

ELECTRICAL ENGINEERING

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Overview

Electrical Engineering Programs

Modern electrical engineering is a very broad and diverse field. Never before has there been such a challenge and opportunity for electrical engineering to serve mankind. Today's electrical engineers are involved in the development of technology, materials and products to improve the quality of life. They are concerned with the generation and transmission of power, the control and utilization of natural and synthetic resources, the communication of data and information and the intelligent use of computers in consumer as well as industrial products and processes. Systems in electrical engineering range in size from microprocessors through megawatt energy conversion systems to global audio and video communication networks.

Mission Statement

We provide graduate programs and an ABET-accredited undergraduate program that are accessible to a diverse group of students—students of different racial and cultural backgrounds, full-time students as well as those who have considerable work and family commitments outside their academic learning and students with a wide variety of work experiences.

Graduate Program

The Department of Electrical Engineering offers graduate programs with the following areas of emphasis: communications and signal processing; controls and signal processing; microelectronics and VLSI; fields, waves and optics; computer engineering and embedded systems design; and energy and power systems. The department offers graduate programs leading to the degrees of master of science in electrical engineering (<http://catalog.ucdenver.edu/cu-denver/graduate/schools-colleges-departments/college-engineering-design-computing/electrical-engineering/electrical-engineering-ms/>) and master of engineering (<http://catalog.ucdenver.edu/cu-denver/graduate/schools-colleges-departments/college-engineering-design-computing/electrical-engineering/electrical-engineering-meng/>). In addition, the multidisciplinary engineering and applied science doctor of philosophy (<http://catalog.ucdenver.edu/cu-denver/graduate/schools-colleges-departments/college-engineering-design-computing/engineering-applied-science-phd/>) degree is available through the Department of Electrical Engineering.

Requirements for Admission

Additional admissions information, including links to the online application, is available on the college website.

The minimum requirements for “regular” admission to the master’s program are: BS in electrical engineering, or equivalent degree in math, physics or other engineering disciplines, from a reputable institution, with a GPA of at least 3.0, on a 4.0 scale. Satisfaction of minimum requirements does not guarantee admission: The grades obtained

in the student’s area of concentration are important factors in the consideration, and so are possible multiple repetitions of fundamental courses. Students who do not meet the requirements for direct admission to the program may be admitted “conditionally”: that is, they may be required to take or repeat certain undergraduate courses before their admission to the program is official.

For those undergraduate students with degrees in science and non-electrical engineering wishing to pursue graduate study in the electrical engineering department, there is no restriction or constraint in being admitted into the master of science in electrical engineering graduate program. However, they must fulfill any prerequisite course requirements assigned to any graduate course in the department. Students with an undergraduate degree in areas other than electrical engineering must receive approval from their graduate advisor before registering for a class in electrical engineering. All students must plan a program of study in consultation with their departmental advisor(s), during the first semester of study, and submit for approval to the department.

Applicants must submit evidence of adequate preparation for graduate study by either

1. submitting official GRE scores, or
2. documenting an earned bachelor’s degree with a GPA of 3.00 or higher from an institution accredited by a U.S. accreditation body, or an earned master’s degree with a GPA of 3.50 or higher from an institution accredited by a U.S. accreditation body.

All applications must be submitted online (<https://graduateschool.ucdenver.edu/admissions/apply/>). Send all supporting application materials to the Graduate School at the following address:

Mailing Address:

Graduate School
Campus Box 163
P.O. Box 173364
Denver, CO 80217-3364

Courier Address (UPS, FEDEX, etc.):

Graduate School
1380 Lawrence Street, Suite 1251
Denver, CO 80204

For admissions questions, contact graduateadmissions@ucdenver.edu or 303-315-2179.

International Applicants

More information for international applicants is available through the Office of International Admissions (<http://catalog.ucdenver.edu/cu-denver/graduate/international-admissions/>).

Programs

- Electrical Engineering, MEng (<http://catalog.ucdenver.edu/cu-denver/graduate/schools-colleges-departments/college-engineering-design-computing/electrical-engineering/electrical-engineering-meng/>)
- Electrical Engineering, MS (<http://catalog.ucdenver.edu/cu-denver/graduate/schools-colleges-departments/college-engineering-design-computing/electrical-engineering/electrical-engineering-ms/>)
- Engineering and Applied Science, PhD (<http://catalog.ucdenver.edu/cu-denver/graduate/schools-colleges-departments/college-engineering-design-computing/electrical-engineering/engineering-applied-science-phd/>)

Faculty

Professors

Hamid Fardi, PhD, University of Colorado Boulder

Stephen Gedney, PhD, University of Illinois at Urbana-Champaign

Mark Golkowski, PhD, Stanford University

Fernando Mancilla-David, PhD, University of Wisconsin at Madison

Miloje Radenkovic, PhD, University of Belgrade, Yugoslavia

Associate Professors

Dan Connors, PhD, University of Illinois Urbana-Champaign

Tim Chifong Lei, PhD, University of Michigan

Jaedo Park, PhD, The Pennsylvania State University

Assistant Professors

Vijay Harid, PhD, Stanford University

Chao Liu, PhD, Purdue University

Alireza Vahid, PhD, Cornell University

Senior Instructor:

