ELECTRICAL AND COMPUTER ENGINEERING (ECEN)

Courses

ECEN 1030 (1-4) Special Topics
Special topics class.

ECEN 1100 (1) Exploring ECE
Introduces students to areas of emphasis with the ECE department through seminars presented by faculty and outside speakers. Emphasizes career opportunities, professional ethics and practices, history of the profession, and resources for academic success. Several sessions promote team building and problem solving, and provide opportunities for first year students to meet their classmates.
Requisites: Restricted to College of Engineering (ENGRU) undergraduates only.
Additional Information: Departmental Category: General

ECEN 1310 (4) Introduction to C Programming
This introductory programming course teaches fundamental concepts using the C programming language. The class generally meets programming requirements for majors within the engineering school and assumes no prior programming experience. Includes a weekly computer lab session. Covered topics include pointers, control flow, dynamic memory, and abstract data types. Recommended co-requisite: APPM 1350 or equivalent.
Equivalent - Duplicate Degree Credit Not Granted: CSCI 1300 or CSPB 1300
Additional Information: Departmental Category: General

ECEN 1400 (3) Introduction to Digital and Analog Electronics
This course introduces students to electrical and computer engineering centered around creative projects in a team based setting. Through the design and implementation of functional engineering systems, students gain an understanding of the engineering design process, using real-world design tools such as prototyping, computer-aided design (CAD), 3D printing, laser cutting, printed circuit board (PCB) manufacturing and testing. The projects-based curriculum provides students with a basis in the fundamentals of analog and digital electronics with an emphasis of developing student¿s understanding of how the electronics and software operate within an interdisciplinary context. Students gain hands-on experience with the creation of systems using sensors, actuators, programming microcontrollers, prototyping circuits using breadboards, and designing systems. No prior experience or knowledge of electronics or software is required.
Equivalent - Duplicate Degree Credit Not Granted: ASTR 2500, GEEN 1400, ASEN 1400 and ASE
Requisites: Restricted to students with 0-56 credits (Freshmen or Sophomore) College of Engineering majors only.
Additional Information: Departmental Category: General

ECEN 1500 (3) Sustainable Energy
Explores how energy is generated and used in today's society. Through collaborative discussion and hands-on data collection, students will analyze the engineering challenges, fundamental limits, and potential solutions to meeting our energy needs sustainably. Students will learn to analyze numerical data, estimate orders of magnitude, and apply mathematical methods in their own lives and in the ongoing energy debate. Basic algebra required.
Requisites: College of Engineering majors are excluded from this course.
Additional Information: Arts Sci Core Curr: Quant Reasn Mathmat Skills
Arts Sci Gen Ed: Quantitative Reasoning Math
Departmental Category: General

ECEN 1840 (1-6) Independent Study
Provides an opportunity for freshmen to do independent, creative work. Department consent required.
Repeatable: Repeatable for up to 6.00 total credit hours.
Additional Information: Departmental Category: General

ECEN 2010 (1-5) Special Topics
Examines a special topic in Electrical, Computer and Energy Engineering.
Repeatable: Repeatable for up to 6.00 total credit hours.
Additional Information: Departmental Category: General

ECEN 2020 (1-5) Special Topics
Repeatable: Repeatable for up to 6.00 total credit hours.
Additional Information: Departmental Category: General

ECEN 2050 (1-5) Special Topics
Additional Information: Departmental Category: General

ECEN 2060 (3) Special Topics
Examines a special topic in Electrical, Computer and Energy Engineering.
Repeatable: Repeatable for up to 6.00 total credit hours.
Recommended: Prerequisite or corequisite PHYS 1140.
Additional Information: Departmental Category: General

ECEN 2250 (3) Introduction to Circuits and Electronics
Introduces linear circuit analysis and design, including OP-Amps. Presents DC networks, including node and mesh analysis with controlled sources. Analysis of RL and RC circuits for both transient and sinusoidal steady-state responses using phasors.
Requisites: Requires prerequisite course of (APPM 1360 or MATH 2300) and PHYS 1120 (all minimum grade C-) and pre OR corequisite course of (APPM 2360 or MATH 3430). Restricted to College of Engineering majors or IUT On Track applicants or Electrical Eng minors.
Recommended: Prerequisites ECEN 1310 or CSCI 1300.
Additional Information: Departmental Category: General

ECEN 2260 (3) Circuits as Systems
Continues basic circuit analysis of ECEN 2250: Laplace transform techniques, transfer functions, frequency response, Bode diagrams, resonant circuits, Fourier series expansions, and convolution.
Requisites: Requires prerequisite course of ECEN 2250 and (APPM 2360 or MATH 3430) (minimum grade C-). Restricted to College of Engineering students or Electrical Engineering minors.
Recommended: Corequisite ECEN 2270.
Additional Information: Departmental Category: General

ECEN 2270 (3) Electronics Design Lab
Provides an introduction to analysis, modeling, design, and testing of analog electronic circuits in a practical laboratory setting. The laboratory is centered around a robot platform and includes design, SPICE simulations, prototyping and testing of circuits necessary to drive and remotely control the robot.
Requisites: Requires prerequisite course of ECEN 2260 or corequisite course of ECEN 2260. Restricted to College of Engineering majors or Electrical Engineering minors.
Additional Information: Departmental Category: General

ECEN 2350 (4) Digital Logic
Covers the design and applications of digital logic circuits, including both combinational and sequential logic circuits. Introduces hardware descriptive language, simulating and synthesis software, and programming of field programmable arrays (FPGAs). This course is 3 lectures and 1 lab per week.
Requisites: Requires prerequisite course of ECEN 1310 or CSCI 1300 or ASEN 1320 (minimum grade C-). Restricted to College of Engineering majors or IUT On Track applicants or Computer Engineering minors.
Additional Information: Departmental Category: General

ECEN 2360 (3) Programming Digital Systems
Explores how computers and programmable hardware in general are used to implement digital systems by looking at the capabilities of central processing units, the use and control of various input/output (I/O) devices, memory organization, and concurrency management. Topics include computer architecture, instruction sets, I/O device programming, interrupts, data transfer mechanisms, semaphores, and memory management.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 3350
Requisites: Requires prerequisite course of ECEN 2350 (minimum grade C-). Restricted to College of Engineering majors or Computer Engineering minors.

