

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.

At CU Denver, the electrical engineering curriculum prepares students for careers in product design, manufacturing, research, development, operation and plant engineering, technical sales and application engineering. The goal is to educate and inspire students to achieve their maximum career potential.

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.

Undergraduate Information

Entering students begin their program with a solid foundation in mathematics, physics, chemistry and computers. Social science, humanities and communication courses provide a diverse background. Intensive courses follow in the theory and laboratory application of digital logic and electrical circuits, electromagnetic fields, electronics, computer engineering, Internet of Things (IoT), signals and systems, controls, electrical machines and power systems and microprocessors. Throughout the entire course of study, students reinforce their understanding of theory through laboratory experience and extensive design projects. A strong background is provided in all of the major fields of electrical engineering: circuits and electronics, microcomputers, signal and image processing, communications, autonomous and robotic systems, power and energy conversion, and automatic control systems and instrumentation. Ethics is an integral part of the curriculum. During the senior year, advanced undergraduate-level courses in different specialty areas, design projects and professional electives allow the student to explore areas of special interest.

Students should supplement this information about the curriculum by consulting a copy of the *Department of Electrical Engineering Advisement Guide*, which may be obtained in the Department of Electrical Engineering

office located in North Classroom 2615. The *Department of Electrical Engineering Advisement Guide* contains the latest information concerning the curriculum as well as guidelines and procedures with which each student should be familiar. To be awarded the bachelor of science in electrical engineering, a student must satisfactorily complete 128 semester hours, satisfy all university graduation requirements and maintain at least a 2.0 GPA in all electrical engineering courses attempted. Appointments to see any of the departmental advisors may be made by calling 303-315-7520.

Programs

- Electrical Engineering, BS (<http://catalog.ucdenver.edu/cu-denver/undergraduate/schools-colleges-departments/college-engineering-design-computing/electrical-engineering/electrical-engineering-bs/>)
- Computer Engineering Minor (<http://catalog.ucdenver.edu/cu-denver/undergraduate/schools-colleges-departments/college-engineering-design-computing/electrical-engineering/computer-engineering-minor/>)
- Electrical Engineering Minor (<http://catalog.ucdenver.edu/cu-denver/undergraduate/schools-colleges-departments/college-engineering-design-computing/electrical-engineering/electrical-engineering-minor/>)

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

Jaedo Park, PhD, The Pennsylvania State University

Miloje Radenkovic, PhD, University of Belgrade, Yugoslavia

Associate Professors:

Tim Chifong Lei, PhD, University of Michigan

Dan Connors, PhD, University of Illinois Urbana-Champaign

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

Electric Engineering (ELEC)

ELEC 1510 - Digital Logic (3 Credits)

The design of combinatorial and sequential switching circuits. Topics include Boolean algebra, Boolean function minimization technique, combinatorial circuit analysis and synthesis, synchronous sequential circuit analysis and synthesis, algorithmic state machine design, asynchronous sequential circuit analysis and synthesis. Max hours: 3 Credits.

Grading Basis: Letter Grade

ELEC 1520 - Programming for Electrical Engineers (3 Credits)

An introductory course in programming using C/C++ and Python. The objective of the course is to examine the design of programs using language concepts, data structures, algorithms, and object-oriented design techniques to solve fundamental engineering problems. Students develop skills to program, construct data structures, and test & debug solutions, while gaining knowledge of the fundamental elements and operation of computer systems. Max Hours: 3 Credits.

Grading Basis: Letter Grade

ELEC 2132 - Circuit Analysis I (3 Credits)

Introduces circuit analysis: basic principles, operational amplifier circuits, first-order and second-order circuits, steady-state sinusoidal analysis with phasor mathematics. Prerequisite: Math 2411 with a C- or higher and Phys 2311 with a C- or higher. Repeatable. Max Hours: 9 Credits.

Grading Basis: Letter Grade

Repeatable. Max Credits: 9.