Lary Speakman, BS, University of Colorado Denver

Electrical Engineering (ELEC) Courses

ELEC 5005 - IC Design (3 Credits)

Explores digital integrated circuit design including MOS processing steps, physical operation, building blocks of digital circuits, advanced nMOS, pMOS and CMOS circuit design, silicon VLSI technology and circuit and chip level. Spice and lay-out Editor are used. The physical relationship between circuit design and actual silicon layout and structure and technology are emphasized. Prereq: Graduate standing or permission of instructor. Cross-listed with ELEC 4005. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Restriction: Restricted to students with graduate standing.

ELEC 5025 - Device Electronics (3 Credits)

A course relating performance and limitations of solid state devices to their structures and technology. For both advanced circuit and device engineers. Semiconductor physics and technology, pn-junction and MOS devices used in modern integrated circuits. Prereq: ELEC 3225 and senior standing. Cross-listed with ELEC 4025. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: ELEC 3225 Restriction: Senior standing

ELEC 5033 - Advanced Electromagnetic Fields (3 Credits)

A course focused on electromagnetic waves. Topics include: Poynting's power theorem, reflection and transmission of uniform plane waves in layered media, two-conductor transmission lines, rectangular wave guides, Smith Chart elements of radiation and antenna. Prereq: ELEC 3133 and permission of instructor for undergraduates. Cross-listed with ELEC 4133. Max Hours: 3 Credits.

Grading Basis: Letter Grade

ELEC 5133 - Electromagnetic Radiation and Antenna (3 Credits)

Solution of inhomogeneous wave equation. Radiation fields of elementary dipole, linear wire antenna, uniform and non-uniform linear arrays. Array synthesis. Farzone field patterns, directivity and beamwidth. Diffraction fields of aperture sources, horn antenna, conic surface reflector sources, lens antenna. Ray tracing methods. Transient-receive link. Selected Topics. Prereq: ELEC 4133, graduate standing and permission of instructor for undergraduates. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: ELEC 4133 or ELEC 5033

ELEC 5134 - Introduction to Microwave Circuit Design (3 Credits)

This course provides the basic principles of microwave circuit design, including transmission line theory, network parameters, signal flow graphs, design of high frequency matching networks, filters, hybrids and couplers using waveguide elements, high frequency amplifier and mixer design. Prereq: ELEC 3133. Cross-listed with ELEC 4134. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: ELEC 3133 or graduate standing

ELEC 5164 - Electric Drive Systems (3 Credits)

Covers power electronics drives for rotating electric machinery. Topics include power electronics elements for drives, load characteristics, dynamic modeling of AC machines, fundamental control algorithms, simulation and practical commercial drives. Prereq: ELEC 3164. Cross-listed with ELEC 4164. Repeatable. Max Hours: 9 Credits.

Grading Basis: Letter Grade

Repeatable. Max Credits: 9.

ELEC 5170 - Electric Drives Systems Laboratory (1 Credit)

Offers hands-on experience on rotating electric machine drive simulations and commercial systems. Sessions include pulse-width modulation (PWM) inverter, induction, DC, and synchronous machine drives. Matlab/Simulink and a commercial inverter will be utilized. Cross-listed with ELEC 4170. Prereq: ELEC 4164 or equivalent. Max Hours: 1 Credit.

Grading Basis: Letter Grade

ELEC 5174 - Power Electronic Systems (3 Credits)

Topics to be covered include: power electronics fundamentals and applications in power systems; uncontrolled, semi-controlled and fully controlled power semiconductors; converters design and control. Prereq: ELEC 3164 and graduate standing or permission of instructor. Cross-listed with ELEC 4174. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: ELEC 3164 or Graduate Standing

ELEC 5184 - Power Systems Analysis (3 Credits)

Topics to be covered include: complex power; per-unit quantities; modeling of generators, transformers and transmission lines; power flow problem; economic dispatch; faults and sequence networks; and an introduction to power system protection and dynamics. Prereq: ELEC 3164 and graduate standing or permission of instructor. Cross-listed with ELEC 4184. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: ELEC 3164 or Graduate Standing

ELEC 5194 - Power Systems Operation and Control (3 Credits)

This course introduces the student to various operational strategies the power industry uses today to operate the power system. Topics to be covered include: economic dispatch, unit commitment, optimal power flow (linear and nonlinear), transmission congestion, control areas, state estimation, and an introduction to power markets. Prereq: ELEC 4184 or ELEC 5184 or graduate standing. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: ELEC 4184 or ELEC 5184 or graduate standing.

