Freie Universität Bozen
Libera Università di Bolzano
Università Lledla de Bulsan

CORSO DI LAUREA IN INGEGNERIA ELETTRONICA E DEI SISTEMI CIBERFISICI

BACHELOR IN ELEKTROTECHNIK UND CYBERPHYSISCHEN SYSTEMEN

Contenuto degli insegnamenti
Inhalt der Lehrveranstaltungen

Primo anno / Erstes Jahr
Mathematical Analysis I (I year, I semester, 9 CFU) • Elements of set theory, number sets and properties of real numbers. • Real functions of one real variable: elementary functions, graphs and operations on graphs, composition and inversion. • Sequences and limits for sequences. • Limits and continuity of functions. • Infinite and infinitesimal functions: Landau symbols and rate of convergence. • Differential calculus and study of a function's graph. • Numerical real series and fundamentals of Taylor series. • Antiderivatives and integral calculus for functions of one real variable. • Use of the symbolic calculus software Maple.
Mathematical Analysis II (I year, II semester, 9 CFU) • Functions of several real variables, limits and continuity. • Elements of differential calculus for functions of several variables. • Differential calculus for vector functions. • Curvilinear integrals of scalar functions. • Curvilinear integrals of vector fields. • Double integrals. • Triple integrals. • Surface integrals. • Elements of ordinary differential equations.

Linear Algebra (I year I semester, 9 CFU)

- Vector spaces and their operations. Spaces R^n. Bases. Scalar product and norm.
- Matrices and their operations. Inverse matrix, transposed and conjugate matrix and their properties.
- Linear systems. Matrix form, homogeneous case. Dimension of the solution space, Gauss triangulation method. Linear dependence and independence of vectors.
- Determinant and rank. Recursive definition, Laplace rule, properties. Rank of a matrix. Rouchè-Capelli theorem.
- Linear transformations in R^n. Kernel, image. Eigenvalues and eigenvectors. Isometries and homoteties in R^2.
- Geometry of space. Vector product, mixed product. Cartesian equation of a plan in space. Cartesian and parametric equation of a straight line in space. Skew lines.
- Complex numbers. Properties and operations in the complex field.
- Trigonometric form of complex numbers. N-roots of complex numbers. Equations in a complex variable.
- Representation of linear operators in different bases. Quadratic forms and their diagonalization. LU and QR decomposition, Gram-Schmidt orthogonalization method (also with the use of a software).

Physics I (I year, I semester, 6 CFU)

- Measurement and vectors: units of measurement, dimensions of physical quantities, mathematical operations with vectors.
- Kinematics: mean and instantaneous velocity and acceleration, uniformly accelerated motion.
- Dynamics: Newton's three axioms, work, energy, law of conservation of energy, linear momentum.
- Rotation: angular displacement, mean and instantaneous angular velocity and acceleration, torque, moment of inertia, angular momentum
- Fluids: Ideal fluids, Pascal's and Archimedes' principles, Bernoulli's equation.
- Thermodynamics: thermal expansion, kinetic theory of gases, heat, ideal gases, first and second law, circular processes, entropy.

Physics 2 (I year, II semester, 9 CFU)

- Electrostatics (charge; coulomb; electric field; electric potential; capacity; dielectrics; permittivity).
- Electrical current (Ohm's law; resistance; Joule's effect; power; direct/alternating current; electrical circuits; Kirchhoff's laws).
- Magnetostatics (magnetostatic field; magnetic induction; Lorentz's forces; Ampère's laws; magnetic dipoles; magnetic energy).
- Dynamic electromagnetism (Faraday-Lenz; self-induction).
- Electromagnetic waves (Maxwell's equation; light propagation; polarization of electromagnetic waves).
- Photonics: optical phenomena (optics, refraction, interference), introduction to photonic devices.
- Introduction to quantum mechanics.

Fundamentals of Programming (I year, I + II semester, 12 CFU)

Module 1: Fundamentals of Programming I (I year, I semester, 6 CFU)

- Software development (IDEs; software management tools: DVCS and cloud-based tools).
- Introduction to programming languages (compiled vs interpreted; core tools: compilers, linkers; programming paradigms).
- Models of computation (memory management; execution flow).
- Debugging and software testing (debugging tools; writing safe and secure programs; type checking).
- Using programming languages (data types and expressions; control flow; recursion; input/output; error handling).
- Basic algorithms and data structures

Module 2: Fundamentals of Programming II (I year, II semester, 6 CFU)

- Software development in Python (development tools).
- Introduction to Python.
- Using Python to develop software solutions.
- Algorithms and Data Analysis with Python.