Prereq: PHYS 2311 and MATH 2411 with a C- or higher

ELEC 2142 - Circuit Analysis II (3 Credits)

Sequential course after ELEC 2132. Topics include: Solution of circuits using Laplace transforms, frequency domain analysis, additional steady-state solutions, Bode plots, active filters, pulses, impluses, and computer-aided analysis. Prerequisite: Math 2421 with a C- or higher and Phys 2331 with a C- or higher, Elec 2132 with a C- or higher. This course can be taken stand alone without a lab. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: ELEC 2132, MATH 2421 and PHYS 2331 with a C- or higher.

ELEC 2520 - Embedded Systems (3 Credits)

A second semester computer engineering course covering microcontroller & microprocessor-based embedded system design and interfaces including peripherals, development tools, constraints and interfacing between physical world and device. Prereq: ELEC 1520 with a C- or higher. Repeatable. Max Hours: 6 Credits.

Grading Basis: Letter Grade

Repeatable. Max Credits: 6.

Prereq: ELEC 1520 with a C- or higher.

ELEC 2531 - Logic Laboratory (1 Credit)

Experiments in digital logic utilizing both computer simulation and actual analysis using integrated circuits. Initially, combinational logic circuits are studied, including circuits such as binary adders and multipliers, followed by sequential circuits, including counters. Meters and oscilloscopes are introduced. Use of computer-aided design tools facilitating design, simulation, and implementation of digital systems using field-programmable logic devices are an integral part of the entire course. Coreq: ELEC 1510. Max hours: 1 Credit.

Grading Basis: Letter Grade

Coreq: ELEC 1510.

ELEC 2651 - Signal Processing (3 Credits)

Introduction to discrete-time signal processing and frequency domain analysis. Sampling and interpolation, discrete Fourier transform, effects of filtering and modulation of signals. Concepts are explored in the context of multimedia, communications, and data analysis applications. Emphasizes computer-based signal processing using MATLAB. Prereq: ELEC 1520. Coreq: MATH 3195 or MATH 3191. Max hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: ELEC 1520. Coreq: MATH 3195 or MATH 3191.

ELEC 3030 - Electric Circuits and Systems (3 Credits)

This basic electrical engineering course is for non-majors (does not apply to BSEE degree). Students study circuit analysis, transformers, electric motors, and simple electronic circuits (diodes and transistors). Prereq: MATH 2421 and PHYS 2331 with a C- or higher. Restriction: Restricted to majors within the College of Engineering, Design and Computing. Cross-listed with MECH 3030. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: MATH 2421 and PHYS 2331 with a C- or higher Restriction: Restricted to majors within the College of Engineering, Design and Computing

ELEC 3133 - Electromagnetic Fields (3 Credits)

Fundamental physics and applications of electric and magnetic fields are covered. Topics include: vector analysis in multiple coordinate systems, Maxwell's equations in free space and material regions including boundary conditions, static and quasi-static electric and magnetic fields, uniform plane waves for free space and for materials. Prerequisite: MATH 2421 with a C- or higher and PHYS 2331 with a C- or higher, ELEC 2132 with a C- or higher, MATH 3195 with a C- or higher. Restriction: Restricted to students within the College of Engineering, Design and Computing. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: ELEC 2132, MATH 2421, MATH 3195 (or MATH 3191 and MATH 3200), and PHYS 2331 all with a grade of C- or higher. Restriction: Restricted to students within the College of Engineering, Design and Computing

ELEC 3164 - Energy Systems (3 Credits)

Explores various energy resources and modern conversion systems utilized to generate, store, process, and deliver electric power. Topics include electromechanical, electrochemical, and renewable energy systems, as well as switch-mode power processing and power networks. Prereq: ELEC 2142 with a C- or higher, and ENGR 1130 with a C- or higher. Max hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: ELEC 2142 with a C- or higher, and ENGR 1130 with a C- or higher.