ECEN 2370 (3) Embedded Software Engineering
Introduces digital system design, including system software and hardware building blocks, and system software-hardware integration. Emphasizes hands-on system development and debugging. Uses mainstream electronic system design platforms, featuring ARM processors, embedded and mobile computing platforms, using the C programming language.
Requisites: Requires prerequisite courses of ECEN 1310 and ECEN 2350 and prerequisite or corequisite course of ECEN 2360 or CSCI 2400 (all minimum grade C-). Restricted to College of Engineering majors or IUT On Track applicants or Computer Engineering minors.

ECEN 2410 (3) Renewable Sources and Efficient Electrical Energy Systems
Introduces electrical power generation and renewable energy, including solar, wind, micro, hydro, coal, nuclear and natural gas and some of the issues in integrating renewable energy sources in the grid.
Requisites: Requires prerequisite course of PHYS 1120 (minimum grade C-). Requires prerequisite OR corequisite course of ECEN 2250. Restricted to College of Engineering majors only.
Additional Information: Departmental Category: General

ECEN 2420 (3) Electronics for Wireless Systems
Explores fundamental principles behind the operation of a radio, including a practical introduction to circuit elements. Covers the components and operation of a radio (transmitter and receiver) with simple signals. Students learn lab exercises the operation principles behind components of a complete practical radio system.
Requisites: Requires prerequisite course of PHYS 1120 and (APPM 1360 or MATH 2300) (all minimum grade C-). Requires prerequisite course of ECEN 2250 (min grade C-). Restricted to Electrical and Computer Engineering (ECEN) or Electrical Engineering (EEEN) majors onl
Additional Information: Departmental Category: General

ECEN 2440 (3) Application of Embedded Systems
Introduces embedded systems and key computer architecture concepts through a variety of projects involving programming a microcontroller in C. Provides students hands-on projects that combine the knowledge gained in their digital and analog coursework in order to engineer hardware, firmware and application software design solutions. Includes a weekly lecture and two weekly laboratory sessions.
Requisites: Requires a prerequisite course of ECEN 1310 or CSCI 1300 or ASEN 1320 (minimum grade C-). Requires prerequisite OR corequisite course of ECEN 2250.
Additional Information: Departmental Category: General

ECEN 2450 (3) Electronic and Semiconductor Device Laboratory
Explores the operation of electronic and semiconductor devices, including: resistors, transparent conductors, capacitors, inductors, diodes and light emitting diodes, photovoltaics, photodiodes, bipolar junction and field effect transistors, organic electrochemical transistors, and various sensor devices. Laboratories will involve device characterization and implementation into simple circuits, data analysis, and function fitting. Some of the laboratories will involve partial fabrication of the devices. Previously offered as a special topics course. Recommended restriction: sophomores or juniors; seniors cannot enroll in the course.
Requisites: Requires prerequisite or corequisite course of ECEN 2250 (minimum grade C-). Restricted to College of Engineering students only.
Recommended: Prerequisite PHYS 1140.

ECEN 2703 (3) Discrete Mathematics for Computer Engineers
Emphasizes elements of discrete mathematics appropriate for computer engineering. Topics: logic, proof techniques, algorithms, complexity, relations, and graph theory.
Requisites: Requires prerequisite courses of ECEN 1310 or CSCI 1300 or ASEN 1320 and APPM 1360 or MATH 2300 (all minimum grade C-). Restricted to College of Engineering students only.
Additional Information: Departmental Category: Computer and Digital Systems

ECEN 2830 (1-5) Special Topics
Examines a special topic in Electrical, Computer and Energy Engineering.
Repeatable: Repeatable for up to 9.00 total credit hours. Allows multiple enrollment in term.
Additional Information: Departmental Category: General

ECEN 2840 (1-6) Independent Study
Offers an opportunity for sophomores to do independent, creative work. Department consent required.
Repeatable: Repeatable for up to 6.00 total credit hours.
Additional Information: Departmental Category: General

ECEN 3002 (3) Special Topics
Examines a special topic in Electrical, Computer and Energy Engineering.
Additional Information: Departmental Category: Digital Signal Processing Communications

ECEN 3003 (3-5) Special Topics
Additional Information: Departmental Category: Computer and Digital Systems

ECEN 3004 (3-5) Special Topics
Additional Information: Departmental Category: Electromagnetics and Remote Sensing

ECEN 3010 (3) Circuits and Electronics for Mechanical Engineers
Covers analysis of electrical circuits by use of Ohm's law, network reduction, node and loop analysis, Thevenin's and Norton's theorems, DC and AC signals, transient response of simple circuits, transfer functions, basic diode and transistor circuits, and operational amplifiers. Includes introductory digital electronics and microprocessors/microcontrollers.
Equivalent - Duplicate Degree Credit Not Granted: MCEN 3017
Requisites: Requires prereq course of PHYS 1120 and a prereq or coreq course of APPM 2360 or APPM 3310 or MATH 3430 (all min grade C). Restricted to MCEN or EVEN or Integrated Design Engr (IDEN-BSIDE) students.
Additional Information: Departmental Category: General

