Power Electronic Engineering

2. Semester

Subject to Approval by the Relevant Bodies

Course	Type	THW	ECTS
Radio Frequency Engineering	IC	4	7
Machine Learning and Optimization	IC	3	6
Digital Control Systems	IC	4	6
Digital Signal Processing	IC	3	5
Power Electronic Components	IC	4	6
		18	**30**

ILV Integrated course

THW Hours per week

ECTS European Credit Transfer and Accumulation System

Radio Frequency Engineering 4 SWS/7 ECTS

Teaching Content

- Introduction: Electrodynamics, Maxwell's equations
- Transmission line theory: telegraph equation, time-independent wave-equation, voltage- and current-waves on lossless transmission lines, characteristic impedance, wavelength, phase velocity, reflection coefficient, VSWR, matching, Smith chart, S-parameters microstrip lines, impedance matching networks
- Electromagnetic waves: plane waves in vacuum, plane waves in linear media (skin effect, eddy current, proximity effect, displacement current), electromagnetic waves in wave guides
- Antennas and antenna arrays: Hertz antenna (properties of the electromagnetic field, far-field), linear radiators, antenna arrays
- RF Components: baluns, directional couplers, power divider, circulator, double balanced mixers

Competence Acquisition

After finishing this course, students can

- an explain the mechanism of wave propagation on conductors,
- are able to calculate characteristic impedance, reflection factor and impedance of conducted waves,
- can explain the effects in the quasi-stationary field (skin and proximity effect) and can calculate the penetration depth and the increase in resistance,
- can explain the mechanism of the propagation of electromagnetic waves,
- can calculate the characteristic impedance, reflection factor and velocity of electromagnetic waves in free space and in media,
- can explain the operation principles of RF components and their application,
- can explain the basic operation of antennas,
- can design matching networks, and
- can operate high-frequency measuring devices and carry out measurements with them.

Machine Learning and Optimization 3 SWS/6 ECTS

Teaching Content

- General concepts, algorithms, and models in machine learning such as constrained and unconstrained optimization, cross-validation, and model overfitting and underfitting.
- Data preparation techniques such as handling missing values and outliers, transforming data, binning, and encoding categorical variables
- Selection and application of appropriate machine learning models for clustering, classification, and regression
- Metrics-dependent model evaluation and model deployment into existing systems or processes

Competence Acquisition

After finishing this course, students can

- identify and articulate the key steps in the machine learning process and address their associated challenges,
- apply key algorithms for both constrained and unconstrained optimization to various problem sets,
- implement techniques to prevent overfitting and underfitting in machine learning models,
- select and use appropriate clustering and classification methods to categorize data effectively, and
- construct both shallow and deep neural networks and apply them to real-world data sets for predictive modelling, given appropriate Python knowledge and practice.

Digital Control Systems 4 SWS/6 ECTS

Teaching Content

- Review of Control Systems: operation of analog and digital control systems, components, analog vs digital, transfer function, PID
- Identification of dynamic systems based on discrete time models
- Design and Implementation of Digital Controllers for SISO systems based on discrete transfer functions
- Design and Implementation of Digital Controllers for multivariable systems (MISO, MIMO) using state space representation
- Stability and robustness: design of control systems considering uncertainties of the plant’s parameters and disturbances
- Application of control design for electrical and electromechanical systems

Competence Acquisition

After finishing this course, students can

- explain the difference between continuous-time control and discrete-time control,
- explain the operation of discrete-time control systems,
- justify the relevance of the sampling frequency in the design of digital controllers,
- set up a model of a dynamic system based on sampled input-output measurement,
- apply direct synthesis methods for digital controllers using plant’s transfer function,
- describe the state space model and use it for digital control design of multivariable systems including reference tracking,
- evaluate the influence of uncertainties of the plant’s model and disturbances and design controllers to reject them,
- perform computer-aided control design and implement the designed controller, and
- apply the control systems studied in real systems, especially electrical and electromechanical systems.

Digital Signal Processing 3 SWS/5 ECTS

Teaching Content

- Review of discrete-time signals and systems, including signal representation, discrete-time convolution, eigen-signals, the discrete-time Fourier transform (DTFT), and the z-transform
- Analysis of the sampling theorem for sampling and reconstructing signals
- Analysis of the relationships between the continuous-time Fourier transform (CTFT), the discrete-time Fourier transform (DTFT), the discrete Fourier transform (DFT) and the fast Fourier transform (FFT)
- Design of finite impulse response (FIR), infinite impulse response (IIR), and adaptive filters to attenuate, equalize and generate signals
- Design of multi-rate systems to implement sample rate conversion and polyphase filters

Competence Acquisition

After finishing this course, students can

- explain the implications of finite signal and finite word length,
- apply sampling and quantization theory to the analysis of continuous-time signals in the digital domain,
- explain digital filters, including FIR, IIR, adaptive and multirate filters,
- design digital filters using software tools and implement them on a digital signal processor, and
- implement signal transformations such as the Fast Fourier Transform on a digital signal processor.

Power Electronic Components 4 SWS/6 ECTS

Teaching Content

- Overview of basic topologies of DC-DC Conversion (buck, boost)
- Gate drivers for MOSFET half-bridges, switching analysis
- Design and implementation of input/output filters
- Analysis of passive power components (capacitors, inductors, transformers)
- Structure and operation of power semiconductors (diodes, Si-MOSFETs, SiC-MOSFETs, IGBTs, GaN-HEMTs)
- Analysis of sensors in power electronic circuits (temperature, speed, vibration, voltage, current)
- 3D modelling of power electronic components for thermal simulation

Competence Acquisition

After finishing this course, students can

- explain the principles and operation of DC-DC converters, e.g., buck and boost topologies,
- analyse the switching behaviour and select gate drivers for MOSFET half-bridge circuits,
- design input and output filters to fulfil the performance specifications of power electronic circuits,
- compare the characteristics of passive power electronic components such as capacitors, inductors, and transformers and select the most adequate for the application in turn,
- explain and compare the structure, operation, and selection criteria of power semiconductors such as diodes, Si MOSFETs, SiC MOSFETs, IGBTs, and GaN HEMTs, and select the most appropriate ones for each application,
- design power electronic circuits that integrate sensors to measure physical quantities such as voltage, current, temperature, speed, vibration, and
- apply 3D modelling and thermal simulation tools to analyse and optimize the performance of power electronic modules.