ELEC 3225 - Electronics (4 Credits)

BJT and FET transistor models at high frequencies, multistage amplifiers, frequency response of amplifiers. Feedback, operational amplifiers, oscillators, power amplifiers, and introduction to power electronics. Prereq: ELEC 2142, PHYS 2331 and ENGR 1130. Restriction: Restricted to students within the College of Engineering, Design and Computing. Max hours: 4 Credits.

Grading Basis: Letter Grade

Prereq: ELEC 2142, PHYS 2331 and ENGR 1130. Restriction: Restricted to students within the College of Engineering, Design and Computing.

ELEC 3316 - Signals and Systems (3 Credits)

Introduces the fundamentals of signals and systems analysis. Topics include: time domain analysis of continuous and discrete time systems, frequency domain (Laplace and z-transform) analysis, applications to filters and feedback systems, Fourier transform for both continuous and discrete time signals, sampling and signal reconstruction, applications to communication systems and state space representation. Learning experience is enhanced by using MATLAB-based examples and experiments. Prereq: ELEC 2142 with a C- or higher, MATH 3195 with a C- or higher or MATH 3191 and MATH 3200 with a C- or higher. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: ELEC 2142 with a C- or higher, MATH 3195 with a C- or higher or MATH 3191 and MATH 3200 with a C- or higher.

ELEC 3520 - Intelligent Systems: IoT & Cyber-Physical Systems (3 Credits)

A computer engineering course covering intelligent systems that include applications with connected Internet-of-Things (IoT) devices and cyber-physical elements. An intelligent system consists of a collection of computing devices communicating with one another and capable of interacting with the physical world. The course explores the system design and software development process to deploy real-time embedded applications in real-world scenarios. Topics include multiple hardware and software systems necessary to perform sensing, actuation, processing, and communication with connected computing devices.
Prereq: ELEC 2520. Max hours: 3 Credits
Grading Basis: Letter Grade
Prereq: ELEC 2520.

ELEC 3701 - Machine Learning for Engineers (3 Credits)

The course introduces the mathematical formalism and software for machine learning approaches in electrical engineering problems. Selected applications include signal detection, signal classification, remote sensing, imaging, and model optimization. Topics include: linear and logistic regression, support vector machines, clustering, artificial neural networks, hypothesis testing, and Bayesian analysis. Prereq: ELEC 3618 with a C- or better and MATH 3195 with a C- or better or MATH 3191 and MATH 3200 and ELEC 2520 with a C- or better. Max hours: 3 Credits.
Grading Basis: Letter Grade
Prereq: ELEC 3817 with a C- or better AND (MATH 3195 or (MATH 3191 and MATH 3200 with a C- or better and ELEC 2520))

ELEC 3724 - Energy Systems Laboratory (1 Credit)

Provides hands-on experience on electromechanical, electrochemical, and semiconductor-based energy conversion systems. Sessions include operation of induction motor and generator, energy storage, and renewable energy experiments. Prereq: ELEC 2142. Prereq or Coreq: ELEC 3164. Max hours: 1 Credit.
Grading Basis: Letter Grade
Prereq: ELEC 2142 Coreq: ELEC 3164 Restriction: Restricted to students within the College of Engineering, Design and Computing

ELEC 3817 - Engineering Probability and Statistics (3 Credits)

Topics include: definition of probability, conditional probability, independence, combined experiments and Bernoulli trials, random variables, joint distribution and density functions, correlations, sample mean and variance. Also, introduction to random processes, auto and cross correlation functions, spectral density of random signals, responses of a linear system to random inputs. Prereq: MATH 3195 and 2421. Max Hours: 3 Credits.
Grading Basis: Letter Grade
Prereq: MATH 2421 and 3195 (or MATH 3191 and MATH 3200)
Restriction: Restricted to students within the College of Engineering, Design and Computing

ELEC 3900 - Circuit Design and Fabrication Laboratory (3 Credits)

Hands on laboratory course that involves electrical measurement and diagnosis in the context of electrical circuit design, fabrication, and validation. Standard benchtop tools of oscilloscope, signal generator, digital multi-meter, DC power supply are introduced. Final project involves layout and fabrication of a printed circuit board (PCB). Prereq: ELEC 3225 and ELEC 2142. Max hours: 3 Credits.
Grading Basis: Letter Grade
Prereq: ELEC 3225 and ELEC 2142.