ELEC 5210 - Optimization Methods in Engineering (3 Credits)

Unconstrained optimization, gradient methods, conjugate direction methods, data fitting and function estimation. Applications in control, system identification and radar systems. Optimization over a convex set, LMS algorithms in adaptive systems, convergence properties. Nonlinear programming, Lagrange multipliers, projection algorithms, games and minimax theorem, application to H infinity control, communication and signal processing. Prereq: MATH 3191 and 3200/3195. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: MATH 3191 and (3200 or 3195)

ELEC 5220 - Methods of Engineering Analysis (3 Credits)

Real sequences and infinite series, convergence of the parameter estimates in self-tuning control. Uniform convergence and application to adaptive FIR filters. Improper integrals, application in filtering, prediction and communication. Analytic functions, Hardy spaces, maximum modulus theorem. Argument principle and Nyquist stability criteria. Calculus of residues, LQG problem. Conformal mappings, Nevelinna-Pick problem. Prereq: MATH 3191 and 3200/3195, graduate standing. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: (MATH 3191 and 3200) or MATH 3195 or Graduate Standing

ELEC 5230 - Advanced Linear Systems (3 Credits)

Mathematical description of both continuous and discrete-time systems; vector, normed and inner-product spaces; state-space, impulse response and transfer function descriptions; state-transition response matrices; eigenvalues and eigenfunctions; controllability; canonical form; state feedback; observers; realization theory. Prereq: MATH 3191, MATH 3200/3195 and permission of instructor. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: (MATH 3191 and 3200) or MATH 3195 or Graduate Standing

ELEC 5248 - Digital Communication Systems (3 Credits)

Introduces digital communication systems covering elements of information theory; mathematical representation of signals and systems; modulation and demodulation for the additive Gaussian noise channel; Performance analysis of various transmission formats; synchronization; coded waveforms; decoding algorithms; and other related topics. Prereq: ELEC 3316, 3817; recommended ELEC 4247. Cross-listed with ELEC 4248. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: (ELEC 3316 and 3817) OR Graduate Standing

ELEC 5249 - Wireless networking (3 Credits)

Fundamentals of wireless communication from a physical-layer perspective. Multipath signal propagation and fading channel models. Design of constellations to exploit time, frequency, and spatial diversity. Reliable communication and single-user capacity. Interference management, multiple-access protocols, and multi-user capacity. Cellular uplink and downlink. Multiple-antenna systems and architectures. Communications with Intelligent Reflecting Surfaces. mmWave and THz communications. Connections to modern standards. Prereq: Elec 3817 and Elec 3316. Cross-listed with ELEC 4249. Max hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: ELEC 3316 and ELEC 3817

ELEC 5250 - Information Theory (3 Credits)

Introduces information theory and its application in computer science, communication theory, coding and applied mathematics. Entropy, mutual information, data compression and storage, channel capacity, rate distortion, hypothesis testing. Error detecting and correcting codes, block codes and sequential codes. Prereq: ELEC 3817 or CSCI 4535 or MATH 3800. Max hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: ELEC 3817 OR CSCI 4535 OR MATH 3800 OR Graduate Standing

ELEC 5252 - Computer Communication Networks (3 Credits)

Comprehensive study of issues arising in modern computer-communication networks, both wire-line and wireless, carrying traffics with heterogeneous characteristics. A conceptual and analytical approach to the design of network protocols in harmony with the appropriate modeling of the traffic and network environments. Issues covered include routing, transmission, performance monitoring, as well as and network management in ATM multi-media networks. Prereq: Graduate standing or permission of instructor. Max Hours: 3 Credits.

Grading Basis: Letter Grade

ELEC 5276 - Digital Control Systems (3 Credits)

Analysis and design of discrete-time systems, as occurs when a digital computer is used to control physical systems. Topics include difference equations, Z-transform, sampled-data system modeling, sampling, discrete equivalents, stability, and discrete control design by root locus, direct design, frequency-response, and state space. Prereq: ELEC 3316, ELEC 3817, and graduate standing. Cross-listed with ELEC 4276.

Repeatable. Max Hours: 9 Credits.

Grading Basis: Letter Grade

Repeatable. Max Credits: 9.