ECEN 3090 (3) Introduction to Quantum Computing
Covers the basics of quantum computation, including the basics of quantum information; axioms of quantum mechanics; quantum circuits and universality; the relationship between quantum and classical complexity classes; simple quantum algorithms such as the quantum Fourier transform; Shor factoring algorithm; Grover search algorithm; physical implementation of quantum computation; error correction and fault tolerance.
Equivalent - Duplicate Degree Credit Not Granted: CSCI 3090 and PHYS 3090
Requisites: Requires prerequisite course of APPM 2360 or APPM 3310 or CSCI 2820 or MATH 2130 or MATH 2135 (minimum grade C-).

ECEN 3103 (3) Automation of Industrial Processes
Introduces students to Programmable Logic Controller (PLC) architecture, ladder logic programming, and programming Human Machine Interfaces (HMI). Students learn how to automate manufacturing processes and applications of PID control.
Requisites: Requires prerequisite course of ECEN 2250 (minimum grade D-). Restricted to students in the CMU/CU-Boulder Engineering Partnership Program only.

ECEN 3170 (3) Electromagnetic Energy Conversion 1
Real and reactive power in single phase circuits, power triangle, balanced three-phase circuits, wye and delta connections, introduction to electromagnetic machines, transformers (single and three-phase) and their equivalent circuits, AC-machinery fundamentals, synchronous generator from a magnetic field point of view, synchronous motors and condensers, three-phase induction motors, DC machinery fundamentals, DC motors, single phase motors. Matlab/Simulink will be used.
Requisites: Requires prerequisite courses of ECEN 2260 and PHYS 1120 (minimum grade C-). Restricted to College of Engineering majors only.
Additional Information: Departmental Category: Power

ECEN 3250 (3) Microelectronics
Develops a basic understanding of active semiconductor devices. Focuses on building an understanding of BJT and CMOS devices in both digital and analog applications.
Requisites: Requires prerequisite course of ECEN 2250 (minimum grade C-). Restricted to College of Engineering students or Electrical Engineering minors.
Additional Information: Departmental Category: General

ECEN 3300 (3) Linear Systems
Characterization of linear time-invariant systems in time and frequency domains. Continuous time systems are analyzed using differential equations and Laplace and Fourier transforms. Discrete time systems are analyzed using difference equations, Z-transforms and discrete time Fourier transforms. Sampling and reconstruction of signals using the sampling theorem. Applications of linear systems include communications, signal processing, and control systems.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 3301
Requisites: Requires prerequisite course of ECEN 2260 (minimum grade C-). Restricted to College of Engineering majors only.
Additional Information: Departmental Category: General

ECEN 3301 (3) Biomedical Signals and Systems
Introduces theory and methods to characterize and process biological signals from a variety of sources and engineering applications in the time and frequency domains. This course covers mathematical and computational tools for signal analysis with emphasis on discrete time signals and digital processing. Topics include noise, sampling, Fourier transforms, filter design, LTI systems, and image processing with exercises in MATLAB.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 3300
Requisites: Requires prerequisite course of ECEN 2260 (minimum grade C-).
Recommended: Prerequisite BMEN 3030.

ECEN 3303 (3) Introduction to Robotics
Introduces students to fundamental concepts in autonomous robotics: mechanisms, locomotion, kinematics, control, perception and planning. Consists of lectures and lab sessions that are geared toward developing a complete navigation stack on a miniature mobile robotic platform.
Equivalent - Duplicate Degree Credit Not Granted: CSCI 3302 and CSPB 3302
Requisites: Requires prerequisite courses of (CSCI 2270 or CSCI 2275) and (APPM 3170 or CSCI 2824 or ECEN 2703 or MATH 2001) and (APPM 2360 or APPM 3310 or CSCI 2820 or MATH 2130 or MATH 2135) (all minimum grade C-).
Additional Information: Departmental Category: Computer and Digital Systems

ECEN 3320 (3) Semiconductor Devices
Highlights the fundamentals of semiconductor materials and devices. Topics include the electrical and optical properties of semiconductors, the theory of Pn junctions, bipolar and field-effect transistors, and optoelectronic devices.
Requisites: Requires prerequisite course of ECEN 2250 (minimum grade C-). Restricted to College of Engineering students or Electrical Engineering minors.
Additional Information: Departmental Category: General

ECEN 3350 (3) Programming Digital Systems
Explores how computers and programmable hardware in general are used to implement digital systems by looking at the capabilities of central processing units, the use and control of various input/output (I/O) devices, memory organization, and concurrency management. Topics include computer architecture, instruction sets, I/O device programming, interrupts, data transfer mechanisms, semaphores, and memory management.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 2360
Requisites: Requires prerequisite course of ECEN 2350 (minimum grade C-). Restricted to College of Engineering majors only.
Additional Information: Departmental Category: Computer and Digital Systems

ECEN 3400 (3) Electromagnetic Fields and Waves
Electromagnetic fields are covered at an introductory level, starting with electrostatics and continuing with DC current, magnetostatics, time-varying magnetic fields, waves on transmission lines, Maxwell's equations and the basics of plane waves. The use of fields in inductors, capacitors, resistors, transformers, and energy and power concepts are studied.
Requisites: Requires prerequisites (APPM 2350 or MATH 2400) and (APPM 2360 or MATH 3430) and PHYS 1120 and ECEN 2250 (all minimum grade C-). Restricted to College of Engineering majors or Electrical Engineering minors.
Additional Information: Departmental Category: General

