Sprite*
    - *2.3. Choose Your Background*
    - *2.4. Let's Begin the Programming*
        - *2.4.1. Code*
            - *2.4.1.1. Motion*
            - *2.4.1.2. Events*
            - *2.4.1.3. Looks*
            - *2.4.1.4. Sound*
    - *2.5. Presentation Mode*
3. *Wrapping Up*
    - *3.1. Key Takeaways*

Teaching methods

This is a self-paced eLearning module and comprises of a mixture of written passages and interactive blocks.

Assessment

No assessment at the moment

Recommended reading

N/A

Syllabus – Training description –

Logic Gates and Binary Calculations

Name of the course:
Logic Gates and Binary Calculations

Course topic:
In this module, we will explore what logic gates are and their types. We will also learn how to perform binary calculations.

Duration:
0.5 hours

Participants of the course:
Highschool students and above who want to learn about logic gates and binary calculations.

Educational background:
Highschool students, diploma students, bachelor students, master students, doctorate students, and professionals with elementary background in science and knowledge of operating computers.

Course responsible:
Company: SEMI
Department: SEMI University

Course lecturers:
N/A

Educational prerequisites
N/A

Learning outcomes

- ***Knowledge***
  - *Explain what logic gates and truth tables are.*
  - *Explain types of logic gates.*
  - *Explain binary calculations.*

Abstract
In this module, we will explore what logic gates are and their types.
We will then discover how to perform binary calculations.

Content
1. *Course Overview*
2. *Objectives*
3. *Section 1: What Are Logic Gates and Binary Calculations*
   - *3.1. What Are Logic Gates?*
   - *3.2. Knowledge Check*
   - *3.3. Logic Gate Symbols*
   - *3.4. What Are Truth Tables?*
   - *3.5. Basic Logic Gates – AND*
   - *3.6. Basic Logic Gates – OR*
   - *3.7. Basic Logic Gates – NOT*

3.8. Derived Gates – NAND
3.9. Derived Gates – NOR
3.10. Arithmetic Gates – XOR
3.11. Arithmetic Gates – XNOR
3.12. Knowledge Check
3.13. Binary Number System
3.14. Binary Mathematical Operations
3.15. Binary Addition
3.16. Binary Subtraction
3.17. Binary Multiplication
3.18. Binary Division
4. *Summary*
5. *Knowledge Checks*

Teaching methods
This is a self-paced eLearning module and comprises of a mixture of written passages and interactive blocks.

Assessment
Non-graded knowledge checks

Recommended reading
N/A

Syllabus – Training description –

Intro to Semiconductors

Name of the course:
Intro to Semiconductors

Course topic:
In this course, we are going to learn about what the semiconductors are, how they work, and the science behind them.

Duration:
0.25 hours

Participants of the course:
Highschool students and above who want to learn about the basics of semiconductors.

Educational background:
Highschool students, diploma students, bachelor students, master students, doctorate students, and professionals with elementary background in science and knowledge of operating computers.

Course responsible:
Company: SEMI
Department: SEMI University

Course lecturers:
N/A

Educational prerequisites
N/A

Learning outcomes

- ***Knowledge***
  - *Define conductor, insulator, and semiconductor.*
  - *Define Doping.*
    - *List the two types of semiconductor materials formed with doping.*
  - *Name the current carriers in N and P-type material.*
  - *Explain how current flows in semiconductor material.*

Abstract
In this course, we will look at what conductors, insulators, and semiconductors are.
We will then dive into understanding semiconductors in detail.
We will talk about doping and how doping results into N- and P-type semiconductors.

Content
1. *Course Overview*
2. *Objectives*
3. *Section 1: Science behind Semiconductors*
   - *3.1. Conductors*
   - *3.2. Atomic Structure of Conductors*
   - *3.3. Atomic Structure of Insulators*
   - *3.4. Semiconductors*

3.5. More about Semiconductors
3.6. Semiconductor Valence Orbit
3.7. Semiconductors—Crystal Lattice Structure
3.8. Doping
3.9. Semiconductor as a Conductor
3.10. Can We Dope Differently?
3.11. Types of Semiconductors
3.12. Current Flow in N-Type Semiconductor
3.13. Current Flow in P-Type Semiconductor
4. *Summary*

Teaching methods
This is a self-paced eLearning module and comprises of a mixture of written passages and interactive blocks.

Assessment
No assessment at the moment

Recommended reading
N/A

Syllabus – Training description –

Education and Career Pathways

Name of the course:
Education and Career Pathways

Course topic:
In this module, we will explore the skills needed in the high-tech industry and the education pathways you can take to acquire those skills. We will also learn about the career pathways that we can choose from in the high-tech industry.

Duration:
0.5 hours

Participants of the course:
Highschool students and above who want to learn about the education and career pathways that exist in the high-tech industry.

Educational background:
Highschool students, diploma students, bachelor students, master students, doctorate students, and professionals with elementary background in science and knowledge of operating computers.

Course responsible:
Company: SEMI
Department: SEMI University

Course lecturers:
N/A

Educational prerequisites
N/A

Learning outcomes

- ***Knowledge***
  - *Outline the skills necessary for jobs in the high-tech industry.*
  - *List your personality type and the corresponding traits.*
  - *List the factors which you should consider while deciding about college.*

Abstract
It is important to identify relevant skills used in high tech and understand where you can learn about them. In this module, we will explore the skills needed in the high-tech industry and the education pathways you can take to acquire those skills.

Career exploration and planning are KEY components to launching a satisfying career in high tech. We will learn about the career pathways that you can choose from in the high-tech industry.

Content
1. *Course Overview*
2. *Objectives*
3. *Section 1: Education and Career Pathways in the High-Tech Industry*
   3.1. Preparing for High-Tech Jobs

- *3.2. High-Tech Jobs*
- *3.3. Education and Pay*
- *3.4. Goal Settings—Considerations*
- *3.5. Personality Types*
- *3.6. Educational Foundation*
- *3.7. Considering about College*
- *3.8. Funding Your Education*

4. *Summary*

Teaching methods
This is a self-paced eLearning module and comprises of a mixture of written passages and interactive blocks.

Assessment
No assessment at the moment

Recommended reading
N/A

Syllabus – Training description –

Engineering Design Process

Name of the course:
Engineering Design Process

Course topic:
In this module, we will explore the meaning of the engineering design process and talk about the steps included in the engineering design process.

Duration:
0.5 hours

Participants of the course:
Highschool students and above who want to learn about the Engineering Design Process.

Educational background:
Highschool students, diploma students, bachelor students, master students, doctorate students, and professionals with elementary background in science and knowledge of operating computers.

Course responsible:
Company: SEMI
Department: SEMI University

Course lecturers:
N/A

Educational prerequisites
N/A

Learning outcomes

- ***Knowledge***
  - *Explain the meaning of the engineering design process.*
  - *List a series of steps in the engineering design process.*
  - *Describe each step of the engineering design process.*

Abstract
In this module, we will explore the meaning of the engineering design process.
We will delve into the series of steps included in the engineering design process.

Content

1. *Course Overview*
2. *Objectives*
3. *Section 1: Steps of the Engineering Design Process*
   - *3.1. Engineering Design Process*
   - *3.2. Steps in the Engineering Design Process*
   - *3.3. Define the Problem or Need*
   - *3.4. Research and Gather Relevant Information*
   - *3.5. Specify Design Requirements*
   - *3.6. Knowledge Check*
   - *3.7. Create Multiple Solutions*

3.8. Analyse Potential Solutions
3.9. Create Design Plan and Methodology
3.10. Develop and Prototype Solution
3.11. Knowledge Check
3.12. Test the Prototype
3.13. Communicate the Results
4. *Summary*
5. *Knowledge Checks*

Teaching methods
This is a self-paced eLearning module and comprises of a mixture of written passages and interactive blocks.

Assessment
No assessment at the moment

Recommended reading
N/A

Syllabus – Training description –

Microchips and Solar Chips

Name of the course:
Microchips and Solar Chips

Course topic:
In this module, we will explore what microchips and solar chips are and learn about the series of steps involved in the microchip-making process.

Duration:
0.5 hours

Participants of the course:
Highschool students and above who want to learn about microchips and solar chips.

Educational background:
Highschool students, diploma students, bachelor students, master students, doctorate students, and professionals with elementary background in science and knowledge of operating computers.

Course responsible:
Company: SEMI
Department: SEMI University

Course lecturers:
N/A

Educational prerequisites
N/A

Learning outcomes

- ***Knowledge***
  - *Explain what microchips and solar chips are.*
  - *List a series of steps in the microchip-making process.*
  - *Describe each step of the microchip-making process.*

Abstract
In this module, we will explore what microchips and solar chips are.
We will then examine the series of steps included in the microchip-making process.

Content
1. *Course Overview*
2. *Objectives*
3. *Section 1: Microchips and Solar Chips*
   - *3.1. What Is a Microchip?*
   - *3.2. Material Used to Make Microchips*
   - *3.3. Knowledge Check*
   - *3.4. Size of a Microchip*
   - *3.5. Types of Microchips*
   - *3.6. Microchip-Making Process*
   - *3.7. Uses of a Microchip*

3.8. Solar Chips
4. *Summary*
5. *Knowledge Checks*

Teaching methods
This is a self-paced eLearning module and comprises of a mixture of written passages and interactive blocks.

Assessment
No assessment at the moment

Recommended reading
N/A

"Introduction to Test Engineering for IC Development"

Name of the course
Introduction to Test Engineering for IC Development
Course topic
Test Engineering for IC Development
Duration:
3 hours
Participants of the course:
Students or R&D employees, without previous knowledge of test engineering
Educational prerequisites:
Bachelor degree in electrical engineering (or equivalent)
Course responsible
Infineon Austria AG
Course lecturer
Riccardo Dapretto, Senior Staff Engineer, Test Development
Giulia Ferrari, Staff Engineer, Test Development

Educational Prerequisites
Previous understanding of microelectronics technology, hardware and software development.

Learning outcomes
Upon successful completion of this course students should be able to:

- Understand the role of a test engineer in an IC company
- Distinguish test engineering from other verification roles
- Understand the working principle of automated test equipment, its architecture, advantages and limitations
- Define test methods for a mixed signal circuit
- Evaluate the quality of a test method
- Understand which tests are commonly implemented for a mixed signal IC

Abstract
Test engineering is a key role within an IC company but it is generally unknown to students and graduates without work experience. This course aims to close this learning gap by giving a deep overview to test engineering, including theory and practical examples. The course is kept at a general abstraction level to be independent from the specific test equipment and processes which might be in use in a particular IC company.

Content

1. Introduction: what is production test?
2. Test Engineering Team: overview about the different roles in the test engineering group
3. Test Equipment: hardware used in production test
4. ATE (Automatic Test Equipment) Architecture: architectural description of the modern automatic test equipment
5. Test Methods: applied numerical methods for test (ramps, search methods, digital processing)
6. Mixed Signal Testing: overview about most common tests and issues

Teaching methods
Slide presentation with registered audio, including theory and practical examples.

Assessment

At the moment there is no training internally. We could prepare questions upon request.

Recommended readings

Burns M., Roberts G.W., An Introduction to Mixed-Signal IC Test and Measurement, Oxford University Press Inc., 2000, ISBN-13: 978-0195140163

Gizopoulos D. (ed.), Advances in Electronic Testing, Challenges and Methodologies, Springer, 2006, ISBN 978-0-387-29409-4

Chapra S.C., Canale R.P., Numerical Methods for Engineers, McGraw-Hill Professional, 2014, ISBN-13: 978-0073397924

Syllabus – Training description – Introduction to Plasmaetching

Instruction for filling the template:
Please find bellow the template for Training descriptions needed for METIS project. Comments in grey are made for guidance and for help to understand what is each section about. Please also refer to separate document - "Example of Syllabus" for more information.

Name of the course:
Introduction to Plasmaetching
Course topic:
Plasmaetching isotropic and an-isotropic
Duration:
2 hours
Participants of the course:
Engineers, Technicians, highshool students
Educational background:
high school or bachelor or master diploma
Course responsible:
Infineon Technologies Austria AG UPD4 Unit Process Developement Plasma Etch
Course lectures :
Joachim Hirschler

Educational prerequisites
Basic technical understanding, no specific knowledge

Learning outcomes
Upon successful completion of this course students should be able to:
- Explain the different kinds of plasma etching which are existing
- Judge whether plasma etching is a method to solve a specific topographic structuring requirement
- Have an idea which plasma chemistry helps for specific etching requirement
- Know how endpointing of plasma processes work and where it is needed
- Explain the basic expressions plasma potential, self Bias , external Bias, DC / AC plasma working principle
- Know basic plasma chamber configurations

Abstract
Plasma etching is one of the four big methods to structure semiconductors.
This course develops an understanding to the basic concepts of plasmaetching in a today state of the art Semiconductor manufacturing environement

Content
- *Definition of plasma and the role of electrons*
- *Magnetic fields in plasma*
- *The interesting species in plasma*
- *The meaning of free mean path*
- *What to etch / chemicals to etch / chemical reactions for etch*
- *The plasma zoo*
- *The numbers of molecules and various particles in plasma*
- *The effect of plasma potential and plasma self bias*
- *Principle chamber configurations and applications for isotropic etch*
- *Typical daily work troubles to takle*
- *Summary*

Teaching methods

Presentation, video material of process chambers, processes and visual practical demonstration

Assessment

Interactive communication during lesson.
No assessment at the end of the course

Recommended reading

Plasma School for Semiconductor Manufacturing
By Plasmetrex GmbH 2014 www.plasmetrex.com

Annual International Cources in Semiconductor Technology and Nanotechnology (2004, 2006)
Course 87: „Plasma-Assisted Etching and Reactive Ion Etching Using High and Low Density Plasmas ans Ion Beams“

Syllabus – Semiconductor Carrier Technology

Name of the course:
Semiconductor Carrier Technology
Course topic:
Types and applications of Carrier used for Semiconductor manufacturing
Duration:
8 hours
Participants of the course:
Process-Engineers, Product-Developer, Young Professionals
Educational background:
Basic knowledge of semiconductor manufacturing processes
Course responsible:
Infineon Technologies AG
Course lectures :
Dr. Carsten v. Koblinski

Educational prerequisites
Basic principles of semiconductor manufacturing processes

Learning outcomes
After completion of this course, the participants will know

- *What is the advantage of thin-wafer for electrical performance*
- *What are the challenges with respect to thin-wafer-production in high-volumes*
- *What types of Carrier-technology are available and when are they used*
- *What advantages / disadvantages come with the different types of Carrier Technologies*

Abstract
In this training the different types of Wafer-Carrier-technologies are presented. After a historic development of different carrier-technologies, the most efficient reversible and irreversible techniques are presented. The different mechanism of bonding and debonding is explained and the use of different carrier for different purpose are shown.

Content

i) Introduction; Classification and physical / chemical basics of Wafer-Support-Carrier
ii) Reversible Carrier technologies
  a. "Foil"-Carrier
  b. REVALPHA®-Carrier
  c. 3M®-Carrier / long-, mid- & short Thin-Wafer-Process
  d. "DBG&M"-approach
  e. Bow-topics
iii) Irreversible Carrier technologies
  a. SOI- / Direct- / Anodic-bonding
  b. "GlassGrid"-approach e

Teaching methods
The course is held as a front-of-class-teaching and PowerPoint-presentation

Assessment

During the course there is no assessment. There is a short online training available in parallel, which ends in a small multiple-choice-test.

Recommended reading

Ramm, P., Lu, J. J.-Q., Taklo, M. M. V., & ProQuest. (2012). Handbook of wafer bonding. Wiley-VCH

Gessner, T., Otto, T., Wiemer, M., Frömel J. (2005). "Wafer bonding in micro mechanics and microelectronics - an overview". The World of Electronic Packaging and System Integration. The World of Electronic Packaging and System Integration. pp. 307–313.H.

Training description – OptiGEN – Scheduling and Optimization

Name of the course:
OptiGEN – Scheduling and Optimization
Course topic:
Scheduling in a Wafer Fab
Duration:
1
Participants of the course:
Students of Mathematics, Information Technologies, Operations Research or similar
Educational background:

Course responsible:
Infineon Technologies
Course lectures :
Herbert Forstner

Educational prerequisites
Basic knowledge of the production processes in a Wafer Fab

Learning outcomes

Abstract

Content

- What is scheduling?
- Difference between Scheduling and dispatching
- Challenges of Scheduling in a wafer fab
- Benefits of scheduling

Teaching methods
Presentation
Assessment

Recommended reading

Training Description for "Integrated Circuits design flow and transfer of digital / analog macros into system on chip (SoC)"

Instruction for filling the template:
Please find bellow the template for Training descriptions needed for METIS project. Comments in grey are made for guidance and for help to understand what is each section about. Please also refer to separate document - "Example of Syllabus" for more information.

Name of the course:
Integrated Circuits design flow and transfer of digital / analog macros into system on chip (SoC)
Course topic:
Development of analog and digital IP blocks and their transfer into a mixed-signal system on chip (SoC)
Duration:
~ 4hours
Participants of the course:
Students
Educational background:
Bachelor/Master degree students
Course responsible:
Infineon Technologies Austria AG
Course lectures :
Irina Schell, Bala Paladugu Venkata Tejomayee

Educational prerequisites
Previous understanding of microelectronics and computer aided design in electronics

Learning outcomes
Upon successful completion of this course students should be able to:

- *Explain the steps in analog and digital IP Block design*
- *Understand the challenges of building mixed-signal IC designs*
- *Explain the steps in transfer of digital IP blocks into an analog domain and vice versa*

Abstract
Analog and digital IP blocks are developed using different methodologies and EDA tools. But when integrating them into one SoC they have to function together. This is a big challenge with respect to fulfilling the required functionality, reliability, performance and quality.

Content

- *Analog/digital IP blocks: concept, design entry, physical implementation, verification*
- *Transfer of analog/digital IP blocks into the SoC*
- *Integration of analog/digital IP blocks into an mixed-signal SoC*

Teaching methods
The course is presented in the Moodle learning environment

Assessment
Please insert information if there is some assessment at the end of the course. If there is not at the moment existing, can it be developed in forms of questionnaire, project, presentation… etc? (please see separate document "Example of Syllabus" for more information on content and structure)

Recommended reading

Please insert recommendation on literature on the subject of the training (if applicable)

Syllabus – Training description

Name of the course:
Process Control Monitoring – manufacturing overview
Course topic:
Process Control Monitoring measurement in wafer manufacturing
Duration:
0,75h
Participants of the course:
Students
Educational background:
High school
Course responsible:
Infineon Technologies Austria
IFAT FE PV VM5 IC UPE
Course lectures :
Thomas Beyreder

Educational prerequisites
Basic understanding of semiconductor manufacturing

Learning outcomes
- *Know the most important facts about PCM in wafer manufacturing*
  - *Measurement process*
  - *Equipment*
  - *Recipe components*
  - *Position in the overall chip manufacturing flow*

Abstract
Process Control Monitoring is an electrical measurement at PCM test structures to ensure that the manufacturing processes have been executed as specified. Process deviations can be detected early long before the chip is delivered to the customer by stability monitoring.
The course focuses on the manufacturing part of the PCM wafer testing by explaining the overall measurement process and giving some insights to used equipment/recipe components.

Content
1. *Purpose of PCM*
   - *1.1. Function: detect deviations, stability monitoring, corrective actions*
   - *1.2. PCM in the overall manufacturing process flow*
2. *PCM measurement process at wafer level*
   - *2.1. Measurement location at wafer: PCM modules*
   - *2.2. Equipment: Tester, Prober, Probecard*
   - *2.3. Recipe components: Test program, Limits, Userfile, Wafermap, Module coordinates, Prober setup*

Teaching methods
Presentation

Assessment

100% multiple choice questionnaire -> not available, can be created from presentation material

Recommended reading

Syllabus – Introduction to power MOSFETs

Name of the course:
Introduction to power MOSFETs
Course topic:
Introduction to power MOSFETs
Duration:
1,5h
Participants of the course:
Engineers, Technicians
Educational background:
Bachelor or Master`S degree
Course responsible:
Infineon Technologies Austria AG
Course lectures :
Andrew Wood

Educational prerequisites
Basic understanding of physics

Learning outcomes
Participants will know:

- What is a power MOSFET and how does it differ from CMOS device
- How does power MOSFET work
- How does a power MOSFET behave electrically
- How are power MOSFET chips made

Abstract
The participant will learn power MOSFET electrical behaviourB and device physics. They will understand factors to consider when using power MOSFETs in their applications and understand how these factors depend on the underlying power MOSFET technology. (They will understand the key processes involved in manufacturing a power MOSFET : optional).

Content

- Basic overview of Power MOSFETs
- Structure of a power MOSFET
- Electrical behavior of power MOSFETs
- Device physics of power MOSFETs

Teaching methods
On-line presentation with voice over

Assessment
No

Training Description

"Lithography-Teaser" – (A Hitchhiker's Guide to Lithography)

Name of the course:
Lithography Teaser – (A Hitchhiker's Guide to Lithography)
Course topic:
Introduction to Semiconductor Photolithography
Duration:
6 hours
Participants of the course:
Students, Engineers, Technicians; anyone with technical interest
Educational background:
Bachelor degree in science or engineering, or experience of working in the semiconductor or related industry
Course responsible:
Infineon Technologies Austria AG
Department for Unit Process Development, Lithography (UPD2)
Course lecturer:
Dr. techn. Jörg Ortner, Dr. Magdalena Forster

Educational prerequisites:
Basic knowledge of natural sciences (physics, chemistry) and interest in aspects of manufacturing processes in the semiconductor industry.

Learning outcomes:

- Knowledge:
  - Basic understanding of the techniques of photolithography for creating patterns and processing semiconductor devices.
  - Fundamentals of Photoresist chemistry, in particular differences of iline (365nm) and chemically amplified resists often used for e.g. 248nm lithography.
  - Basics of optics and imaging; understand why wavelength and lens diameter are key factors for resolution.
  - The different types of exposure tools, how they work and when they are used. Individual components of lithography tools and how they contribute to the final process results.
  - The 'Process Window' as a requirement for stable production; FEM (Focus Exposure Matrix) plots.
  - Properties of semiconductor wafers and how they influence the lithographic processes.

- Skills:
  - Ability to apply simple formulas to calculate minimum resolution, depth of focus and periodicity of swing curves
  - Interpreting typical plots of FEM results and swing curves
  - Understanding basic working principles and components of manufacturing tools, and how they contribute to the process results

- Competence:
  - Understand how basic principles of natural science come to life in patterning tools and processes in semiconductor industry.
  - Improved ability to follow technical discussions related to device manufacturing and the interaction of lithography with other processes e.g. deposition, implant or etch.
  - The acquired knowledge will help to get you started in interdisciplinary communication.

Abstract:

Photolithography is used to define the lateral structures and patterns of semiconductor devices. The wafers are coated with a photoactive resist layer, and exposure tools transfer the image from a mask or a reticle into the resist, which is subsequently developed. This resulting pattern is a temporary mask, aiding subsequent processes such as etch or implant to modify defined areas of the device. State of the art semiconductor devices often require dozens of lithography layers.

This training offers a short but concise overview of different lithographic processes and typical tools, and gives an insight into how basic physical laws interact with the real-world mass manufacturing environment. The examples and principles described cover broadband exposure as well as 365 nm and 248 nm lithography processes on steppers, scanners, and mask aligners. The examples selected aim to highlight, how the process' outcome relies on a combination of basic principles of natural science, highly advanced production materials and equipment, as well as properties of the incoming wafers.

Content:

1. General Aspects of Lithography:

What litho is trying to achieve, typical process sequence, basic terms and physics.

2. Coating and Chemistry:

Coating wafers, spin curves, photoactive materials, difference between iline and DUV resists and chemical background, development, the role of temperature steps (bakes) in the coating and development processes.

3. Exposure Tools:

Typical components, the role of light, typical tool types (mask aligners, steppers, scanners), pellicles and reticles. Why different process goals require different tools.

4. Imaging:

What's the fuzz about diffraction orders, their role in imaging. Imaging concepts of typical exposure tool types. The limitations of minimum resolution and depth of focus.
The role of NA and σ and how they affects the imaging result.

5. Process and Process Windows:

The role of dose and focus, exploring process windows and typical FEM-plots.
Dealing with standing waves and swing curves.

Teaching methods:
The course material is presented in the Moodle learning environment in the form of pdf documents, covering above listed subjects with theory and corresponding examples. Those scripts include a set of questions and simple calculations, that are intended to support the student with checking the level of understanding.

(note: as by the time this version of training description is written, it is not yet defined in detail, how training should be presented, this is the initial working assumption. Method can get tweaked to match the needs of METIS project).

Assessment:
The course grade consists of these components:
100% – Knowledge test questionnaire (multiple choice for majority of questions)

Recommended Literature:
Okoroanyanwu U., Chemistry and Lithography, SPIE and Wiley & Sons, Inc., 2010, ISBN: 978-0-8194-7562-6.

Dammel R., Diazonaphtoquinone-based Resists, SPIE, 1993, ISBN: 0-8194-1019-5.

Mack Ch., Fundamental Principles of Optical Lithography, John Wiley & Sons, Inc., 2007, ISBN: 9780470727300.

Munnig Schmidt, R., Schitter, G. , Rankers, A., Van Eijk, J., The Design of High Performance Mechatronics, Delft University Press, 2014, ISBN: 978-1-61499-367-4.

Recommended Online Material:
Mack Ch., Online Courses, 2006-current © Chris A. Mack
[http://www.lithoguru.com/scientist/onlinecourses.html]

TRAINING
Probabilistic System Architecture Definition and Verification

Name of the course
Probabilistic System Architecture Definition and Verification
Course topic
System definition and verification under uncertainty
Duration:
8 hours
Participants of the course:
Students and Employees
Educational prerequisites:
Bachelor degree in electrical/electronic/mechatronics engineering
Course responsible
IFAT PSS SIS UPC in cooperation with University of Klagenfurt
Course lecturer
Dr. Wolfgang Granig
Prof. Dr. Hubert Zangl (University of Klagenfurt)

Educational Prerequisites
Understanding of basics in electrical and electronical engineering
Basics of statistical mathematics

Learning outcomes
Upon successful completion of this course students should be able to:

- Understand uncertainties coming from semiconductor production and application
- Be able to collect and define statistical requirements for system definition
- Learn basic principles of statistical uncertainty propagation
- Learn basic principles for statistical optimizations
- Learn to know and use tooling for statistical uncertainty propagation and optimization
- Apply statistical uncertainty propagation on real-world applications
- Apply statistical optimization on real world applications

Abstract
Problems related to the design and investigation of submicron and nanoscale MOS integrated circuits are covered by this course. Currently there are some nanotechnologies in the means of 14 nm design kits, which are available via the EUROPRACTICE organization. The main attention is drawn to the theoretical and practical usage of state-of-the-art industrial CAD systems, e.g. CADENCE, SYNOPSYS and others. The designers who use those systems can implement nanoscale elements from the relevant standard cell libraries. The specific parameters, related to the nanoscale effects are represented in the embedded system models of the elements.

Content
1. Introduction and Motivation
    a. Development Flows and its need for estimating uncertainties (V-Model, Agile)
    b. Basics on statistics and statistical parameters (Probability Distributions and Random Variables)
2. Measurement Uncertainty
    a. Measurement Uncertainty defined in GUM
    b. Probabilities of limit fulfilment

3. General Uncertainty Propagation
    a. Functions of a random variable (incl. application examples)
    b. Functions of multiple random variables (incl. application examples)
    c. Influence of correlations to multiple random variables on functions of multiple random variables
4. First Order Taylor Series Approximation
    a. Basic principle of first order Taylor-series approximation
    b. Simple application example for error propagation using first order series approximation
    c. Simple application example extension applying parameter correlations
5. Uncertainty Propagation Tooling
    a. Introduction into MATLAB tooling “The Uncertainty Toolbox”
    b. Simple application example solved with Uncertainty Toolbox
    c. Hall-Sensor Example
6. Applications of Uncertainty Propagation and Optimization
    a. Sensor Calibration
    b. Temperature Sensor Example
    c. Angle Sensor Example

Teaching methods

The theoretical part of the course is presented in the Moodle learning environment in the form of HTML tutorials.
The practical work represents a project for statistical design and optimization of an electronical system.

