Module description
of
Electronic Systems S7

Exchange program Fall 2023 – 2024

This exchange program is an advanced program in the field of electrical and electronic engineering. This program is designed to address the entire design challenge of electronic systems. The two mandatory courses for the electronic systems S7 program, together with the two generic courses, will give the students a solid hardware-focused design platform. The course work is deepened by a design project, where the knowledge and skills are put to use in the design of a prototype electronic system that addresses a real life challenge. Students will also be exposed to the latest designs of (low) power electronics, interfacing systems, sensors technologies, antenna design, printed electronics, and PCB design. The students will learn how to:

- specify, design, implement, and verify an electronic assembly for a real life challenge.
- predict and manage system behaviour, from physical inputs through to software responses
- design efficient power conversion and management solutions i.e., managing battery powered devices, creating energy-harvesting solutions, designing intrinsically safe circuits, and more.
- design highly integrated electronics: integrated antennas, 3D printed PCB, EMC compliant electronic assemblies.
- self-learning in a multi-disciplinary knowledgebase.
- design user friendly and reliable smart and sustainable systems that measurably enhance the quality and richness of the user's life.

ELECTRONIC SYSTEMS

1	2	3–8	9–10	11–16	17–20
INTRODUCTION	GENERIC MODULE	SENSOR TECHNOLOGY	GENERIC MODULE	ADVANCED POWER ELECTRONICS	PROJECT
		CHOOSE 1 ELECTIVE ADVANCED EMBEDDED SYSTEMS ADVANCED CONTROL SYSTEMS		**CHOOSE 1 ELECTIVE** IOT/ADVANCED TELECOM DIGITAL SYSTEM DESIGN	
PROJECT					

First Quarter:
Mandatory Course: Sensor Technology (ST)
ST: This course focuses on the basic principles and practical applications of sensors. The sensors that the students explore find application in Internet of Things devices, wearables, industrial automation, and smart cars. In a mix of theory and practical assignments, the students will learn how to implement sensing systems, how to ensure that the sensor data is reliable, and how to use multiple sensors in different domains to enrich the accuracy and precision of a sensor system..

Elective Course: Either Advanced Embedded Systems (AES) or Advanced Control Systems (ACS)
AES: This course focuses on practical applications of advanced embedded systems design concepts. It is focused on the specification, design and implementation of a significant project to be implemented in a System on Chip (SoC). It provides the student with the opportunity to design real digital systems containing significant amounts of hardware and software. Most of the course will be focused on design project related activities, where you will have the opportunity to design a real system, using state-of-the-art tools and technology.
ACS: In the present dynamic world of robots, drones and autonomous driving cars, knowledge about control theory is essential for the future Engineer. Control Theory is also a critical part of the Model Based System Engineering approach. This course focusses on system analysis, system modelling, and, in relation to this, the design and implementation of controllers (P, PI, PD, and PID controllers). The student will learn how to use controllers to optimize the behaviour of systems with feedback, both for analogue and digitally controlled systems. The book Control Systems Engineering from Norman S Nise is used as a guide. An essential part of the course is the investigation of real world control problems as virtual case studies using Matlab/Simulink. These provide the student with the opportunity to experience the potential of analogue and digital control.

Second Quarter:
Mandatory Course: Advanced Power Electronics (APE)
APE: This course is devoted to Power Electronics. Power Electronics is an important and large part of the Analog Electronic Design discipline. Our future is all about sustainability and energy efficiency. Power Electronics enables us to process and convert electrical energy with very high efficiency. An example of a power electronic circuit is the Switched Mode Power Supply (SMPS) that can have an efficiency of 99% whereas the efficiency of a linear Power Supply can be as low as 25%. High efficiency SMPS circuits make energy harvesting units for sensors and RFID tags possible. However, the scale of energy conversion ranges from just milliwatts to Megawatts. These include phone chargers, delivering several Watts, class-D amplifiers of 1 kW, electric cars that handle hundreds of kWs, and windmills, harvesting Megawatts. The student will learn to use commonly used tools, analysis, and design methods to design power electronic circuits.