ELEC 3939 - Internship (1-3 Credits)

Students gain engineering design experience involving application of specific technical concepts and skills in a supervised industrial environment. (Must have approval from ELEC faculty.) Prereq: ELEC 2142. Repeatable. Max Hours: 9 Credits.
Grading Basis: Letter Grade
Repeatable. Max Credits: 9.
Prereq: ELEC 2142

ELEC 4005 - 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: ELEC 3225. Cross-listed with ELEC 5005. Max Hours: 3 Credits.
Grading Basis: Letter Grade
Prereq: ELEC 3225.

ELEC 4025 - 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 5025. Max Hours: 3 Credits.
Grading Basis: Letter Grade
Prereq: ELEC 3225 Restriction: Senior standing

ELEC 4133 - Advanced Electromagnetic Fields (3 Credits)

A course focused on electromagnetic waves. Topics include: electromagnetic power, reflection and transmission of uniform plane waves in layered media, rectangular wave guides, two-conductor transmission lines, Smith Chart representation of wave impedance and reflection. Prereq: ELEC 3133. Cross-listed with ELEC 5033. Max Hours: 3 Credits.
Grading Basis: Letter Grade
Prereq: ELEC 3133 Restriction: Restricted to students within the College of Engineering, Design and Computing

ELEC 4134 - 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 5134. Max Hours: 3 Credits.
Grading Basis: Letter Grade
Prereq: ELEC 3133

ELEC 4136 - Control Systems Analysis (3 Credits)

Introduces students to the fundamentals of analysis and design of feedback systems. Topics include: mathematical models of linear continuous-time systems applied to modeling physical systems in the time and frequency domain, control system characteristics, Routh's stability and transient response analysis, Nyquist stability and polar plots, analysis and design of linear control systems by root locus and frequency response, methods, compensator implementation, finite-precision numerical effects, round-off errors, and computer-based design applications. Prereq: ELEC 3316. Coreq: ELEC 3817. Max Hours: 3 Credits.
Grading Basis: Letter Grade
Prereq: ELEC 3316 Coreq: ELEC 3817 Restriction: Restricted to students within the College of Engineering, Design and Computing

ELEC 4164 - 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 5164. Repeatable. Max Hours: 9 Credits.

Grading Basis: Letter Grade

Repeatable. Max Credits: 9.

Prereq: ELEC 3164 Restriction: Restricted to students within the College of Engineering, Design and Computing

ELEC 4170 - Electric Drive 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 5170. Prereq or Co-req: ELEC 4164/5164 or equivalent.

Max hours: 1 Credit.

Grading Basis: Letter Grade

Prereq or Coreq: ELEC 4164 or ELEC 5164

ELEC 4174 - 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. Cross-listed with ELEC 5174. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: ELEC 3164 Restriction: Restricted to students within the College of Engineering, Design and Computing

ELEC 4184 - 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. Cross-listed with ELEC 5184. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: ELEC 3164 Restriction: Restricted to students within the College of Engineering, Design and Computing

ELEC 4225 - Advanced Electronics (3 Credits)

Switching state models of discrete components and integrated circuits, including logic gates, comparators, and operational amplifiers. Input, output, and transfer characteristics. Non-ideal properties. Analog-digital and digital-analog conversion. MOS-integrated circuits. Prereq: ELEC 3215, 3225. Restriction: Restricted to students within the College of Engineering, Design and Computing. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: ELEC 3215, 3225. Restriction: Restricted to students within the College of Engineering, Design and Computing.