Assessment

The course grade consists of these components:
40% – Knowledge test with a multiple choice questionnaire
60% – Final Application Project

Recommended reading

H. P. Hsu. Functions of Random Variables, McGRAW-HILL, 1997. ISBN ISBN 0-07-030644-3.

S.M. Kay. Fundamentals of Statistical Signal Processing: Estimation Theory. Prentice Hall Signal Processing Series. Prentice Hall, New Jersey, 1993. ISBN 0-13-345711-7

K. O. Arras. An introduction to error propagation: Derivation, meaning and examples of equation CY = FXCX F T X . Technical Report No. EPFL-ASL-TR-98-01 R3, 1998.

International Electrotechnical Committee. IEC/TR 62380:2004 Reliability data handbook - Universal model for reliability prediction of electronics components, PCBs and equipment, 2004.

Joint Committee for Guides in Metrology. JGCM 100:2008, Evaluation of measurement data - Guide to the expression of uncertainty in measurement, 2008

Zangl and K. Hoermaier. Educational aspects of uncertainty calculation with software tools. Measurement, 101:257–264, 2017. doi: 10.1016/j. measurement.2015.11.005.

W. Granig, D. Hammerschmidt, and H. Zangl. Diagnostic coverage estimation method for optimization of redundant sensor systems. In IEEE Sensors Conference, volume 1, pages 636–638, Glasgow, UK, Nov 2017 2017. IEEESensors. doi: 10.1109/ICENS.2017.8234088.

W.Granig, S. Aoudjit, L.-M. Faller, and H. Zangl. Statistical modeling of integrated sensors for automotive applications. In 2018 International Conference of Electrical and Electronic Technologies for Automotive (AUTOMOTIVE2018), pages 1–5, Milano, Italy, July 2018. doi: 10.23919/EETA.2018.8493172

W. Granig, L.-M. Faller, D. Hammerschmidt, and H. Zangl. Dependability considerations of redundant sensor systems. Elsevier, 190:1–12, 2019. doi: 10.1016/j.ress.2019.106522

W. Granig, L.-M. Faller, and Hubert Zangl. Sensor System Optimization under Uncertainty, chapter 10. Springer, 2019. ISBN 978-3-030-16576-5.

Example of training description
"Magnetic Speed Sensors"

Name of the course
Magnetic speed sensors
Course topic
Magnetic speed sensors
Duration:
1,5 h
Participants of the course:
Students and engineers
Educational prerequisites:
Bachelor and Master's degree
Course responsible
Infineon Technologies Austria AG
Course lecturer
MSc. Elisa de la Torre, Dr. Dirk Hammerschmidt

Educational prerequisites
Basic understanding of microelectronic, circuit design, signal processing and system development

Learning outcomes
Upon successful completion of this course students should be able to:

- How magnetic speed sensor works
- Basics of magnetic circuit design for magnetic speed sensor.
- Knowledge about available "state of the art" sensing technologies. From Hall to sensing technologies base on tunnel effects.
- How to apply speed-sensing technologies to real environments. Main challenges and applications

Abstract

The measurement of the rotational speed and angle of a rotating shaft is one of the most frequently used measurement in all fields of mechanical engineering. Different sensing principles are commonly used. This course shortly introduces the sensing arrangement for speed measurement of a rotating shaft. The state of the art magnetic sensing technologies (Hall, AMR, GMR, TMR) are described and their limitations are shown. The key parameters of magnetic speed sensors as well as the challenge on real applications.

Content

- Types of magnetic field sensors (Hall, AMR, GMR and TMR)
- Incremental speed and position detection sensing using encoders
- Linear measurement of magnetic fields
- Measurement of magnetic field angle including auto calibration
- Applications of magnetic field sensors in automotive applications

Teaching methods

Online presentation (slides and voice recording)

Assessment

no

Recommended reading

Syllabus – Power semiconductor overview

Name of the course:
Power semiconductor overview
Course topic:
General overview of power semiconductors
Duration:
1h
Participants of the course:
Everyone
Educational background:
In general, everyone can listen to the course. Basic physics knowledge could be needed
Course responsible:
Infineon Technologies Austria AG
Course lectures :
Herbert Pairitsch

Educational prerequisites
None needed. Basic physics knowledge would be beneficial but not necessary.

Learning outcomes
- To hear about semiconductor industry and market trends as well to understand what are power semiconductors, what is their application and why they are so important
- To understand the challenges of the power semiconductor design
- To understand the "big picture" and how power semiconductors are contributing to the more sustainable world from the energy point of view

Abstract
The goal of this course is to introduce audience to the bigger picture of the world today and to emphasize why power semiconductors are important today and in the future.

Content
- What are power semiconductors
- Sustainable energy – how do we save energy and what is role of Power semiconductors
- Power semiconductors design – little box challenge
- Look into the future – fight for efficiency

Teaching methods
On-line presentation with voice over

Assessment
None needed

Recommended reading
Please insert recommendation on literature on the subject of the training (if applicable)

Syllabus – Training description

Name of the course:
Chip-Package-PCB Co-Design Methodology
Course topic:
Basic parts and concepts of a concise chip-package-PCB co-design flow for modern heterogeneous integration products
Duration:
1-2 hours
Participants of the course:
Students, chip top-level designers, layout engineers, chip concept engineers, package concept engineers, PCB designers
Educational background:
Bachelor degree students
Course responsible:
Infineon Technologies Austria AG
Course lectures :
Dr. Thomas Brandtner

Educational prerequisites
Basic knowledge of chip top level design; chip, package, or PCB layout design; overview of packaging technologies

Learning outcomes
Upon successful completion of this course, students or engineers should be able to:

- Understand the challenges of chip-package-PCB co-design
- Understand the different steps of a chip-package-PCB co-design workflow
- Understand concepts to optimize a complete chip-package-PCB product more efficiently during design implementation
- Promote the novel concepts of assembly design kits (ADKs) and a coherent chip-package-PCB co-design flow for upcoming heterogeneous integration designs.

Abstract
Heterogeneous integration leads to significant increase in design complexity. We present a modular full-custom chip-package-board/system co-design environment based on a versatile backbone idea, which has already been applied successfully to various system-in-package (SiP) designs. We show challenges and solutions for co-design applied to traditional lead frame assembly and packaging (e.g. QFP, QFN, TO, SON, DSO) as well as more recent technologies like FOWLP or laminate BGA and LGA.

Content

1. Design methodology for heterogeneous integration
2. The need for a versatile chip-package-PCB co-design flow based on multi-dimensional modularization
   Flow configuration, data exchange and storage, design environments, design tools, workflows
3. Connectivity entry across chip, package, and PCB domain
   Schematics, tables, hierarchy across domains
4. Concurrent layout design
   IO cell ring, pad/bump placement, chip footprint extraction, bidirectional data exchange, export-compare-import data interfaces
   Concurrent layout viewing and editing inside Cadence tool suite
   Implementation design flow for fan-out wafer-level-packages (FOWLP)

5. Physical verification
   Layout-versus-Schematic on package level, assembly design rule check (ADRC)
6. Electrical simulation and verification
   3D-model generation across chip, package, and PCB domain. 3D electromagnetic field simulation, parasitic extraction, broadband models, backannotation to Spice simulation, signal and power integrity, multi-tech Spice simulations.
7. Assembly Design Kits
   Concept (comparison to chip PDK), content, structure

Teaching methods
Video lecture with Powerpoint slides and software demonstration

Assessment
Knowledge test with a multiple-choice questionnaire

Recommended reading

Syllabus – Training description – Template

Instruction for filling the template:
Please find bellow the template for Training descriptions needed for METIS project. Comments in grey are made for guidance and for help to understand what is each section about. Please also refer to separate document - "Example of Syllabus" for more information.

Name of the course:
GaN Electronics: an overview on material properties, technology and characterization
Course topic:
Principle of GaN power devices
Duration:
1,5 hrs
Participants of the course:
Bachelor's degree, Master ad Ph.D student
Educational background:
Students in Electrical and Electronic engineers, Physics, Material science
Course responsible:
Infineon Technologies Austria, Power & Sensor System division
Course lectures :
Dr. Gianmauro Pozzovivo

Educational prerequisites
Basic physical concepts, principal operation and functioning of the main semiconductor devices used in electronic applications as well as the technological processes used to manufacture semiconductor devices.

Learning outcomes
At the end of the course, students will be able to:

- *Understand the main differences between Si, SiC and GaN based power electronic devices;*
- *Get familiar with material advantages and key figure of merits*
- *Acquire knowledge on technological process steps starting from GaN growth on Si substrate up to the final passivation.*
- *Knowledge on different concepts on how to fabricate normally-off devices.*
- *Describe the most important reliability aspects (i.e. trapping effect).*
- *Understand applications and benefits by using GaN power devices.*

Abstract
Gallium nitride (GaN) offers fundamental advantages over silicon. In particular, the higher critical electrical field makes it very attractive for power semiconductor devices with outstanding specific dynamic on-state resistance and smaller capacitances compared to silicon MOSFETs, which makes GaN HEMTs great for high speed switching. Not only because of the resulting power savings and total system cost reduction, it also allows a higher operating frequency, improves the power density as well as the overall system efficiency. The training will give a comprehensive overview of Gallium Nitride technology, covering different aspects like material properties, physics, technology and reliability.

Content

1) *Introduction to GaN semiconductor material and devices compared to Si and SiC*
    a. *Device principles Si. vs SiC vs. GaN (lateral vs vertical device concept)*
    b. *Material advantages*
    c. *Key figure of merit*
2) *The key building blocks of GaN power devices*
    a. *GaN epitaxy with focus on GaN on Si*
    b. *GaN/AlGaN heterojunction and 2DEG formation*
    c. *Gate module (normally-on vs. Normally-off)*
    d. *Power metallization for later devices*
3) *The reliability challenges*
    a. *Time-dependent dielectric breakdown*
    b. *Charge trapping, dynamic RDSon and current collapse*
    c. *Gate module reliability*
4) *Manufacturing aspects*
    a. *GaN wafer production in high-volume Si fab*
    b. *Ga cross-contamination control*

Teaching methods

Presentation

Assessment

Not at moment

Recommended reading

Please insert recommendation on literature on the subject of the training (if applicable)

Training description

A/D- and D/A-Converters: Fundamental Considerations and Definitions

Name of the course:
A/D- and D/A-Converters: Fundamental Considerations and Definitions
Course topic:
Fundamental Considerations and Definitions with respect to Analog-to-Digital and Digital-to-Analog Converters
Duration:
1.5 hours
Participants of the course:
Students and Engineers
Educational background:
Very basic understanding of signal processing (signals, bits, sampling, Fourier transform, Nyquist theorem)
Course responsible:
Infineon Technologies Austria AG (in cooperation with TU Graz)
Course lectures :
Dr. Dieter Draxelmayr

Educational prerequisites
Very basic understanding of signal processing (signals, bits, sampling, Fourier transform, Nyquist theorem)

Learning outcomes
After successful completion of this training students should be able to:

- *Understand specifications in data sheets of existing data converters*
- *Understand terminology and relationships used in scientific articles on data converters*
- *Create measurement concepts for specifying a data converter*
- *Report relevant specification data out of measurements*

Abstract
Analog-to-Digital- and Digital-to-Analog converters (ADCs and DACs) are the binding elements connecting the analog and the digital world. A fundamental understanding is needed to successfully use the right ADC / DAC at the right place for the right purpose. Several different metrics are used to describe the behavior of a data converter. This training explains these metrics and tries to give some motivation what to use when and why.

Content
Sampling, quantization, reconstruction, several errors (e.g. offset, gain, INL, DNL, missing codes, (non)monotonicity, SNR, SNDR, SFDR, THD …). Some fundamental relations (timing / quantization with respect to SNR). Introduction to FoM (Figure of Merit).

Teaching methods
On-line e-learning

Spoken words backed up by slides and computer animations

Assessment
Multiple choice test (to be developed).
Numerical examples to calculate (to be developed).

Recommended reading
After completion of the training details can be found in:
IEEE Standard for Terminology and Test Methods for Analog-to-Digital Converters

Syllabus – Training description

Name of the course:
Selected Topics on Chip Assembly for Chip Designers
Course topic:
Overview about chip assembly and packaging technologies
Duration:
4-5 hours
Participants of the course:
Students, chip circuit designers, layout engineers, and chip concept engineers
Educational background:
Bachelor degree students
Course responsible:
Infineon Technologies Austria AG
Course lectures :
Dr. Thomas Brandtner

Educational prerequisites
Basic knowledge of analog or digital chip design and chip layout

Learning outcomes
Upon successful completion of this course, students or engineers should be able to:

- Understand the basic challenges in chip packaging assembly
- Know different types of packaging technologies
- Cooperate with assembly engineers more efficiently because special terms of chip assembly are understood also by the chip design colleagues

Abstract
In order to be able to optimize the complete product in terms of size and cost, it is essential for chip designers to collaborate with their packaging and assembly colleagues. Therefore, it is beneficial to understand the challenges in chip assembly and to know the various available technologies. Especially novel approaches in heterogeneous integration ("More than Moore") like system-in-package, die-stacks, wafer-level-packages, and 3D-integration will be the basis of miniaturization and innovation in future electronic products. This course will provide a basic overview about different assembly technologies, their process steps, and integration opportunities for product design.

Content

1. Motivation and Introduction
   "More Moore" vs "More than Moore"
2. Basic Challenges in Chip Assembly
   Interconnect gap, area efficiency, thermal expansion, mixture of materials, reliability
3. Overview of package platforms
   a. Difference in 1st and 2nd level interconnect (chip-package-PCB)
   b. Difference in interconnect re-distribution (leadframe, laminate, thin-film)
   c. Going to 3D (package-on-package, die-stacks, …)
   d. Chip embedding
   e. JEDEC package naming convention
4. Leadframe Packages
   a. Process steps
      Leadframe manufacturing, pre-assembly, adhesive bonding, soldering

   b. Wirebonding
      Materials, nailheads, wedge, special options
   c. Molding
5. Laminate/BGA Packages
   a. Laminate/substrate material
   b. Substrate manufacturing
   c. Special layout techniques (plating lines, etch-back, back-drill, vias)
   d. Bumps, Copper-Pillars
6. Chip-Embedding, Wafer-Level-Packages
   a. Embedding in mold compound, laminate, PCB
   b. Wafer level packages (WLP)
      Process steps (chip first, face up/down, reconstituted wafer, …)
      Infineon eWLB, TSMC InFO
   c. Package-on-Package, Through-Mold-Vias
   d. Passives and antennas in WLP
   e. Panel Level Packaging
7. 3D IC & Silicon Integration
   a. Through-Silicon-Vias (TSV)
   b. 3D Die Stacks
   c. Passive interposers (2,5D integration)
      TSMC Chip-on-Wafer-on-Substrate (CoWoS)
      Intel Embedded Multi-Die Interconnect Bridge (EMIB)
   d. 3D Silicon Integration
      Wafer-to-Wafer Bonding – adhesive, metal, hybrid bonding
      True 3D-VLSI – LETI CoolCube
8. Product examples
   E.g. Xilinx Virtex7 FPGA, Nvidia Pascal GPU, Apple A12, Apple S4

Teaching methods
Video lecture with Powerpoint slides

Assessment
Knowledge test with a multiple-choice questionnaire

Recommended reading
R. Tummala: Microsystems Packaging. McGraw Hill, 2001
R. Tummala, M. Swaminathan: Introduction to System-on-Package. McGraw Hill, 2008
C. F. Coombs, H. T. Holden: Printed Ciruits Handbook. McGraw Hill, 2016
J. H. Lau: Fan-Out Wafer Level Packaging. Springer, 2018

Syllabus – Training description – Template

Instruction for filling the template:
Please find bellow the template for Training descriptions needed for METIS project. Comments in grey are made for guidance and for help to understand what is each section about. Please also refer to separate document - "Example of Syllabus" for more information.

Name of the course:
Ion Implantation for Semiconductor Industry
Course topic:
The participant receives basic knowledge about the implantation process (process flow, used equipment, limits of the process)
Duration:
4h
Participants of the course:
Students, Process Engineers
Educational background:
Bachelor degree students or engineers with experience in semiconductor processing
Course responsible:
Infineon Technologies Austria AG
IFAT FE UPD10
Dr. Werner Schustereder
Course lectures :
Dr. Werner Schustereder

Educational prerequisites
Basic understanding of microelectronics technology, solid state physics and ion physics.

Learning outcomes
Upon successful completion of this course students should be able to:

- Understand motivation, benefits and limitations of the ion implantation process
- Explain basic implanter concepts
- Apply basic ion implantation knowledge for semiconductor device development
- Recognize most important security measures for ion implanters
- Understand differences in processing Silicon compared to new materials like SiC and GaN

Abstract
Ion Implantation processes contribute significantly to the development of semiconductor devices. This course covers different types and details of ion implantation equipment along with security topics. From a process point of view theory of the implantation process as well as process control concepts are discussed.
Accurate treatment of the wafer frontside and backside structures as well as sometimes influencing the bulk material itself play a crucial role to guarantee for key parameters such as highest power densities and minimal losses at required switching behaviour. Some representative examples of the needs of high, medium and low power devices based on silicon technology are described and challenges for ion implantation processing are concluded.
Additionally, other semiconductors like SiC and GaN obtain superior material characteristics compared to silicon and are therefore about to get of economic importance in the near future. That is why considerable development effort is put into the understanding of how to fabricate

devices based on those materials. One ingredient is the knowledge how ion implantation can affect and tailor their semiconductor properties.

Content

- Introduction:
Development and use of ion implantation, implantation tool types
- Theory of the implantation process:
Deceleration of ions and their range in solids, crystal damage, channeling, activation
- Implantation concepts:
Ion source, ion transport and mass separation, homogeneous scanning of the ion beam, process chambers and dosimetry
- Security:
Toxic gases, high voltage, radiation
- Process control:
Dose and energy, contamination, charge exchange, interactions with masks, implantation angle
- Proton implantation:
Physical basics, implantation concept, security concept, radiation, process control
- Implantation in new materials
Specialities for SiC, GaN
- Summary and Outlook

Teaching methods

I would strongly prefer an interactive face-to-face session in order to place direct questions and interact with the participants. I learned that this way of conducting trainings is most effective.
In case that will not be possible I will have to go with presentation only.

Assessment

I could prepare a kind of questionnaire in case there is the wish to have something like that.

Recommended reading

Not really necessary.
Example for literature could be: Ion Implantation Science and Technology, Edition: 2018, ISBN – 0-9654207-4-4

Syllabus – Basics of Sensors

Name of the course:
Basics of Sensors

Course topic:
Sensors in general

Duration:
4h

Participants of the course:
Students and engineers

Educational background:
Bachelor and above

Educational prerequisites
Basic understanding of physics, microelectronics, circuit design, signal processing and system development

Learning outcomes
To be able to define basic sensor concepts such as noise, signal-to-noise ratio, dynamic range, saturation, hysteresis, crosstalk, interference, calibration, and to be able to use these concepts effectively. Capable of understanding types of noise, to be able to identify sources of noise in measurements, to be able to develop solutions in hardware and software that will eliminate the effects of noise on the signals read by sensor systems, to establish a hardware / software balance in the solution. Monitoring the technological advancements of each sensor according to the sensor categories i.e. Optical, mechanical, pressure, acoustic, light, piezoelectric, magnetic etc.

Abstract
This course intends to provide knowledge about the basics of sensors and sensing concept that are required for practical applications. In addition to that, a roadmap relating to the innovation in sensor technologies will also be introduced.

Content
- *Basic sensor knowledge*
- *Signal*
- *Noise*
- *Signal-to-noise ratio*
- *Dynamic range*
- *Saturation*
- *Hysteresis*
- *Crosstalk, interference)*
- *Analog and digital sensors*
- *Calibration of sensors*
- *Sensors according to Growth Phase, Sensors used today (Phase 3), Sensors in development (Phase 2), Innovations in sensors (Phase 1)*

Teaching methods
Online presentation

Sensitivity: Public

Assessment
Evaluation in the form of multiple answer test.

Recommended reading

- *Fraden, J. Handbook of Modern Sensors: Physics, Designs, and Applications. 4th ed. Springer, 2010. ISBN: 9781441964656.*
- *Horowitz, P., and W. Hill. The Art of Electronics. 2nd ed. Cambridge University Press, 1989. ISBN: 9780521370950.*

Sensitivity: Public

Syllabus – Optical Sensors

Name of the course:
Optical Sensors

Course topic:
Optical sensors and their applications

Duration:
4h

Participants of the course:
Students and engineers

Educational background:
Bachelor and above

Educational prerequisites
Basic understanding of physics, microelectronics, circuit design, signal processing and system development

Learning outcomes
To understand the working mechanisms of Optical Sensors.

Abstract
This course intends to provide knowledge about the principle of operation of optical sensors and introduces examples of optical sensing.

Content

- *Optical sensor materials and measurement system of performances (Standard Ashby diagrams comparing different materials according to multiple performance metrics and their advantages / disadvantages)*
- *Optical Sensor types and designs: Photodetectors: General ambient light sensors (Ambient Light Sensors, PIR sensors)*
- *Digital Light sensors (light to digital Converters)*
- *Fibreoptic sensors (Fibre Optic Sensors): Sensors converting light into square waves (Light To Frequency & Light To Voltage)*
- *Time-of-flight sensors*
- *Photoelectric Sensors*
- *Image sensors (Image Sensors) and LIDAR systems*
- *Optical Switches*
- *Photodetectors and phototransistors*
- *Solar cells*
- *Infrared detectors and thermal cameras*
- *Charge coupled devices (CCD).*

Teaching methods
Online presentation

Assessment
Evaluation in the form of multiple answer test.

Sensitivity: Public

Recommended reading

- *Fraden, J. Handbook of Modern Sensors: Physics, Designs, and Applications. 4th ed. Springer, 2010. ISBN: 9781441964656.*
- *Horowitz, P., and W. Hill. The Art of Electronics. 2nd ed. Cambridge University Press, 1989. ISBN: 9780521370950.*

Sensitivity: Public

Syllabus – Mechanical Sensors

Name of the course:
Mechanical Sensors

Course topic:
Mechanical sensors and their applications

Duration:
4h

Participants of the course:
Students and engineers

Educational background:
Bachelor and above

Educational prerequisites
Basic understanding of physics, microelectronics, circuit design, signal processing and system development

Learning outcomes
To understand the working mechanisms of Mechanical Sensors.

Abstract
This course intends to provide knowledge about the principle of operation of mechanical sensors and introduces examples of mechanical sensing.

Content

- *Mechanical sensor materials and measurement system of performances (Standard Ashby diagrams comparing different materials according to multiple performance metrics and advantages / disadvantages)*
- *Force sensors (potentiometric, capacitive, membrane, film and other)*
- *Tension meters (strain gauges, T rosette)*
- *Linear accelerometers - MEMS / NEMS systems*
- *Angular accelerometers (gyroscopes)*
- *Flexible sensors whose resistance changes due to flexing (flex sensors)*
- *IMUs (Inertial mass units, accelerometer, gyroscope, pressure, magnetometer, 3- & 6-axis)*
- *Pressure sensors*
- *Microphones and ultrasonic receivers*
- *Piezoelectric sensors*

Teaching methods
Online presentation

Assessment
Evaluation in the form of multiple answer test.

Sensitivity: Public

Recommended reading

- *Fraden, J. Handbook of Modern Sensors: Physics, Designs, and Applications. 4th ed. Springer, 2010. ISBN: 9781441964656.*
- *Horowitz, P., and W. Hill. The Art of Electronics. 2nd ed. Cambridge University Press, 1989. ISBN: 9780521370950.*

Sensitivity: Public

Syllabus – Temperature Sensors

Name of the course:
Temperature Sensors

Course topic:
Temperature sensors and their applications

Duration:
4h

Participants of the course:
Students and engineers

Educational background:
Bachelor and above

Educational prerequisites
Basic understanding of physics, microelectronics, circuit design, signal processing and system development

Learning outcomes
To understand the working mechanisms of Temperature Sensors.

Abstract
This course intends to provide knowledge about the principle of operation of Temperature sensors and introduces examples of Temperature sensing.

Content
- *Temperature sensor materials and measurement system of performance comparisons,*
- *Temperature sensors with positive / negative temperature constant (PTC / NTC sensors)*
- *Thermocouple*
- *Thermopile*
- *Acoustic temperature sensors (surface acoustic wave temperature sensors)*
- *Transistor-based temperature sensors*
- *Thermostats*
- *Analog and resistance-based temperature sensors*

Teaching methods
Online presentation

Assessment
Evaluation in the form of multiple answer test.

Recommended reading

- *Fraden, J. Handbook of Modern Sensors: Physics, Designs, and Applications. 4th ed. Springer, 2010. ISBN: 9781441964656.*
- *Horowitz, P., and W. Hill. The Art of Electronics. 2nd ed. Cambridge University Press, 1989. ISBN: 9780521370950.*

Sensitivity: Public

Syllabus – Magnetic Sensors

Name of the course:
Magnetic Sensors

Course topic:
Magnetic sensors and their applications

Duration:
4h

Participants of the course:
Students and engineers

Educational background:
Bachelor and above

Educational prerequisites
Basic understanding of physics, microelectronics, circuit design, signal processing and system development

Learning outcomes
To understand the working mechanisms of Magnetic Sensors.

Abstract
This course intends to provide knowledge about the principle of operation of Magnetic sensors and introduces examples of Magnetic sensing.

Content

- *Performance comparisons of magnetic and sensor materials*
- *Hall sensors*
- *2 or 3 wire magnetic sensors*
- *Magnetic angle sensors and compasses*
- *Digital Magnetic Field sensors*
- *Large magnetoresistance sensors (Giant magnetoresistance GMR)*
- *High resolution magnetic field sensors*

Teaching methods
Online presentation

Assessment
Evaluation in the form of multiple answer test.

Recommended reading

- *Fraden, J. Handbook of Modern Sensors: Physics, Designs, and Applications. 4th ed. Springer, 2010. ISBN: 9781441964656.*
- *Horowitz, P., and W. Hill. The Art of Electronics. 2nd ed. Cambridge University Press, 1989. ISBN: 9780521370950.*

Sensitivity: Public

Syllabus – Gas Sensors

Name of the course:
Gas Sensors

Course topic:
Gas sensors and their applications

Duration:
4h

Participants of the course:
Students and engineers

Educational background:
Bachelor and above

Educational prerequisites
Basic understanding of physics, microelectronics, circuit design, signal processing and system development

Learning outcomes
To understand the working mechanisms of Gas Sensors.

Abstract
This course intends to provide knowledge about the principle of operation of Gas sensors and introduces examples of Gas sensing.

Content
- *Performance comparisons of gas sensor materials*
- *Metal oxide (MOX) gas sensors*
- *Polymer gas sensors*
- *Electrochemical sensors*
- *Humidity sensors*
- *Toxic gas sensors*

Teaching methods
Online presentation

Assessment
Evaluation in the form of multiple answer test.

Recommended reading

- *Fraden, J. Handbook of Modern Sensors: Physics, Designs, and Applications. 4th ed. Springer, 2010. ISBN: 9781441964656.*
- *Horowitz, P., and W. Hill. The Art of Electronics. 2nd ed. Cambridge University Press, 1989. ISBN: 9780521370950.*

Sensitivity: Public

Syllabus – Sensor System Design

Name of the course:
Sensor System Design

Course topic:
Sensor System Design

Duration:
4h

Participants of the course:
Students and engineers

Educational background:
Bachelor and above

Educational prerequisites
Basic understanding of physics, microelectronics, circuit design, signal processing and system development

Learning outcomes
To understand the basic designing and working of sensing systems

Abstract
This course intends to provide basic knowledge about designing the sensing systems along with how they work, their suppliers, together with data reading and power circuits of the types of sensors that are used today.

Content

- *Sensor system design and implementation*
- *Defining System Requirements*
- *Defining the system in functional blocks*
- *Defining the properties of the components of the functional blocks according to the requirements and selecting the components*
- *Preparing the circuit diagrams of the system*
- *Development of algorithms and embedding codes*
- *Common critical objectives of sensor system designs (cost, safety, packaging and aesthetics, repeatability and functional reliability, resistance to failure modes)*
- *Errors that can be avoided during the design process*

Teaching methods
Online presentation

Assessment
Evaluation in the form of multiple answer test.