Prereq: ELEC 4136 or Graduate Standing

ELEC 5294 - Advanced Power Electronic Systems (3 Credits)

The course focuses on the design, modeling, modulation, control and simulation of three-phase two-level voltage sourced inverters with emphasis on applications. Student will also be introduced to advanced topologies including diode clamped multilevel inverters, modular multilevel inverters and matrix converters. Prereq: ELEC 4174 or ELEC 5174. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: ELEC 4174 or 5174

ELEC 5333 - Introduction to Computational Electromagnetics (3 Credits)

An intro to computational electromagnetics based on the Finite Difference Time-Domain (FDTD) covering, finite difference methods, the Yee algorithm, numerical error, stability, boundary conditions, source excitations, hands-on programming experience and application of FDTD to real problems. Prereq: ELEC 3133 or grad standing. Cross-listed with ELEC 4333. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: ELEC 3133 or graduate standing

ELEC 5334 - Advanced Computational Electromagnetics (3 Credits)

This course on advanced computational electromagnetics covers Green's theorems and identities, vector potential theory, equivalence principles, numerical linear algebra, numerical integration, method of weighted residuals, integral equation methods, method of moments, and Prereq: ELEC 4133 or ELEC 5133 or grad standing. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: ELEC 4133 or ELEC 5133 or grad standing

ELEC 5373 - Optical Engineering (3 Credits)

This course introduces some of the most important concepts in optical engineering and prepares students a solid foundation to apply them to applications in the industry and academic research. Prereq: ELEC 3133. Cross-listed with ELEC 4373. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: ELEC 3133 Restriction: Restricted to students within the College of Engineering, Design and Computing

ELEC 5375 - Engineering Neuroscience (3 Credits)

In this course, mathematical models and data processing strategies will be introduced as well as other cutting-edge research techniques to help students understand how these techniques can be applied to solve modern neuroscience problems. Prereq: ELEC 3316 or graduate standing. Cross-listed with ELEC 4735 and NRSC 7674 (Anschutz Medical Campus course). Max Hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: ELEC 3316 or Graduate Standing

ELEC 5423 - Radio Frequency Laboratory (1 Credit)

Projects involve modern RF analyzers, waveguide devices, time-domain techniques, characterization of devices, signal propagation and scattering, harmonic mixing, and radio frequency identification. Students will gain experience using MATLAB for data acquisition and processing. Graduate students will explore projects in greater detail. Cross-listed with ELEC 4423. Max Hours: 1 Credit.

Grading Basis: Letter Grade

Typically Offered: Fall, Spring.

ELEC 5433 - Fundamentals and Applications of Plasmas (3 Credits)

This course provides an introduction to plasmas, also known as the fourth state of matter, in nature and industry. Topics covered include single particle motions, plasma kinetic and fluid theory, cold and warm plasma models and interaction of electromagnetic waves with plasmas. Applications ranging from space sciences to medicine are explored.

Prereq: ELEC 3133 for undergraduate students or permission of the instructor. No prerequisite for CEDC graduate students. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: ELEC 3133 + Engineering undergraduates or Prereq: Graduate Engineering

Typically Offered: Fall, Spring.

ELEC 5436 - Nonlinear Control Systems I (3 Credits)

Analysis and synthesis of nonlinear feedback control systems. Linearization's and stability in the small, equivalent linearization and the describing function. The dual input describing function. Stability in the large and the second method of Lyapunov. Stability of time-varying systems. Popov's method and extensions. Prereq: ELEC 4136 or 4276. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: ELEC 4136 or ELEC 4276 or Graduate Standing

ELEC 5444 - Power System Laboratory (1 Credit)

This lab introduces the student to modern computational tools used in power system analysis. Algorithms to solve the "power flow problem", the "economic dispatch problem", and the "optimal power flow problem" are discussed and implemented in the Matlab-Simulink mathematical analysis software package. Coreq: ELEC 4184. Max hours: 1 Credit.

Grading Basis: Letter Grade

Coreq: ELEC 4184.

ELEC 5446 - Introduction to Modern Control Theory (3 Credits)

State space representation of dynamic systems. Canonical forms. Frequency domain analysis. Controllability and observability. Design by statespace methods: pole-placement, linear observers, separation principle, robustness. Linear, quadratic optimum control. Prereq: ELEC 4136 or 4276. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: ELEC 4136 or ELEC 4276.

ELEC 5455 - Computer Methods for Device Electronics (3 Credits)

Numerical analysis of PN junctions, Bipolar transistors, GAAS MESFETS, and MOSFETS. Numerical solution of discrete-form equations. Finite-difference method for semiconductor devices. Two-dimensional models: DC, transient, and small signal numerical analysis. Prereq: Graduate standing or permission of instructor. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Restriction: Restricted to students with graduate standing.

ELEC 5456 - Sampled Data and Digital Control Systems (3 Credits)

Elements of sampling theory. Overview of design approaches via transform methods. Analysis and design in state space. Optimal control systems. Emphasis is placed on computer-aided design projects. Prereq: ELEC 4276. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: ELEC 4276 or Graduate Standing

ELEC 5466 - Adaptive Control System Design (3 Credits)

Basic concepts in adaptive feedback control. Overview of application areas. Stability of non-linear systems and hyperstability approach to the design of adaptive controllers. Passivity concept and Liapunov stability. Design of model reference adaptive systems, self-tuning regulators, stochastic adaptive, and dual control systems. Computer-based design applications. Emphasis is placed on design projects. Prereq: ELEC 4136 or 4276. Cross-listed with ELEC 4466. Max hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: ELEC 4136 or ELEC 4276.