Basics of Electronics (I year, II year, 6 CFU)

- Basics of electrotechnics: the concept of bipole; electrical quantities; measurement units.
- Adynamic bipoles and circuits: pure resistive bipoles; Thevenin and Norton models; real generators; energy phenomena in bipoles; nodal analysis of circuits; the superposition principle.
- Dynamic bipoles and circuits: dynamic bipoles; elemental circuits; circuits in sinusoidal regime.
- Introduction to semiconductor devices: diodes; MOS transistors.
- Basics of digital electronics: logic gates.
- Basics of analog electronics: single MOSFET amplifier stages; operational amplifiers.

Secondo anno / Zweites Jahr

Algorithms and Programming (II year, I semester, 6 CFU)

- Searching and sorting.
- Analysis of algorithms: correctness and complexity.
- Algorithm techniques: divide and conquer, recurrences, dynamic programming.
- Elementary data structures: Pointers, dynamic data structures, linked lists.
- Abstract data types: stacks, queues, priority queues, maps.
- Binary trees, red-black trees, elementary graph algorithms.

Operating Systems and networks (II year, II semester, 12 CFU)

Module 1: Operating and real-time systems (II year, II semester, 6 CFU)

- Operating systems and computer architecture principles.
- Communication, scheduling, and management of processes.
- Memory management.
- Multi-programming, multi-tasking, and synchronization.
- Real time systems principles.
- Real time scheduling and communication.

Module 2: Networks of electronic devices (II year, II semester, 6 CFU)

- Introduction to technology trends (e.g., embedded processors; miniaturized sensors; new materials; ubiquitous computing characteristics and systems).
- Sensor characteristics and fundamentals (e.g., sensitivity; offset, accuracy, dynamic range, linearity; conditioning; filtering; ADC/DAC).
- Mobile ad-hoc networks and routing protocols (e.g., flooding; distance vector routing; DSDV Routing; DSR and zone routing).
- Wireless Communication Technologies (e.g., WLAN/IEEE 802.11; Bluetooth/IEEE 802.15.1, ZigBee/IEEE 802.15.4; RFID; NFC).
- Wireless sensor networks (e.g., communication architecture, sensor nodes etc.).
- Machine-to-machine protocols in the cloud, e.g., MQTT and HTTPs.
- Further data representations and protocols for sensor and control data with a focus on OSC (open sound control) that allows developers to implement a sensor that communicates with 3rd party applications and framework (e.g., MATLAB, Grasshopper, Unity etc.).

Electronic Devices (II year, I semester, 9 CFU)

- Semiconducting materials.
- Semiconductor fabrication and characterization techniques.
- PN junctions and diodes.
- Transistors (MOSFETs; MESFETs; heterojunction transistors)
- Memories (DRAM; SRAM; Flash; resistive).
- Sensors (physical; chemical; biological sensors).
- Photonic devices (LEDs; lasers; photodiodes; solar cells).
- Passive electronic components (antennas; batteries).
- Internet-of-things and sensor networks.

Electronic Circuit Design (II year, II semester, 6 CFU)

- Elementary logic circuits (the binary system; Boolean algebra; circuit equivalence; inverter, NAND, and NOR; logic gate characteristics; NMOS, CMOS, TTL technologies: operating principle and comparison).
- Combinatory logic circuits (multiplexers and demultiplexers; encoders and decoders; comparators; shifters; binary adders; arithmetic logic units).
- Elementary analog circuits (FET small signal behavior; common source amplifiers; common gate amplifiers; source follower amplifiers; differential amplifiers; noise analysis).
- Multi-stage linear amplifiers (AC-DC connection; impedance matching; current mirrors).
- Frequency behavior of amplifiers (recall of transfer functions, poles and zeros; Bode plot; frequency behavior of FETs; cut-off frequency; gain-bandwidth product; frequency analysis of multi-stage circuits).
- Feedback amplifiers (basics of reaction principles; input to output transfer; open-loop gain calculation; real gain of feedback amplifiers with finite loop gain; analysis of noise in feedback circuits).