Recommended reading

- *Fraden, J. Handbook of Modern Sensors: Physics, Designs, and Applications. 4th ed. Springer, 2010. ISBN: 9781441964656.*
- *Horowitz, P., and W. Hill. The Art of Electronics. 2nd ed. Cambridge University Press, 1989. ISBN: 9780521370950.*

Sensitivity: Public

Syllabus – Sensor Data Analytics

Name of the course:
Sensor Data Analytics

Course topic:
Data Analysis

Duration:
24h

Participants of the course:
Students and engineers

Educational background:
Bachelor and above

Educational prerequisites
Basic understanding of Mathematics, Physics, Python, R and Sensors

Learning outcomes
To understand the basics of Sensor Data Analytics

Abstract
This course intends to provide knowledge about the basics of data analytics and machine applications by using collective sensor data (sensor fusion) from various sensors and to create added value.

Content
- *Advantages of using multi-sensor data (sensor fusion)*
- *Use of either MATLAB, or Python, or R software packages to analyse sensor data*
- *Data analytics methods and applications based on real sensor data*
- *Machine learning methods*
- *Artificial neural networks and deep learning methods*

Teaching methods
Online presentation

Assessment
Evaluation in the form of multiple answer test.

Recommended reading

- *Richard Cotton, "Learning R", O'Reilly, 2013*
- *Dalgaard, Peter, "Introductory statistics with R", Springer Science & Business Media, 2008.*
- *Brain S. Everitt, "A Handbook of Statistical Analysis Using R", Second Edition, 4 LLC, 2014.*
- *Samir Madhavan, "Mastering Python for Data Science", Packt, 2015.*
- *Sheldon M. Ross,"Introduction to Probability and Statistics for Engineers and Scientists", 4 th edition, Academic Press; 2009.*
- *Paul Teetor, "R Cookbook, O'Reilly, 2011. 7. Mark Lutz ,"Learning Python", O'Reilly,5th Edition,2013*

Sensitivity: Public

Syllabus – Agile Project Management

Name of the course:
Agile Project Management

Course topic:
Project Management

Duration:
16h

Participants of the course:
Students and engineers

Educational background:
Bachelor and above

Educational prerequisites
Basic understanding of English and general project management

Learning outcomes
To understand the basics of Agile project management

Abstract
This course intends to provide knowledge about the history, approach, and philosophy of Agile project management, including the Scrum framework. It will also teach students how to differentiate Agile and other project management approaches.

Content

- *Identifying the differences between project types and methods that goes with, Agile principles and different agile techniques*
- *SCRUM as an agile method*
- *Role and responsibilities*
- *Process and agile artifacts:*
  - *Product backlog*
  - *Stories and sizing*
  - *Sprint & sprint backlog*
  - *Kanban & Burndown charts*
  - *Sprint review*
- *Retrospective*

Teaching methods
Online presentation

Assessment
Evaluation in the form of multiple answer test.

Recommended reading

- *The Power of Scrum, Jeff Sutherland, Rini van Solingen, Eelco Rustenberg, 2012.*
- *Manage Your Project Portfolio, Joanna Rothman, Pragmatic Bookshelf, 2009.*
- *User Story Mapping, Jeff Patton, O'Reilly Books, 2014.*
- *Agile Retrospectives, Esther Derby and Diana Larsen, Pragmatic Bookshelf, 2006.*

Sensitivity: Public

Syllabus – Design Thinking

Name of the course:
Design Thinking

Course topic:
Design Thinking

Duration:
24h

Participants of the course:
Students and engineers

Educational background:
Bachelor and above

Educational prerequisites
Basic understanding of English

Learning outcomes
To understand the basics of Design Thinking approach

Abstract
This course intends to provide knowledge regarding the Theoretical and Practical Knowledge about Design Thinking, Five steps of Design Thinking; Empathize, Define, Ideate, Prototype and Test to get acquainted with the design process and creative thinking.

Content

- *What is Design Thinking?*
- *How to Develop New Products/Models/Services through Design Thinking?*
- *Worldwide Case Studies*
- *Steps of design thinking:*
  - *1st Step : Empathise*
  - *2nd Step : Define*
  - *3rd Step. : Ideate*
  - *4th Step : Prototype*
  - *5th Step : Test*
- *Pitching:*
  - *Pitching Methodology*
  - *Pitching Practice*

Teaching methods
Online presentation

Assessment
Evaluation in the form of multiple answer test.

Recommended reading

- *Change by Design, Tim Brown*
- *Design Thinking, by Nigel Cross*

Sensitivity: Public

Syllabus – Training description – ElectrONics MOOC

Name of the course:
ElectrONics MOOC
Course topic:
Basics of Electronic Circuit Design
Duration:
80 learning hours
Participants of the course:
Pupils and students, as well as employees who are considering a re-education or advanced training in the field of electronics.
Educational background:
High School, EQF level 4-6
Course responsible:
Graz University of Technology
Institute of Electronics
Dominik Zupan, Michael Fuchs
Course lecturers:
Dominik Zupan
Michael Fuchs
Nikolaus Czepl
Patrick Schrey

Educational prerequisites
Electrical engineering fundamentals (Ohm's law, Kirchhoff's law, superposition principle, resistor networks, bode plots, basic passive elements) as well as fundamentals of calculus.

Learning outcomes
The Electronics MOOC is intended to provide a basis for an in-depth study of electronics, and requires only fundamental prior knowledge.

After completion of the course, participants are able to:

Knowledge
- …explain the behaviour of active components (diodes, bipolar, FETs) in electronics.
- …explain fundamental large and small signal relationships in simple electronic circuits.

Skills
- …analyse, design, and build simple amplifier and other transistor circuits (e.g. current mirror).
- …build simple linear regulators and switched mode power supplies.
- …use operational amplifiers in various applications.
- …analyse, design, and build simple electronic filters.

Competence
- ...confidently design a circuit, or discuss a circuit design with colleagues.
- …talk from experience about building simple audio synthesizers.

Abstract
Many engineers who take advanced electronics courses often experience gaps in their basic understanding of individual components or circuit blocks. This course is designed to fill these gaps with a focus on practical applications (EQF 4-6) and to align the basic knowledge of participants of more advanced courses. In addition, it serves as a reference for possibly forgotten basics. The course is fully

digital, open and freely licensed (OER). Participants can also purchase a voluntary exercise kit to build basic circuits.

Content

1. *Component Level*
   1.1. *Fundamental components in electronics → Diodes, bipolar transistors, MOSFETs*
   Identify, classify and choose basic electronic components (diodes & transistors) for a given task and judge their applicability depending on given datasheet values and application. Get in touch with their simplified mathematical models.

   Tasks for additional electronic kit:
   - check diode & transistors for functionality
   - measure z-diode in blocking direction
   - measure input, transfer and output characteristic of transistors

   1.2. *Current sources*
   Explain the functionality of basic current sources and compare their features regarding temperature behaviour and stability.

   Tasks for additional electronic kit:
   - build a MOSFET current source
   - expand it to a current mirror
   - check temperature stability

   1.3. *Transistor amplifiers → Emitter follower, common-emitter amplifier*
   Construct different amplifier circuits by applying different transistors and calculate the output values, using small-signal analysis.

   Tasks for additional electronic kit:
   - build a current amplifier with a fixed gain
   - build a voltage amplifier with adjustable gain

   1.4. *Differential amplifiers*
   Explain the functionality of differential amplifiers with different complexity and calculate the most important values like differential gain an common-mode rejection ratio.

   Tasks for additional electronic kit:
   - build a differential amplifier
   - measure common mode rejection & gain
   - explore temperature behaviour

   1.5. *Operational amplifier circuits → non-idealities, comparators, negative feedback, Schmitt trigger*
   Explain the basic functionality of an operational amplifier and summarize the most important non-linearities. Calculate the output voltages of various OpAmp circuits and select the appropriate OpAmp for a given task considering various values in a data sheet.

   Tasks for additional electronic kit:
   - measure offset voltage of OpAmp
   - build an amplifier with given gain
   - construct an amplifier using an OpAmp and a piezo speaker to make a heartbeat audible

   1.6. *CMOS circuits → basic inverter, logic circuits, transmission gate*
   Explain important properties of a basic CMOS inverter circuit and transmission gate. Explain the

functionality of a given CMOS logic circuit. Develop simple CMOS logic circuits with 3-4 input variables depending on a given task with the minimum amount of transistors.

Tasks for additional electronic kit:
- build 2 CMOS inverters
- add them together in series and connect the output to the input
- continue with section "multivibrators"

1.7. *Multivibrators → latches, flip flops, monoflops, oscillators*
Classify different types of multivibrators and design a monoflop and a relaxation oscillator with different duty cycles / frequency.

Tasks for additional electronic kit:
- build a memory circuit with 2 transistors, 2 resistors and 2 diodes
- take a 555 timer and build a monoflop
- build an oscillator with the 555 timer
- later synthesizer project with two 555 timer: Atari Punk Console

1.8. *Analog-to-digital converters → flash, successive approximation, delta-sigma converters*
Identify different topologies of analog-to-digital converters (flash, SAR, delta-sigma) and choose an appropriate ADC for a specific task depending on its values in the data sheet.

Tasks for additional electronic kit:
- simulate a charge balance ADC
- later project: Arduino synthesizer ?
- later project: smart scale with strain gauge and 12 bit ADC

2. *System Level*

2.1. *Basics of electronics → oscilloscopes and other basic lab equipment*
Explain how to use an oscilloscope and a frequency generator. Adjust the voltage probe and measure continuous signals, switching events with internal and external trigger, hysteresis of a Schmitt trigger and the output characteristic of a transistor.

2.2. *Resonance circuits → RLC resonance circuits*
Simulate two RLC circuits with a serial and a parallel resonance and calculate the resonance frequency and the impedance at a certain frequency.

2.3. *Passive filter circuits → passive high pass, low pass, band pass, band stop & applications*
Build a third order low pass / band pass / high pass filter with the help of capacitors / inductors with an accurate cut-off frequency. Develop a filter for high frequency disturbances when the source has high/low impedance and the load has high/low impedance.

2.4. *Active filter circuits → active filtering, typologies (multiple feedback, Sallen-Key), filter design*
Design an active filter with given order, passband, transition band, stop band and gain. Simulate the frequency response of the filter.

Tasks for additional electronic kit:
- Design a 4th order active filter with two OpAmps and listen what it does to your audio signal

2.5. *Linear voltage regulators → linear regulators, LDOs*
Summarize different topologies (standard and low dropout) of linear regulators and construct a

simple regulator from scratch with regard to given output values.

Tasks for additional electronic kit:
- build your own linear regulator with a transistor, a zener diode and resistor
- compare your linear regulator to the 7800 regulator

2.6. *Switched mode power supplies → buck-, boost- & inverting converters, flyback, secondary and primary SMPS (forward, push-pull converter), basics of regulation, PFC*
Explain the functionality of buck-, boost-, inverting and flyback converters. Simulate a basic buck/boost converter and design a control circuit for the MOSFET.

2.7. Basic hardware interfaces → I2C, SPI, limits
Analyze an SPI/I2C signal and find out the transmitted ASCII character with the given settings.

2.8. *Fundamentals of EMC → spectrum of a pulse train, layout mistakes, measurement equipment (spectrum analyzer & EMI receiver)*
Show the frequency spectrum of a pulse train with given frequency and duty cycle. Explain how and what a spectrum analyzer would measure compared to an EMI receiver.

Teaching methods
The theory is taught entirely in the form of a Massive Open Online Course (MOOC) on the Moodle-based platform iMoox.at. The MOOC includes interactive learning videos (using H5P), as well as interactive lessons (HTML).
Calculation examples and simple dimensioning tasks are given for practical exercise. In addition, an electronics kit can be purchased voluntarily for hands-on experience.

Assessment
The learning objectives are tested completely automated in various formats (multiple choice, assignment tasks with drag and drop, sequencing tasks, cloze tests and free arithmetic problems with a given margin for rounding).

Recommended reading
Paul Horowitz and Winfried Hill, The Art of Electronics, 3rd Edition, 2015, ISBN: 978-0521809269.

Syllabus
"Reliable Integrated Circuits in Design and Application"

Name of the course:
Reliable Integrated Circuits in Design and Application

Course topic:
Reliability issues, measures to improve the reliability and influence of the environment on circuit/system operation and its reliability.

Duration:
25 learning hours

Participants of the course:
Students, Engineers, Technicians

Educational background:
Bachelor degree in electronics or physics

Course responsible:
Graz University of Technology
Institute of Electronics
Alicja Michalowska-Forsyth

Course lecturers:
Alicja Michalowska-Forsyth

Educational prerequisites
Background in electronics and microelectronics basic analog and digital building blocks, basics of theory of electrical circuits, basics of statistics.

Learning outcomes

- ***Knowledge***
  Mathematical models in reliability;
  Failure mechanisms in ICs;
  Environmental influence on device characteristics and on IC reliability;
  Impact of process type as well as technology node scaling on device sensitivity to various environmental factors;
  Examples of mitigation techniques;
- ***Skills***
  Identifying impact of given external environmental factors on given electronic devices;
  Interpreting physical significance of failure distribution functions;
  Identifying the sensitive parts in the circuit under environmental stress;
  Identifying reliability-robust design approaches for analog and mixed-signal circuits;
- ***Competence***
  Select the steps in the product development cycle that improve quality and reliability of product
  Specify environmental tests relevant and necessary for given device and application;
  Calculate failure rate, referring to the appropriate standards and guidelines;

Abstract

The reliable operation of integrated circuits and devices is a key attribute for their final application. Meanwhile over the lifetime external factors originating from the operating environment influence the device degradation and a likelihood of an abrupt failure. Reliability issues discussed in this course are related to temperature, overvoltage, high energy radiation, mechanical stress and beyond. A detailed introduction to main degradation mechanisms and modes classification is foreseen. The subject of accelerated testing is also highlighted. Next, the modeling of reliability functions along with the physical interpretation is covered. A further important aspect discussed is the device sensitivity to environmental factors in different fabrication processes and process nodes. In this course examples of device-level mitigation techniques as well as selected robust analog and mixed-signal circuits proposed for standard applications are discussed, overlapping with the extreme environment examples.

Content

Reliability of Electronic Components

- *Why reliability is important*
- *Definition of reliability and distinghishing from product quality*
- *Economical drivers*
- *History of reliability of microelectronics*
- *Brief view into the first reliability handbook*
- *Origin of failures with random, systematic and wear-out classification*
- *Basic terminology (reliability function, time to failure and MTTF, failure rate)*
- *Bathtub curve in reliability*
- *Failure modes*
- *Accelerating factors and accelerated testing*
- *Classification of failure mechanisms into electrical stress, chip-level, package level and soft errors*
- *Examples of mechanism / stress factor / failure mode*
- *Screening in reliability*
- *Exercise based on "Zero-Defect Framework"*
- *Exercise to understand JESD94B and JESD47G standards on application-driven and stress-driven qualifications*

Model Description in Applied Reliability

- *Descriptive methods in statistics: from parameters to distribution*
- *Concept of probability density function and cumulative distribution function on the intuitive example of normal distribution*
- *Probability density function as a function of time to describe reliability*
- *Cumulative distribution function as a failure function*
- *PDF, CDF, Failure rate – reliability examples with data*
- *Series and parallel system and their reliability function and failure function*
- *Exponential distribution and its properties*
- *Flexible distributions: Weibull and Lognormal and their properties*
- *Exercise with FIDES Guide – Reliabilty Methodology to identify necessary device input parameters: operating conditions, environmental factors and other factors in order to calculate failure rate in FIT units*

Wear-out aware circuit design for selected damage mechanisms

- *Time dependent dielectric breakdown (TDDB) mechanism*
- *Examples of TDDB-problematic circuits and reliability-degrading operation (overshoots, high impedance nodes) and methods to fix it*
- *Bias temperature instability (BTI) mechanism and related MOSFET parameter degradation*

- *Examples of circuit examples sensitive to BTI and mitigation strategies (chopping stabilization, autozero, avoiding static parking of digital blocks in particular clock chains)*
- *Hot carrier injection (HCI) mechanism and related MOSFET parameter degradation*
- *Oxide wearout and scaling – examples of evolution in TDDB, HCI and BTI degradation*
- *Summary of good practices (rebalance, recover, sense, compensate)*

Failures caused by electrostatic discharge and overvoltage stress

- *Explanation of EOS and ESD*
- *Human Body and Charged Device Models*
- *Device level vs system level ESD testing*
- *ESD protections*
- *ESD damage (junction breakdown, oxide punch-through, metallization burnout, latent failures)*
- *TLP characterization method*
- *I-V characteristics of diode and of snap-back devices*
- *Surface and bulk conduction in diode and bipolar substrate based devices (GGNMOS, GCNMOS)*
- *Latch-up of parasitic PNPN structure and trigger mechanisms*
- *Methods to reduce latch-up sensitivity*

Environmental influence on integrated circuits

- *Is it good or bad*
- *Temperature and extreme temperatures*
- *Vibration*
- *Magnetic field*
- *Electromagnetic field*
- *Ultraviolet light*
- *Humidity*
- *Ionizing radiation – single events and cumulative damage*
- *Standards for environmental testing*
- *Exercise to get familiar with MIL STD 883 – Test Method Standard for Microcircuits*

Teaching methods

Webinar-video consisting of 5 lectures to follow in own pace. Extending knowledge on a selected subject with self-studies based on provided literature. Practical exercises, independently working with reliability standards and guidelines provided in the literature list (some available only upon registration: to JEDEC and to FIDES, however all available free of charge).

Assessment

Written 3-page protocol on: the result from self-conducted exercises and an self-study of a selected topic from the course material (based on a proposed literature or further sources).

Recommended reading

„Failure Mechanisms in Semiconductor Devices“, Wiley 1997, E. Ajith Amarasekera, Farid N. Najm
„Reliability and Failure of Electronic Materials and Devices“, Academic Press 2015, Milton Ohring
„Applied Reliability“, CRC Press 2012, Paul A. Tobias, David C. Trindade
„Extreme Environment Electronics“, CRC Press 2013, John D. Cressler, H. Alan Mantooth
“JESD94B-Application Specific Qualification using Knowledge Based Test Methodology”
https://www.jedec.org/standards-documents/docs/jesd-94a
“JESD47G Stress-Test-Driven Qualification of Integrated Circuits”
https://designers-guide.org/forum/Attachments/JESD47G.pdf
“MIL-STD-883”
http://scipp.ucsc.edu/groups/fermi/electronics/mil-std-883.pdf
“UTE_FIDES_Guide_2009 Reliability Methodology for Electronics Systems”
https://www.fides-reliability.org/
“AEC_Q004- Automotive Zero Defects Framework”
http://www.aecouncil.com/Documents/AEC_Q004_Rev-.pdf

Syllabus – Basics of Microelectronics

Name of the course:
Basics of Microelectronics

Course topic:
Most important topics of microelectronics, CMOS semiconductor devices, fabrication, scaling issues and modern technologies.

Duration:
40 hours

Participants of the course:
Bachelor-level students

Educational background:
High school diploma, usually at the end of Bachelor's degree

Course responsible:
Alicja Michalowska-Forsyth

Course lecturers:
Bernd Deutschmann
Alicja Michalowska-Forsyth

Educational prerequisites
Basics of Electrical Engineering, Basics of Electronics, Basics of Physics and Mathematics

Learning outcomes

- *Knowledge*
  Semiconductor physics – basic phenomena, active devices: diode, MOSFET, bipolar, semiconductor technologies, scaling issues in fabrication, modern devices and technologies overcoming these scaling challenges, most important players in the development of the microelectronic branch;
- *Skills*
  - *Identify and understand issues in scaled CMOS processes,*
  - *Identify parasitic devices and safe biasing of the semiconductor devices*
  - *Identify operating mode and operating region of MOSFET transistor knowing its terminal voltages and device parameters, Recognize limitations of used technology and reasons behind;*
- *Competence*
  Device selection for a specific application – temperature, operating voltages, parasitics tolerance.

Abstract
This course provides a brief introduction to microelectronics. It covers a large selection of subjects, from semiconductor physics, through CMOS technologies, fabrication of integrated circuits, scaling issues as well as history of microelectronics. The most emphasised topics are the operation and biasing of the MOSFET transistor, parasitic devices and scaling trends. With regard to semiconductor physics and devices, complex phenomena are explained in an intuitive way.

Content

- *History of microelectronics*
- *Semiconductor conductivity*
    - *From single atom model to energy bands in crystals*
    - *Bandgap energies of different materials*
    - *Fermi energy*
    - *Charge carriers, concentration, generation and recombination in semiconductors*
    - *Continuity equation*
    - *Charge transport: drift and diffusion*
    - *Conductivity*
    - *Minority carrier lifetime*
    - *Drift-diffusion equation*
- *Doping and crystals*
    - *Importance of controlling the conductivity in active semiconductor devices*
    - *Donors and acceptors in energy bands model*
    - *What determines minimum and maximum doping concentration*
    - *Lattice vs crystal*
    - *Primitive vectors and Bravais Lattice*
    - *Unit cell of silicon crystal*
    - *Planes in crystals*
    - *Inverse room in crystallography – reciprocal lattice*
    - *Direct and indirect bandgap semiconductors*
- *Diode and bipolar transistor*
    - *Charge carrier concentration*
    - *PN junction and space charge region*
    - *Energy bands of PN junction in equilibrium and under forward and reverse bias*
    - *Built-in potential and what it depends on*
    - *PN junction current, Shockley equation and IV characteristics*
    - *PN junction equivalent circuit: capacitances and resistances*
    - *Metal contacts: blocking and ohmic*
    - *Bipolar transistor in active bias*
    - *Output characteristics, saturation region*
    - *Early effect*
    - *Bipolar transistor parameters vs properties (doping level at emitter/base/collector vs current gain, Early effect, leakage current)*
    - *Latchup in CMOS circuits*
- *MOSFET transistor*
    - *CMOS technology overview, MOSFET cross-section*
    - *Energy bands in MOS structure in flatband, accumulation, depletion, inversion*
    - *Threshold voltage in MOS structure*
    - *MOSFET structure with applied drain-source voltage*
    - *Linear and saturation operating regions, with intuitive examples*
    - *Current equation and pinchoff voltage*
    - *Example case studies on operating region and mode*
    - *Depletion and enhancement MOSFET*
    - *Body effect*
    - *P-channel and N-channel transistors*
    - *Output and transfer characteristics*
    - *Transconductance*
    - *On-resistance*
    - *Subthreshold operation*
    - *MOS capacitance*

    - *Transistor switching*
- *Wafer fabrication and defects*
    - *Why silicon, why crystal, why pure*
    - *IC fabrication overview (wafer preparation, wafer processing, wafer sort, assembly and packaging, burn-in, final test)*
    - *Purification of silicon and ingot growth*
    - *Crystallographic orientation of wafer*
    - *Wafer quality*
    - *Cleanroom*
- *Silicon wafer processing*
    - *Key microfabrication processes*
    - *Lithography basics*
    - *Lithography and scaling down*
    - *Etching*
    - *Doping: diffusion and ion implantation*
    - *Chemical vapour deposition and which layers are formed*
    - *Self-aligned gate and metal gate in the past and today*
    - *Chemical-mechanical polishing*
    - *Sputtering*
    - *Epitaxial growth*
    - *Backend*
    - *Fabrication issues (thermal budget, economic factors)*
- *Scaling and advanced IC technologies*
    - *Tripple well CMOS process*
    - *Shallow trench isolation*
    - *Scaling and key modifications in integrated circuits technologies over the past years*
    - *Issues in scaled ICs and solutions*
    - *FinFET*
    - *Silicon on Insulator and Fully Depleted SOI*
    - *3D integration*

Teaching methods
Video-webinar allowing students learning in their own pace. Literature for self-studies of selected subjects of device physics and microfabrication.

Assessment
Evaluation in the form of multiple answer test.

Recommended reading
"Physics of Semiconductor Devices" S.M. Sze, K. Kwok 2007 (Wiley and Sons) IFE
"Modern Semiconductor Devices for Integrated Circuits" Chenming Hu 2010 (Pearson Education) (available online from Berkeley)
http://www.eecs.berkeley.edu/~hu/Book-Chapters-and-Lecture-Slides-download.html
"Introduction to Microfabrication" S. Franssila 2010 (Wiley) IFE
"The Science and Engineering of Microelectronic Fabrication", S.A. Campbell 2001 (Oxford University Press) IFE

Syllabus – Training description
"Electromagnetic Compatibility Essentials"

Name of the course:
Electromagnetic Compatibility Essentials
Course topic:
The seamless use of electronics appears natural to us. In reality, however, a lot of know-how is required to design products in a way that they work in their electromagnetic environment.
Duration:
25 learning hours
Participants of the course:
MSc students in electronics and microelectronics; Engineers in electronics willing to upskill in EMC
Educational background:
Electronics and Electronics Design or equivalent Bachelor level courses
Course responsible:
Ko Odreitz
Course lecturers:
Ko Odreitz (course author)
David Pommerenke (course reviewer)
Bernd Deutschmann (project leader)

Educational prerequisites
Electronics and Electronics Design or equivalent Bachelor level courses

Learning outcomes
Upon successful completion of this course students should be able to:

- *Knowledge*
  - *Name everyday situations where EMC is relevant.*
  - *Formulate the definition of EMC*
  - *List the most important aspects of EMC.*
  - *Summarize the electromagnetic spectrum from 3 kHz up to 3 GHz.*
  - *Explain how electromagnetic waves propagate.*
  - *Recognize some advantages of a small loop area.*
  - *Forecast the spectrum of a rectangular, triangular and trapezoidal signal.*
  - *recognize that the current path plays a crucial role in EMC issues.*
  - *distinguish between differential and common-mode.*
  - *explain how a common-mode choke works.*
  - *illustrate the origin of electromagnetic radiation at dipole level.*
  - *choose correct settings to set up a VNA.*
  - *plan what special equipment is needed for basic emissions and immunity testing.*
  - *express the international relevance of EMC regulations.*
  - *illustrate the legally relevant steps until a product may be sold.*
  - *identify relevant EMC markings on products.*
  - *summarize the concept of a semi-anechoic chamber.*
  - *interpret a test report from an accredited test house.*
  - *describe the measurement of radiated emissions at system and chip level.*
  - *explain the root causes of ESD.*
- *Skills*
  - *Calculate the amplitude of a wave in dBµV.*
  - *Calculate the reflection coefficient of a load resistance.*
  - *Interpret the behavior of a component based on its Smith chart.*
  - *Calculate the spectrum of periodic and non-periodic functions.*

- *derive the classical filter design including transfer function and Bode plot.*
- *apply a best practice EMI filter for the supply lines.*
- *design a PCB EMC-aware.*
- *implement traces for guiding RF signals.*
- *select the right decoupling capacitors.*
- *estimate the values of parasitic elements.*
- *calculate the resonant frequency of real passive components.*
- *calculate the S-parameters of simple resistor networks.*
- *execute measurements for characterizing passive components.*
- *implement basic measures in order to protect against ESD.*

- *Competence*
  - *Identify how an interference signal could couple into a victim.*
  - *Implement a proper microstrip line for efficient transmission.*
  - *Discuss the advantages of the frequency domain.*
  - *Compare simple measures in order to mitigate coupling.*
  - *choose a suitable filter for a given noise and load impedance.*
  - *draft a basic shielding concept.*
  - *decide which shielding material to use.*
  - *sketch a resistor with low parasitic inductance.*
  - *compare spectral analyzer, EMI receiver and VNA.*
  - *setup simple lab experiments.*
  - *perform simple ESD tests on your product.*

Abstract

Why can't I connect to WiFi? Why does my Bluetooth stop working when I use USB 3.0? Oh! I just sparked into my computer after sitting down; is it damaged now? All of these issues have to do with electromagnetic compatibility (EMC). International EMC experts David Pommerenke and Bernd Deutschmann break down situations that seem highly complex in order to highlight the causes of interference.

This course is designed to gain essential know-how in today's world of very high frequencies. For instance, smartphone CPUs already work with clock frequencies above 3 GHz. But did you know that such fast switching disturbs other devices nearby? Such disturbances are either simply annoying or can become a real problem. As a consequence, international regulations exist which demand for emission and immunity tests before selling an electronic device.