ELEC 5474 - Power Electronics Laboratory (1 Credit)

The power electronics laboratory introduces students to seven fundamental switchmode power conversion topologies, along with voltage and current feedback control, assembled on a reconfigurable power pole circuit board with external power supplies and laboratory. Cross-listed with ELEC 4474. Max Hours: 1 Credit.

Grading Basis: Letter Grade

ELEC 5476 - Optimal Control Systems (3 Credits)

Liapunov stability and quadratic optimal control problems. The minimum principle and the Pontryagin maximum principle. Variational calculus and Hamilton-Jacoby-Bellman equation. The separation principle of LQG control. Combined optimal state estimation and control. Differential and difference Riccati equations. Tracking and disturbance rejection. Computer-aided design applications. Prereq: ELEC 4136 or 4276. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: ELEC 4136 or ELEC 4276 or Graduate Standing

ELEC 5486 - Modeling and System Identification (3 Credits)

Linear time-invariant and time-varying models. Nonlinear state space models. Non-parametric methods. Parameter estimation methods. Convergence and consistency. Computational methods in estimation. Recursive estimation methods. Experiment design and choice of identification criterion. Model structure selection and model validation. Prereq: ELEC 3817 or MATH 3800, and ELEC 4136 or 4276. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Pre-req: (ELEC 3817 or MATH 3800) AND (ELEC 4136 or 4276) OR Graduate Standing

ELEC 5496 - Robust Control (3 Credits)

Background mathematics: function spaces and operators, and factorization theory. Stability theory: stability and stabilizability parameterization, closed-loop transfer matrices. Model-Matching Theory: solution existence, SISO Design, the Nehari problem. Performance bounds. Prereq: Graduate standing or permission of instructor. Max Hours: 3 Credits.

Grading Basis: Letter Grade

ELEC 5501 - Microprocessor-Based Design (3 Credits)

Covers advanced treatment of embedded system design using microprocessors. Analog input circuitry is interfaced to a microprocessor, and a PC board layout is created to develop a complete system design. Software/Operating System is implemented for realtime I/O. Prereq: Graduate standing or permission of instructor. Cross-listed with ELEC 4501. Max Hours: 3 Credits.

Grading Basis: Letter Grade

ELEC 5511 - Hardware-Software Interface (3 Credits)

Computer engineering methods in hardware and software design applied to problems drawn from the mini- and micro-computer systems field. Hardware and software techniques for the design of combined hardware or software are developed. Interface and real-time programming techniques are considered. Graduate level requires additional projects and homework. Prereq: ELEC 3520. Cross-listed with ELEC 4511. Max hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: ELEC 3520.

ELEC 5521 - Design and Test of Digital Systems (3 Credits)

Application of hardware description languages to the design, synthesis, analysis, and testing of digital and computer systems; modeling and simulation constructs; modern hardware description languages, including VHDL, logic and behavioral synthesis; rapid-prototyping; FPGA and standard-cel ASIC design; design for testability; and electronic design automation. Prereq: ELEC 3651 or graduate standing. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: ELEC 3651 or Graduate Standing

ELEC 5522 - VLSI Systems (3 Credits)

Examines the design of very large-scale integrated (VLSI) systems from the logic to physical levels, including MOS transistor design, CMOS fabrication and design rules, device and wafer processing, inverter and complex gate design, mask level layout, VLSI system components and architectures, algorithms for VLSI computer-aided design, and testability. Prereq: ELEC 3215 and 3651 or graduate standing. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Pre-req: (ELEC 3215 and 3651) or Graduate Standing

ELEC 5551 - Pattern Recognition (3 Credits)

Pattern recognition techniques from image processing and artificial intelligence are explored. Topics include neural networks, morphological processing, wavelets, fractals, and basic image understanding. Prereq: ELEC 3316 and 3651. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: (ELEC 3316 and 3651) or Graduate Standing

ELEC 5555 - VLSI Circuit Simulation (3 Credits)

Computer methods for large integrated circuits. Theory and practice of VLSI circuit simulation. Nodal formulations of networks. Computer generation of sensitivities. Modeling active devices. DC solution of nonlinear networks. Prereq: Graduate standing or permission of instructor. Cross-listed with ELEC 4555. Max Hours: 3 Credits.