ECEN 3410 (3) Electromagnetic Waves and Transmission
Covers reflected and transmitted plane waves in layered media, Poynting's theorem of electromagnetic power, two-conductor transmission line theory and practice, Smith chart usage and impedance matching, waveguides, and elements of antenna theory.
Requisites: Requires prerequisite course ECEN 3400 (minimum grade C-). Restricted to College of Engineering majors or Electrical Engineering minors.
Additional Information: Departmental Category: Electromagnetics and Remote Sensing

ECEN 3593 (3) Computer Organization
Studies computer design at the microarchitecture level. Discusses instruction set architecture design, arithmetic and logic unit design, control logic, memory design and caches, simple pipelining, I/O and peripheral devices. Briefly covers aspects of modern computer architecture, such as multicore processors and hardware security.
Equivalent - Duplicate Degree Credit Not Granted: CSCI 3593 ECEN 5590
Requisites: Requires prerequisite course of ECEN 3350 or CSCI 2400 (minimum grade C-). Restricted to College of Engineering majors only.
Additional Information: Departmental Category: Computer and Digital Systems

ECEN 3730 (3) Practical Printed Circuit Board Design and Manufacture
This course prepares students with all skills needed to convert a back-of-the-napkin circuit sketch into a working widget with first time success. Students will master the seven steps in every board project: planning, selecting components, schematic entry, layout, assembly, bring up and debug, and documentation. This process will be exercised with three different board design projects with increasing challenge. A commercial EDA tool widely used in the electronics industry will be used for all projects. Previously offered as a special topics course. Formerly ECEN 4730.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 4720 or ECEN 5720 or ECEN 5730
Requisites: Requires prerequisite courses of ECEN 2250 and ECEN 2260 and ECEN 2270 (all minimum grade C-).

ECEN 3753 (3) Real-Time Operating Systems
Today's electronic systems require real-time management and scheduling of hardware resources alongside complex multi-threaded software applications. This course covers what is an Operating Systems, the development of multi-threaded applications, and satisfying real-time system obligations. Real-Time profiling tools will be used to learn and visualize how the operating system is scheduling the software tasks and hardware resources to meet resource constraint embedded system applications. Formerly offered as a special topics course.
Requisites: Requires prerequisite course (ECEN 2370 or ECEN 3360) and CSCI 2270 (all minimum grade C-). Restricted to College of Engineering students only.

ECEN 3763 (3) FPGA Design and HDL
Build upon the foundations of Digital Logic to learn the theory of FPGA architectures, design practices, and design processes. The emphasis is to architect and design complex FPGA based projects demonstrating overall project organization and creation of milestones, testing requirements, proper use of physical and design constraints, and successful implementation and demonstration. Previously offered as a special topics course.
Requisites: Requires prerequisite courses of ECEN 2350 and (ECEN 1310 or CSCI 1300 or ASEN 1320) (minimum grade C-). Restricted to College of Engineering students only.
Recommended: Prerequisites ECEN 2360 and ECEN 2370.

ECEN 3810 (3) Introduction to Probability Theory
Covers the fundamentals of probability theory, and treats the random variables and random processes of greatest importance in electrical engineering. Provides a foundation for study of communication theory, control theory, reliability theory, and optics.
Equivalent - Duplicate Degree Credit Not Granted: MATH 4510 or APPM 3570
Requisites: Requires prerequisite course of APPM 2350 or MATH 2400 (minimum grade C-). Restricted to College of Engineering majors only.
Additional Information: Departmental Category: General

ECEN 3840 (1-6) Independent Study
Offers an opportunity for juniors to do independent, creative work. Department consent required.
Repeatable: Repeatable for up to 6.00 total credit hours.
Additional Information: Departmental Category: General

ECEN 3841 (1-6) Independent Study
Offers an opportunity for juniors to do independent, creative work.
Repeatable: Repeatable for up to 6.00 total credit hours.
Additional Information: Departmental Category: General

ECEN 3915 (3) Foundations of Quantum Engineering
Introduces engineers to quantum theory. In this course you will learn how to describe many different physical systems (such as atoms, electrons, light, mechanical oscillators, and tops) mathematically. It also explores different notions of quantumness such as entanglement and non-contextuality. The foundations obtained in this course are important for further study of quantum hardware (sensors), communication, and computing. Formerly ECEN 4915.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 5915
Requisites: Requires prerequisite courses of (ASEN 1320 OR ECEN 1310 OR ECEN 2310 OR CSCI 1300 OR APPM 3050 OR PHYS 2600) (MATH 3135 OR MATH 2130 OR MATH 2135 OR APPM 2360 OR APPM 3310 OR CSCI 2820) all minimum grade C-.
Recommended: Prerequisite MATH 3430 or APPM 2360.

ECEN 4000 (1-3) Special Topics
Examines a special topic in Electrical, Computer and Energy Engineering.
Repeatable: Repeatable for up to 9.00 total credit hours. Allows multiple enrollment in term.
Additional Information: Departmental Category: General

ECEN 4001 (1-4) Special Topics
Examines a special topic in Electrical, Computer and Energy Engineering.
Repeatable: Repeatable for up to 9.00 total credit hours. Allows multiple enrollment in term.
Additional Information: Departmental Category: Bioengineering

ECEN 4002 (1-4) Special Topics
Credit and subject matter to be arranged. Department enforced prerequisite: varies
Repeatable: Repeatable for up to 6.00 total credit hours. Allows multiple enrollment in term.
Additional Information: Departmental Category: Digital Signal Processing Communications

ECEN 4003 (1-4) Special Topics
Credit and subject matter to be arranged. Department enforced prerequisite: varies
Repeatable: Repeatable for up to 12.00 total credit hours. Allows multiple enrollment in term.