The topic of EMC must be considered in all aspects of circuit design in order to reduce the number of prototypes. We would like you to gain an intuition for EMC with the help of lab examples. We emphasize basic physical principles and avoid highly complex mathematical derivations instead.

Content

1. Introduction
1.1 What is EMC?
1.2 Electromagnetic Wave
1.3 50 Ohm System
1.4 Time and Frequency Domain
1.5 Coupling Mechanisms
2. EMC Design
2.1 Differential- vs. Common-mode
2.2 Filtering
2.3 Shielding
2.4 PCB Design
2.5 Passive Components
3. EMC Testing
3.1 S-parameters

3.2 Test Equipment
3.3 International Regulations
3.4 Radiated Emissions
3.5 Electrostatic Discharge (ESD)

Teaching methods
The theory is taught entirely in the form of a Massive Open Online Course (MOOC) on edX.org. The MOOC includes interactive learning videos, recaps and knowledge checks.

Assessment
- *Free version:*
  - *Voluntary self-assessment*
- *Paid version:*
  - *80% in order to get the certificate (24 out of 30 points)*
  - *Short exam after each chapter (3 in total)*
  - *Infinite number of attempts; no time limits*

Recommended reading
- *Henry W. Ott - Electromagnetic Compatibility Engineering*
- *Clayton R. Paul - Introduction to Electromagnetic Compatibility*
- *Eric Bogatin - Signal and Power Integrity : Simplified*
- *Tim Williams - EMC for Product Designers*
- *Patrick G. André and Kenneth Wyatt - EMI Troubleshooting Cookbook for Product Designers*
- *Joachim Franz - EMV : Störungssicherer Aufbau elektronischer Schaltungen (German only)*

Syllabus – Training description – Electromagnetic Compatibility of Integrated Circuits

Name of the course:
Electromagnetic Compatibility of Integrated Circuits

Course topic:
Theoretical and practical applications to improve the electromagnetic compatibility of ICs (i.e. reduce the electromagnetic emission and improve the immunity against electromagnetic interferences).

Duration:
75h (learning hours), 3 ECTS

Participants of the course:
Students, lateral entrants

Educational background:
High school diploma, usually during a Master's degree

Course responsible:
Bernd Deutschmann

Course lectures:
Bernd Deutschmann
Ko Odreitz
Nikolaus Juch

Educational prerequisites
Basic knowledge of electronic circuit technology (components with characteristic properties, analog and digital). Ability to understand basic mathematical operations (matrix calculation). Basic understanding of common behavioural representations (large-signal, frequency-domain, time-domain behaviour). Basic calculation steps for dimensioning electronic circuits.

Learning outcomes
Knowledge:

- *EMC measurement methods and international standards for the EMC characterization of ICs*
- *EMC aware IC design*
- *Generation of emission due to the switching activity of digital ICs*
- *Awareness of susceptibility issues of IC*

Skills:

- *Explain causes for the generation of the electromagnetic emission generated by ICs*
- *Describe the root causes of typical EMC problems and show possible solutions to the problem*
- *Outline galvanic, capacitive, inductive and radiated coupling with examples*
- *Explain how these coupling mechanisms occur and how interference from these couplings can be reduced*
- *Understand how the most important IC-level measurement techniques work and how they can be used to characterize electromagnetic emission and immunity of ICs*

Competence:

- *Interpret an emission and immunity plot and extract information out of that*
- *Perform EMC measurements of IC to characterize their emission and immunity behaviour*

- *Apply important design guidelines during the IC design to ensure electromagnetic compatibility of ICs*
- *Solve typical susceptibility and emission problems with ICs*

Abstract
The electromagnetic compatibility (EMC) of electronic systems and in particular of integrated circuits (ICs) has become increasingly important in recent years. From the formulation of the product idea to series production, the integration of EMC measures at IC and system level is indispensable today. An IC designer does not only have the task of developing an IC according to economic and functional aspects, but the device must also comply with the EMC regulations and standards i.e. does not produce too much electromagnetic emission and is not susceptible to interferences. It is often a long way until an IC or, subsequently, an electronic system has successfully passed all EMC tests. With the help of the necessary basic knowledge in the field of EMC and some important design guidelines an electromagnetically compatible design of an IC can often be ensured very quickly.

The aim of this lecture is to provide this basic knowledge and the necessary IC design guidelines as well as an overview of the most important EMC characterization methods for ICs.

Content

- ***Introduction to electromagnetic compatibility (EMC) of integrated circuits***
- ***Why is the electromagnetic compatibility of IC so important?***
- ***Coupling of interference signals (capacitive, inductive, galvanic coupling)***
- ***Decoupling of ICs (use of the right decoupling capacitors)***
- ***Ground bounce and signal integrity problems***
- ***EMC aware IC design***
- ***Parasitic properties of components (package parasitics)***
- ***Electromagnetic emissions of digital ICs***
- ***Susceptibility of analog ICs***
- ***Examples from the practice of IC designs to reduce unwanted emissions of an IC (on-chip decoupling, slew rate controlled output drivers...)***
- ***Characterization of electromagnetic emission and immunity of ICs (IEC 61967, IEC 62132 standards)***

Teaching methods
In general, the course should be hosted on a Moodle LMS platform.
The theoretical part is presented by means of (recorded or live) presentations, scripts, online interactive lessons/quizzes and video tutorials through a Moodle LMS platform.
The practical part provides exercises that the participants should work on (e.g. calculate the ground bounce noise caused by the switching activity of digital ICs).For the lectures online support by a forum is provided.

Assessment

75% Theoretical test, with multiple choice and other similar question types. For mathematical methods maybe also STACK question type.
25% practical examples to be worked out

Recommended reading

- *Lecture notes that will be provided (~145 pages)*
- ***Ben Dhia**, Sonia, **Ramdani**, Mohamed, **Sicard**, Etienne (Eds.), "Electromagnetic Compatibility of Integrated Circuits", Springer, ISBN 978-0-387-26601-5*
- ***Redouté**, Jean-Michel, **Steyaert**, Michiel, "EMC of Analog Integrated Circuits", Springer, ISBN 978-90-481-3230-0*

Syllabus – Training description – Template

Instruction for filling the template:
Please find bellow the template for Training descriptions needed for METIS project. Comments in grey are made for guidance and for help to understand what is each section about. Please also refer to separate document - "Example of Syllabus" for more information.

Name of the course:
Introduction to nanoscale CMOS technology: Process flow and process modules
Course topic:
This course covers the general CMOS process flow, how a circuit is manufactured starting from a clean wafer up to a final circuit ready for testing, dicing and packaging. Challenges of the general process flow and the different process modules will be discussed.
Duration:
17 hours
Participants of the course:
Managers, but also process and tool engineers who need to learn about trends and about process steps outside their own field of expertise will benefit from this course. This course also addresses process equipment sales staff, who need to understand the world their customers operate in. It targets people who need to have a complete overview in CMOS process modules, and it will allow unit step experts to position their expertise in the global process flow.
Course responsible:
Imec vzw, imec.academy
Course lecturers:
Jan Van Houdt, Andreas Frommhold, Pierre Eyben, Daisy Zhou, Andriy Hikavyy, Tom Schram, Steven Demuynck, Basoene Briggs, Victor Vega

Content
Lecture 1: CMOS Introduction, chip production and further scaling
The lecture starts with a short history of electronics to explain the rationale of the integrated circuit as basic technology in modern systems. Then, the basic concept of planar technology is explained (patterning) followed by an overview of the different unit process steps and their purpose. This part will be introductory to the more detailed presentations afterwards. Walk-through: the general CMOS process flow, how a circuit is manufactured starting from a clean wafer up to a final circuit ready for test, based upon generic technology, with copper interconnect. Finally, we'll discuss an outlook of where the semiconductor industry is going based on extrapolating from current scaling trends, leading to the optimized case of the finfet.

Lecture 2: Advanced lithography
Basics of image formation in projection exposure systems; i-line and deep-UV (248nm, 193nm) photoresist technology; photoresist processing issues; reflection effects and reflection reduction strategies; principles and trends of optical enhancement techniques (phase shift masks, off-axis illumination, optical proximity correction); trends in optical (including immersion lithography) and post-optical lithography; EUV and double patterning.

Lecture 3: Ultra-shallow junctions
The fundamentals of the p-n junctions will be briefly discussed going back to solid state physics. Electrical characteristics of MOSFETs will be presented, including typical limitations (SCE, parasitic resistance). This will be followed by a discussion of the technological aspects of junction formation. Traditionally, junctions are formed by ion implantation of dopants followed by rapid thermal annealing to activate the dopants. However, standard ion implantation causes doping damages to FinFETs and Gate-All-Around

FETs. Advanced approaches are needed: high temperature ion implantation, solid source doping, in-situ doping.

Lecture 4: Gate patterning
In this lecture, the trends in gate patterning will be discussed as a logical consequence driven by the down-scale of the gate CD and the requirements for its line width control. This will cover several patterning aspects, such as lithography, etch, and their relations to the gate stack. Lithography requires a continuously better ARC-strategy, more complex masks, illumination conditions, and resist processes to achieve optimum CD-control. Dry etch requires introduction of hard masks, optimization towards profile control, and the development of trim techniques. In this presentation, the requirements for future device concepts, e.g. FinFETs, will also be discussed.

Lecture 5: Epitaxial growth
This lecture will cover the full epitaxial growth process with a main focus on Si and SiGe. After a short introduction to epitaxial growth techniques, we will give a general introduction to CVD (Chemical Vapor Deposition) and CVD growth kinetics. Next, we will review specific epitaxial growth aspects such as pre-epi silicon substrate cleaning, epi nucleation, epitaxial defects, selective epitaxial growth, epi doping, epitaxial growth of SiGe.

Lecture 6: Gate stack
Content to be covered: from poly, over MIPS to RMG; high-k & workfunction metal requirements; RMG processing aspects.

Lecture 7: FIN process
This lecture will cover the basics of the FinFET processes / integration. This includes a self-aligned double patterning (SADP) for the fin formation, an advanced gap-filling, planarization technique, fin recesses, well formation, etc.; covering the integration challenges of 3D FinFET era..

Lecture 8: MOL: ILD0 and contact
The process steps involved in contact metallization and metal CMP are discussed. Different approaches for barrier and W deposition are compared and evaluated with respect to filling and electrical performance of advanced contacts. Insight will be given into optimizing these processes for integration with the underlying junctions & silicides and subsequent Cu metallization.

Lecture 9: BEOL
Review the patterning and metallization techniques used in recent technology nodes.

Lecture 10: Memory technology
In this part of the course, the main principles of the currently used memory concepts and technologies are explained. For volatile memories, static and dynamic RAMs are introduced, while for the nonvolatile ones, the focus lies on Flash memory, both the 2D and the 3D variant.

Teaching methods
Onsite/online presentations

Assessment
No assessment

Syllabus – Training description – Template

Instruction for filling the template:
Please find bellow the template for Training descriptions needed for METIS project. Comments in grey are made for guidance and for help to understand what is each section about. Please also refer to separate document - "Example of Syllabus" for more information.

Name of the course:
Hardware-efficient machine learning: Designing across the algorithm-architecture-circuit stack
Course topic:
One sentence overview
Duration:
12h
Participants of the course:
Engineers, IC designers and engineering managers who are interested in the hardware implementation of machine learning and deep learning systems should follow this course. Furthermore, this course is of great interest to people who work on the software implementation of machine learning and artificial intelligence algorithms, and want to understand the implications of algorithmic choices within a complete embedded system.
Educational background:
Please insert information on what is usual level of education these profiles must have in order to be able to understand the training (high school, bachelor or master diploma…)
Course responsible:
Please insert the name of the company and the department in charge
Course lecturers:
Prof. Marian Verhelst, KU Leuven, imec

Educational prerequisites
Some knowledge in CMOS technology, analog and digital IC design and signal processing is required to follow this course.

Learning outcomes
*Please insert description on what students should be able to **DO** after completion of this course (please see separate document "Example of Syllabus" for more information on content and structure)*
Learning outcomes are defined as knowledge, skills and competencies participants will have after completion of the course:

- ***Knowledge** means the outcome of the assimilation of information through learning. Knowledge is the body of facts, principles, theories and practices that is related to a field of work or study;*
- ***Skills** means the ability to apply knowledge and use know-how to complete tasks and solve problems;*
- ***Competence** means the proven ability to use knowledge, skills and personal, social and/or methodological abilities, in work or study situations and in professional and personal development.*

In this 2-day program the participant will learn about:

- *Deep learning concepts and algorithm-driven efficiency enhancement techniques*
- *Digital processor and datapath architectures for neural network execution*
- *Exploiting mixed-signal processing for machine learning*
- *Exploiting in-memory computations and emerging memory devices for machine learning*
- *Cross-layer dataflow and scheduling optimizations across algorithms - architecture - circuits*

Abstract
Machine Learning is rapidly gaining importance. Due to the advance in computational power more and more applications for machine learning and deep learning systems are becoming reality and are increasingly deployed into embedded, resource-constrained devices. This puts stringent requirements on electronic and integrated system design. In this course we will focus on the hardware-efficient implementation of machine learning, more specifically deep neural networks. It will become clear that a truly efficient design must be, optimized across the complete algorithmic / architecture / circuit level design space. The course will go in depth on all these aspects.

Content

Day 1: Deep learning algorithms and processor basics
General overview on the history of machine learning, neural networks and deep learning
- *From neural networks to deep neural networks*
- *From training to inference*
- *Applications*

Trends in neural network topologies
- *Basic concepts of deep neural networks*
- *Classes and evolution of deep neural networks*
- *Algorithmic efficiency enhancement techniques*

Processor architectures for deep neural networks
- *Basic processor components*
- *Efficiency enhancement techniques exploiting sparsity*
- *Efficiency enhancement techniques exploiting reduced and variable precision processing*
- *Illustrations with various recent chips from the international state-of-the-art*

.

Day2: Optimizing across the complete algorithms – architecture – circuits stack
Benchmarking the ML systems

The impact of data flow on system efficiency
- *Parameters impacting processor efficiency*
- *Dataflow impacting data reuse*
- *Dataflow-driven processing architectures and memory achitectures*

Algorithm-hardware co-optimization for energy efficient inference
- *Cross-layer optimization strategy*
- *Benchmarking ML systems: recap*

Discussion and wrap up, trends and outlook

Teaching methods
Presentations

Assessment
No assessment

Recommended reading
Please insert recommendation on literature on the subject of the training (if applicable)

Syllabus – Training description – Template

Instruction for filling the template:
Please find bellow the template for Training descriptions needed for METIS project. Comments in grey are made for guidance and for help to understand what is each section about. Please also refer to separate document - "Example of Syllabus" for more information.

Name of the course:
VHDL Language and Design flow
Course topic:
One sentence overview
Duration:
30h
Participants of the course:
This course focuses on (junior) system design engineers targeting FPGA and ASIC.
Educational background:
Please insert information on what is usual level of education these profiles must have in order to be able to understand the training (high school, bachelor or master diploma…)
Course responsible:
Geert Vanwijnsberghe, imec
Course lecturers:
Umut Eksi (imec), Jan-Willem Weijers (imec), Steven Dupont (imec), Jorgo Tsouhlarakis (imec) and Fradaric Joseph (imec).

Educational prerequisites
Please insert information on what is the requirement for person to attend this training (in terms of previous knowledge/experience needed to understand it)

Learning outcomes
During the course the participants will:
- *be introduced to VHDL and the test-bench concepts.*
- *learn how to efficiently simulate VHDL models.*
- *be introduced to the VHDL synthesizable sub-set.*
- *learn that 'what you write is what you get', i.e. that the synthesized netlist is dependent on how the code is written.*
- *learn how to tackle issues like: sharing, asynchronous logic, initialization.*
- *get some experience with synthesis of the VHDL code into a gate level netlist using clock gating techniques to reduce the power.*
- *learn how to insert basic test logic and generate test patterns.*
- *be introduced to performing power analysis, generating testpatterns and running logic equivalence checks.*

Abstract
The increasing complexity of digital circuits brings about the need fora design methodology that allows a short design cycle, while maintaining architectural flexibility, re-use of IP blocks and easy documentation.VHDL is a standard worldwide language for the design, documentation and description of electronic systems on the component, board or system level. It supports design verification through simulation and design creation through synthesis. Simulation and synthesis are however not the only tools used in the design flow of an ASIC. Digital frontend designers nowadays also have need of knowledge about a whole set of tools such as static timing analysis, test insertion, power analysis and testpattern generation. This 5-day course 'VHDL language and design flow' is centered on VHDL syntax (through example) while emphasizing good code style and the link to hardware.

Content

Day 1: Introduction

- *Complete flow overview: from specification to tested dies*
- *VHDL background, versions & basics concepts*
- *Entities, architectures , process, hierarchy*
- *Labs*
- *Tools used: Modelsim for simulation*

Day 2: VHDL for synthesis

- *Packages, libraries, types, signals, variables*
- *Logic and memory inference*
- *High level optimizations (resource sharing etc..)*
- *Labs*
- *Tools used: Synopsys Design Compiler*

Day 3: VHDL testbenches (VHDL 2008)

- *Functions, procedures, records, file IO*
- *Self checking / self stopping*
- *Coverage*
- *Labs*
- *Tools used: Modelsim*

Day 4: Introduction to logic synthesis

- *Logic synthesis design flow basics with DC compiler of Synopsys*
- *Timing constraints*
- *Optimisation control*
- *Datapath synthesis*
- *Clock gate insertion*
- *Scan insertion*
- *Labs*
- *Tools used: Synopsys Design Compiler*

Day 5: Final steps before transferring the netlist to the layout team

- *ATPG*
- *Power analysis*
- *Formal verification*
- *Labs*
- *Tools used: Synopsys TetraMax for ATPG, Synopsys Primetime for Power analysis, Cadence Formality for Formal verification*

Teaching methods

This is a lecture-based and hands-on course.

Assessment

No assessment

Recommended reading

Please insert recommendation on literature on the subject of the training (if applicable)

Syllabus – Training description – Template

Instruction for filling the template:
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Name of the course:
Advanced cleaning and surface preparation in advanced CMOS technologies
Course topic:
Imec is one of the world's leading research institutes doing research in the field of wafer cleaning, surface preparation, contamination control, and related metrology for advanced processing nodes (+1,+2,+3). This course will bring you up-to-date, and will provide valuable background for those working in related fields.
Duration:
19 hours
Participants of the course:
The width of the course topics covered and the large number of lecturers covering the relevant topics ensures that this course addresses both experts and people with a general interest in the topic, including cleanroom and equipment staff.
We strongly recommend this course to chip manufacturers, tool manufacturers, tool component manufacturers, and chemical suppliers that use cleaning in their processing or equipment. The course gives basic knowledge on issues like contamination and metrology, and on the physics and chemistry of particle removal. It also gives an overview of cleaning and surface preparation. Part of the course is dedicated to cleaning equipment and the best cleaning practices.
Educational background:
Please insert information on what is usual level of education these profiles must have in order to be able to understand the training (high school, bachelor or master diploma…)
Course responsible:
Imec vzw, imec.academy
Course lecturers:
Paul Mertens, Iino Hideaki, Thierry Conard, Jens Rip, Maarten Liebens, Guy Vereecke, Kurt Wostyn, Frank Holsteyns, Silvia Armini, Karolien Jans, Annemies Delabie, Toan Le Quoc, Els Kesters, Harold Philipsen, Dennis van Dorp, Prof. J. De Coninck (Uni. Mons).

Educational prerequisites
Please insert information on what is the requirement for person to attend this training (in terms of previous knowledge/experience needed to understand it)

Learning outcomes
*Please insert description on what students should be able to **DO** after completion of this course (please see separate document "Example of Syllabus" for more information on content and structure)*
Learning outcomes are defined as knowledge, skills and competencies participants will have after completion of the course:

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- ***Competence** means the proven ability to use knowledge, skills and personal, social and/or methodological abilities, in work or study situations and in professional and personal development.*

Abstract

Please insert short description on what is the aim of the training, why it is important, what is it about…? (please see separate document "Example of Syllabus" for more information on content and structure)

Content

Day 1

- *Welcome & agenda review - Paul Mertens*
- *Semiconductor surface properties (chemistry and passivation) - Paul Mertens*
- *Fouling and impact of contamination: Motivation for cleaning - Paul Mertens*
- *General introduction and basic aspects of: contamination - surface interactions and cleaning - Paul Mertens*
- *Common cleaning mixtures: SPM, SOM, O3-water, SC1, SC2 - Paul Mertens*
- *Measurement of trace contamination in fluids (liquids): ICP-MS, AAS, particle measurements, TOC,... - Iino Hideaki*
- *XPS, Tofsims, for surface contamination and surface chemical groups - Thierry Conard*
- *Contamination and metrology: TXRF, VPD, ICP-MS, AAS, TD GC-MS - Jens Rip*
- *Defect metrology, detection, sizing,... - Maarten Liebens*

Day 2

- *Removal of metallic contamination - Paul Mertens*
- *Particle removal - TBD*
- *Rinsing and drying: defects, collapse - Paul Mertens*
- *Challenges in wet processing of high aspect ratio nanostructures - Guy Vereecke*
- *Pre-epi cleaning - Kurt WostynEquipment for cleaning and liquid-based etching - Frank Holsteyns*
- *SAM - Silvia Armini*
- *Surface functionalisation (for life sciences) - Karolien Jans*
- *pre-ALD and selective ALD (cleaning and) surface prep - Annelies Delabie*

Day 3

- *BEOl post-etch residue removal - Toan Le Quoc, Els Kesters*
- *Basic aspects of HF chemistry (liquid, gas, binary and ternary systems) - Paul Mertens*
- *Fluid chemical etching of dielectric layers: SiO2, si3N4: HF, Siconi, H3PO4 - TBD*
- *Etching of Si, acid etching of Si, alkaline etching of Si - Paul Mertens and Harold PhilipsenSemiconductor etching: Ge, III-V - Dennis Van Dorp*
- *Contact angle wettability and adhesion - Prof. J. De Coninck*

Teaching methods

Presentations

Assessment

No assessment

Recommended reading

Please insert recommendation on literature on the subject of the training (if applicable)

Syllabus – Training description – Template

Instruction for filling the template:
Please find bellow the template for Training descriptions needed for METIS project. Comments in grey are made for guidance and for help to understand what is each section about. Please also refer to separate document - "Example of Syllabus" for more information.

Name of the course:
Frontier and trends of IC industry technology, overview of nanoscale technology and recent and emerging applications leveraging on nanoelectronics
Course topic:
One sentence overview
Duration:
23.5 hours
Participants of the course:
Please insert information for which profiles this training is designed and delivered (for example, Engineers, Technicians etc…)
Educational background:
Please insert information on what is usual level of education these profiles must have in order to be able to understand the training (high school, bachelor or master diploma…)
Course responsible:
Imec academy, imec vzw
Course lecturers:
Prof. dr. Marc Heyns

Educational prerequisites
Please insert information on what is the requirement for person to attend this training (in terms of previous knowledge/experience needed to understand it)

Learning outcomes
*Please insert description on what students should be able to **DO** after completion of this course (please see separate document "Example of Syllabus" for more information on content and structure)*
Learning outcomes are defined as knowledge, skills and competencies participants will have after completion of the course:

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- ***Competence** means the proven ability to use knowledge, skills and personal, social and/or methodological abilities, in work or study situations and in professional and personal development.*

Abstract
Please insert short description on what is the aim of the training, why it is important, what is it about…? (please see separate document "Example of Syllabus" for more information on content and structure)

Content

- Introduction
- Patterning
- Deposition and cleaning
- FEOL
- BEOL

- Beyond CMOS

Teaching methods
Presentations

Assessment
No assessmernt

Recommended reading
Please insert recommendation on literature on the subject of the training (if applicable)

Syllabus – Training description – Template

Instruction for filling the template:
Please find bellow the template for Training descriptions needed for METIS project. Comments in grey are made for guidance and for help to understand what is each section about. Please also refer to separate document - "Example of Syllabus" for more information.

Name of the course:
EUROPRACTICE PIC Training
Course topic:
This training course aims to give a jump-start on PIC technology from a fabless manufacturing perspective by providing:

1) *Technology overview - through one day of seminar sessions conducted by experts from the PIC industry and academia, and*
2) *Design overview - through two days of hands-on training on Synopsys PDA tools.*

Duration:
18h
Participants of the course:
Please insert information for which profiles this training is designed and delivered (for example, Engineers, Technicians etc…)
Educational background:
Please insert information on what is usual level of education these profiles must have in order to be able to understand the training (high school, bachelor or master diploma…)
Course responsible:
Adil Masood, imec
Course lecturers:
Experts from imec, EUROPRACTICE, Tyndall National Institute, JePPiX, Synopsys, Luceda

Educational prerequisites
Please insert information on what is the requirement for person to attend this training (in terms of previous knowledge/experience needed to understand it)

Learning outcomes
It is intended that the training will help the trainees to gain a background on PIC technology, and its academic and industrial eco-system. After the hands-on sessions, the trainees should be able to understand the PIC design flow and be able to perform basic simulations, designing and generations of mask layouts.

*Please insert description on what students should be able to **DO** after completion of this course (please see separate document "Example of Syllabus" for more information on content and structure)*
Learning outcomes are defined as knowledge, skills and competencies participants will have after completion of the course:

- ***Knowledge** means the outcome of the assimilation of information through learning. Knowledge is the body of facts, principles, theories and practices that is related to a field of work or study;*
- ***Skills** means the ability to apply knowledge and use know-how to complete tasks and solve problems;*
- ***Competence** means the proven ability to use knowledge, skills and personal, social and/or methodological abilities, in work or study situations and in professional and personal development.*

Abstract

The structure and content of this training encompasses various aspects of PIC technology – physics of basic building blocks, systems and sub-systems, applications, simulations, designing, mask layout, fabrication and packaging platforms and their access routes.

Content

Tentative program
Day 1 – Technology Overview (Seminars)

- *Welcome note (10 mins)*
- *Photonic Integrated Circuit Fundamentals Tutorial – imec (120 minutes)*
- *EUROPRACTICE & Photonics MPW Access – EUROPRACTICE (30 minutes)*
- *Imec Silicon Photonics Platform – imec (30 minutes)*
- *Imec Silicon Nitride Photonics Platform – imec (30 minutes)*
- *Photonics Packaging Solutions – Tyndall National Institute (45 minutes)*
- *III-V Photonic Integrated Circuits – JePPiX (45 minutes)*
- *Photonic Integrated Circuit – Design Concepts 1 – Synopsys (30 minutes)*
- *Photonic Integrated Circuit – Design Concepts 2 – Luceda (30 minutes)*

Day 2 & Day 3 – Design Overview (Hands-on)

- *PIC design training on Synopsys & Luceda software (full day)*
- *Imec CR tour (30 minutes)*

Teaching methods

Seminars and hands-on courses

Assessment

No assessment

Recommended reading

Please insert recommendation on literature on the subject of the training (if applicable)

Syllabus – cleanroom technology

Name of the course:
Cleanroom technology / cleanroom behavior

Course topic:
Employees are the decisive factor for the hygienic status of cleanrooms - and the most common cause of errors for contamination.
The high quality requirements in clean rooms represent a great challenge. Only those who have appropriate knowledge of how to behave in clean room zones can meet the requirements
.

Duration:
24 hours

Participants of the course:
All levels

Educational background:
-

Course responsible:
SBH Südost GmbH, dresden chip academy

Course lecturers:
Different teacher of the SBH, dresden chip academy

Educational prerequisites
-

Learning outcomes
Knowledge
In our training we convey the basic requirements according to ISO standards. The focus is on correct behavior patterns
.

Skills,
Correct behavior in the clean room

- ***Competence***
  Basic knowledge of how a clean room works and what standards there are.

Abstract
Clean room technology, clean room behavior

Content
- Clean room technology, clean room behavior
- Comply with guidelines on cleanroom clothing and behavior in the cleanroom

- Measurement of particles and determination of clean room classes according to various standards
- Air flow principles in the clean room

Teaching methods
Video-webinar allowing students learning in their own place. Supporting material for reading and self-study is made available on our learning management portal. The lecturer conducts practical experiments on systems via video conference.