ELEC 4247 - Communication Theory (3 Credits)

Introduces the principles of analog and digital communication systems. Series expansion and Fourier Series and transforms. The sampling theorem. Stochastic principles and noise. Linear systems and Fourier analysis. Design of transmitters and receivers: modulation and demodulation schemes. Some information theoretic concepts: source coding, channel coding, channel capacity and performance measures. Prereq: ELEC 3316 and 3817. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Pre-req: ELEC 3316 and 3817

ELEC 4248 - 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 5248. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Pre-req: ELEC 3316 and 3817

ELEC 4249 - Space Communications Systems (3 Credits)

Presents the art of space communications system design around the framework of the link budget and the essential analysis tool of the radio system designer. The budget is examined from theoretical and practical viewpoints. Pointers and motivation for further study in each of the related engineering disciplines are provided. Topics to be examined include satellite orbits, propagation, antennas, noise, modulation, coding and hardware or software. Prereq: Permission of instructor. Cross-listed with ELEC 5249. Max Hours: 3 Credits.

Grading Basis: Letter Grade

ELEC 4276 - Digital Control Systems (3 Credits)

Topics to be covered include: discrete-time systems and the z-transform, characteristics of open-loop and closed-loop discrete-time systems, time-response characteristics and stability analysis, design of digital and hybrid control systems using z-transform, root locus, frequency domain, and state variable compensation techniques, compensator on, implementation, and computer-based design applications. Prereq: ELEC 3316 and ELEC 3817. Cross-listed with ELEC 5276. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: ELEC 3316

ELEC 4309 - Senior Design Project I (3 Credits)

Design methodology and tools, project planning and team building, ethics in engineering and research, career planning and portfolio building. Project designs are completed and presented to the class. Prereq: Students must complete their Senior/30 hour check prior to enrollment. Coreq: ELEC 3133, 3164, 3225, 3316, 3520, 3701, 3724, 3817 and 3900.

Restriction: Restricted to undergraduate majors within the College of Engineering, Design and Computing. ELEC 4309 and ELEC 4319 must be completed in subsequent academic semesters. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Coreq: ELEC 3133, 3164, 3225, 3316, 3520, 3701, 3724, 3817 and 3900.

Restriction: Restricted to undergraduate majors within the College of Engineering, Design and Computing

ELEC 4319 - Senior Design Project II (3 Credits)

Project designs completed in ELEC 4309 are constructed and tested. Oral and written presentations of the completed project performance are required. Prereq: ELEC 4309 in subsequent academic semester. Students must complete their Graduation Agreement prior to enrollment. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: ELEC 4309 Restriction: Restricted to majors within the College of Engineering, Design and Computing

ELEC 4333 - 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. Cross-listed with ELEC 5333. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: ELEC 3133

ELEC 4373 - 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 Electromagnetic Fields. Cross-listed with ELEC 5373. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: ELEC 3133

ELEC 4375 - 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 5735 and NRSC 7674 (Anschutz Medical Campus course). Max hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: ELEC 3316 or Graduate Standing

ELEC 4406 - Control Systems Laboratory (1 Credit)

This lab includes system identification, design of velocity control systems, design of PID controllers and control systems using state variable feedback. Prereq or Coreq: ELEC 4136 or 4276. Max hours: 1 Credit.

Grading Basis: Letter Grade

Prereq or Coreq: ELEC 4136 or 4276.

ELEC 4423 - Radio Frequency Laboratory (1 Credit)

Projects involve modern RF analyzers, wave-guide devices, time-domain techniques, characterization of filters/amplifiers, signal propagation and scattering, harmonic mixing, and radio frequency identification. Students will gain experience using MATLAB for data acquisition and processing. Prereq: ELEC 3133 and ELEC 3225. Cross-listed with ELEC 5423. Max hours: 1 Credit.

Grading Basis: Letter Grade

Prereq: ELEC 3133 and ELEC 3225.