ECEN 4004 (1-4) Special Topics
Examines a special topic in Electrical, Computer and Energy Engineering.
Repeatable: Repeatable for up to 9.00 total credit hours. Allows multiple enrollment in term.

ECEN 4005 (3) Special Topics
Examines a special topic in Electrical, Computer and Energy Engineering.
Repeatable: Repeatable for up to 9.00 total credit hours. Allows multiple enrollment in term.

ECEN 4006 (3) Special Topics
Examines a special topic in Electrical, Computer and Energy Engineering.
Repeatable: Repeatable for up to 9.00 total credit hours.
Additional Information: Departmental Category: Optics

ECEN 4007 (1-4) Special Topics
Examines a special topic in Electrical, Computer and Energy Engineering.
Repeatable: Repeatable for up to 9.00 total credit hours. Allows multiple enrollment in term.

ECEN 4009 (1-4) Special Topics
Examines a special topic in Electrical, Computer and Energy Engineering.
Repeatable: Repeatable for up to 9.00 total credit hours. Allows multiple enrollment in term.
Additional Information: Departmental Category: VLSI CAD Methods

ECEN 4011 (1-4) Special Topics
Examines a special topic in Electrical, Computer and Energy Engineering.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 5011
Repeatable: Repeatable for up to 9.00 total credit hours.
Additional Information: Departmental Category: Bioengineering

ECEN 4012 (1-4) Special Topics
Examines a special topic in Electrical, Computer and Energy Engineering.
Additional Information: Departmental Category: Digital Signal Processing Communications

ECEN 4013 (3) Special Topics
Examines a special topic in Electrical, Computer and Energy Engineering.
Repeatable: Repeatable for up to 9.00 total credit hours. Allows multiple enrollment in term.
Additional Information: Departmental Category: Computer and Digital Systems

ECEN 4016 (1-4) Special Topics
Examines a special topic in Electrical, Computer and Energy Engineering.
Additional Information: Departmental Category: Optics

ECEN 4017 (1-4) Special Topics
Examines a special topic in Electrical, Computer and Energy Engineering.
Additional Information: Departmental Category: Power

ECEN 4018 (1-4) Special Topics
Examines a special topic in Electrical, Computer and Energy Engineering.
Additional Information: Departmental Category: Dynamical Systems and Control

ECEN 4021 (1-4) Special Topics
Examines a special topic in Electrical, Computer and Energy Engineering.
Repeatable: Repeatable for up to 9.00 total credit hours.
Requisites: Restricted to students with 87-180 credits (Senior, Fifth Year Senior) College of Engineering majors only.
Additional Information: Departmental Category: Bioengineering

ECEN 4024 (1-4) Special Topics
Examines a special topic in Electrical, Computer and Energy Engineering.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 5024
Repeatable: Repeatable for up to 9.00 total credit hours. Allows multiple enrollment in term.
Additional Information: Departmental Category: Electromagnetics and Remote Sensing

ECEN 4028 (1-4) Special Topics
Examines a special topic in Electrical, Computer and Energy Engineering.
Additional Information: Departmental Category: Dynamical Systems and Control

ECEN 4031 (1-4) Special Topics
Examines a special topic in Electrical, Computer and Energy Engineering.

ECEN 4033 (3) Special Topics
Examines a special topic in Electrical, Computer and Energy Engineering.
Repeatable: Repeatable for up to 9.00 total credit hours. Allows multiple enrollment in term.

ECEN 4043 (1-4) Special Topics
Examines a special topic in Electrical, Computer and Energy Engineering.

ECEN 4053 (1-4) Special Topics
Special topics course.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 5053
Repeatable: Repeatable for up to 4.00 total credit hours.
Additional Information: Departmental Category: Computer and Digital Systems

ECEN 4111 (3) Engineering Applications in Biomedicine: Cardiovascular Devices and Systems
Application of engineering in medicine has grown dramatically in recent years. Engineers enter the clinical and experimental medical arenas with many new devices and procedures emerging as alternatives to conventional surgical and pharmacological treatments. This course, presents general principles of biomedical engineering as applied to the development of a variety of specific devices and techniques for therapy and diagnosis, with a focus on devices and systems for the cardiovascular system. This class will present relevant anatomy and physiology as part of the class discussion, which will be supplemented by a physiology reference text. Questions, exchanges of ideas, and active classroom discussion are encouraged. Biomedical engineering is an emerging field which is highly interdisciplinary- engineers and scientists from all fields are invited and encouraged to participate in this course. There are no formal prerequisites.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 5111
Recommended: Prerequisite ECEN 2250 or equivalent circuits course.

ECEN 4121 (3) Design of Implantable Medical Devices: Neuromodulation
Application of engineering in medicine has grown dramatically in recent years. Engineers enter the clinical and experimental medical arenas with many new devices and procedures emerging as alternatives to conventional surgical and pharmacological treatments. This course, presents general principles of biomedical engineering as they are applied to the development of a variety of specific implantable devices.It will present relevant anatomy and physiology as part of the class discussion, which will be supplemented by a physiology reference text. Questions, exchanges of ideas, and active classroom discussion are encouraged throughout the course. Biomedical engineering is an emerging field which is highly interdisciplinary- engineers and scientists from all fields are invited and encouraged to participate in this course.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 5121
Recommended: Prerequisite ECEN 2250 or equivalent circuits course.