Assessment
Evaluation in the form of multiple answer test.

Recommended reading
-

Syllabus – electronic

Name of the course:
Electronic, basics of manufacturing

Course topic:
getting to know Electronic basics of manufacturing

Duration:
24 hours

Participants of the course:
Skilled workers, microtechnologist, Mechatronics engineer

Educational background:
Secondary School or highschool

Course responsible:
SBH Südost GmbH, dresden chip academy

Course lecturers:
Different teacher of the SBH, dresden chip academy

Educational prerequisites
Basics of electrical engineering

Learning outcomes

- ***Knowledge***
  Functional analysis of selected semiconductor materials

- ***Skills***
  Measurement method

- ***Competence***
  Arten und

Abstract
Knowledge of electronic components is imparted so that one is able to identify and correct errors in electronic devices.
And to get a basic understanding

Content

- Types and functions of transistors
- Gate source, drain circuit
- Analog, digital technology
- Digital technology signals
- Circuits
- Structure and functional explanation of circuits
- Laws of Switching Algebra

Teaching methods
Video-webinar allowing students learning in their own place. Supporting material for reading and self-study is made available on our learning management portal. The lecturer conducts practical experiments on systems via video conference.

Assessment
Evaluation in the form of multiple answer test.

Recommended reading
-

Syllabus – Integrated Circuits

Name of the course:
Integrated Circuits

Course topic:
Indepth knowledge of integrated systems and their areas of application.

Duration:
24 hours

Participants of the course:
Engineers college or university degree

Educational background:
Engineers or technicians

Course responsible:
SBH Südost GmbH, dresden chip academy

Course lecturers:
Different teacher of the SBH, dresden chip academy

Educational prerequisites
Basic knowledge of integrated circuits and systems as well as their applications

Learning outcomes
Knowledge
The module provides an overview of the operation, design and technology of integrated electronic circuits in microelectronics.

- **Skills**
  to understand integrated circuits, their structure and mode of operation
- **Competence**
  design integrated circuits yourself

Abstract
Digital technology is one of the most important areas of electrical engineering. Digital circuits can be found in almost all electronic devices today. Due to the availability of inexpensive integrated circuits, highly integrated digital components are now also often used in simple devices, which, due to their complexity, hinder the view of the essential digital functional principles and thus make entry into the world of digital technology more difficult

Content

- Introduction
- Basic digital circuits
- MOS and CMOS
- Silicon wafer production
- MOSFET process technology
- Nanolithography
- Etching techniques and oxidation
- Design automation, design rules and assembly techniques
- Back end technologies
- Modern developments: storage technologies

Teaching methods

Video-webinar allowing students learning in their own place. Supporting material for reading and self-study is made available on our learning management portal.

Assessment
Evaluation in the form of multiple answer test.

Recommended reading
-

Syllabus – manufacturing and assembly process

Name of the course:
Manufacturing and assembly process

Course topic:
Basics of semiconductor technology, electrical quantities, electrical parameters, overall processes, front-end and back-end processes

Duration:
24 hours

Participants of the course:
Skilled workers, microtechnologist, Mechatronics engineer

Educational background:
Secondary School or highschool

Course responsible:
SBH Südost GmbH, dresden chip academy

Course lecturers:
Different teacher of the SBH, dresden chip academy

Educational prerequisites
Basics of electrical and electronic engineering, basics chemestry

Learning outcomes

- ***Knowledge***
  Functional analysis of selected semiconductor materials

- ***Skills***
  Measurement method

- ***Competence***
  Arten und

Abstract
Get to know processes of semiconductor production and the interrelationships

Content
Production plants for the manufacture of semiconductor components
serve and load. Processes
control and monitor, in particular
- carry out surface treatments,
- Thin grinding, chemical-mechanical polishing and anneal
- Structures by varnishing, exposure, developing and produce etching
- Layers, in particular by oxidation, gas deposition, Epitaxy, vapor deposition and sputtering
- Perform doping processes

- wet chemical processes, in particular cleaning and Etching processes
- Separate wafer
- Mount, contact and housing chips

Teaching methods
Video-webinar allowing students learning in their own place. Supporting material for reading and self-study is made available on our learning management portal.

Assessment
Evaluation in the form of multiple answer test.

Recommended reading
-

Syllabus – programmable logic controller (plc) advanced

Name of the course:
programmable logic controller (plc) advanced

Course topic:
Programmable logic controllers, or PLCs for short, are now considered to be the core of every automation. With these controls, the most varied of automation tasks can be carried out economically, depending on the problem. For the processing of the addresses of memory cells, inputs, outputs, times, flags etc. by a programmable logic controller, not the decimal system but the dual system is used. The conversion of the different number systems among each other is based on simple rules.

Duration:
24 hours

Participants of the course:
Specialists from production, repair and service in the metal and electrical sector who use PLC-controlled automation systems as part of their tasks. Service technicians, fitters and employees from repair and maintenance areas

Educational background:
Secondary School or highschool

Course responsible:
SBH Südost GmbH, dresden chip academy

Course lecturers:
Different teacher of the SBH, dresden chip academy

Educational prerequisites
Basic knowledge of electrical control, PC knowledge and the basics of Simatic S7 should already be available.

Learning outcomes

- **Knowledge**
  The ability to raise programmable logic controllers to the higher level of word processing in order to maintain, commission, correct or develop complex PLC programs on this basis
- **Skills**,
  Maintain, commission, correct or develop complex PLC programs yourself

- **Competence**
  In this seminar you will learn how to master the conversion rules as a PLC user. You will learn everything about processing word functions in the PLC.

Abstract
After the course you will be able to convert numbers into different formats, to link and use the different number systems and to read in, process and output analog values. The topics covered in the lesson are implemented on a SIMATIC S7 automation system with the SIMATIC Step 7 programming software.

Content
Digital operations, Programming of sequence controls, Block calls, declarations, reference data, Commissioning, fault diagnosis, Analog value processing

Teaching methods
Video-webinar allowing students learning in their own place. Supporting material for reading and self-study is made available on our learning management portal. The lecturer conducts practical experiments on systems via video conference.

Assessment
Evaluation in the form of multiple answer test.

Recommended reading
-

Syllabus – visualization with WINCC

Name of the course:
Visualization with WINCC

Course topic:
Understand and apply the basics and applications of visualization systems

Duration:
24 hours

Participants of the course:
Skilled workers from the technical field with a professional qualification and practical work experience in the field of PLC programming.

Educational background:
Secondary School or highschool

Course responsible:
SBH Südost GmbH, dresden chip academy

Course lecturers:
Different teacher of the SBH, dresden chip academy

Educational prerequisites
advanced knowledge of PLC programming

Learning outcomes

- ***Knowledge***
  Load and save programs and data, check and adapt the program sequence,
  Check signal transmission systems, especially field buses, and put them into operation, commission mechatronic systems, carry out functional tests
- ***Skills***
  Provided that the graphic representation of process flows with process data can be linked and stored, a
  Process analysis in terms of time, costs, quality are carried out.
  Furthermore, a process simulation is possible from the data collection in order to Finding optimization potential within the value chain.

- ***Competence***

  Short training through self-documenting work and business processes

Abstract

Conscious knowledge and standardization of operational processes,
Avoidance of unnecessary "work loops",
Hohe Transparenz durch klare Definition der Schnittstellen und Ansprechpartner

Content

- Introduction to WinCC flex,
- Creation of images and variables
- Allocation of functions,
- Setting of attributes,
- Fault and operating messages,
- Set up messages and message archives,
- visualization tasks

Teaching methods

Video-webinar allowing students learning in their own place. Supporting material for reading and self-study is made available on our learning management portal. The lecturer conducts practical experiments on systems via video conference.

Assessment

Evaluation in the form of multiple answer test.

Recommended reading

-

Syllabus – programmable logic controller - basic

Name of the course:
programmable logic controller - basic

Course topic:
Programmable logic controllers (PLC) are used in almost all automated systems. Accordingly, technical specialists should have knowledge of creating and optimizing PLC programs
.

Duration:
24 hours

Participants of the course:
Skilled workers, foremen, technicians and other skilled workers from the electrical sector who are used for project planning, maintenance, servicing and commissioning of PLC-controlled systems
.

Educational background:
Secondary School or highschool

Course responsible:
SBH Südost GmbH, dresden chip academy

Course lecturers:
Different teacher of the SBH, dresden chip academy

Educational prerequisites
Basic knowledge of electrical control and PC skills should already be available.

Learning outcomes

- ***Knowledge***
  Basic knowledge of handling, application and programming of PLC controls in machines and production systems. Practical work with S7 controllers in simulation software consolidates the fundamentals

- ***Skills***
  Understand the basics of a programmable logic controller

- ***Competence***
  You will be able to quickly localize malfunctions and errors in automation systems

.

Abstract
Up-to-date knowledge of PLC technology has become indispensable for employees in the process control and electrical engineering departments. They receive a sound insight into the structure and functionality of current PLC systems and learn how to use the software.

Content

- Structure, function and mode of operation,
- Hardware functions,
- Binary links,
- time functions,
- counters and comparators
- Fixed point functions,
- Data and function blocks,
- Diagnosis

Teaching methods

Video-webinar allowing students learning in their own place. Supporting material for reading and self-study is made available on our learning management portal. The lecturer conducts practical experiments on systems via video conference.

Assessment

Evaluation in the form of multiple answer test.

Recommended reading

-

Syllabus – PLC, controlling and networking

Name of the course:
PLC, controlling and networking

Course topic:
Set up and commission SIMATIC bus systems, identify faults and eliminate their causes

Duration:
24 hours

Participants of the course:
Specialists from production, repair and service in the metal and electrical sector who use PLC-controlled automation systems as part of their tasks. Service technicians, fitters and employees from repair and maintenance areas

Educational background:
Secondary School or highschool

Course responsible:
SBH Südost GmbH, dresden chip academy

Course lecturers:
Different teacher of the SBH, dresden chip academy

Educational prerequisites
Knowledge of programming and electrical engineering, electronics and PC skills

Learning outcomes

- ***Knowledge***
  Load and save programs and data, check and adapt the program sequence,
  Check signal transmission systems, especially field buses, and put them into operation, commission mechatronic systems, carry out functional tests

- ***Skills***
  Carry out error diagnoses and remedies in bus systems
- ***Competence***
  To program complex tasks in a structured manner and to carry them out independently.

Abstract
In automation technology, the networking of controls and systems is of particular importance.
As part of this training, you will deepen your previous experience and knowledge of stored-program control and working with automated systems. They supplement these with skills and abilities in the construction and error diagnosis and rectification in bus systems.

Content
Integration of system blocks and IEC functions in the user program, Error handling and alarm processing, Start-up behavior of the control, Basics of the field bus systems, Bus systems of the SIMATIC (MPI, ASi, Profibus), Commissioning and diagnosis

Teaching methods
Video-webinar allowing students learning in their own place. Supporting material for reading and self-study is made available on our learning management portal. The lecturer conducts practical experiments on systems via video conference.

Assessment
Evaluation in the form of multiple answer test.

Recommended reading
-

Syllabus – preventive maintenance

Name of the course:
Preventive maintenance

Course topic:
Due to increasing customer requirements, steady inventory reductions and unplanned incoming orders, the requirements for the maintenance of machine tools and production systems are getting higher and higher. If faults occur, this can quickly lead to long downtimes, loss of customers and high costs. These challenges can only be successfully mastered through current strategies, efficient organization and target-oriented controlling in maintenance.

Duration:
24 hours

Participants of the course:
Employees in the areas:
• Maintenance
• Production
• Manufacturing
• Procurement and purchasing
• Mechanical and plant engineering
• Operations and technical services

Educational background:
Secondary School or highschool

Course responsible:
SBH Südost GmbH, dresden chip academy

Course lecturers:
Different teacher of the SBH, dresden chip academy

Educational prerequisites
Basics of mechanics and electrical engineering

Learning outcomes
Knowledge
Expertise as well as economic and organizational knowledge for professional maintenance.

Skills,

- Implement preventive maintenance successfully
- Classify and prioritize plants and machines
- Correctly select and implement strategies and measures
- Measure and control with meaningful key figures

- ***Competence***
  Ability to classify maintenance as a necessity in order to maintain optimal production conditions for machines and systems and to initiate decisive processes.

Abstract
You will learn how you can decisively improve the cooperation between maintenance and production and how you can use it for common goals. You will also acquire knowledge of how to deal with a limited budget. You can handle the gap between cost pressures and system availability.

Content
Maintenance task
- Maintenance, inspection and repair
- Documentation, create maintenance plans
- Determine the actual condition, carry out maintenance
- Maintenance methods, preventive + failure-related
- Troubleshooting strategies (split-half, fault tree)
- Repair training, troubleshooting training
- Fault analysis (Analytik trouble shooting)

Teaching methods
Video-webinar allowing students learning in their own place. Supporting material for reading and self-study is made available on our learning management portal. The lecturer conducts practical experiments on systems via video conference.

Assessment
Evaluation in the form of multiple answer test.

Recommended reading
-

Syllabus – printed circuit board production

Name of the course:
Printed circuit board production

Course topic:
The requirements for printed circuit boards have changed considerably in recent years. The circuit board is no longer just a carrier element for wiring electrical components, but an independent, complex component

Duration:
24 hours

Participants of the course:
PCB users, assembly and system developers, PCB designers and PCB manufacturers

Educational background:
Secondary School or highschool

Course responsible:
SBH Südost GmbH, dresden chip academy

Course lecturers:
Different teacher of the SBH, dresden chip academy

Educational prerequisites
Basics of electrical engineering and electronics, PC knowledge

Learning outcomes

- **Knowledge**
  The most important parameters of materials and circuit boards as well as the production of base materials and multilayer circuit boards are dealt with.

- **Skills**

Read and create production-ready printed circuit board documents, optimal specifications, drawings and layout and drilling data

- **Competence**
  be able to control and influence the technologies of the printed circuit board

Abstract
The most important parameters of materials and circuit boards as well as the production of base materials and multilayer circuit boards are dealt with. Essential aspects and manufacturing processes in the manufacture of complex assemblies, flexible circuit boards and new technologies are shown.

Content

Creation of circuit board layouts
- Structure and materials of printed circuit boards
- Basic knowledge and processes of printed circuit board production
- the types, handling and functioning of systems for the production of printed circuit boards
- Determination of paint quantities
- Exposure and etching times
- Drilling and assembling of printed circuit boards

Teaching methods

Video-webinar allowing students learning in their own place. Supporting material for reading and self-study is made available on our learning management portal. The lecturer conducts practical experiments on systems via video conference.

Assessment
Evaluation in the form of multiple answer test.

Recommended reading
-

Syllabus – Quality management

Name of the course:
Quality management

Course topic:
Quality management (QM) basic knowledge offers you a comprehensive, yet easily understandable overview of the entire range of quality management topics.

Duration:
24 hours

Participants of the course:
The quality management basic knowledge seminar is aimed at employees who want to participate in the establishment or further development of a quality management system, are or want to / should be part of such a team, as well as employees who want to acquire basic knowledge of quality management

Educational background:
Not relevant

Course responsible:
SBH Südost GmbH, dresden chip academy

Course lecturers:
Different teacher of the SBH, dresden chip academy

Educational prerequisites
In this seminar you will learn the basics of quality management according to the ISO 9001: 2015 standard and learn how to optimize the processes in your organization through professional quality management. You will learn how to introduce, maintain and continuously improve a QM system.

Learning outcomes
Knowledge
The contents, requirements and the structure of quality management systems according to the current standards are presented

.

- **Skills**
  Basic knowledge and a comprehensive overview of the entire range of quality management topics.

  Competence
  Establishment or further development of a quality management system

Abstract
Quality is still the most decisive unique selling point. Competent quality managers are required to ensure the quality of products and services over the long term. Quality planning and management can only succeed with a set of specialist know-how and practical skills.
Quality assurance is always faced with new requirements. Digital technologies and environmental changes bring complex challenges with them. These require innovative solutions, modern management systems and a strong skill set. Our advanced training courses for quality managers strengthen your skills and prepare the way for a successful future. Because quality has to be learned.

Content

- Importance of quality in all parts of the company
- Classification of standards and regulations
- Determination of influences on product quality
- Getting to know the most important management systems
- Handling of QM methods
- Working with quality documents
- Recognizing connections
- Creation of quality documents
- The most important QM tools (SPC / FMEA / SSB)
- Relationship between QM and business successes

Teaching methods

Video-webinar allowing students learning in their own place. Supporting material for reading and self-study is made available on our learning management portal. The lecturer conducts practical experiments on systems via video conference.

Assessment
Evaluation in the form of multiple answer test.

Recommended reading
-

Syllabus – Semiconductor Sensors

Name of the course:
Semiconductor sensors

Course topic:
Important topic of semiconductor technologies.

Duration:
24 hours

Participants of the course:
Engineers or Technicians

Educational background:
University of Applied Sciences

Course responsible:
SBH Südost GmbH, dresden chip academy

Course lecturers:
Different teacher of the SBH, dresden chip academy

Educational prerequisites
basics of semiconductor

Learning outcomes

- ***Knowledge***
  After completing the seminar, the participants will have a basic understanding of the most important processes for modeling, manufacturing and characterizing micro / nanomechanical semiconductor sensors

- ***Skills***,
  Identify and understand issues Semiconductor sensors

- ***Competence***
  practical experience for assessment and evaluation semiconductor sensors

Abstract

This course provides a brief introduction to sensors. The main theme are the process for modeling, manufacturing and characterization of micro / nanomechanical semiconductor sensors.

Content

- Elementary transducer,
- Converter,
- Surface micromechanics,
- Epi-micromechanics,
- Machine monitoring,
- Engine management

Teaching methods
Video-webinar allowing students learning in their own place. Supporting material for reading and self-study is made available on our learning management portal. The lecturer conducts practical experiments on systems via video conference.

Assessment
Evaluation in the form of multiple answer test.

Recommended reading
-

Syllabus – signal processing

Name of the course:
Signal processing

Course topic:
Digital circuits and their backgrounds and especially the processing

Duration:
24 hours

Participants of the course:
Skilled workers, microtechnologist, Mechatronics engineer

Educational background:
Secondary School or highschool

Course responsible:
SBH Südost GmbH, dresden chip academy

Course lecturers:
Different teacher of the SBH, dresden chip academy

Educational prerequisites
Basics of electrical engineering

Learning outcomes

- ***Knowledge***
  You will acquire a basic understanding of electronic processes as well as skills in handling electronic components, circuits and devices.

- ***Skills***
  Measurement method

- ***Competence***
  Assessment, recording and presentation of signal processing procedures and basic electrical quantities

Abstract
Knowledge of electronic components is imparted so that one is able to identify and correct errors in electronic devices.
And to get a basic understanding

Content
Electrical quantities and their interrelationships and display options.
Analog and digital signals.
Measurement methods for recording electrical quantities
Function and structure of passive components

Protective provisions, protective measures, safety rules.

Teaching methods
Video-webinar allowing students learning in their own place. Supporting material for reading and self-study is made available on our learning management portal. The lecturer conducts practical experiments on systems via video conference.

Assessment
Evaluation in the form of multiple answer test.

Recommended reading
-

Syllabus – Vacuum technology

Name of the course:
Vacuum technology

Course topic:
Vacuum processes play a dominant role in semiconductor technology.

Duration:
24 hours

Participants of the course:
Skill workers, Technicians or Engineers

Educational background:
secondary school or Highschool

Course responsible:
SBH Südost GmbH, dresden chip academy

Course lecturers:
Different teacher of the SBH, dresden chip academy

Educational prerequisites
basics of Electrical engineering

Learning outcomes

- ***Knowledge***
  Applying knowledge of vacuum technology
- ***Skills***,
  The knowledge acquired enables both a thorough understanding of the physical processes in a vacuum process
- ***Competence***
  The basic vacuum technology knowledge required to understand these processes should be imparted.

Abstract
This includes gas kinetics, vacuum and flow areas, pump principles and pump designs, vacuum and gas flow measurement.

Content

- Applying knowledge of vacuum technology
- Know the types, handling and functioning of vacuum pumps
- Understand the selection of vacuum sensors

- Being able to record and interpret pumping curves
- Know components and materials in vacuum technology
- Know how to identify leaks and how to use the leak detector
- Know and carry out residual gas analyzes

Teaching methods
Video-webinar allowing students learning in their own place. Supporting material for reading and self-study is made available on our learning management portal. The lecturer conducts practical experiments on systems via video conference

Assessment
Evaluation in the form of multiple answer test.

Recommended reading
-

Syllabus – Mechanics of Si beam and diaphragm structures

Name of the course:
Mechanics of Si beam and diaphragm structures
Course topic:
Mechanical fundamentals of Si MEMS sensors and actuators
Duration:
80 learning hours
Participants of the course:
Students and design engineers
Educational background:
Master students in electronics, mechanics, material science and physics
Course responsible:
University of South-Eastern Norway, USN
Department of Microsystems, IMS
Course lecturer:
Prof. Ulrik Hanke

Educational prerequisites
Advance engineering mathematics, Engineering physics

Learning outcomes

Upon successful completion of this course the student should be able to:

Knowledge

- *Mathematically model and analyze mechanical performance of common structures used for micro sensors and actuators.*
- *Become familiar with state-of-the art mechanical design tools for micromechanical structures using Comsol.*
- *Give some examples of Si structures used as sensors and actuators.*
- *Read and understand scientific papers in the relevant field.*

Skills

This course aims to provide understanding of operation principles and mathematical modelling of selected micro-Si structures used as sensors and actuators. By analysing simple physics-based models, the aim is to evaluate mechanical performance and trade between critical design parameters. Further this course aims to enable detailed Finite Element simulations that will be used for device optimization.

General Competence

The course also aims to train students in reading scientific papers within the relevant field.

Abstract

Designing micro sensors and actuators requires the ability to analyse and synthesize devices working in several physical domains. This course focus on modelling and design of Si mechanical structures often utilized in MEMS devices.

Content

- *Introduction to tensors and how material properties are represented by tensors. Si crystal structure and its impact on mechanical and thermal properties. Calculation of mechanical material parameters for general Si crystal orientation.*
- *Stress, strain and Hooks law using tensor notation. Euler-Bernoulli theory for bending of beams. Rotation of torsion bar structures. Bending of composite beams and the Stoney equation*
- *Vibration resonance frequency by the spring-mass model*
- *Vibration frequency by energy methods*
- *Vibration modes and the buckling of a beam*
- *Damped and forced vibration*
- *Basic mechanics of diaphragms*

Teaching methods

Four lectures pr. week will be given. Additional two hours pr. week is set aside to discuss home work assignments. It is expected that students engage in presenting solutions to assignments for the other students and take part in class-room discussion.
All students also select a project work where they use COMSOL to perform Finite Element simulations. The results of the project should be presented for the rest of the class.

Assessment

All given assignments should be approved with a pass/no-pass. The Comsol project is also graded with pass/no-pass.

Recommended reading

M. H. Bao, Analysis and Design Principles of MEMS Devices, Elsevier, 2005, 1st edition. ISBN: 0 444 51616 6.

Syllabus – Viscous damping in microstructures

Name of the course:
Viscous damping in microstructures
Course topic:
Basic physics and modelling of viscous damping in MEMS
Duration:
40 learning hours
Participants of the course:
Students and design engineers
Educational background:
Master students in electronics, mechanics, material science and physics
Course responsible:
University of South-Eastern Norway, USN
Department of Microsystems, IMS
Course lecturer:
Prof. Ulrik Hanke

Educational prerequisites
Advance engineering mathematics, Engineering physics and mechanics

Learning outcomes

Upon successful completion of this course the student should be able to:

Knowledge

- *Understand the basic physics of viscosity in a fluid.*
- *Perform analytical calculations of damping coefficients for various microstructures.*
- *Become familiar with state-of-the art FEM tools for simulating damping performance of microstructures e.g., Comsol.*
- *Give examples of sensors and actuators where damping control is important.*
- *Take part in design, support fabrication and testing of damped microstructures.*
- *Read and understand scientific papers in the relevant field.*
- *Give oral presentation of design activity.*

Skills

This course aims to provide understanding of fundamental principles and mathematical modelling of viscous damping of microstructures. By analysing simple physics-based models, the aim is to evaluate damping performance and trade between critical design parameters. Further this course aims to enable Finite Element simulations that will be used for device optimization.

General Competence

The course also aims to train students in reading scientific papers within the relevant field and to present results from design activity.

Abstract

Designing micro sensors and actuators requires the ability to analyse and synthesize devices working in several physical domains. First the fundamental issues related to gas damping is discussed. Then this is applied for specific structures often utilized in MEMS devices.

Content

- *Viscosity of a fluid and the drag effect*
- *Reynolds equation and squeeze film air damping*
- *Modified Reynolds equation for thick perforated plate*
- *Navier-Stokes equation and Slide-film air damping*
- *Effective viscosity of rarefied gas*

Teaching methods

Four lectures pr. week will be given. Additional two hours pr. week is set aside to discuss home-work assignments. It is expected that students engage in presenting solutions to assignments for the other students and take part in class-room discussion.
All students also select a project work where they use COMSOL to perform Finite Element simulations. The results of the project should be presented for the rest of the class.

Assessment

All given assignments should be approved with a pass/no-pass. The Comsol project is also graded with pass/no-pass.

Recommended reading

M. H. Bao, Analysis and Design Principles of MEMS Devices, Elsevier, 2005, 1st edition. ISBN: 0 444 51616 6.
M. H. Bao, Micro Mechanical Transducers, Volume 8, Handbook of Sensors and Actuators, Elsevier, 2000, 2nd edition 2004. ISBN: 0-444-50558-X.

Syllabus – Non-viscous damping in microstructures

Name of the course:
Non-viscous damping in microstructures
Course topic:
Basic physics and modelling of non-viscous damping in MEMS
Duration:
40 learning hours
Participants of the course:
Students and design engineers
Educational background:
Master students in electronics, mechanics, material science and physics
Course responsible:
University of South-Eastern Norway, USN
Department of Microsystems, IMS
Course lecturer:
Prof. Ulrik Hanke

Educational prerequisites
Advance engineering mathematics, Engineering physics and mechanics

Learning outcomes

Upon successful completion of this course the student should be able to:

Knowledge

- *Understand the basic physics of internal material and structural damping mechanisms.*
- *Perform analytical calculations of damping coefficients for various microstructures.*
- *Become familiar with state-of-the art FEM tools for simulating damping performance of microstructures e.g., Comsol.*
- *Give examples of sensors and actuators where damping control is important.*
- *Take part in design, support fabrication and testing of damped microstructures.*
- *Read and understand scientific papers in the relevant field.*
- *Give oral presentation of design activity.*

Skills

This course aims to provide understanding of fundamental principles and mathematical modelling of inherent and structural damping mechanisms of microstructures. By analysing simple physics-based models, the aim is to evaluate damping performance and trade between critical design parameters. Further this course aims to enable Finite Element simulations that will be used for device optimization.

General Competence

The course also aims to train students in reading scientific papers within the relevant field and to present results from design activity.

Abstract

Designing micro sensors and actuators requires the ability to analyse and synthesize devices working in several physical domains. First the fundamental issues related to rare gas damping is discussed. Then intrinsic damping given by material properties and structural design is discussed.

Content

- *Momentum and energy transfer model for damping in rarefied air*
- *Thermoelastic damping (TED) of microbeams*
- *Support/Anchor loss*

Teaching methods

Four lectures pr. week will be given. Additional two hours pr. week is set aside to discuss home-work assignments. It is expected that students engage in presenting solutions to assignments for the other students and take part in class-room discussion.
All students also select a project work where they use COMSOL to perform Finite Element simulations. The results of the project should be presented for the rest of the class.

Assessment

All given assignments should be approved with a pass/no-pass. The Comsol project is also graded with pass/no-pass.

Recommended reading

M. H. Bao, Analysis and Design Principles of MEMS Devices, Elsevier, 2005, 1st edition. ISBN: 0 444 51616 6.
M. H. Bao, Micro Mechanical Transducers, Volume 8, Handbook of Sensors and Actuators, Elsevier, 2000, 2nd edition 2004. ISBN: 0-444-50558-X.