Grading Basis: Letter Grade

ELEC 5617 - Random Processes for Engineers (3 Credits)

Probability, sequences of random variables, specification of stochastic processes, stationarity, correlation functions and spectral densities, linear mean-square estimation, central limit theorems, law of large numbers, non-stationary random processes, stochastic differential equations and Karhunen-Loeve expansion, Kalman filtering. Prereq: ELEC 3316 and ELEC 3817 and permission of instructor. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: (ELEC 3316 and 3817) OR Graduate Standing

ELEC 5627 - Stochastic Point Processes (3 Credits)

Presents modeling physical phenomena characterized by highly localized events distributed randomly in a continuum. Applications include optical communications, queuing theory, decision theory, nuclear medicine and electron microscopy. Topics include Poisson counting processes and its generalizations; stochastic differential equations used in filtering; martingales and Brownian motion. Prereq: ELEC 3817 or ELEC 5617. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: ELEC 3817 or 5617

ELEC 5637 - Digital Signal Processing (3 Credits)

Discrete-time signals and systems in the time and frequency domain. Digital filter structures, design of FIR filters by windowing, optimum approximations of FIR filters. Design of digital IIR filters from continuous time domain. Computer-aided design of digital filters. The discrete Fourier transform and DSP algorithm implementation. Analysis of finite word length effects. Application of digital signal processing. Prereq: ELEC 3316 and 3817. Cross-listed with ELEC 4637. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: (ELEC 3316 and 3817) OR Graduate Standing

ELEC 5638 - Digital Image Processing (3 Credits)

Basics of two-dimensional (2-D) systems theory, including 2-D Fourier transform, Z-transform, and difference equations. Design of 2-D filters for image processing applications. Image transforms, including the 2-D FFT, cosine, Hadamard and KL. Image enhancement and restoration techniques. Method of image coding and compression. Prereq: ELEC 3133, 3215, 3225, 3316, 3817 or graduate standing. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: ELEC 3133, 3215, 3225, 3316, 3817 or graduate standing

ELEC 5644 - Introduction to Biomedical Imaging (3 Credits)

An important component of the recent expansion in biomedical engineering is the area of biomedical imaging. This ELEC 4644/5644 course is an introduction to biomedical imaging systems, not only covering the fundamentals of imaging physics but also the applications of four primary biomedical imaging modalities: X-Ray Computed Tomography (CT), Magnetic Resonance Imaging (MRI), Nuclear Medicine (i.e. PET, SPECT), and Ultrasound Imaging. Prereq: Graduate standing, or permission of instructor. Cross-listed with ELEC 4644. Max Hours: 3 Credits.

Grading Basis: Letter Grade

ELEC 5647 - Adaptive Signal Processing (3 Credits)

Optimal filtering and identification of signal processing models. Martingales and analysis of recursive estimation algorithms. LMS and RLS adaptive filters. Stability, convergence and robustness of adaptive algorithms. Adaptive noise cancellation, time delay estimation and blind equalization. Adaptive differential pulse code modulation, adaptive prediction, adaptive Kalman Filters. Applications and implementation of adaptive algorithms. Prereq: ELEC 5637. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: ELEC 5637

ELEC 5648 - Blind Signal Processing (3 Credits)

Introduction to gradient optimization methods. Introduction to adaptive filtering. Principal component analysis and whitening. Robust and adaptive PCA. Blind SOS parameter estimation and deconvolution. Fundamentals of independent component analysis. Blind equalization of SIMO and MIMO systems. ICA by maximization of nongaussianity. ICA by MLE and minimization of mutual information. Applications and practical considerations. Prereq: Graduate standing. Cross-listed with ELEC 6648. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Restriction: Restricted to graduate students

ELEC 5657 - Detection and Estimation Theory (3 Credits)

Introduces detection and extraction methods used in signal processing, including decision theory; detection of known and random signals; optimum receiver design; estimation theory; Wiener filtering; Kalman-Bucy filtering; and applications to communication systems. Prereq: ELEC 5617. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: ELEC 5617

ELEC 5667 - Wavelet Theory and Applications (3 Credits)

Topics include: fundamentals of signal decomposition; theory of filter banks; multi-resolution analysis and fast wavelet transforms; applications image and video image and video compression; and denoising and feature detection. Prereq: Graduate standing or permission of instructor. Max Hours: 3 Credits.

Grading Basis: Letter Grade

ELEC 5678 - Quantum Computing (3 Credits)

The course teaches students the principles, the algorithms and the programming methods of quantum computing, and also discusses the associated physics and mathematics background required. Other related topics such as quantum communication and quantum entanglement will also be discussed. Prereq: PHYS 2331 and ELEC 3817 with a C- or better. Cross-listed with ELEC 4678. Max hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: PHYS 2331 with a C- or better, and ELEC 3817 with a C- or better.