ELEC 4435 - Advanced Electronics Laboratory (1 Credit)

Projects related to digital logic, analog and digital switches, A/D and D/A converters, and design of signal filters. Prereq: ELEC 3225 and 3735; Prereq or Coreq: ELEC 4225. Max Hours: 1 Credit.

Grading Basis: Letter Grade

Prereq: ELEC 3225, 3735 Coreq: ELEC 4225

ELEC 4444 - Power Systems 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 4466 - 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 5466. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: ELEC 4136 or 4276 Coreq: ELEC 4247 or 4248

ELEC 4467 - Communications Laboratory (1 Credit)

Analysis and design in three main areas: traditional analog communications at low and medium frequencies, digital communications, and microwave communications systems. Extensive use of spectrum analysis from low frequencies up to microwave range. Projects include noise, AM, FM, PM, PLL, sampling, quantizing, encoding, TDM, FSK, QPSK, 16QAM, receivers, and satellite communications systems. Prereq: ELEC 3735; Prereq or Coreq: ELEC 4247 or ELEC 4248. Max Hours: 1 Credit.

Grading Basis: Letter Grade

Prereq: ELEC 3735 and 4247 or 4248

ELEC 4474 - 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. Coreq: ELEC 4174. Cross-listed with ELEC 5474. Max Hours: 1 Credit.

Grading Basis: Letter Grade

Coreq: ELEC 4174 Restriction: Restricted to students within the College of Engineering, Design and Computing

ELEC 4501 - 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/ Coreq: ELEC 3520. Cross-listed with ELEC 5501. Max hours: 3 Credits.

Grading Basis: Letter Grade

Prereq/Coreq: ELEC 3520.

ELEC 4511 - 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 5511. Max hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: ELEC 3520.

ELEC 4521 - Microprocessor Laboratory (1 Credit)

Provides support for the projects assigned in ELEC 4501 - a complete embedded system is designed, built and tested. Coreq: ELEC 4501. Max Hours: 1 Credit.

Grading Basis: Letter Grade

Coreq: ELEC 4501

ELEC 4555 - 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: ELEC 3225. Cross-listed with ELEC 5555. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: ELEC 3225.

ELEC 4561 - Hardware-Software Lab (1 Credit)

Projects related to the software interface of a processor to external devices. Topics include A/D converters, serial and parallel interfaces.

Prereq: ELEC 3520 and Coreq: ELEC 4511. Max hours: 1 Credit.

Grading Basis: Letter Grade

Prereq: ELEC 3520 and Coreq: ELEC 4511.

ELEC 4637 - 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 5637. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: ELEC 3316 and ELEC 3817

ELEC 4644 - 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: ELEC 3316. Cross-listed with ELEC 5644. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: ELEC 3316

ELEC 4678 - 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 5678. 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 4688 - 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: ELEC 3316. Cross-listed with ELEC 5688. Max hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: ELEC 3316

ELEC 4723 - 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 3520. Cross-listed with ELEC 5723. Max hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: ELEC 3520.

ELEC 4727 - 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 5727. Max hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: ELEC 3520.

ELEC 4755 - Renewable Energy Systems (3 Credits)

This course focuses on the modeling, analysis and control of grid-connected wind and photovoltaic energy systems. Prereq: ELEC 3164. Cross-listed with ELEC 5755. Repeatable. Max Hours: 9 Credits.

Grading Basis: Letter Grade

Repeatable. Max Credits: 9.

Prereq: ELEC 3164 Restriction: Restricted to students within the College of Engineering, Design and Computing

ELEC 4800 - Special Topics (1-3 Credits)

Repeatable. Max hours: 9 Credits.

Grading Basis: Letter Grade

Repeatable. Max Credits: 9.

ELEC 4840 - Independent Study: ELEC (1-3 Credits)

An opportunity for independent creative work. Prereq: Permission of instructor. Repeatable. Max Hours: 9 Credits.

Grading Basis: Letter Grade

Repeatable. Max Credits: 9.

Restrictions: Restricted to majors within the College of Engineering, Design and Computing.