Syllabus
"Resistive sensor front-end"

Name of the course
Resistive sensor front-end
Course topic
Various front-end techniques for resistive microsensor
Duration:
40 learning hours
Participants of the course:
Students
Educational background:
Master degree students in electronics or physics
Course responsible
University of South-Eastern Norway
Department of Microsystems
Assoc. Prof. Mehdi Azadmehr
Course lecturer / tutor
Assoc. Prof. Mehdi Azadmehr

Educational Prerequisites
Analog electronics.

Learning outcomes
Upon successful completion of this course students should be able to:

Knowledge:
- Compare the different resistive sensor front-end principles
- Explain the basic steps of designing resistive sensors front-end
- Design advanced front-end circuits for resistive microsensors

Skills:
- Have an understanding of the properties and challenges of resistive microsensors
- Understand the different resistive sensor front-end principles
- Be able to characterize the different types of resistive sensors front-end
- Know the most common interface circuits for resistive sensors.

Competence:
- The student shall have knowledge of the designing sensors front-end circuits for resistive microsensors. Furthermore, students must be able to convey their work in a scientific way by written scientific report and oral presentation.

Abstract
The purpose of the course is to provide an understanding of the most common front-end techniques for resistive microsensors. The main focus of the course will be on circuits and techniques suited for use as front-end for resistive microsensors.

Content
Resistive microsensor properties
Wheatstone bridge
Active Bridge
Delta-Sigma front-end

High resistivity sensor front-ends

Teaching methods
Lectures based on text book and selected papers, individual home work assignments, paper presentation and a design project. In this project students must design a proper interface circuit for a sensor with given properties. This front-end circuit should be modelled, simulated and analysed and the result must be compared with similar published circuits.
The theoretical part of the course through online courses or pre-recorded videos.
In both cases on-line support by the tutor is provided.

Assessment
The course grade consists of these components:
60% – project-report
40% – Oral exam

Recommended reading

D. Johns and K. Martin - Analog Integrated Circuit Design, 2nd Int. version - Wiley, 2012,

978-1-118-09233 -0

Syllabus
"Capacitive sensor front-end"

Name of the course
Capacitive sensor front-end
Course topic
Various front-end techniques for capacitive sensor
Duration:
40 learning hours
Participants of the course:
Students
Educational background:
Master degree students in electronics or physics
Course responsible
University of South-Eastern Norway
Department of Microsystems
Assoc. Prof. Mehdi Azadmehr
Course lecturer / tutor
Assoc. Prof. Mehdi Azadmehr

Educational Prerequisites
Analog electronics.

Learning outcomes
Upon successful completion of this course students should be able to:

Knowledge:
- Compare the different capacitive front-end principles
- Explain the basic steps of designing front-end circuits for capacitive sensors
- Design advanced front-end circuits for capacitive microsensors

Skills:
- Have an understanding of the properties and challenges of capacitive microsensors
- Understand the different capacitive sensor front-end principles
- Be able to characterize the different types of capacitive front-end sensors
- Know the most common interface circuits for capacitive sensors.

Competence:
- The student shall have knowledge of the designing sensors front-end circuits for capacitive microsensors. Furthermore, students must be able to convey their work in a scientific way by written scientific report and oral presentation.

Abstract
The purpose of the course is to provide an understanding of the most common front-end techniques for capacitive microsensors. The main focus of the course will be on circuits and techniques suited for use as front-end for microsensors.

Content
Capacitive microsensor properties
Correlated double sampling
Switch-cap techniques
Autozeroing techniques

Delta-sigma methods
Chopper stabilization

Teaching methods
Lectures based on text book and selected papers, individual home-work assignments, paper presentation and a design project. In this project students must design a proper interface circuit for a sensor with given properties. This front-end circuit should be modelled, simulated and analysed and the result must be compared with similar published circuits.
The theoretical part of the course through online courses or pre-recorded videos.

Assessment
The course grade consists of these components:
60% – project-report
40% – Oral exam

Recommended reading

D. Johns and K. Martin - Analog Integrated Circuit Design, 2nd Int. version - Wiley, 2012,

978-1-118-09233 -0

Syllabus – Physics of resistivity measurements

Name of the course:
Physics of resistivity measurements
Course topic:
Physics and mathematical foundation of four-probe and van der Pauw resistivity measurements
Duration:
60 learning hours
Participants of the course:
Students and design engineers
Educational background:
Master students in electronics, mechanics, material science and physics
Course responsible:
University of South-Eastern Norway, USN
Department of Microsystems, IMS
Course lecturer:
Prof. Ulrik Hanke

Educational prerequisites
Advance engineering mathematics, Engineering physics

Learning outcomes

Upon successful completion of this course the student should be able to:

Knowledge

- *Calculate and measure sheet resistance and resistivity of a semiconductor.*
- *Understand and explain the benefit of four-probe versus two-probe experiments.*
- *Understand and derive the mathematical expressions relating resistance, probe geometry and experimental parameters like current and voltage.*
- *Mathematically derive and apply correction factors due to material thickness and sample size.*
- *Understand the theory and application of the dual configuration method, the van der Pauw method and the cross-bridge structure.*
- *Read and understand scientific papers in the relevant field.*

Skills

This course aims to provide understanding of operation principles and mathematical modelling of semiconductor resistivity measurements. Further this course aims to enable Finite Element simulations that may be used for analysing test sample performance.

General Competence

The course also aims to train students in reading scientific papers within the relevant field.

Abstract

The resistivity of a semiconductor is important because it contributes to many of the critical device parameters. Resistivity monitoring is therefore important both for device design and processing. This module discusses the physics and theoretical foundation for common measurement setups.

Content

- *Resistivity two-probe versus four-probe measurements.*
- *Calculation of voltage distributions from current probes using the 3D Laplace equation.*
- *Develop a model for the resistivity calculation for co-linear and square electrode configurations.*
- *Derive correction factors due to sample thickness.*
- *Use conformal mapping theory to develop correction factors due to small lateral sample geometry.*
- *Theory of dual configuration and van der Pauw samples and their use for resistivity measurements.*
- *Measurement errors and Precautions*

Teaching methods

Four lectures pr. week will be given. Additional two hours pr. week is set aside to discuss home work assignments. It is expected that students engage in presenting solutions to assignments for the other students and take part in class-room discussion.
All students also select a project work where they use COMSOL to perform Finite Element simulations. The results of the project should be presented for the rest of the class.

Assessment

All given assignments should be approved with a pass/no-pass. The Comsol project is also graded with pass/no-pass.

Recommended reading

Dieter K. Schroder, Semiconductor material and Device Characterization, Wiley, 3. edition 2006. Available online via IEEE https://ieeexplore.ieee.org/book/5237928.

Syllabus – Piezoresistive Si sensors

Name of the course:
Piezoresistive Si sensors
Course topic:
Basic physics and design principles of piezoresistive sensors
Duration:
80 learning hours
Participants of the course:
Students and design engineers
Educational background:
Master students in electronics, mechanics, material science and physics
Course responsible:
University of South-Eastern Norway, USN
Department of Microsystems, IMS
Course lecturer:
Prof. Ulrik Hanke

Educational prerequisites
Advance engineering mathematics, Engineering physics and mechanics

Learning outcomes

Upon successful completion of this course the student should be able to:

Knowledge

- *Understand the basic semiconductor physics of piezoresistivity.*
- *Outline in detail operation principle, and perform design of piezoresistive sensors*
- *Become familiar with state-of-the art design tools for piezoresistive structures using Comsol.*
- *Give examples of application of sensors implemented in micro systems*
- *Take part in design, support fabrication and testing of piezoresistive sensors.*
- *Read and understand scientific papers in the relevant field.*
- *Give oral presentation of design activity.*

Skills

This course aims to provide understanding of operation principles and mathematical modelling of piezoresistivity and micro-Si structures used as piezoresistive sensors. By analysing simple physics-based models, the aim is to evaluate sensor performance and trade between critical design parameters. Further this course aims to enable detailed Finite Element simulations that will be used for device optimization.

General Competence

The course also aims to train students in reading scientific papers within the relevant field and to present results from design activity.

Abstract

Designing micro sensors and actuators requires the ability to analyse and synthesize devices working in several physical domains. This course focus on modelling and design of Si piezoresistivel structures often utilized in MEMS devices.

Content

- *Piezoresistance effect in Si*
- *The piezoresistive tensor and its tensor transformations*
- *Two-terminal and four-terminal piezoeresistive sensing elements*
- *Polysilicon piezoeresistive sensing elements*
- *Analyzing piezoresistive bridge with respect to offset voltage, temperature coefficient and nonlinearity.*
- *Piezoresistive pressure transducers*
- *Piezoresistive accelerometers*

Teaching methods

Four lectures pr. week will be given. Additional two hours pr. week is set aside to discuss home-work assignments. It is expected that students engage in presenting solutions to assignments for the other students and take part in class-room discussion.
All students also select a project work where they use COMSOL to perform Finite Element simulations. The results of the project should be presented for the rest of the class.

Assessment

All given assignments should be approved with a pass/no-pass. The Comsol project is also graded with pass/no-pass.

Recommended reading

M. H. Bao, Analysis and Design Principles of MEMS Devices, Elsevier, 2005, 1st edition. ISBN: 0 444 51616 6.
M. H. Bao, Micro Mechanical Transducers, Volume 8, Handbook of Sensors and Actuators, Elsevier, 2000, 2nd edition 2004. ISBN: 0-444-50558-X.

Syllabus
"Piezoelectric sensors"

Name of the course
Piezoelectric microsensors
Course topic
understanding piezoelectric microsensor principals
Duration:
40 learning hours
Participants of the course:
Students
Educational background:
Bachelor degree students in electronics or physics
Course responsible
University of South-Eastern Norway
Department of Microsystems
Assoc. Prof. Mehdi Azadmehr
Course lecturer / tutor
Assoc. Prof. Mehdi Azadmehr

Educational Prerequisites
Basic understanding of solid state physics, electrical circuits and electronics.

Learning outcomes
Upon successful completion of this course students should be able to:

Knowledge:
- Basic understanding of piezoelectricity
- Compare the different piezoelectric sensing principles
- Explain the basic steps of designing piezoelectric sensors
- Design basic front-end circuits for piezoelectric sensors

Skills:
- Have an understanding of the basic electrical and mechanical properties of piezoelectric material
- Understand the different piezoelectric sensor principles
- Be able to evaluate applications for piezoelectric sensors
- Be able to characterize the different types of piezoelectric sensors
- Know the most common interface circuits for sensors based on piezoelectric.

Competence:
- The student shall have knowledge of the use of piezoelectric sensors and their areas of application in practical life. Furthermore, students must be able to convey their work in a scientific way by written scientific report and oral presentation.

Abstract
The purpose of the course is to provide a basic understanding of the piezoelectricity. The main focus of the course will be on application areas within medical and subsea. Basic electrical properties of piezoelectric materials will be covered.

Content
Basic properties of electric materials

Important piezoelecric sensor properties
Beams, theory
Interface circuits suchas VGAs and oscillators.
Construction of piezoelectric microsensors
Use of piezoelectric microsensors

Teaching methods
The theoretical part of the course through online courses or pre-recorded videos
The practical work is laboratory experiments of a piezoelectric sensor with its front-end circuit
In both cases on-line support by the tutor is provided.

Assessment
The course grade consists of these components:
40% – Lab-report
60% – Oral exam

Recommended reading

Foundation of MEMS, Forfatter Chang Liu, 2014, Pearson Education Limited, ISBN: 9781292013985

Syllabus
"Capacitive microsensors"

Name of the course
Capacitive microsensors
Course topic
understanding capacitive microsensor principals
Duration:
40 learning hours
Participants of the course:
Students
Educational background:
Bachelor degree students in electronics or physics
Course responsible
University of South-Eastern Norway
Department of Microsystems
Assoc. Prof. Mehdi Azadmehr
Course lecturer / tutor
Assoc. Prof. Mehdi Azadmehr

Educational Prerequisites
Basic understanding of solid state physics, electrical circuits and electronics.

Learning outcomes
Upon successful completion of this course students should be able to:

Knowledge:
- Compare the different capacitive sensing principles
- Explain the basic steps of designing capacitive sensors
- Design basic front-end circuits for capacitive sensors

Skills:
- Have an understanding of the basic electrical and mechanical properties of material used in capacitive sensing
- Understand the different capacitive sensor principles
- Be able to evaluate applications for capacitive sensors
- Be able to characterize the different types of capacitive sensors
- Know the most common interface circuits for capacitive sensors.

Competence:
- The student shall have knowledge of the use of capacitive sensors and their areas of application in practical life. Furthermore, students must be able to convey their work in a scientific way by written scientific report and oral presentation.

Abstract
The purpose of the course is to provide a basic understanding of the capacitive microsensors. The main focus of the course will be on application areas and important sensor properties such as linearity, sensitivity. Electrical properties of semiconductors, i.e. resistivity and conductivity, will be taught. Then we take a closer look at the mechanical properties of semiconductors, especially silicon structures such as beams and membranes.

Content

Electrical properties of semiconductors
Mechanical properties of semiconductors
Silicon properties
Important capacitive sensor properties
Capacitive sensor principles
Beams, theory
Interface circuits, measuring bridge, oscillators.
Construction of capacitive silicon microsensors
Characterization of capacitive microsensors
Use of capacitive microsensors

Teaching methods
The theoretical part of the course through online courses or pre-recorded videos
The practical work is laboratory experiments of a capacitive sensor with its front-end circuit
In both cases on-line support by the tutor is provided.

Assessment
The course grade consists of these components:
40% – Lab-report
60% – Oral exam

Recommended reading

Foundation of MEMS, Forfatter Chang Liu, 2014, Pearson Education Limited, ISBN: 9781292013985

Syllabus
"Thermal and radiation sensors"

Name of the course
Thermal and radiation sensors
Course topic
understanding Thermal and radiation sensing
Duration:
40 learning hours
Participants of the course:
Students
Educational background:
Bachelor degree students in electronics or physics
Course responsible
University of South-Eastern Norway
Department of Microsystems
Assoc. Prof. Mehdi Azadmehr
Course lecturer / tutor
Assoc. Prof. Mehdi Azadmehr

Educational Prerequisites
Basic understanding of solid state physics, electrical circuits and electronics.

Learning outcomes
Upon successful completion of this course students should be able to:

Knowledge:
- Compare the different thermal and radiation sensors sensing principles
- Explain the basic steps of designing Thermal and radiation sensors

Skills:
- Have an understanding of the basic electrical and mechanical properties of material used in thermal and radiation sensing
- Understand the different thermal sensor principles
- Understand the different radiation sensor principles
- Be able to evaluate applications for thermal and radiation sensors

Competence:
- The student shall have knowledge of the use of thermal and radiation sensors and their areas of application in practical life. Furthermore, students must be able to convey their work in a scientific way by written scientific report and oral presentation.

Abstract
The purpose of the course is to provide a basic understanding of the thermal and radiation microsensors. The main focus of the course will be on application areas and important sensor properties such as linearity, sensitivity. Electrical properties of semiconductors, i.e. resistivity and conductivity, will be taught.

Content
Electrical properties of semiconductors

Mechanical properties of semiconductors
Silicon properties
Important thermal and radiation sensor properties
thermal and radiation sensor principles
Interface circuits

Teaching methods
The theoretical part of the course through online courses or pre-recorded videos
The practical work is laboratory experiments of a capacitive sensor with its front-end circuit
In both cases on-line support by the tutor is provided.

Assessment
The course grade consists of these components:
40% – Lab-report
60% – Oral exam

Recommended reading

Foundation of MEMS, Forfatter Chang Liu, 2014, Pearson Education Limited, ISBN: 9781292013985

Co-funded by the Erasmus+ Programme of the European Union

Syllabus of the Course on Nanomaterials for Electronics

Course topic
Nanomaterials for Electronics
Number of credits
5 ECTS
Course responsible
TUS Sofia
Department of Microelectronics
Prof. DSc. Slavka Tzanova
Course lecturer
Ass. Prof. Dr. Elitsa Gieva
Assoc. Prof. Dr. Mariya Alexandrova-Pandieva
Ass. Prof. Maria Angelova
Prerequisites
Microelectronics technology and design rules, solid state physics, computer added design in electronics.

Learning outcomes
Upon successful completion of this course students should be able to:

- Compare the properties of materials for deep-submicron and nanometre CMOS IC, HEMT, single electron transistors and resonant tunnelling devices;
- Discuss the advantages of devices on carbon nanotubes and graphene;
- Explain the physical principles of spintronic devices and choose appropriate materials for them;
- Select a method and plan the procedures for characterisation of molecular systems;
- Plan the fabrication procedure for deep-submicron and nanometre CMOS IC with the proper technological process for the materials of the substrate, implanted areas, isolation, metallisation.

Abstract
This course will take an in-depth look at nanomaterials used in nanoelectronics. Theory and concepts of nanomaterials will be covered, including the chemistry and physics of nanomaterials. The course will also focus on major classes of nanomaterials, including carbon nanotubes, nanostructured materials, nanowires, nanoparticles, nanoclays, and other nanomaterials. Applications of nanomaterials to technology areas in nanoelectronics will also be discussed.

Content
1. Current trends in nanoelectronics
The course will cover the materials for:
- Deep-submicron and nanometre CMOS IC (under 50 μm);

- HEMT (high electron mobility transistor);
- Devices on carbon nanotubes and graphene;
- Resonant tunnelling devices and circuits;
- Single electron transistors;
- Spintronics;
- Quantum electronics;
- Bioelectronics and molecular electronic devices.

2. Materials for deep-submicron and nanometer CMOS IC:
   - Materials for the substrate – tight Si;
   - Alternative materials for the gate insulator: high K gate insulators;
   - Gate electrode materials (n+ polysilicon, mid-gap, metals);
   - SOI;
   - Double-Gate Transistor Structures and Multi-Gate Transistor Structures.

3. Materials for HEMT:
   - Heterostructures on A3B5 (GaAs/ AlGaAs, InGaAs/InAlAs etc.).

4. Materials for devices on carbon nanotubes and graphene:
   - CNT – Carbon nanotubes – physical characteristics.
   - CNT devices: CNT Transistor, CNT –Based Field Emission Devices, Junctions, Heterojunctions and Quantium Confined Structures Based on Carbon Nanotubes, Microwave Devices Based on Carbon Nanotubes, CNT Based Electrical Sensors;
   - Graphene.

5. Materials for resonant tunnelling devices:
   - Structures of resonant tunnelling devices and circuits: AlAs/GaAs/AlAs, AlSb/InAs/AlSb.

6. Materials for single electron transistors:
   - Single Electron Transistors structure and materials: Si, GaAS.

7. Spintronics:
   - Physical principles and materials for spintronic devices;
   - Spintronic structures: Spin Valves, Spin Pumps, Spin Diodes, Spin Transistors, Spin Based Optoelectronics Devices, Spintronic Computation.

8. Quantum electronics:
   - Quantum electronic devices (QED) – physical principles and materials;
   - Short-Channel MOS Transistor, Split-Gate Transistor, Electron-Wave Transistor, Electron-Spin Transistor, Quantium Cellular Automata (QCA).

9. Materials for bioelectronics and molecular electronic devices:
   - Characterisation of molecular systems: electrical properties of molecules;
   - Molecular electronic devices, polymer electronics, self-assembling circuits, optical molecular memories;
   - Molecular processor, DNA analyzer as biochip.

Teaching methods

The course is presented in the Moodle learning environment in the form of HTML tutorials.
On-line support by the tutor is provided.
There is optional practical work (mandatory of rthe students at TUS) in the laboratory of vacuum layer deposition of the Dep. of Microelectronics at TU-Sofia.

Assessment

Knowledge test with a multiple choice questionnaire

Recommended Readings

Vajtai, R. (Ed.), Springer Handbook of Nanomaterials, Springer, 2013, ISBN 978-3642205958

Bhushan, B. (Ed.), Springer Handbook of Nanotechnology, Springer, 2010, ISBN 978-3642025259

Wiliams A.,Semiconductor Nanomaterials for Flexible Technologies, Sun&Rogers, 2012, ISBN: 978-1437778236

Kumar V., Nanosilicon, 2013, Elsevier Science, ISBN: 9780080445281

Baldo M., Introduction to Nanoelectronics, MIT course materials, http://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-701-introduction-to-nanoelectronics-spring-2010/download-course-materials/

Co-funded by the Erasmus+ Programme of the European Union

Syllabus of the Course

"Design, Prototype Fabrication and Challenging Applications of Silicon Microsystems with Piezoresistive Feedback"

Course topic
The course highlights the synergy between design and processing for the fabrication of microsystems dedicated to advanced applications. Knowledge and skills for creative work in the practice of microsystems will be acquired by the learners.

Number of credits
3ECTS

Course responsible[1]
Prof. Slavka Tsanova
Technical University Sofia (TUS)
Vladimir Stavrov
AMG Technology Ltd. (AMGT)

Course lecturers
Vladimir Stavrov
Prof. Slavka Tsanova
Galina Stavreva

Prerequisites
Microsystems' related fundamentals of: material science, micro technologies, methods for control and analyses of fabrication processes, and basic knowledge for compliant mechanisms.

Learning outcomes

Knowledge: Knowledge of most important part of the theory, facts, and principles of embodiment of application specific microsystems with piezoresistive feedback - emphasize on synergy between electronic and mechanical properties of materials, exploited technologies, microsystems' design rules, and devices' performance

Skills: Ability to transduce the targeted specification of the microsystem into a relevant selection of base material, exploited technology and microsystems' layout in application specific prototyping, emphasizing on the differences between microelectronics and microsystems

Competences: Ability to provide autonomously exploitable outcomes of all main intermediate stages of design, computer simulation, mask layers' extraction, selection of

[1] This course is developed in collaboration of TU-Sofia and the company AMG Technology

the best processing option for microsystems' fabrication, and implementation of devices' validation in accordance to the specific application

Abstract

Microsystems deal with the miniature mechanical mechanisms with embedded electronic elements fabricated by technologies similar to microelectronics. The synergy between fabrication technology and design will be demonstrated on various devices with piezoresistive feedback. Based on device specifications this course addresses the whole development cycle, incl. selection of materials and exploitable technology, as well as the design of different functional elements. The impact of different process steps and design parameters on microsystems' performance is illustrated, emphasising the options for technology or layout modifications. Examples of specific applications of cantilevers and in-plane moveable flexure mechanisms are in-depth analyzed.

Content

1. **Introduction**:
    - 1.1. Why microsystems with piezoresistive feedback? Motivation, definitions, challenges and perspectives; definition of the specific area of the course
    - 1.2. Principle of operation of different silicon microsystems – detection of flexure bending; explanation of the examination method
2. **Fabrication of microsystems**
    - 2.1. Review of materials for silicon microsystems: Why still silicon is the raw material? Short review of the materials used in fabrication of silicon microsystems?
    - 2.2. Facilities for prototyping of microsystems: issues from the practice
    - 2.3. Technology background: review, critical assessment and constrains due to the available processes in microsystems' development and prototyping
    - 2.4. Technology integration issues: process/materials' compatibility, selectivity, anisotropy, economical, etc. aspects
    - 2.5. Examples for process integration - 1: self-sensing and self-actuated cantilevers for chemical recognition and AFM
    - 2.6. Examples for process integration - 2: microsystems with sidewall piezoresistors
3. **Design aspects of microsystems' prototyping**
    - 3.1. Test procedures at development and fabrication of microstructures
    - 3.2. Design of Microdevices with Piezoresistive Feedback: examples for microsystems with planar and sidewall piezoresistors
    - 3.3. Design options for microdevices with sidewall piezoresistors. Multi-Project Wafer process – a roadmap to a one-day prototyping of microsystems
4. **Advanced applications of microsystems with piezoresistive feedback**

4.1. Cantilever sensors with embedded strain sensing for advanced applications; self-sensing cantilever sensors for AFM
4.2. Position sensors with piezoresistive feedback: 1D, 2D and 3D cases
4.3. Applications of 1D and 2D piezoresistive position sensors: scan stages for SPM and structural health monitoring (SHM)
4.4. Force measurement with sidewall piezoresistive sensors – mechanical transducers, examples and critical analysis. Weight based traceability and monitoring

Teaching methods
The theoretical part of the course, related to theory of the fabrication processes, principles of operation of microsystems and design related constrains, is presented in PowerPoint slides. The correlation between available technologies, microsystems' specifications and design rules of electrical and mechanical elements, is highlighted. Also, practical examples and results obtained at microsystems' exploitation are analyzed in details. Based on the MECA Knowledge Alliance project in partnership with TU Sofia, Bulgaria, learning environment in the form of HTML tutorials is also considered. The practical laboratory is based on interactive design and simulation activities implementing step-by step optimization using various CAD-CAM tools. Additionally, students solve practical problems found in design of application specific cases, during the lab exercises. Simultaneous meeting the microsystems' specifications and constrains of the available manufacturing technologies by means of different design approaches, is addressed in the course.

Evaluation/Assessment
The evaluation is based on the examination of concepts acquired in the course and consists of the following components:
40% - Final report targeting various problems and issues, according to those solved during the lectures and the labs;
60% - Final design project of a small complexity microsystem.

Recommended reading

- Senturia, S. D., Microsystem Design. Dordrecht: Kluwer Academic Publishers, 2021.
- Mahalik N. P., Micromanufacturing and Nanotechnology, Springer – Verlag, Berlin, 2016.
- Hsu, T.R., MEMS and Microsystems Design and Manufacture, McGraw Hill, 20012.
- Smith C. S., Piezoresistance Effect in Germanium and Silicon, Phys. Rev., vol. 94, no. 1 pp 42-49, 1954Kanda Y., A graphical representation of on piezoresistance coefficient in Silicon, IEEE Trans. Electron Devices ED29, 1982, pp 64-70.
- Schomburg W. K., Introduction to Microsystem Design, Springer-Verlag Berlin, 2011

Syllabus
"Materials in Microelectronics"

Name of the course:
Materials in Microelectronics
Course topic:
Basics of materials used in microelectronics and material processing technologies
Duration:
40 hours
Participants of the course:
Students (EQF level 6-7)
Educational background:
Bachelor and master students in electronics, electrical engineering or mechanical engineering
Course responsible:
BME-VIK Budapest
Department of Electronics Technology
Assoc. Prof. Bálint Medgyes
Course lecturers:
Assoc. Prof. Bálint Medgyes
Prof. Balázs Illés

Educational prerequisites
Basic understanding of mathematics, physics, chemistry and informatics.

Learning outcomes

Upon successful completion of this course students should be able to:

Knowledge:

- Overview the properties of metals, insulators (ceramic, plastic) and semiconductors used in microelectronics, and overview banned materials in microelectronics
- Explain the basics of materials processing technologies: semiconductor technologies, microelectromechanical systems (MEMS), thin- and thick-film technologies
- Explain typical failure mechanism in microelectronics and related (surface) analysis techniques
- Understand the basics of big data analyses in materials engineering

Skills:

- Read material documentation, technical data sheets
- Distinguish hazardous and non-hazardous materials and technologies
- Apply basic joining technologies like soldering techniques, join metals
- Inspect semiconductor components; test and characterize materials and material systems
- Perform material reliability tests

Competence:

- Choose and apply appropriate materials for different semiconductor technologies Develop and supervise material test procedures, interpret and report test results independently
- Investigate the root causes and solve material related failures in microelectronics systems
- Actively collaborate with production departments in the elimination of material related failures

Abstract

The course will cover the knowledge about materials and technologies relating to semiconductor chips including, but not limited: properties of semiconducting materials, elemental semiconductors, compound semiconductors, doping, diffusion, ion-implantation, fabrication of semiconductor wafers, Layer deposition and doping technologies, construction of transistors, patterning and device structuring of semiconductor wafers. The course overviews the material related failure mechanisms in microelectronics, and the analysis techniques aiding the reveal of these failures root causes. Furthermore, the course covers also basic knowledge of big data analyses in materials engineering.