ELEC 5687 - Optical Communication Systems (3 Credits)

System aspects of optical communication system design. Basic principles of sources, channels, detectors, counting statistics, amplifiers, and coding with regard to the performance limitations they place on the communication system. Prereq: ELEC 3133. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: ELEC 3133 Restriction: Restricted to students within the College of Engineering, Design and Computing

ELEC 5688 - Introduction to Nondestructive Testing (3 Credits)

A basic, broad understanding of the principles of nondestructive testing and evaluation is provided. The main objective of this course is to attract students to NDT fields and eventually help address the increasing needs of NDT engineers and technicians. Interaction and collaboration with local NDT industries will also be emphasized. As an introductory course, a broad interdisciplinary knowledge of NDT will be covered in the following sub-areas: Visual, Penetrant, Magnetic Particle, Eddy Current, Microwave, Ultrasonic, and Radiography. Prereq: Graduate standing, or permission of instructor. Cross-listed with ELEC 4688. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Restriction: Graduate level students

ELEC 5697 - Optical and Spatial Information Processing (3 Credits)

Processing of two- and three-dimensional spatial information. The scalar diffraction theory necessary to describe the information-bearing wave-front. Wave-front recording, modulations, and reconstruction. Holography, Fourier transform properties of lenses, two-dimensional convolution and correlation, pattern recognition, and optical information processing.

Prereq: ELEC 3316. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: ELEC 3316 or Graduate Standing

ELEC 5710 - Advanced Electric Drive Systems (3 Credits)

Covers advanced theory and implementation techniques for rotating electric machinery drives. Topics include field oriented control theory, detailed dynamic modeling of induction machine/drive system, advanced control algorithms and controller design. Prereq: ELEC 4164/5164 or equivalent. Max Hours: 3 Credits.

Grading Basis: Letter Grade

ELEC 5714 - Energy Systems Analysis (3 Credits)

Transmission line constants, including details of GMD methods, skin effect. Analysis of balanced and unbalanced line using distributed parameters, energy flow from circle diagram approach, traveling-wave phenomena, corona, power cables and fundamentals of DC transmission. Prereq: ELEC 4184. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: ELEC 4184

ELEC 5720 - Practical Electric Drive Systems (3 Credits)

Covers practical control theory and implementation techniques for electric machine drives for rotating electric machinery using high-performance hardware and software. Topics include machine theory review, power converter, control theory, controller design and actual implementation of an induction machine drive using up-to-date microcontroller hardware and software. Prereq: ELEC 2520, ELEC 4164/5164 or equivalent. Max Hours: 3 Credits.

Grading Basis: Letter Grade

ELEC 5723 - High Performance Computer Architecture (3 Credits)
 High Performance Computer Architecture covers the design of advanced computing systems. In particular, the course includes the design of modern microprocessors, characteristics of the memory hierarchy, and issues involved in multithreading and multicore architectures. Prereq: ELEC 3651 Digital Hardware Design. Cross-listed with ELEC 4723. Max Hours: 3 Credits.
 Grading Basis: Letter Grade

ELEC 5725 - Advanced Electric Machinery (3 Credits)
 Covers theoretical principles and techniques of electric machine analysis focusing on rotating machinery. Topics include various machine definitions, properties and analysis, software tools, and examples. Prereq: ELEC 3164 or equivalent. Max Hours: 3 Credits.
 Grading Basis: Letter Grade

ELEC 5727 - Computer Vision & Image Processing Acceleration (3 Credits)
 Real-time constraints on computer-vision and image processing applications have motivated numerous explorations of multicore architectures to provide more efficiency through hardware parallelism and acceleration. This course undertakes the study of image processing and computer vision algorithms in the context of parallel hardware. Prereq: ELEC 3520. Cross-listed with ELEC 4727. Max hours: 3 Credits.
 Grading Basis: Letter Grade
 Prereq: ELEC 3520.

ELEC 5755 - Renewable Energy Systems (3 Credits)
 This course focuses on the modeling, analysis and control of grid-connected wind and photovoltaic energy systems. Prereq: permission of instructor. Cross-listed with ELEC 4755. Repeatable. Max Hours: 9 Credits.
 Grading Basis: Letter Grade
 Repeatable. Max Credits: 9.

ELEC 5764 - Power Distribution Systems (3 Credits)
 Use of per-unit methods to find transient voltage behavior of industrial power systems resulting from motor starting, spotwelders and similar stimuli. System and device responses due to series and shunt capacitors and problems of subharmonics and over-excitation on induction motors. Design of power distribution systems. Prereq: ELEC 4184. Max hours: 3 Credits.
 Grading Basis: Letter Grade
 Prereq: ELEC 4184

ELEC 5774 - Power Systems Dynamics and Protection (3 Credits)
 Topics to be covered include: power system dynamic fundamentals, various stability problems, such as angle, frequency and voltage stability; protection of power systems apparatus and protective relays coordination. Prereq: ELEC 4184/5184 or graduate standing. Max Hours: 3 Credits.
 Grading Basis: Letter Grade
 Prereq: ELEC 4184 or Graduate Standing

ELEC 5800 - Special Topics (1-3 Credits)
 Intermediate courses of variable title and variable credit, usually offered once by guest lecturers. See current departmental notices for details. Repeatable. Max hours: 9 Credits.
 Grading Basis: Letter Grade
 Repeatable. Max Credits: 9.

ELEC 5840 - Independent Study: ELEC (1-6 Credits)
 Offers the opportunity for independent, creative work. Prereq: Permission of instructor. Repeatable. Max Hours: 6 Credits.
 Grading Basis: Letter Grade
 Repeatable. Max Credits: 6.