Elective Course: Either Advanced Telecommunication (ATEL/IoT) or Digital System Design (DSD)
ATEL: This course starts with an introduction of the Internet-of-Things. The basic concepts, application scenarios and key enabling technologies will be briefly discussed. Afterwards, we will focus on wireless technologies for the IoT. The basics of a wireless communication system will be introduced, i.e., signal and modulation, channels, antennas, transmitters and receivers. We will also review the most popular wireless technologies for both short and long range communication, and discuss their key technical concepts and engineering trade-offs. This review will provide guidelines to the students for selecting the proper wireless technology for different IoT applications.
DSD: This course focuses on advanced digital systems and enables students to navigate through the complex world of digital technology and design. It is not unusual for designers to integrate old and new technologies, combining traditional design principles with innovative applications. During their time in the program, students are encouraged to explore a structured design method to design a real world digital system using state of the art tools and prototyping boards like Altera Quartus and De1-SOC board. All of the design steps, from specification to implementation will be realized with practical assignments and projects that must be carried out individually. In this course it is possible students to define their own projects or assignments in their field of interest, and to develop their skills and ambitions. Also a number of guest lectures are part of this course.

Generic Courses:
MBSE: This course is devoted to the design of complex cyber physical systems and focuses on the application of the modelling language SysML for conveying system requirements and architectural/ design decisions to stakeholders and peers. In this course, students will experience how to obtain a comprehensive/complete set of stakeholder requirements and how to translate these requirements into an architecture and design that can be used for a straightforward implementation. After this course students will be able to create, interpret and discuss (architectural and design decisions expressed in) SysML diagrams of medium complexity and will be able to elaborate these diagrams into a physical implementation.

EMC7: Electromagnetic compatibility (EMC) is the branch of electrical engineering concerned with the unintentional generation, propagation and reception of electromagnetic energy which may cause unwanted effects such as electromagnetic interference (EMI) or even physical damage in operational equipment. The goal of EMC is the correct operation of different equipment in a common electromagnetic environment.

Module : Advanced Embedded Systems (*elective course*)

Module code : EEBAES

Size : 4 EC (112 hours)

Main objectives/goals

After completing this course the student is able to:

- design, implement, and verify digital systems using SoC solutions – understand and explain the methodology
- make a well thought decision between software and custom hardware solutions to computing problems in CPU based system.
- explain and put into practice techniques for accelerating computation in hardware in CPU based system.
- explain and put into practice techniques for interfacing different types of hardware blocks in a CPU based system
- test and debug advanced embedded systems using modern tools (simulators using instrumentation tools).
- test and debug advanced embedded systems using modern tools (simulators using instrumentation tools).

Content of the module

This course focuses on practical applications of advanced embedded systems design concepts. It is focused around the specification, design and implementation of a significant project to be implemented in a System on Chip (SoC). It provides the student with the opportunity to design real digital systems containing significant amounts of hardware and software. Most of the course will be focused on a design project related activities, where you will have the opportunity to design a real system using state-of-the-art tools and technology.

Topics:

- Introduction to SoCs, technology trends, design challenges e.g ZYNQ
- Overview of SoC Design Flow & key steps involved e.g. ZYNQ Design flow
- General Purpose Input Output, GPIO, AXI GPIO
- HW/SW partitioning (Designing HW accelerators, interfacing accelerators to software: AXI4, AXI4-lite and AXI4-stream interfacing
- Intellectual Property (IP) reuse and IP Creation.
- On-chip communication architecture design: Efficient Communication Between Hardware Accelerators and processing system.
- Operating system on SoC: (Linux in Zynq)

Prerequisite requirement

- Good knowledge of VHDL/Verilog and experience implementing designs in FPGA boards.
- Good knowledge of embedded system and programming in C language

Module : Sensor Technology (*mandatory course*)

Module code : EECST

Size : 4 EC (112 hours)

Main objectives/goals

After completing this course the student is able to:

- Explain how sensors in modern microelectronic systems create knowledge from raw measured data
- Illustrate and examine basic sensor principles (drift, calibration, selectivity, sensitivity, linearity, dynamic range) to design a sensor system
- Assess a sensor as an equivalent circuit (transducer element using lumped elements)
- Use equivalent circuit to assess appropriateness of sensor to application
- Understand (and for the case of two sensors implement) how to use multiple sensors to obtain a richer dataset
- Describe and classify commonly used resistive, capacitive, inductive and optical sensors and their operational principles
- Analyse and calculate basic sensor read-out electronics principles (Wheatstone bridge, biasing, filtering, modulation) to design a sensor system
- Describe and (in software) implement simple filtering schemes (e.g. lock-in amplification and box-car integration)

Content of the module

Theory

This course focuses on the basic principles of sensors used in mechatronic applications and other modern Cyber-Physical Systems like Internet of Things, Body Area Networks, industrial automation and smart cars. The theory will give the students a thorough background in sensor design and sensor-signal conditioning and processing.

Practical

In practical work, the students will, over the course of the module, build an increasingly sophisticated sensor. Along with the sensor, the students will create software to analyse and appropriately present the sensor output for a user. The in-lab practical work is designed to give students a thorough understanding of the measurement chain.

Topics:

- Sensor theory and methods to create knowledge from data
- Correlated sensor measurements: triangulation, and correlation
- Resistive sensor like strain gauges and temperature sensors (NTC, PT100)
- Capacitive sensors
- Optical measurement principles
- Inductive and magnetic sensors
- Acceleration sensors
- Interface circuits and measurement circuits with op-amps

Prerequisite requirement

The student should have a thorough understanding of circuit theory and electronics. The students should also have had introductory mathematics, measurement and modelling, and signal processing.

Module : Advanced Power Electronics (*mandatory course*)
Code : EEAAPE
Size : 4 EC (112 hours)

Main objectives/goals

After completing this course the student is able to:

- calculate and determine the waveforms in a Zero Voltage Switching Boost Converter based upon the components values, or vice versa
- calculate and determine the waveforms in a Resonant Converter based upon the components values using the First Harmonic Approximation method, or vice versa
- analyze the behavior of a Zero Voltage Switching converter and determine the right order of the switching time intervals
- analyze the dynamic behavior of a Switch Mode Power Supply by using the Averaged Switch Modeling approach, the Canonical Model, transfer functions and Bode diagrams

Content of the module

This course is devoted to Power Electronics. Power Electronics is an important and large part of the Analog Electronic Design discipline. Our future is all about sustainability and energy efficiency. Power Electronics enables us to process and convert electrical energy with very high efficiency. Example of power electronic circuits are the Switched Mode Power Supply (SMPS) that can have an efficiency of 99% where the efficiency of a linear Power Supply can be as low as 25%. These circuits are used in energy harvesting units for sensors and RFID converting just 1mW, phone chargers delivering several Watts, class-D amplifiers of 1kW, electric cars handling hundreds of kWs and wind mills harvesting Mega Watts. The student will learn the widely used tools, analysis and design methods to design power electronic circuit.

Topics:

- Overview discussion of current mode controlled flyback converter
- Switching losses in PWM converters
- Zero Voltage Switching in PWM converters
- Resonant converters
- First Harmonic Approximation
- Zero Voltage Switching in resonant converters
- Dynamics and Control
- Voltage mode PWM control circuit
- Iterative calculation of DC operating point
- Instable boost converter
- Averaged switch model
- How to derive Transfer functions and Bode diagrams
- Canonical model of PWM Buck, Buck-Boost and Boost converters
- Frequency compensation using the bode diagrams of the loop gain

Prerequisite requirement

The student should have attended courses on circuit theory, signal processing and electronics.