Content

0. Introduction:
   0.1 Classification of electronic components: substrates, subassemblies, materials for electronics
   0.2 Basic assembling technologies: reflow and wave soldering, wire and dye bonding technologies.
   0.3 Mounting and packaging of semiconductor chips and module circuits

1. Basics of materials in microelectronics
   1.1 Basics of crystallography: Bravais lattice, Miller indices, crystallographic defects (point defect, dislocations), growth of single crystals, recrystallization
   1.2 Metals: mechanical characteristics and properties (tensile strength, yield point), conduction, materials of wires and resistors, temperature dependence, structure and thermal behaviour of alloys, phase-diagram, eutectics, solid solution, intermetallic compounds.
   1.3 Electrical properties: electrical properties of insulating materials, ceramics, composites, glasses, plastics

2. Materials and technologies in semiconductors:
   2.1 Properties of semiconducting materials: elemental semiconductors, compound semiconductors, doping, diffusion, ion-implantation
   2.2 Wafer technologies: fabrication of semiconductor wafers, layer deposition and doping technologies, construction of transistors, patterning and device structuring of semiconductor wafers, materials
   2.3 MEMS technologies and applications; Bulk micromachining with Si anisotropic etching, Bulk micromachining combined with CMOS, Sacrificial surface micromachining, SIMPLE, SCREAM, SOI surface technology, Packaging related technologies, application examples
   2.4 Thin film technologies: basics of vacuum technologies, vacuum sputtering, and evaporation techniques and materials. Properties of thin films, application examples

2.5 Thick film technologies: basics of ceramic based thick-films technology, polymer thick-films and multilayer ceramic technologies and materials, application examples

3. Analysis techniques in microelectronics:
   4.1 Basic analysis: metallographic investigations, cross-sectioning, optical investigations, X-ray microscope, mechanical tests, environmental tests
   4.1 Advanced analysis: scanning electron microscopy (SEM), transmission electron microscopy TEM, focused ion beam (FIB), X-ray diffraction (XRD), scanning acoustic microscope (SAM), Atomic Force Microscopy (AFM), X-Ray Fluorescence Spectroscopy (XRF), X-ray photoelectron spectroscopy (XPS)

4. Failure mechanisms in microelectronics
   4.1 Electrochemical Corrosion (ECC) and Electrochemical Migration (ECM): Basics of ECC and ECM mechanism, models, prevention methods, case studies
   4.2. Tin whisker growth: basics of tin (and other type) whisker growth, initializing factors, caused failures in microelectronics, and whisker prevention methods, case studies
   4.3 Tin pest phenomenon: basics of tin pest phenomenon, initializing factors, caused failures in microelectronics, and prevention methods, case studies

5. Big Data Analysis in Materials engineering
   5.1 Fundamentals of Big Data analysis
   5.2 Machine learning method for materials engineering

Teaching methods

The course is presented in the Moodle learning environment in the form of HTML tutorials.

Assessment

The course grade consists of these components:
100% – Knowledge test with a multiple choice questionnaire

Recommended reading

William D. Callister Jr., David G. Rethwisch, Materials Science and Engineering: An Introduction, (10th Edition), 2018, ISBN: 978-1-119-40549-8

Rao Tummala, Fundamentals of Device and Systems Packaging: Technologies and Applications, (Second Edition), ISBN-10: 1259861554

G Dartmann, H Song, A Schmeink, Big data analytics for cyber-physical systems: machine learning for the internet of things (Elsevier), 2019, ISBN: 978-0-12-816637-6

Jing Wei, Xuan Chu, Xiang-Yu Sun, Kun Xu, Hui-Xiong Deng, Jigen Chen, Zhongming Wei, Ming Lei, Machine learning in materials science, INFOMAT, Vol 1, Issue 3, September 2019, Pages 338-358.

Syllabus
"Nanomaterials in Microelectronics"

Name of the course
Nanomaterials in Microelectronics
Course topic
Nanomaterials in Microelectronics – properties and applications
Duration:
40 learning hours
Participants of the course:
Students (EQF level 6-7)
Educational background:
Bachelor and master students in electronics, electrical engineering or physics
Course responsible
BME-VIK Budapest
Department of Electronics Technology
Assoc. Prof. Dr. Attila Bonyár
Course lecturer / tutor
Assoc. Prof. Dr. Attila Bonyár

Educational Prerequisites
Previous understanding of microelectronics technology, basic knowledge in materials science

Learning outcomes

Upon successful completion of this course students should be able to:

Knowledge:

- Understand fundamental nanoscience concepts and phenomena
- Understand the effects of geometrical downscaling and the changes in materials properties on the nanoscale
- Understand the structure of materials
- Overview the special physical properties of nanomaterials: metals, semiconductors, nanocomposites, carbon allotropes
- Explain in the applicability of these nanomaterials in micro/nanoelectronics.
- Overview nanometrology methods, testing and characterization techniques of nanomaterials

Skills:

- Perform laboratory tests, and testing nanomaterials
- Perform data analysis related to nanomaterial testing and provide technical documentation
- Read and understand materials documentation

Competence:

- Choose and apply appropriate materials independently for different semiconductor technologies; take responsibility in integrating new products in manufacturing

- Develop nanomaterial test procedures based on the understanding of their properties in the nanoscale, record, analyze, and report data of material test procedures independently

Abstract
The course aims to provide students knowledge regarding the phenomena occurring in material systems where the size of the structures is between a hundred and a few million atoms (between 0.2 to 100 nm). The course has a theoretical part focusing on the changes in the physical properties of materials in the nanoscale, both from a top-down and bottom-up approach. The main focus is on the nanomaterial types and their metrology.

Content

1. The main principles of nanoscience.
    1.1 Changing of the physical properties of materials on the nanoscale.
    1.2 The structure of materials in a bottom-up approach.
    1.3 Classification of nanomaterials.
    1.4 The effects of geometrical downscaling, the problems of top-down design.
    1.5 Macroscopic physical properties (mechanical, electrical, thermal, optical, etc.) and their microscopic approach.

2. The allotropes of carbon (diamond, fullerenes, carbon nanotubes and graphene).
    2.1 Physical properties, fabrication technologies.
    2.2 The application areas of carbon nanotubes and graphene.
    2.3 Electronics (passive and active), carbon-based composites, graphene-based electronics and displays. Carbon nanotubes in sensors.

3. Metallic nanomaterials
    3.1 Electrical and optical properties.
    3.2 Theoretical background of surface plasmon resonance.
    3.3 Application areas of metallic nanoparticles.

4. Advanced material systems
    4.1 Nanocomposites
    4.2 Biomaterials for electronics
    4.3 Examples for application areas

5. Nanometrology and spectroscopy
    5.1 Comparison of microscopy methods that are applicable on the nanoscale.
    5.2 Electron microscopy (SEM, TEM).
    5.3 Scanning probe microscopy (STM, AFM, MFM, EFM, KPFM, etc).
    5.4 Spectroscopy methods (EDS, WDS, XPS, XRF, EELS, SIMS, AES, FTIR, SERS, TERS, etc.)

Teaching methods
The theoretical part of the course is presented in the Moodle learning environment in the form of HTML tutorials.

Assessment
The course grade consists of these components:
100% – Knowledge test with a multiple choice questionnaire

Recommended reading

Bhushan, Bharat: Handbook of Nanotechnology, 2003. (Spinger)

Maria Benelmekki: Nanomaterials, 2019 (IOP)

James Morris: Nanopackaging: Nanotechnologies and Electronics Packaging, 2008 (Springer)

Syllabus
"Nanotechnology in Microelectronics"

Name of the course
Nanotechnology in Microelectronics
Course topic
Nanotechnology in Microelectronics – fabrication and characterization
Duration:
20 learning hours
Participants of the course:
Students (EQF level 6-7)
Educational background:
Bachelor and master students in electronics, electrical engineering or physics
Course responsible
BME-VIK Budapest
Department of Electronics Technology
Assoc. Prof. Dr. Attila Bonyár
Course lecturer / tutor
Assoc. Prof. Dr. Attila Bonyár

Educational Prerequisites
Previous understanding of microelectronics technology, basic knowledge in materials science

Learning outcomes

Upon successful completion of this course students should be able to:

Knowledge:

- Understand basic nanotechnology concepts, top-dow and bottom-up approaches
- Understand nanomaterial types and classifications (role of quantum confinement) and respective technologies
- Explain vapour-, liquid- and solid-phase nanomaterials fabrication technologies, nanolithography-based nanofabrication technologies
- Understand the concept of nanopackaging

Skills:

- Perform data analysis related to nanomaterial testing and provide technical documentation.
- Perform advanced manufacturing and fabrication technologies.
- Read and understand materials documentation.

Competence:

- Chose and apply appropriate technologies and operate advanced manufacturing equipment for the fabrication of nanomaterials and nanosystems
- Integrate new materials and technologies in manufacturing, aid and supervise processes using nanopackaging

Abstract
The course aims to provide knowledge regarding that can be used for the fabrication and subsequent characterization of various material structures on the nanoscale. The course has three main parts: after an introduction and the classification of top-down and bottom-up approaches, the main focus is placed on the vapour, liquid and solid-phase technologies and nanofabrication. The concept of nanopackaging is also introduced.

Content

1. The main principles of nanotechnology.
    1.1 Classification of nanomaterials.
    1.2 Top-down and bottom-up approaches.

2. Nanomaterial fabrication technologies
    2.1 Vapour phase methods (PVD, PVC, CVD, CCVD, CVC, ALD, laser ablation, spray pyrolysis and coating, cryogen melting etc.)
    2.2 Liquid phase methods (electrochemical methods, sol-gel synthesis, controlled chemical reduction, self-assembly, Langmuir-Blodget technique etc.)
    2.3 Solid-state methods (transfer technologies, solid-state dewetting, milling, severe plastic deformation, etc.)
    2.4 Nanolithography (optical lithography, electron and ion beam methods, nanoimprint lithography, nano lift-off, SPM lithography etc.)

3. Nanopackaging
    3.1 The connection between electronics packaging and nanotechnology
    3.2 Nanomaterials for packaging, application areas (nanosolders, conductive adhesives, nano-interconnections, etc.)
    3.3 Advanced packaging concepts

Teaching methods
The theoretical part of the course is presented in the Moodle learning environment in the form of HTML tutorials.

Assessment
The course grade consists of these components:
100% – Knowledge test with a multiple choice questionnaire

Recommended reading

Bhushan, Bharat: Handbook of Nanotechnology, 2003. (Spinger)

Maria Benelmekki: Nanomaterials, 2019 (IOP)

James Morris: Nanopackaging: Nanotechnologies and Electronics Packaging, 2008 (Springer)

Syllabus
"Printed Circuit Design"

Name of the course
Printed Circuit Design
Course topic
Application Printed Circuit Design aspects and tools in microelectronics
Duration:
60 learning hours
Participants of the course:
Students (EQF level 6-7)
Educational background:
Bachelor and master students in electronics, electrical engineering or informatics
Course responsible
BME-VIK Budapest
Department of Electronics Technology
Assoc. Prof. Dr. Attila Géczy
Course lecturer / tutor
Assoc. Prof. Dr. Attila Géczy
Dániel Straubinger, Msc

Educational Prerequisites
Previous understanding of microelectronics technology, knowledge and practice on basic graphical editing software.

Learning outcomes

Upon successful completion of this course students should be able to:

Knowledge:

- Understand the basic concepts of CAD, CAM, CAE software tools, and their workflow
- Overview electronic components, semiconductors, sensors, integrated circuits, and system design concepts
- Understand manufacturing processes and explain the concept of design for manufacturing
- Explain printed circuit board (PCB) technologies, their quality and reliability aspects
- Overview assembly, prototyping and production basics

Skills:

- Set up a CAD working environment for efficient work
- Read assembly drawings, PCB engineering drawings
- Decompose the design workflow to specific sub-tasks, and composing circuit diagrams
- Design printed circuits using CAD tools, create virtual models of PCB assemblies, design prototypes, prepare assembly drawings, provide technical documentation on PCBs

Competence:

- Proactively participate in each step of the design workflow
- Interpret electronic design specifications, take responsibility in adjusting engineering designs, approve engineering design
- Abide by regulations on banned materials in the scope of PCB design
- Actively communicate with production, assembly and technology engineers

Abstract

The aim of the course is to get the students acquainted with the basics of PCB design. Presents the basics of PCB manufacturing and assembly technologies to prepare the students for the actual work in Computer Aided Engineering (CAE), Computer Aided Design (CAD), and Computer Aided Manufacturing (CAM) tools. The course presents the connection between the three tool types (CAE, CAD, CAM), clears up the workflow and enables PCB designing tasks on a fundamental level. The course offers actual design tasks in a CAD tool from start to finish for the students as project work. PCB design is a life-long learning knowledge, so the course sets a starting path for students who want to start their own designs and want to know the exact position of their part in the entire production chain of microelectronic assemblies.

Content

1. Basics of PCB Assembly technologies
   1.1 Classification of electronic components, substrates, subassemblies, materials for electronics; through-hole and surface mounted component.
   1.2 Reflow soldering technology, selective soldering technologies
   1.3 Mounting and packaging of semiconductor chips and module circuits
   1.4 Single-sided and double-sided printed wiring boards, multilayer printed wiring

2. Design of PCB Assemblies
   2.1 Basics of PCB CAD design
      Basic terms of CAE, CAD, CAM
      Design Flow
      How to extend the design flow with additional tasks
      Structure of a computer-aided design system.
      Methods, possibilities and functions of the conceptual circuit diagram design.
   2.2 CAD Design Flow
      Circuit module design steps. Schematic diagram design. Component decals and symbols.
      Using and editing the library of symbols in the conceptual circuit diagram.
      Manual and interactive methods of layout design. Machine design capabilities, strategies. Manual layout (wiring) design. Interactive wiring design. Autorouter.
      Inspection (DRC), Documentation preparation. Generating production files.
      Schematic diagram finalization, role of Bill-of-Materials (BOM), preparation of design rules.
      AM connections, manufacturability design.
   2.3 Additional techniques
      Using library editor tools.
      Using third party component design tools.
      Datasheets and microelectronic component information for design.

Teaching methods
The practical method of the course is supported by online video tutorials.
The theoretical part of the course is presented in the Moodle learning environment in the form of HTML tutorials.

Assessment
The course grade consists of these components:
50% – Knowledge test with a multiple choice questionnaire
50% – Project task

Recommended reading

Clyde F. Coombs, Printed Circuits Handbook, 2015., McGraw-Hill Professional, 9780071833950

Rao R. Tummala: Fundamentals of Microsystems Packaging, McGraw-Hill, 2001, 0071371699

Chris Robertson, Printed Circuit Board Designer's Reference; Basics, 2003. Prentice Hall PTR, 9780130674814

Leonard Marks, James Caterina, Printed Circuit Assembly Design, 2000., McGraw-Hill Professional, 9780070411074

Shawn Wallace, Jumpstarting Your Own PCBs: Learn How to Design and Make Customized Circuit Boards, 2013. Maker Media, 9781680455083

David L. Jones, PCB Design Tutorial, Revision A-June 29th 2004

Syllabus
"Quality assurance techniques in microelectronics"

Name of the course
Quality assurance techniques in microelectronics
Course topic
Application of quality assurance techniques and statistical tools in microelectronics
Duration:
20 learning hours
Participants of the course:
Students (EQF level 6-7)
Educational background:
Bachelor and master students in electronics, electrical engineering or informatics
Course responsible
BME-VIK Budapest
Department of Electronics Technology
Prof. Dr. Balázs Illés
Course lecturer / tutor
Prof. Dr. Balázs Illés
Assoc. Prof. Dr. Krammer Olivér

Educational Prerequisites
Previous understanding of microelectronics technology, basics of statistics and probability theories.

Learning outcomes

Upon successful completion of this course students should be able to:

Knowledge:

- Understand test procedures, standardization, and audit techniques in microelectronics
- Overview quality standards, quality assurance methodologies, and quality assurance procedures
- Explain statistical concepts in quality control
- Understand the basics of artificial intelligence and big data handling

Skills:

- Support implementation of quality management systems
- Establish data processes and manage data collection systems
- Analyse production processes for improvement and execute analytical mathematical calculations, perform risk analysis
- Identify improvement actions and process improvements

Competence:

- Supervise the whole quality control system, set quality assurance objectives and define or approve manufacturing quality criteria in microelectronics
- Develop and approve standardisation procedures, aid standardisation audits

- Actively communicate with the production department in the elimination quality problems in manufacturing

Abstract

The aim of the course is to get the students acquainted with the concept of quality assurance, quality management, quality control, and statistical process control techniques. The course presents the basic statistical methods, which are essential for the quality control of mass production systems in microelectronics. After getting trained with the general concepts and methods of quality assurance, the module discusses special qualification methods for microelectronics and the most important asset testing methods and their tools. It shows the importance of designing for microelectronics testability and its elements. The course touches on the most novel techniques related to the industry 4.0 concept, like the application of artificial intelligence and big data analysis aspects in quality assurance.

Content

1. Basics of quality assurance in microelectronics
   - 1.1 Probability theory and statistics in quality assurance:
     Statistical bases of quality assurance, probability calculations, and statistics. Probability variables and distributions, parameters of fluctuation, laws of large numbers.
   - 1.2 The concept of quality assurance systems
     Quality assurance principles and systems. Origin and principles of TQC, TQM and ISO 9xxx, and other quality assurance systems. Basics of Manufacturing Enterprise Systems (MES).
   - 1.3 Graphical representations of statistical data
     Basic statistical software, normality testing, concept and application of time series, bar charts, and box plots.

2. Sampling in quality assurance
   - 2.1 Basics of sampling techniques
     The basics of sampling and sampling control in quality assurance. Related problems due to mass and high added value production concept. The AQL method and its application. Industrial examples.
   - 2.2 Sample evaluation techniques
     Basics of estimation theory, accuracy of sampling estimations, hypothesis tests, correlation tests and R&R studies.

3. Statistical Process Control (SPC)
   - 2.1 Basics of SPC
     Data collection and classification, process parameters and control cards, acceptance and intervention boundaries, SPC decision algorithms, and industrial examples.
   - 2.2 Machine and process capability tests
     Concept of error rate, machine and process capability indices, concept and calculation of quality capacity, meaning of stabilized production, and industrial examples.

4. Quality 4.0
   - 4.1 Elements of Quality4.0
     - Differences between the traditional quality control and Quality4.0 concepts
     - Overview of the pillars of Quality4.0 framework: aspects from the scope of process, people, technology
     - Management of autonomous and/or connected systems
   - 4.2 Data and analytics
     - Characteristics of data (volume, variety, velocity, veracity, transparency), big data handling, data strategy, data driven decision making
     - Data analytics strategies, descriptive and predictive analytics, visualisation techniques
   - 4.3 Connectivity and scalability
     - Devices, technologies and platforms for connectivity, connected products, quality plans and work instructions, connected testing, connected supply chain, business information connection to Enterprise Quality Management Systems (EQMS), to Product Life-cycle Management (PLM), to Enterprise Resource Planning – and Operational Technology
     - Cloud computing providing Software as a Service (SaaS), Infrastructure as a Service (IaaS), Platform as a Solution (PaaS), and connection of databases;

Teaching methods

The theoretical part of the course is presented in the Moodle learning environment in the form of HTML tutorials.

Assessment

The course grade consists of these components:
100% – Knowledge test with a multiple choice questionnaire

Recommended reading

Michael Pecht, Abhijit Dasgupta, John W. Evans, Jillian Y. Evans (1994), Quality Conformance and Qualification of Microelectronic Packages and Interconnects, ISBN: 978-0-471-59436-9

Ray Tricker (2014), Defence Electronics: Standards and Quality Assurance, Butterworth-Heinemann, ISBN-10: 1483133095

Stebbing, L. (1993). Quality Assurance: The Route to Efficiency and Competitiveness (3rd ed.). Prentice Hall. ISBN 978-0-13-334559-9.

Pyzdek, T, "Quality Engineering Handbook", 2003, ISBN 0-8247-4614-7

Papp, J. (2014). Quality Management in the Imaging Sciences. Elsevier Health Sciences, ISBN 978-0-323-26199-9.

Syllabus
"Smart manufacturing in microelectronics"

Name of the course
Smart manufacturing in microelectronics
Course topic
Design, perform and test assembly processes in microelectronics
Duration:
60 learning hours
Participants of the course:
Students (EQF level 6-7)
Educational background:
Bachelor and master students in electronics, electrical engineering or mechanical engineering
Course responsible
BME-VIK Budapest
Department of Electronics Technology
Assoc. Prof. Dr. Oliver Krammer
Course lecturer / tutor
Assoc. Prof. Dr. Oliver Krammer

Educational Prerequisites
Basic understanding of microelectronics technology, physics and mechanics

Learning outcomes

Upon successful completion of this course students should be able to:

Knowledge:

- Explain the assembly steps of electronic circuits and products, understand the environmental legislation and environmental threats related to electronics substrates
- Explain the inspection methods and strategies of electronics assembly procedures
- Overview the testing and qualification methods of electronic assemblies both from materials and joints points of view
- Understand the concept of Industry4.0, list its elements and explain its application in electronics manufacturing

Skills:

- Assemble printed circuit boards, apply soldering techniques
- Prepare assembly instructions, monitor production processes
- Read assembly drawings, PCB engineering drawings
- Inspect the quality of the products on assembly lines, check the quality of raw materials and end-products
- Perform resource planning, asses the life cycle of resources

Competence:

- Interpret electronic assembly specifications, take responsibility in adjusting process parameters, approve process parameters
- Abide by regulations on banned materials in the scope of electronics assembly
- Be committed to ensure health and safety regulations in manufacturing
- Proactively aids the establishment of data processes in manufacturing
- Actively communicate with design, production, and quality engineers

Abstract

The aim of the course is to get the students acquainted with the assembly technologies of complex electronic circuits, the factors affecting the quality and quality testing methods of electronic circuits. The course covers the main steps of reflow soldering technology in details, the equipment used for in-manufacturing inspection and the equipment for quality checks. The course presents the concept of smart manufacturing and Industry4.0, and their application in microelectronics.

Content

1. Assembly technologies
   1.1 Technological parameters of circuit substrates (coefficient of thermal expansion, glass transition temperature), environmental legislations in materials for substrates, substrate design for manufacturability and assembly
   1.2 Wire bonding in microelectronics, plasma cleaning, die-attach, bonding techniques
   1.3 Manufacturing technologies of stencils and masks, stencil design principles, pin-in-paste technology considerations
   1.4 Rheological properties of suspensions, process parameters of stencil printing, eliminating printing failures
   1.5 Process of component placement, characterising the placement offset of placement machines, eliminating placement failures
   1.6 Physical and physical-chemical processes in soldering technologies, wetting behaviour of liquids, intermetallic compound formation, elimination of soldering failures

2. Inspection and qualification techniques of electronic assemblies
   2.1 Inspection equipment of electronics assembly: manual and automatic solder paste inspection (2D-3D inspections), automatic optical inspections, colour mapping inspection, automatic X-ray inspections, computed tomography inspections
   2.2 Electrical qualification of electronics assemblies, in-circuit tests, flying probe tests, boundary tests
   2.3 Wetting qualification of liquids used in electronics assembly technologies, wetting balance, spreading tests, bridging tests
   2.4 Mechanical qualification of solder materials, solder joints, and wire-bonded joints, tensile and shear tests, hardness tests, dye-penetration tests

3. Industry 4.0 and smart manufacturing
   3.1 Concept of Industry 4.0 and smart manufacturing in microelectronics
   3.2 Autonomous and connected manufacturing equipment, interconnection and interaction between assembly machines (M2M) in electronics assembly
   3.3 Sensor utilisation, data collection, data handling and data analytics, basics of cybersecurity
   3.4 Advanced production control and supervision utilising mobile technologies

3.5 Advanced supply chain management of electronics manufacturing

Teaching methods

The theoretical part of the course is presented in the Moodle learning environment in the form of HTML tutorials.

Assessment

The course grade consists of these components:
100% – Knowledge test with a multiple choice questionnaire

Recommended reading

Clyde F. Coombs, Printed Circuits Handbook, 2015., McGraw-Hill Professional, 9780071833950

Sauer et al., Electronics Process Technology, 2006., Springer, 9781846283536

Illés et al., Reflow Soldering – Apparatus and Heat Transfer Process, 2020., Elsevier, 9780128185056

Shangguan, Lead-Free Solder – Interconnect Reliability, 2005., ASM International, 9780871708168

Syllabus
"System Design for Electronic Modules"

Name of the course
System Design for Electronic Modules
Course topic
System Design for Electronic Modules – aspects for designing a module and system in microelectronics
Duration:
60 learning hours
Participants of the course:
Students (EQF level 6-7)
Educational background:
Bachelor and master students in electronics, electrical engineering or informatics
Course responsible
BME-VIK Budapest
Department of Electronics Technology
Assoc. Prof. Dr. Attila Géczy
Course lecturer / tutor
Assoc. Prof. Dr. Attila Géczy
Dániel Straubinger, Msc

Educational Prerequisites
Previous understanding of microelectronics technology, basic knowledge and practice on electronic components and modules

Learning outcomes

Upon successful completion of this course students should be able to:

Knowledge:

- Understand the basics of electricity principles for design aspects, and physics principles for thermal and electromagnetic compatibility (EMC) aspects
- Overview devices and module components from microelectronics (semiconductor level) to macro building block-components (system level)
- Overview sensor types, and explain their places in a specific system
- Understand the basics of wired and wireless communication technologies

Skills:

- Develop product design, design prototypes, prepare system-level engineering and assembly drawings
- Design electronics systems considering appropriate thermal and EMC performances
- Design electronics systems utilising various sensors
- Design system-communication utilising either wired or wireless technologies

Competence:

- Coordinate engineering team responsible for the entire life cycle of electronics products, aid the integration of new electronics products in manufacturing

- Interpret system design specifications, take responsibility in adjusting system designs, approve system design
- Abide by regulations on banned materials in the scope of electronics system design
- Actively communicate with other departments responsible for the entire value chain of electronics products

Abstract

The aim of the course is to get the students acquainted with the design process in which electronically functionally defined components, modules and systems (that can be operated under specified conditions) can be created; and to illustrate through practical examples the validation of manufacturability, testability, interference protection, thermal protection and safety aspects, which are influencing the electronics system design.

Content

1. Module circuits and constructions
   1.1 Construction principles of electronic appliances
   1.2 Electronic and structural design of devices.
   1.3 Thermal management and construction of electronic appliances - thermal aspects: heat conduction, heat transfer, heat radiation, heatsinks, heat pipe. Design aspects by thermal principles.
   1.4 Basics of electromagnetic compatibility, interference model, signal coupling types. Data and signal line protection, shielding, interference protection, design of earthing systems.
   1.5 Environmental aspects in electronic design, degradable circuits, RFID case study

2. System design
   2.1 System engineering basics.
   What is a system? System levels; task decomposition for a system engineer; AI in design.
   2.2 Sensor basics.
   What is a sensor? Analog sensors; digital sensor matching and coding methods. Special signal transmission methods (light, radio frequency), transmitters, transducers - analog / digital.
   2.3 Basics of wired and wireless communication.
   Wired technologies and coding methods.
   Wireless technologies and wireless system topologies.

Teaching methods

The theoretical part of the course is presented in the Moodle learning environment in the form of HTML tutorials.