ECEN 4133 (3) Fundamentals of Computer Security
Practice thinking like an attacker by exploring several modern computer security attacks and defenses through hands-on programming projects. Topics include applied cryptography (encryption, authentication), web security (XSS, CSRF, SQL Injection), network security (TLS, MITM attacks), application security (shell injection, buffer overflows), and other current events and trends (government surveillance, botnets, cryptocurrencies).
Equivalent - Duplicate Degree Credit Not Granted: CSCI 4133
Requisites: Requires prerequisite courses of CSCI 2270 and ECEN 2360 or CSCI 2400 or ECEN 3350 (all minimum grade C-).
Recommended: Corequisite ECEN 3593 (Computer Organization).

ECEN 4138 (3) Control Systems Analysis
Analysis and design of continuous time control systems using classical and state space methods. Laplace transforms, transfer functions and block diagrams. Stability, dynamic response, and steady-state analysis. Analysis and design of control systems using root locus and frequency response methods. Computer aided design and analysis. Department enforced prerequisite: background in Laplace transforms, linear algebra,and ordinary differential equations.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 5138 MCEN 4138 or MCEN 5138
Requisites: Requires prerequisite course of ECEN 3300 or MCEN 4043 (minimum grade C-). Restricted to College of Engineering majors only.
Additional Information: Departmental Category: Dynamical Systems and Control

ECEN 4224 (3) High Speed Digital Design
Covers fundamentals of high-speed properties of logic gates, measurement techniques, transmission lines, ground planes and layer stacking, terminations, vias, power systems, connectors, ribbon cables, clock distribution and clock oscillators.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 5224
Requisites: Requires prerequisites of ECEN 2260 and ECEN 3400 (minimum grade C-). Restricted to College of Engineering students only.
Additional Information: Departmental Category: Electromagnetics and Remote Sensing

ECEN 4242 (3) Communication Theory
Covers modern digital and analog communication systems. Analysis and design of communication signals, transmitters, channels, and receivers. Amplitude and angle modulation and demodulation are treated as well as theory and application of digital data transmission. Emphasis is also placed on the analysis and mitigation of the effects of noise through signal design at the transmitter and signal processing at the receiver.
Requisites: Requires prerequisite course of (ECEN 3300 or ECEN 3301) and (ECEN 3810 or APPM 3570 or MATH 4510 or STAT 3100) (all minimum grade C-). Restricted to College of Engineering majors only.
Additional Information: Departmental Category: Digital Signal Processing Communications

ECEN 4295 (3) Foundations of Quantum Hardware
Introduces students to the principles and operation of quantum hardware. In this course you will learn how to describe many different physical systems (trapped Ions, superconducting circuits, and optical systems) mathematically. This will allow you to model quantum sensors, communication systems and computing hardware.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 5295

ECEN 4313 (3) Concurrent Programming
Introduces the theory and practice of multicore programming. The first part of the course presents foundations of concurrent programming: mutual exclusion, wait-free and lock-free synchronization, spin locks, monitors, memory consistency models. The second part presents a sequence of concurrent data structures and techniques used in their implementations (coarse-grained, fine-grained, optimistic and lock-free synchronization).
Equivalent - Duplicate Degree Credit Not Granted: CSCI 4313 and ECEN 5313 and CSCI 5313
Requisites: Requires prerequisite courses of CSCI 2270 and (ECEN 2360 or ECEN 3350 or CSCI 2400) (minimum grade C-). Restricted to College of Engineering students only.
Recommended: Prerequisite ECEN 3593.

ECEN 4322 (3) Data and Network Science
The course covers the theory and design of algorithms that are used to model, analyze, and extract information from large scale datasets and networks. The course includes a project.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 5322
Requisites: Prereq of(APPM 2350 or MATH 2400) (APPM 2360 or MATH 3430) (CSCI 1200 or CSCI 1300 or CSCI 1320 or ECEN 1310 or ASEN 1320 or INFO 1201 or ATLS 1300 or CHEN 1310) (ECEN 2703 or CSCI 2824 or APPM 3170 or MATH 2001)(min grade C-).Restricted to ENGR mjrs

ECEN 4341 (3) Bioelectromagnetics
Effects of electric and magnetic fields on biological systems are described with applications to therapy and safety. The complexity of biological systems is described to provide a better understanding of the distribution of fields inside the body. Risk analysis is also introduced.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 5341
Requisites: Requires prerequisite courses of ECEN 3400 and (ECEN 3810 or APPM 3570 or MATH 4510 or STAT 3100) (all minimum grade C-). Restricted to College of Engineering students only.
Additional Information: Departmental Category: Bioengineering

ECEN 4395 (3) Organic Electronic Materials and Devices
Covers the materials and physics principles of organic electronic devices, including organic light emitting diodes (OLEDs), photovoltaics (OPVs), field effect transistors (OFETs), electrochemical transistors (OECTs), and bioelectronic and neuromorphic devices. The molecular, structural, and electronic properties of organic semiconductors are introduced, and the architectures and operating principles of the devices are then taught. Assignments will require computational solutions and simulations. Previously offered as a special topics course.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 5395
Recommended: Prerequisite ECEN 5345.