Module : Advanced Control Systems (*elective course*)
Code : EECACS
Size : 4 EC (112 hours)

Main objectives/goals

After completing this course the student is able to:

- Derive a model for an electrical circuit with voltage- and/or current sources and components such as L,R,C, OpAmp.
- Derive with additional discipline-specific help a model for mechanical systems such as mass-spring-damper systems and electrical motor drive with load.
- Describe the system- and signal behaviour of LTI-systems in t-, ω-, s- and z-domain including appropriate transformations
- Use block diagrams to represent control systems, reduce block diagrams of multiple subsystems to a single block representing the transfer function from input to output
- Apply techniques such as Nyquist plot, Bode diagram, pole-zero-plot, root-locus in analysing transient behaviour and stability of control systems.
- Determine important control system parameters of a given system (continuous and discrete) such as time constant, settling-time, overshoot, steady-state error, phase- and gain margin, sampling-time, stability, sensitivity for disturbances
- Design a controller that influences the root-locus in such a way that the desired closed-loop behavior is realized.
- Derive a controller in a structured way according to frequency domain criteria.
- Derive the transfer function of a given state-space equations and vice versa (only for SISO systems).

Content of the module

ACS: In the present dynamic world of robots, drones and autonomous driving cars knowledge about control theory is essential for the future Engineer. Control Theory fits perfectly in a Model Based System Engineering approach. The course Advanced Control Theory focusses on system analysis, system modelling and in relation to this the design and implementation of controllers to optimize the system behaviour of feedback systems both for analog and digitally controlled systems. The book Control Systems Engineering from Norman S Nise is used as a guide. Real world virtual case studies using Matlab/Simulink are an essential part of the course and provide the student with the opportunity to experience the potential of analog and digital control.

Topics:

- System description and modelling in time-, frequency-, Laplace- and z-domain
- Optimization of system behaviour (settling time, overshoot, stability) using P, D, I, PID, Lead-Lag controllers
- Design of analog- and digital controllers using appropriate methods such as Bode plots, root locus, state space
- State-space representation of control systems, non-linear and MIMO-systems

Prerequisite requirement

The student should have the basic knowledge on mathematics including differential equations, complex representation, Fourier series, Laplace- and z-transform, and should know the basic control theory principles of time continuous systems and block diagrams.

Module : Advanced Telecom / IoT (*elective course*)

Module code : EEBATEL/IoT

Size : 4 EC (112 hours)

Content of the module

- Define characteristic impedance and calculate the characteristic impedance of a transmission line by using several different methods.
- Define standing wave ratio (SWR), explain its significance for transmission line design, and calculate SWR by using impedance values or the reflection coefficient.
- State the criterion for a perfectly matched line, and describe conditions that produce an improperly matched line.
- Use the Smith chart to make transmission line calculations.
- Compute the length of one-quarter wavelength and one-half wavelength antennas, given frequency of operation.
- Describe ways in which antenna design can be modified to produce an optimal match between the impedances of a transmitter and an antenna.
- IT Security Concepts and Terms; Vulnerabilities and Threats, Countermeasures, Risk Analysis and Mitigation, VPNs vs. Private Data Networks, Critical VPN security requirements, Encryption and authentication, Diffie Hellman, AES, DES, 3DES, RSA, PKI, Ca server types, pre shared keys versus certificates.
- Name the common types of microwave antennas and calculate the gain and beam width of horn and parabolic dish antennas.
- Explain the basic concepts and operation of pulsed and Doppler radar
- Path loss and link budget calculations
- Define the cell phone terms 2G, 2.5G, 3G, 4G, and 5G and list their applications.
- Describe the architecture and operation of a cell phone base station
- Identify the features, benefits, applications, and operation of the wireless technologies Wi-Fi, Bluetooth, ZigBee, WiMAX, and Ultrawideband (UWB).
- Explain the operation and applications of the wireless technologies RFID, NFC, and IR.
- Name common communication equipment tests carried out on transmitters, receivers, and antennas, including frequency measurements

Prerequisite requirement

The student should be familiar with the basics of telecommunication.

Module : Digital System Design (*elective course*)

Module code : EEBDSD

Size : 4 EC (112 hours)

Main objectives/goals

Theory:

The student is introduced into designing of advanced digital systems (techniques) and testing.

Practical:

The student is introduced into applying the digital knowledge to design complex systems by using the so called top-down design methodology and implementing, testing the design in a System-on-Chip (SoC).