ELEC 5939 - Internship Master Student (1-3 Credits)
 Student will outline internship tasks every 2-3 weeks in a progress report. Reports will include the details of exposure to electrical/computer engineering concepts. Each concept will be described with respect to CU Denver Electrical Engineering degree program. Courses that were taken pre-internship that prepared student for successful understanding for the task requirements. In addition, preparations that would be help, will also be mentioned. Engineering training in design and software tools related to internship tasks will be clearly described. Final semester report will describe all experiences and include recommendations on how students might prepare to be successful for other common tasks. Requisite: Graduate students must have completed 6 credit hours with a cumulative GPA of 3.0. Repeatable. Max Hours: 3 Credits.
 Grading Basis: Letter Grade
 Repeatable. Max Credits: 3.
 Graduate students must have completed 6 credit hours with a cumulative GPA of 3.0.

ELEC 5980 - Statistical Quality Control (3 Credits)
 Introduces statistical methods of quality control. Statistical process control, process capability, statistical design of experiments and total quality management. Prereq: Graduate standing or permission of instructor. Max Hours: 3 Credits.
 Grading Basis: Letter Grade

ELEC 6000 - Statistical Signal Processing (3 Credits)
 The objective of this course is to present a systematic coverage of statistical signal processing methods which are fundamental for processing, identifying and classifying stochastically (randomly) generated data sequences. Emphasis will be given to methods which resist data outliers. Important applications include communications and biological systems. Prereq: ELEC 5617 or consent of instructor. Max Hours: 3 Credits.
 Grading Basis: Letter Grade
 Prereq: ELEC 5617

ELEC 6800 - Special Topics (1-3 Credits)
 Repeatable. Max Hours: 9 Credits.
 Grading Basis: Letter Grade
 Repeatable. Max Credits: 9.

ELEC 6950 - Master's Thesis (1-8 Credits)
 Repeatable. Max hours: 8 Credits.
 Grading Basis: Letter Grade with IP
 Repeatable. Max Credits: 8.
 Additional Information: Report as Full Time.

ELEC 6960 - Master's Report (1-8 Credits)
 Repeatable. Max hours: 8 Credits.
 Grading Basis: Letter Grade with IP
 Repeatable. Max Credits: 8.
 Additional Information: Report as Full Time.

ELEC 7800 - Special Topics (1-3 Credits)
 Courses of variable title and variable credit, usually offered once by guest lecturers. See current departmental notices for details. Repeatable. Max Hours: 9 Credits.
 Grading Basis: Letter Grade
 Repeatable. Max Credits: 9.

ELEC 7801 - Special Topics (1-3 Credits)
 Repeatable. Max Hours: 9 Credits.
 Grading Basis: Letter Grade
 Repeatable. Max Credits: 9.

ELEC 7802 - Special Topics (1-3 Credits)

Repeatable. Max Hours: 9 Credits.

Grading Basis: Letter Grade

Repeatable. Max Credits: 9.

ELEC 7803 - Special Topics (1-3 Credits)

Repeatable. Max Hours: 9 Credits.

Grading Basis: Letter Grade

Repeatable. Max Credits: 9.

ELEC 7804 - Special Topics (1-3 Credits)

Repeatable. Max Hours: 9 Credits.

Grading Basis: Letter Grade

Repeatable. Max Credits: 9.

ELEC 7805 - Special Topics (1-3 Credits)

Repeatable. Max Hours: 9 Credits.

Grading Basis: Letter Grade

Repeatable. Max Credits: 9.

ELEC 7806 - Special Topics (1-3 Credits)

Repeatable. Max Hours: 9 Credits.

Grading Basis: Letter Grade

Repeatable. Max Credits: 9.

ELEC 7807 - Special Topics (1-3 Credits)

Repeatable. Max Hours: 9 Credits.

Grading Basis: Letter Grade

Repeatable. Max Credits: 9.

ELEC 7808 - Special Topics (1-3 Credits)

Repeatable. Max Hours: 9 Credits.

Grading Basis: Letter Grade

Repeatable. Max Credits: 9.

ELEC 7809 - Special Topics (1-3 Credits)

Repeatable. Max Hours: 9 Credits.

Grading Basis: Letter Grade

Repeatable. Max Credits: 9.

ELEC 7840 - Independent Study: ELEC (1-6 Credits)

Offers the opportunity for independent, creative work. Prereq: Permission of instructor. Repeatable. Max Hours: 6 Credits.

Grading Basis: Letter Grade

Repeatable. Max Credits: 6.

ELEC 8990 - Doctoral Dissertation (1-10 Credits)

Repeatable. Max hours: 10 Credits.

Grading Basis: Letter Grade with IP

Repeatable. Max Credits: 10.

Additional Information: Report as Full Time.