ECEN 4423 (3) Chaotic Dynamics
Explores chaotic dynamics theoretically and through computer simulations. Covers the standard computational and analytical tools used in nonlinear dynamics and concludes with an overview of leading-edge chaos research. Topics include time and phase-space dynamics, surfaces of section, bifurcation diagrams, fractal dimension and Lyapunov exponents.
Equivalent - Duplicate Degree Credit Not Granted: CSCI 5446 and CSCI 4446 and ECEN 5423
Requisites: Requires prerequisite courses of (APPM 1360 or MATH 2300) and (ECEN 1310 or CSCI 1300 or ASEN 1320) and PHYS 1110 (all minimum grade C-). Restricted to College of Engineering students only.
Recommended: Prerequisites PHYS 1120 and CSCI 3656 and (APPM 3310 or CSCI 2820 or MATH 2130 or MATH 2135 or MATH 3130 or MATH 3135).
Additional Information: Departmental Category: Computer and Digital Systems

ECEN 4517 (3) Power Electronics and Photovoltaic Power Systems Laboratory
Focuses on analysis, modeling, design and testing of electrical energy processing systems in a practical laboratory setting. Studies power electronics converters for efficient utilization of available energy sources, including solar panels and utility. Experimental projects involve design, fabrication and testing of a solar power system.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 5517
Requisites: Requires prerequisite course of ECEN 4797 (minimum grade C-). Restricted to College of Engineering majors only.
Additional Information: Departmental Category: Power

ECEN 4532 (3) Digital Signal Processing Laboratory
Develops experience in code development, debugging and testing of real-time digital signal processing algorithms using dedicated hardware. Applications include filtering, signal synthesis, audio special effects and frequency domain techniques based on the Fast Fourier Transform.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 5532
Requisites: Requires prerequisite course of ECEN 4632 (minimum grade C-). Restricted to College of Engineering majors only.
Additional Information: Departmental Category: Digital Signal Processing Communications

ECEN 4553 (3) Compiler Construction
Introduces the principles and techniques for compiling high-level programming languages to assembly code. Topics include parsing, instruction selection, register allocation, and compiling high-level features such as polymorphism, first-class functions, and objects. Students build a complete compiler for a simple language.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 5523 and CSCI 4555 and CSCI 5525
Requisites: Requires prerequisite courses of (ECEN 2703 or APPM 3170 or CSCI 2824 or MATH 2001) and (ECEN 2360 or ECEN 3350 or CSCI 2400) (all minimum grade C-). Restricted to College of Engineering students or Computer Engineering minors.
Additional Information: Departmental Category: Computer and Digital Systems

ECEN 4555 (3) Principles of Energy Systems and Devices
Develops principles underlying electronic, optical and thermal devices, materials and nanostructures for renewable energy. Provides a foundation in statistical thermodynamics and uses it to analyze the operation and efficiency limits of devices for photovoltaics, energy storage (batteries & ultra-capacitors), chemical conversion (fuel cells and engines), solid state lighting, heat pumps, cooling and potentially harvesting zero-point energy from the vacuum.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 5555
Requisites: Requires prerequisite courses of (ECEN 3810 or APPM 3570 or MATH 4510 or STAT 3100) and (PHYS 2130 or PHYS 2170) (all minimum grade C-). Restricted to College of Engineering students only.
Additional Information: Departmental Category: Nanostructures and Devices

ECEN 4606 (3) Undergraduate Optics Laboratory
Introduces fundamental concepts, techniques, and technology of modern optical and photonic systems. Individual labs cover particular fields of optical technology, including light sources such as lasers and Leds, interferometers, fiber-optic communications, photodetection, spectrometers, and holography. Practical skills such as how to align an optical system will also be emphasized.
Requisites: Requires prerequisite course of ECEN 3400 (minimum grade C-). Restricted to College of Engineering majors only.
Additional Information: Departmental Category: Optics

ECEN 4610 (3) Capstone Laboratory Part 1
Hands-on laboratory experience utilizing teams in the systematic proposal, design, integration, and testing of an electronic/computer based system. Results will be the prototype of a stand-alone analog/digital system. Must have completed all required Advanced Analog Core courses for major, except one course may be taken concurrently by petition. Must take ECEN 4620 to complete the sequence. Minimum required grade for this course and ECEN 4620 is C-. IDEN majors follow different requisites and should work with their advisor for requisite planning and enrollment assistance.
Requisites: Prereqs of ECEN 2270, ECEN 2370, (ECEN 2360 or CSCI 2400) and (ECEN 3250 and ECEN 3300) or (ECEN 3250 and ECEN 3400) or (ECEN 3300 and ECEN 3400) or (ECEN 3753 and ECEN 3250) or (ECEN 3753 and ECEN 3300) or (ECEN 3753 and ECEN 3400) (all min grade C-).
Additional Information: Departmental Category: General

ECEN 4616 (3) Optoelectronic System Design
Examines optical components and electro-optic devices with the goal of integrating into well design optoelectronic systems. Sample systems include optical storage, zoom lenses and telescopes.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 5616
Requisites: Requires prerequisite course of ECEN 3400 (minimum grade C-).
Additional Information: Departmental Category: Optics

ECEN 4620 (3) Capstone Lab, Part 2
Hands-on laboratory experience for teams in the systematic proposal, design, build integration, test and documentation of an electronic/computer based system. Results will be a reliably operating, stand-alone analog/digital system, with publication quality technical documentation. Department enforced prerequisite: advanced analog core courses.
Requisites: Requires prerequisite course of ECEN 4610 (minimum grade C-).
Additional Information: Departmental Category: General

ECEN 4632 (3) Introduction to Digital Filtering
Covers both the analysis and design of FIR and IIR digital filters. Discusses implementations in both software and hardware. Emphasizes use of the FFT as an analysis tool. Includes examples in speech processing, noise canceling, and communications.
Requisites: Requires prerequisite course of ECEN 3300 (minimum grade C-). Restricted to College of Engineering majors only.
Additional Information: Departmental Category: Digital Signal Processing Communications