Assessment

The course grade consists of these components:
100% – Knowledge test with a multiple choice questionnaire

Recommended reading

Clyde F. Coombs, Printed Circuits Handbook, 2015., McGraw-Hill Professional, 9780071833950

Rao R. Tummala: Fundamentals of Microsystems Packaging, McGraw-Hill, 2001

Bosch Automotive Handbook, 2002, Bentley Publishers, 0837610974

Syllabus – Basic Project Management

Name of the course:
Basic Project management
Course topic:
Project work
Agile management
Duration:
64 learning hours
Participants of the course:
Students
Educational background:
Candidates with a secondary education diploma or a four-year diploma of vocational education and training supplemented by an annual course of higher technical education and training (IFTS)
Course responsible:
Kennedy Foundation – IAL FVG
Dr. Valerio Libralato
Dr. Simonetta Moro
Course lecturiers :
Currently not available. At least 50% of the teaching staff comes from the world of work and professions
Educational prerequisites
Students with a good knowledge of computer science and the English language and after passing a selection
Learning outcomes
Upon successful completion of this course students should be able to:
**** Knowledge***
- Basic concepts of project planning, considering elements such as resource constraints, project risks, deadlines.
- Objective and subjective difficulties in dealing with estimates; know tools for collaborative estimating (e.g. planning poker), in order to reduce the possibility of significant errors
- Importance and functioning of version management tools (e.g. git)
- Automated approaches to validation (ATDD/BDD)
- Criticality of deployment operations, from a technical point of view, but also in relation to social dynamics with colleagues and customers

**** Skills***
- managing the entire development cycle of a complex software project, carried out in teams
- knowing how to collect requirements effectively; knowing how to deal with them in the traditional way (with exhaustive documentation), or through user stories, spike solutions and prototypes
- to know how to document a software project, in a more or less formal way (depending on the development methodology chosen, as well as the recipients and the purposes of the documents); hints on the main standards for documentation (e.g. use case, class and sequence diagrams in UML)
- setting up a development process with TDD (Test Driven Development)
- to know how to manage the relationship with the client/manager, even when the latter is not technically prepared and therefore there are difficulties in dialogue

**** Competence***
Apply and integrate the technological skills acquired and follow a complete development cycle with the application of Agile methodologies and with reference to the representation and development standards typical of electronic engineering. Manage the economic and management aspects of a project, as well as the relational and communication aspects with members of the development team, managers and the client.
Abstract
Acquire the knowledge and advanced skills to follow a complete development cycle with the application of Agile methodologies and manage the economic and management aspects of a project.
Content
- Basic concepts of project planning, considering elements such as limited resources, project risks, deadlines
- Objective and subjective difficulties in dealing with estimates; know tools for collaborative estimation (eg planning poker), in order to reduce the possibility of significant errors
- Importance and functioning of version management tools (e.g. git)
- Automated approaches to validation (ATDD / BDD)

- Criticality of deployment operations, from a technical point of view, but also in relation to social dynamics with colleagues and the customer

Teaching methods

- frontal lessons
- individual and group exercises
- individual exercises in the equipped laboratory

Assessment

The course grade consists of these components:
Knowledge test with open and multiple-choice answers
Project Work

Syllabus – Advanced Project Management

Name of the course:
Advanced Project management
Course topic:
Project work
Agile Management II Lev
Duration:
64 learning hours
Participants of the course:
Students
Educational background:
Candidates with a secondary education diploma or a four-year diploma of vocational education and training supplemented by an annual course of higher technical education and training (IFTS)
Course responsible:
Kennedy Foundation – IAL FVG
Dr. Valerio Libralato
Dr. Simonetta Moro
Course lecturiers :
Currently not available. At least 50% of the teaching staff comes from the world of work and professions
Educational prerequisites
Candidates with a good knowledge of computer science and the English language
Learning outcomes
Upon successful completion of this course students should be able to:
**** Knowledge***
- Logic and aims of the TD
- Phases, tools and working methods of DT
- Fundamental aspects of continuous integration and continuous deployment
- Introduction to issue tracking systems for maintenance and extension management
- Characteristics of system and application monitoring systems

**** Skills***
- Designing the prototype of the project work according to the DT methodology for identifying the problem and defining the project requirements
- Planning the updating and maintenance processes of a complex application and carrying out its refactoring
- Evaluate the use of monitoring systems to keep the health of an application under constant control, and be proactive in dealing with any anomalies.
- address and manage problems with debugging and troubleshooting techniques

**** Competence***
Conceive, design, develop a cloud-based business application, experimenting with the Design Thinking methodology
Abstract
Acquire the knowledge and advanced skills to develop a cloud-based business application using the Design Thinking methodology
Content
- Logic and purpose of the TD
- Phases, tools and working methods of the TD
- Fundamentals of continuous integration and continuous deployment
- Introduction to issue tracking systems for the management of maintenance and extension interventions
- Characteristics of the monitoring systems of a system and an application

Teaching methods
- frontal lessons
- individual and group exercises
- individual exercises in the equipped laboratory

Assessment
The course grade consists of these components:
Knowledge test with open and multiple-choice answers

Syllabus – Design of microcontroller devices to project specification

Name of the course:
Design of microcontroller devices to project specification
Course topic:
Design of microcontroller devices
Duration:
87 learning hours
Participants of the course:
Students and Workers
Educational background:
Candidates with a secondary education diploma or a four-year diploma of vocational education and training
Course responsible:
IAL FVG
Dr. Diletta Covre
Dr. Bortolani Mauro
Course lecturiers :
Currently not available. At least 50% of the teaching staff comes from the world of work and professions
Learning outcomes
Upon successful completion of this course students should be able to:
**** Knowledge***
- Basic physics (measurements, forces)
- Elements of mathematics (solving first degree systems, trigonometry)
- Basic laws for solving electrical networks
- Properties and solving techniques of Boolean functions
- Use of sequential logic components
- Main characteristics of commonly used electronic components
- Architecture of microprocessor/microcontroller systems
- Open source electronic design environments
- Hardware communication protocols
- Metrology and measuring instruments
- Safety, hygiene and environmental protection regulations

**** Skills***
- Solving problems related to electrical networks in steady state
- synthesise logic circuits from the problem
- define design parameters
- choose suitable components
- use specific instrumentation to measure and test the system
- apply techniques for the production of prototypes or small series
- Use CAD software to produce the schematic and layout to arrive at the production of the printing master
- Integrate pre-assembled boards for connectivity into projects

**** Competence***
On the basis of the entrusted project specifications, contribute to the realisation of the schematic, the layout of the board and produce the print master for the production of the prototype and the series also with a view to energy/economic sustainability.
Abstract

Content
Electric charges
Electrical forces
Resistive effects
Electric generators
Analysis of networks in steady state
Qualitative behaviour of capacitors and inductors
Generalities on periodic and sinusoidal quantities
Semiconductors (Diode, BJT transistor, MOS, OPAMP)
Power supply circuits

Combinational logic, Gates and application circuits
Sequential logic, registers and counters
Memories
The Microcontroller
Oscillator
GPIO
AD/DC Converter
EDA CAD
Schematic
Layout
Print Master Production
Fabrication Techniques
Component Welding
Electrical Testing

Teaching methods

- frontal lessons
- individual and group exercises
- individual exercises in the equipped laboratory
- Synchronous distance learning (e.g. videoconferencing, webinars, e-learning)
- Dual training in Italian or in European companies

Assessment

The course grade consists in:
Production of microcontroller devices to project specification

Syllabus – Embedded development

Name of the course:
Embedded development
Course topic:
Embedded development
Duration:
44 learning hours
Participants of the course:
Students
Educational background:
Candidates with a secondary education diploma or a four-year diploma of vocational education and training supplemented by an annual course of higher technical education and training (IFTS)
Course responsible:
Kennedy Foundation – IAL FVG
Dr. Valerio Libralato
Dr. Simonetta Moro
Course lecturiers :
Currently not available. At least 50% of the teaching staff comes from the world of work and professions
Learning outcomes
Upon successful completion of this course students should be able to:
**** Knowledge***
- Constructs of the C programming language from the perspective of low-level programming.
- Data structures
- Memory management.

**** Skills***
- Programming a microcontroller for interfacing with peripheral devices
- Manage communication between devices and digital sensors (synchronous bus, I2C, SPI, Modbus)
- Implement the User Interface
- Testing the program
- Manage and resolve hw/sw errors and malfunction

**** Competence***
Write code for microcontrollers considering interconnections with peripheral devices.
Abstract
The course gives specialized training in use of modern methods, techniques, and tools for design of embedded systems **Content**
- Constructs of the C programming language from the perspective of low-level programming.
- Data structures
- Memory management

Teaching methods
- frontal lessons
- individual and group exercises
- individual exercises in the equipped laboratory

Assessment
The course grade consists of these components:
Knowledge test with open and multiple-choice answers
Project Work

Syllabus – Firmware development

Name of the course:
Firmware development
Course topic:
Firmware
Duration:
98 learning hours
Participants of the course:
Students and Workers
Educational background:
Candidates with a secondary education diploma or a four-year diploma of vocational education and training
Course responsible:
IAL FVG
Dr. Diletta Covre
Dr. Bortolani Mauro
Course lecturiers :
Currently not available. At least 50% of the teaching staff comes from the world of work and professions
Learning outcomes
Upon successful completion of this course students should be able to:
**** Knowledge***
- Fundamentals of information coding
- Algorithmic
- C programming language
- Architecture development environment used
- Fundamentals of networking
- Characteristics of communication protocols
- Technical and functional characteristics of networks and computer equipment
- Notes on Internet of Things techniques and technologies
- Safety, hygiene and environmental protection regulations
-Typologies and technical characteristics of the main PLCs and related components installed in industrial automations
- Software development techniques for PLCs
- Types of programming languages for PLCs
- Types of signals and relative connection interfaces
- Signal acquisition methods

**** Skills***
- Configure and manage the development environment
- Develop firmware for microcontroller boards
- Create simple user interfaces on I/O standards
- Perform debugging and testing procedures
- Interface microcontroller devices to the network
- Use processing software to process data and make objects act
- Use networks, sensors and actuators to connect and interact with objects, people and environments
- Operate according to industry-specific safety regulations
- Define customer requirements by proposing the most suitable automation logic
- Developing PLC programs in different languages
- Developing PLC applications based on automation process (P&I) indications
- Developing industrial automation applications and integrating safety management into the software
- Manage and develop supervision applications for industrial automation
- Developing applications for process data management and processing

**** Competence***
According to project specifications, to program microcontroller boards in RTOS environment, embedded systems with operating system and simple PLC system
Abstract
This course is for beginner electronic students who want to gain and increase experience in program microcontroller boards in RTOS environment, embedded systems with operating system and simple PLC system

Content
Boolean logic
Programming languages
The basics of C
Structured programming
Interfacing with external devices
Tasks
File I/O
Protocols
RTOS
Logic Recalls
PLC Programming
Teaching methods
- frontal lessons
- individual and group exercises
- individual exercises in the equipped laboratory
- Synchronous distance learning (e.g. videoconferencing, webinars, e-learning)
- Dual training in Italian or in European companies
Assessment
The course grade consists in:
Practical exercise to program microcontroller in RTOS environment, embedded systems with operating system and simple PLC system

Syllabus – OPC

Name of the course:
OPC
Course topic:
OPC
Duration:
42 learning hours
Participants of the course:
Students
Educational background:
Candidates with a secondary education diploma or a four-year diploma of vocational education and training supplemented by an annual course of higher technical education and training (IFTS)
Course responsible:
Kennedy Foundation – IAL FVG
Dr. Valerio Libralato
Dr. Simonetta Moro
Course lecturiers :
Currently not available. At least 50% of the teaching staff comes from the world of work and professions
Learning outcomes
Upon successful completion of this course students should be able to:
**** Knowledge***
- Role of the OPC standard in IIoT
- Popular OPC specifications (DA, Alarms & Events, Historical Data Access, etc.) and more recent ones (OPC-UA)
- Operation of some popular OPC servers (e.g. Kepware KEPServerEX or Matrikon OPC Server and/or others)

**** Skills***
- Design solutions for interfacing and communicating with devices using the OPC standard
- Choose and apply the most suitable OPC specifications for the context of use
- Connect and interact with an OPC server, managing the associated devices
- Manage the security aspects of communications

**** Competence***
Designing and implementing solutions for interfacing and communicating with automation devices and systems using the OPC (Open Platform Communications) standard
Abstract
Acquire the knowledge and advanced skills to Designing and implementing solutions for interfacing and communicating with automation devices and systems using the OPC (Open Platform Communications) standard
Content
- Role of the OPC standard in the IIoT environment
- Most popular OPC specifications (DA, Alarms & Events, Historical Data Access, etc.) and the most recent ones (OPC-UA)
- Operation of some popular OPC servers (eg Kepware KEPServerEX or Matrikon OPC Server and / or others)

Teaching methods
- frontal lessons
- individual and group exercises
- individual exercises in the equipped laboratory

Assessment
The course grade consists of these components:
Knowledge test with open and multiple-choice answers
Project Work

Syllabus – Sensor assessment applicable to the project

Name of the course:
Sensor assessment applicable to the project
Course topic:
Sensor assessment
Duration:
58 learning hours
Participants of the course:
Students and Workers
Educational background:
Candidates with a secondary education diploma or a four-year diploma of vocational education and training
Course responsible:
IAL FVG
Dr. Diletta Covre
Dr. Bortolani Mauro
Course lecturiers :
Currently not available. At least 50% of the teaching staff comes from the world of work and professions
Learning outcomes
Upon successful completion of this course students should be able to:
**** Knowledge***
Understanding what sensors are and what they are used for
Learn the basics of how the major types of sensors work
Understand the importance of using high-performance sensors in an industrial environment
**** Skills***
Select sensor and interface products suitable for the development of the product and system in use
**** Competence***
Based on project specifications, select sensor and interface products suitable for product development.
Abstract
This course is for beginner electronic students who want to gain and increase experience in select sensor and interface products suitable for product development
Content
- Elements of physics (units of measurement, space, time, speed, acceleration, forces ...)
- Main sensors on the market and their characteristics
- Temperature sensors
- Load Cells
- Vibration sensors - Accelerometer
- Acoustic sensors - Microphones
- Current Sensors
- Voltage Transducers - Potential Transducers
- Optical Sensors
- List of the main sensor suppliers by sensor type
- Practical exercises focused on the comparative evaluation of the characteristics of the main sensors and identification of those that best meet the requirements of the project to be carried out.

Teaching methods
- frontal lessons
- individual and group exercises
- individual exercises in the equipped laboratory
- Synchronous distance learning (e.g. videoconferencing, webinars, e-learning)
- Dual training in Italian or in European companies

Assessment
The course grade consists in:
Practical exercise to select sensor and interface products

Syllabus
"Basic IIoT Systems"

Name of the course:
"Basic IIoT Systems"

Course topic:
- Electronics engineering Principles
- Basic PLC

Duration:
66 learning hours

Participants of the course:
Students

Educational background:
Candidates with a secondary education diploma or a four-year diploma of vocational education and training supplemented by an annual course of higher technical education and training (IFTS)

Course responsible:
Kennedy Foundation – IAL FVG
Dr. Valerio Libralato
Dr. Simonetta Moro

Course lecturiers :
Currently not available. At least 50% of the teaching staff comes from the world of work and professions

Educational prerequisites
Students with a good knowledge of computer science and the English language and after passing a selection

Learning outcomes
Upon successful completion of this course students should be able to:
Knowledge
understand the connections and technologies underlying the sensors, their conditioning and the architecture of the programmable electronic boards.
Skills
Identifying the components that make up the hardware structure of a Siemens PLC
Connect a Siemens S7-300 PLC to your PC
Interface PLC I/O devices
Interpret input and output unit parameters and diagnostic data
Interact with various programming languages (AWL, KOP, FUP)
Make changes to an existing program
Use basic internal functions
Check the status of Input, Output, Memory, Timer, Counter, Data Blocks, Variable Table
Competence
Interpret, modify and write simple programs for the use of PLCs, identifying a failure in the implementation of the program that manages industrial automation systems.

Abstract
Acquiring the basic principles of electrical and electrical engineering in order to understand the connections and technologies behind sensors, their conditioning and the architecture of programmable electronic boards are the subject of this course.
The main focus is on the programming of SIEMENS PLCs in an industrial context, in order to interpret, modify and write simple programs for the use of PLC and identify the faults in the implementation of the program that manages industrial automation systems.

Content

* Electronics and electrical engineering
- Fundamentals of electrical networks: Ohm's laws and Kirchhoff's principles
- Identification of the main electronic components and general knowledge of their operation.
- Digital electronics, combinatorial logic and simplification properties.
- Sequential circuits, Registers.
- Basic microprocessor architecture.
- Signal conditioning circuits.
- ADC, DAC
- Sensors and Actuators
* Basic PLC
- Main fields of application of the PLC in industrial automation
- Hardware structure of the various components that make up the PLCs (power supplies, CPUs, digital units, analogue units, special units for signals, interface units)
- Internal PLC memory functions (storage, timing, counting, mathematical operations, jump and call functions)
- All possible I / O devices
- Linear and structured programming mode: Organization blocks (OB); Program blocks (FC); Functional blocks (FB); Data blocks (DB)
- Know the various languages used in PLC programming: instruction list (AWL); simulated representation of contacts (LAD); representation with logic functions (FBD)
- Basic logical instructions (AND, OR, NOT, SET, RESET, ASSIGNMENT)
- Addressing, cabling and networking methods
- The language with standard blocks
- The technical language of the sector (also in English)
- Guidelines governing the legislation of the sector

Teaching methods

- frontal lessons
- individual and group exercises
- individual exercises in the equipped laboratory

Assessment

The course grade consists of these components:
Knowledge test with open and multiple-choice answers
Project Work

Syllabus –
"Advanced IIoT systems"

Name of the course:
Advanced IIoT systems
Course topic:
PLC adv
IoT protocols
Embedded development
SoC and Single-Board
Duration:
164 learning hours
Participants of the course:
Students
Educational background:
Candidates with a secondary education diploma or a four-year diploma of vocational education and training supplemented by an annual course of higher technical education and training (IFTS)
Course responsible:
Kennedy Foundation – IAL FVG
Dr. Valerio Libralato
Dr. Simonetta Moro
Course lecturiers :
Currently not available. At least 50% of the teaching staff comes from the world of work and professions

Educational prerequisites
Have successfully attended the course "Basic IIoT Systems" or have a similar background in terms of knowledge, skills and competences

Learning outcomes
Upon successful completion of this course students should be able to:
**** Knowledge***
Distinguishing the elements of complex PLC programming and PLC control interface management
Understanding which protocols are suitable in different communication scenarios between intelligent devices.
Understand and be able to choose some of the most used protocols at application level (MQTT, AMQP, CoAP)
Identify which protocols and/or standards are preferred according to the usage scenario
Understanding the general architecture of an SoC, integration between local and cloud systems, software prototyping methodologies for IoT
**** Skills***
Implement and execute a complex PLC program from technical specifications that are realistic for the world of Industrial Automation.
Use the tools of the STEP 7 package for software diagnostics and troubleshooting.
Implement Human Machine Interface systems
Apply some of the most widely used protocols at application level (MQTT, AMQP, CoAP)
Connect and interface devices
Ensure security, authenticity and confidentiality of communications
Programming a microcontroller for interfacing with peripheral devices
Manage communication between devices and digital sensors (synchronous bus, I2C, SPI, Modbus)
Implement the User Interface
Testing the program
Manage and resolve hw/sw errors and malfunctions
Install and configure a Linux system based on SoCs
Use and administer the system via CLI
Configure the system for service delivery (MQTT)
Use the system as an application server (node.js)
Implement interfacing with devices via RS485 via dedicated bus and cloud via defined protocol (based on MQTT and JSON format)
Prototype SW with visual design tool for validation of development models (Node-Red)

**** Competence***
Implementing automation and control systems by programming PLCs and embedded systems, identifying and managing the most suitable protocols for interconnection.

Abstract
Acquire the knowledge and advanced skills to implement automation and control systems by programming PLCs and embedded systems, identifying and managing the most suitable protocols for interconnection.

Content
* PLC
- Parameterization and clock flags
- Conversion and displacement functions
- Capacity of the FB functional blocks with dedicated DB
- Fast counts in order to control the position of an encoder
- Management of analogue inputs and outputs and special inputs for temperature probes
- Management of an inverter through a PLC
> HMI (Human Machine Interface)
*- Introduction and explanation of the potential of a graphical user interface
- Organization of the interface pages
- Management of variables
- Simple object functions (button, switch, graphic bar, graphic I / O field, symbolic I / O field, date and time field, elementary shapes)
- Management of PLC connection settings
* IoT protocols
- Understand and know how to choose some of the most used protocols at the application level (MQTT, AMQP, CoAP)
- Role and status of the main IoT communication standards.
- Identify which protocols and / or standards are to be preferred based on the usage scenario
* Embedded development
- Constructs of the C programming language from the perspective of low-level programming.
- Data structures
- Memory management
* SoC and Single-Board
- Know the general architecture of a SoC
- Integration of three local and cloud systems
- Software prototyping methodologies for the IoT

Teaching methods
- frontal lessons
- individual and group exercises
- individual exercises in the equipped laboratory

Assessment
The course grade consists of these components:
Knowledge test with open and multiple-choice answers
Project Work

Syllabus – IIoT Solutions

Name of the course:
IIoT Solutions
Course topic:
OPC
Cloud for IoT
Design Patterns
Cloud Architectures
BigData Management
AI with Python
Duration:
182 learning hours
Participants of the course:
Students
Educational background:
Candidates with a secondary education diploma or a four-year diploma of vocational education and training supplemented by an annual course of higher technical education and training (IFTS)
Course responsible:
Kennedy Foundation – IAL FVG
Dr. Valerio Libralato
Dr. Simonetta Moro
Course lecturiers :
Currently not available. At least 50% of the teaching staff comes from the world of work and professions
Educational prerequisites
Have successfully attended the course "Advanced IIoT Systems" or have a similar background in terms of knowledge, skills and competences
Learning outcomes
Upon successful completion of this course students should be able to:
**** Knowledge***
- Role of the OPC standard in IIoT
- Popular OPC specifications (DA, Alarms & Events, Historical Data Access, etc.) and more recent ones (OPC-UA)
- Opera
- Principles for distributing processing on a computing infrastructure, possibly cloud-based
- Development models of cloud-based solutions
- Microsoft Azure platform services
- Criteria, methods and tools for scalability and distributed computing
- Knowing the differences between Azure IoT Hub, Service Bus and Event gridtion of some popular OPC servers (e.g. Kepware KEPServerEX or Matrikon OPC Server and/or others)
- The main and most used design patterns (Creational, Structural and Behavioural)
- Design patterns used in libraries to improve the usability of their code
- Concept of replication, both synchronous and asynchronous and its consequences
- Architectural decoupling by means of message queues
- Characteristics of http tools such as load balancers and reverse proxies
- Introduction to mi> Recalls on the relational model and its limitations
- Usage-oriented data modelling and storage (e.g. aggregates)
- Basic characteristics and properties of distributed datastores (e.g. replication, sharding, consistency, availability, partitioning)
- Types of NoSQL datastore and their characteristics cross services: merits and criticalities
- Know how to use rapid prototyping and development methodologies and functional programming techniques Quickly developing scripts in Phyton to approach the solution of recurring problems

**** Skills***
- Design solutions for interfacing and communicating with devices using the OPC standard
- Choose and apply the most suitable OPC specifications for the context of use
- Connect and interact with an OPC server, managing the associated devices
- Manage the security aspects of communications
- Identifying when and if to move to a cloud-based solution

- Create applications capable of exploiting the potential of the cloud
- Integrate in your applications the features offered by the Cloud (Storage, Hosting, Authentication, Services, ...)
- Apply appropriate security measures when managing a cloud application
- Publish your applications on Microsoft Azure
- Implement scalability and calculation distribution functions
- Monitor and manage the billing of a cloud installation
- Leverage services such as Stream analytics for real-time data analysis
- Manage recurring problems by taking advantage of the organisation of problem catalogues and solutions documented in Design Patterns
- Identifying and applying the most suitable pattern in relation to the type of problem, the context and the type of application solution being worked on
- Implement simpler applications using one or more design patterns
- Design and implement scalable and resilient software architectures
- Use architectural decoupling techniques by means of message queues (such as RabbitMQ or similar) with different paradigms
- Install, configure and manage NoSQL systems
- Quickly developing scripts in Phyton to approach the solution of recurring problems

**** Competence***

Designing and implementing IIoT software solutions for the control and management of automation systems by exploiting the features and functions of the OPC standard. Implementing local and/or cloud software architectures suited to the data flows and types to be managed, guaranteeing scalability and resilience criteria, in terms of performance, and authenticity and confidentiality of information, in terms of security.

Abstract

Acquire the knowledge and advanced skills to Designing and implementing IIoT software solutions for the control and management of automation systems according to the OPC standard.

Content

* OPC
- Role of the OPC standard in the IIoT environment
- Most popular OPC specifications (DA, Alarms & Events, Historical Data Access, etc.) and the most recent ones (OPC-UA)
- Operation of some popular OPC servers (eg Kepware KEPServerEX or Matrikon OPC Server and / or others)

* Cloud for IoT
- Principles for the distribution of a processing on a computing infrastructure, possibly cloud-based
- Development models of cloud-based solutions
- Microsoft Azure platform services
- Criteria, methods and tools for scalability and distributed computing
- Know the differences between Azure IoT Hub, Service Bus and Event grid

*Design Patterns
- The main and most used Design Patterns (Creational, Structural and Behavioral)
- Design patterns used in libraries to improve their use by your code

Teaching methods

- frontal lessons
- individual and group exercises
- individual exercises in the equipped laboratory

Assessment

The course grade consists of these components:
Knowledge test with open and multiple-choice answers
Project Work

Syllabus – Cloud for IoT

Name of the course:
Cloud for IoT
Course topic:
Cloud for IoT -
Duration:
28 learning hours
Participants of the course:
Students
Educational background:
Candidates with a secondary education diploma or a four-year diploma of vocational education and training supplemented by an annual course of higher technical education and training (IFTS)
Course responsible:
Kennedy Foundation – IAL FVG
Dr. Valerio Libralato
Dr. Simonetta Moro
Course lecturiers :
Currently not available. At least 50% of the teaching staff comes from the world of work and professions
Learning outcomes
Upon successful completion of this course students should be able to:
**** Knowledge***
- Evaluate the opportunity and the need to move to a cloud-based IoT solution and implement.
- Identify when and if to move to a cloud-based solution

**** Skills***
- Create applications capable of exploiting the potential of the cloud
- Integrate in the applications functionalities offered by the Cloud (Storage, Hosting, Authentication, Services, ...)
- Apply the appropriate security measures in the management of a cloud application
- Publish your applications on Microsoft Azure
- Implement scalability and calculation distribution functions
- Monitor and manage the billing of a cloud installation
- Take advantage of services such as Stream analytics for real-time data analysis

**** Competence***
Assessing the opportunity and need to move to and implement a cloud-based IoT solution
Abstract
The digital convergence of IT, Network and Content produced in recent years has created a new landscape for the definition and delivery of ICT services to citizens. This course enables the student to acquire the advanced knowledge and skills to assess the opportunity and need to move to and implement a cloud-based IoT solution.
Content
- Principles for the distribution of a processing on a computing infrastructure, possibly cloud-based
- Development models of cloud-based solutions
- Microsoft Azure platform services
- Criteria, methods and tools for scalability and distributed computing
- Know the differences between Azure IoT Hub, Service Bus and Event grid

Teaching methods
- frontal lessons
- individual and group exercises
- individual exercises in the equipped laboratory

Assessment
The course grade consists of these components:
Knowledge test with open and multiple-choice answers
Project Work

Syllabus – Protocols for IoT

Name of the course:
Protocols for IoT
Course topic:
Protocols for IoT
Duration:
44 learning hours
Participants of the course:
Students
Educational background:
Candidates with a secondary education diploma or a four-year diploma of vocational education and training supplemented by an annual course of higher technical education and training (IFTS)
Course responsible:
Kennedy Foundation – IAL FVG
Dr. Valerio Libralato
Dr. Simonetta Moro
Course lecturiers :
Currently not available. At least 50% of the teaching staff comes from the world of work and professions
Educational prerequisites
Candidates with a good knowledge of computer science and the English language
Learning outcomes
Upon successful completion of this course students should be able to:
**** Knowledge***
- Understand and be able to choose some of the most used protocols at application level (MQTT, AMQP, CoAP)
- Role and status of the main IoT communication standards.
- Identify which protocols and/or standards are preferred according to the usage scenario

**** Skills***
- Apply some of the most widely used protocols at application level (MQTT, AMQP, CoAP)
- Connect and interface devices
- Ensure security, authenticity and confidentiality of communications

**** Competence***
Identify and select the most suitable protocols for different communication scenarios between smart devices
Abstract
Acquire the knowledge and advanced skills to identify and select the most suitable protocols for different communication scenarios between smart devices
Content
- Understand and know how to choose some of the most used protocols at the application level (MQTT, AMQP, CoAP)
- Role and status of the main IoT communication standards.
- Identify which protocols and / or standards are to be preferred based on the usage scenario

Teaching methods
- frontal lessons
- individual and group exercises
- individual exercises in the equipped laboratory

Assessment
The course grade consists of these components:
Knowledge test with open and multiple-choice answers
Project Work