Fundamentals of Systems and Control (II year, I semester, 6 CFU)

- Dynamic system modelling in frequency domain.
- Dynamic system response.
- Stability of linear control systems.
- Root-locus analysis and design methods.
- Frequency-response analysis and design methods.
- Digital control systems.
- Computer-aided analysis and design.

Modern Control (II year, II semester, 9 CFU)

- Modelling and system analysis in state space (dynamic system modelling in time domain and state-space representation; dynamic system response derived from state-space representation and steady-state error; stability in state space).
- Control design in state space (Pole placement design techniques; controllability, observability, full-state observers).
- Optimal control of dynamic systems (Problems with fixed and variable end-points as well as with equality and inequality constraints; maximum principle and Hamilton-Jacobi-Bellmann equation; linear quadratic regulator).
- Computer-aided analysis and design using Matlab/Simulink.
- Implementation of controllers and experimental evaluation on real-hardware setups.

Fundamentals of Statistics (II year, I semester, 9 CFU)

- Parametric vs non-parametric statistical models (parametric estimation and confidence intervals; sampling distributions and modes of convergence).
- Introduction to hypothesis testing, and type 1 and type 2 errors.
- Distance measures between distributions and methods of estimation, method of moments, maximum likelihood estimation and generalized estimating equations.
- Covariance matrices, multivariate statistics, and Fisher information.
- More on hypothesis testing: Wald's and likelihood ratio tests.
- Introduction to regression analysis: linear multiple regression.
- Beyond the linear regression model: generalized linear models and non-parametric regression.
- Topics on dimension reduction and statistical model selection.

Terzo anno / Drittes Jahr

Electronic Systems (III year, I semester, 6 CFU)

- Programmable logic devices (taxonomy; PLC; FPGA: introduction, interconnection resources, I/O reconfigurable blocks, programming; design flow; principles of design, Verilog, system Verilog and VHDL).
- Power supply generation and distribution, heat management, switching mode power supply, linear regulators. Interference between analog and digital and how to avoid them. Signals and bus signal distribution; crosstalk, glitch, debounce. Clock generation and distribution.
- System on chip, system in package, system on module concept and applications. Input and output devices and high-speed interfaces (PCI-Express, LVDS, SerDes, USB3, ETH).
- Sensors in IoT systems.
- RF transmission concepts: WiFi 802.11x, Bluetooth, LoRa, Zigbee, LTE, 3G, 5G, NBIot. Modulations technique, FSK, PSK, OOK, M-QAM.
- New technical trends (IoT systems; neuromorphic and in-memory systems).

Robot Control (III year, I semester, 6 CFU)

- Robot kinematics and dynamics.
- Trajectory planning.
- Motion control.
- Interaction control.
- Vision-based control.
- Remote control.
- Computer-aided simulation and design.

- Computer Architecture (III year, I semester, 6 CFU)
- Sequential logic circuits (flip-flop and latches; registers and shift registers; counters; design of sequential circuits from state machines).
- General computer architecture (Von Neumann architecture; CPUs; bus; memory; peripherals)
- Instruction set architecture (CISC vs RISC architecture; instructions: data-movement, control-flow, arithmetic/logic; common ISAs: introduction to x86, ARM, RISC-V; assembly programming).
- CPU architecture (control unit, registers, ALU; fetch-decode-execute cycle; pipelining; super-scalar architecture; branch prediction; out-of-order execution; caches).
- Memory and buses (static vs dynamic memory; serial/parallel buses; synchronous/asynchronous buses; bus arbitration strategies; example of buses: PCI, PCI-Express, USB).
- Other topics (multi-processor and multi-core architectures; introduction to GPUs).

Artificial Intelligence and Machine Learning (III year, I semester, 9 CFU)

- Artificial intelligence and agents.
- Search space exploration.
- Automated planning.
- Data analysis.
- Model selection.
- Supervised learning.
- Unsupervised learning.
- Reinforcement learning.
- Elements of deep learning.

Economics and Management (III year, I semester, 6 CFU)

- The company: objectives and context (basic concepts; classifications of companies; value chain; vision and mission; Porter's generic strategies; strategy tools).
- Essentials of financial accounting (accounting principles; balance sheet and income statement; financial statement preparation; ratio analysis).
- Investment analysis (actualization and capitalization; discounted payback period; net present value; internal rate of return).
- Other economic evaluation analyses (classification of costs; break-even point; make or buy choices).