Content of the module

This course focuses on advanced digital systems and enables students to navigate through the complex world of digital technology and design. It is not unusual for designers to integrate old and new technology, combining traditional design principles with innovative applications. During their time in the program, students are encouraged to explore a structured design method to design a real world digital system using state of the art tools and prototyping boards like Altera Quartus and De1-SOC board. All of the design steps, from specification till the implementation will be realized with practical assignments and projects that must be carried out individually. In this course it is possible students define their own projects or assignments in their interested field to develop their skills and ambitions. Also a number of guest lectures is part of this course.

Prerequisite requirements

- Knowledge of event triggered programming and/or embedded programming and/or object oriented programming, FPGA's.
- Good knowledge of basic digital concepts.

Module : Models Based System Engineering
(*general course*)
Module code : EEBMBSE
Size : 2 EC (56 hours)

Main objectives/goals

After this course students will be able to interpret and create SysML diagrams of medium complexity and will be able to elaborate these diagrams into program code.

Content of the module

This course is devoted to the specification and design of complex embedded systems and focuses on the application of the modelling language SysML for conveying system requirements and architectural/ design decisions to stakeholders and peers. In this course, students will experience how to obtain a comprehensive/complete set of stakeholder requirements and how to translate these requirements into an architecture and design that can be used as a basis for a subsequent (and straightforward) coding phase.

Prerequisite requirement

Basic understanding of, and preferably some experience with, the application of the v-cycle (for hard- or software development)

Module : Electromagnetic Compatibility 7 (*general course*)
Module code : EECEMC7
Size : 2 EC (56 hours)

Content of the module

Electromagnetic compatibility (EMC) is the branch of electrical engineering concerned with the unintentional generation, propagation and reception of electromagnetic energy which may cause unwanted effects such as electromagnetic interference (EMI) or even physical damage in operational equipment. The goal of EMC is the correct operation of different equipment in a common electromagnetic environment.
EMC pursues two main classes of issue. Emission is the generation of electromagnetic energy, whether deliberate or accidental, by some source and its release into the environment. EMC studies the unwanted emissions and the countermeasures which may be taken in order to reduce unwanted emissions. The second class, susceptibility is the tendency of electrical equipment, referred to as the victim, to malfunction or break down in the presence of unwanted emissions, which are known as Radio frequency interference (RFI). Immunity is the opposite of susceptibility, being the ability of equipment to function correctly in the presence of RFI, with the discipline of "hardening" equipment being known equally as susceptibility or immunity. A third class studied is coupling, which is the mechanism by which emitted interference reaches the victim.
Interference mitigation and hence electromagnetic compatibility may be achieved by addressing any or all of these issues, i.e., quieting the sources of interference, inhibiting coupling paths and/or hardening the potential victims. In practice, many of the engineering techniques used, such as grounding and shielding, apply to all three issues.
During the design of electronic circuits, control systems and installations are taught to take account of EMC phenomena, then the undue influence by these phenomena, by proper design methodologies, to a minimum. The acquired knowledge and skills will be used when designing electromagnetic compatible circuits/systems and machines.

Module : S7 Project (*mandatory project*)

Module code : EEAPRS7

Size : 10 EC (280 hours)

Objectives

In the Electronic Systems S7 program, the course work is deepened by a design project, where all knowledge and skills acquired during the student's previous education are put to use in the design of a prototype electronic system that addresses a real life challenge. We work in teams on realistic business tasks (the development and realization of innovative products). We address the problem in a systematic, structured manner. The client/company obviously looks for 'value for money'. We will work on a project based approach and according to the principles of Methodical Design.

In implementing the project, we are dealing with (four) generic competencies. These competencies are action-oriented. Conscious acting is always a matter of:

1. UNDERSTAND (reflection, orientation) in the problem situation / task.
2. DESIGN of the product, service or control.
3. PLAN the implementation.
4. EXECUTE the plan.

Examples of actions / operations are: diagnose, analyse, evaluate, reflect, plan, model, create, deploy. These actions lead in turn to a semi-product (intermediate) or a professional product (the production of both products and services, and also provide control for the corresponding production processes).

The project is closed with a professional symposium where the project student teams present their results in the English language and demonstrate their prototype.