ECEN 4634 (3) Microwave and RF Laboratory
This course is a hands-on introduction to RF and microwave topics, from fundamentals including vector network analyzer (VNA) calibration and operation, power measurements, and antenna characterization, to system-level topics such as RADAR systems and superheterodyne links. Students work in small groups on weekly experiments based on both coaxial and waveguide setups. An understanding of electromagnetic waves (such as covered in ECEN 3400 and ECEN 3410) is assumed. The graduate version of the course (ECEN 5634) includes additional homework and exam problems and extended laboratory exercises compared to ECEN 4634.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 5634
Requisites: Requires prerequisite course of ECEN 3410 (minimum grade C-). Restricted to College of Engineering majors only.
Additional Information: Departmental Category: Electromagnetics and Remote Sensing

ECEN 4638 (3) Control Systems Laboratory
Provides experience in control system design and analysis, using both real hardware and computer simulation. Covers the entire control system design cycle: modeling the system, synthesizing a controller, conducting simulations, analyzing the design to suggest modifications and improvements, and implementing the design for actual testing.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 5638, MCEN 4638, and MCEN 5638
Requisites: Requires prerequisite course of ECEN 4138 (minimum grade C-). Restricted to College of Engineering majors only.
Additional Information: Departmental Category: Dynamical Systems and Control

ECEN 4693 (3) Advanced Computer Architecture
Provides a broad-scope treatment of important concepts in the design and implementation of high-performance computer systems. Discusses important issues in the pipelining of a processor, out-of-order instruction issue and superscalar designs, design of cache memory systems for such systems, and architectural features required for multicore processor designs. Also studies current and historically important computer architectures.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 5593 and CSCI 5593
Requisites: Requires prerequisite course of ECEN 3593 or CSCI 3593 (minimum grade C-). Restricted to ECEN or EEEN majors and Computer Engineering minors.
Recommended: Prerequisite knowledge of C/C++ and Assembly programming languages, and computer organization and experience using a Linux system for programming and its associated capabilities of compilation and debugging.

ECEN 4720 (1) Practical Printed Circuit Board Design Accelerator
This course introduces students to the most important skills needed to convert a back-of-the-napkin circuit sketch into a working widget with first time success. Students will learn the seven steps in every board project: planning, selecting components, schematic entry, layout, assembly, bring up and debug, and documentation. This process will be exercised with a custom board design project. A commercial EDA tool widely used in the electronics industry will be used for the project. Previously offered as a special topics course.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 5720 ECEN 3730 or ECEN 5730
Requisites: Requires prerequisite courses of ECEN 2250 and ECEN 2260 and ECEN 2270 (all minimum grade C-).

ECEN 4752 (3) Communication Laboratory
Analysis and design of realistic communication signals in a modern digital signal processing environment. Covers both analog and digital communication signals with and without noise and distortion. Pulse amplitude modulation is used initially at baseband and then combined with amplitude and phase/frequency modulation to produce the kind of bandpass signals that are used in cell phones and wireless data networks. Formerly ECEN 4652.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 5752
Requisites: Requires prerequisite course of ECEN 4242 (minimum grade C-). Restricted to College of Engineering majors only.
Additional Information: Departmental Category: Digital Signal Processing Communications

ECEN 4753 (3) Computer Performance Modeling
Presents a broad range of system measurement and modeling techniques, emphasizing applications to computer systems. Covers topics including system measurement, workload characterization and analysis of data; design of experiments; queuing theory and queuing network models; and simulation.
Equivalent - Duplicate Degree Credit Not Granted: CSCI 5753 and CSCI 4753 and ECEN 5753
Requisites: Requires prerequisite course of CSCI 3753 or ECEN 3753 (minimum grade C-). Restricted to College of Engineering students only.
Recommended: Prerequisite a course in statistics.
Additional Information: Departmental Category: Computer and Digital Systems

ECEN 4763 (3) Embedded Software Algorithms
Embedded Systems are defined by resource restrictions that could include computational performance, energy, memory space, and cost. These algorithms need to be evaluated against the targeted end-system constraints. Applications in many areas of real-time decision-making are discussed, from hybrid vehicle battery usage to queue management systems in real-time-priced tollways, aircraft holding patterns, and hard disk drive performance optimization. This is a programming course.
Requisites: Requires prerequisite courses of (ECEN 2370 or ECEN 3360) and CSCI 2270 (all minimum grade C-). Restricted to College of Engineering students only.

ECEN 4797 (3) Introduction to Power Electronics
An introduction to switched-mode converters. Includes steady-state converter modeling and analysis, switch realization, discontinuous conduction mode and transformer-isolated converters. Ac modeling of converters using averaged methods, small-signal transfer functions, feedback loop design and transformer design.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 5797
Requisites: Requires prerequisite course of ECEN 3250 (minimum grade C-). Restricted to College of Engineering majors only.
Additional Information: Departmental Category: Power

ECEN 4827 (3) Analog IC Design
Covers the fundamentals of transistor-level analog integrated circuit design. Starting with motivations from application circuits, the course develops principles of dc biasing, device models, amplifier stages, frequency response analysis and feedback and compensation techniques for multi-stage operational amplifiers.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 5827
Requisites: Requires prerequisite course of ECEN 3250 (minimum grade C-). Restricted to College of Engineering majors only.
Additional Information: Departmental Category: Power

ECEN 4840 (1-6) Independent Study
Offers an opportunity for seniors to do independent, creative work. Department consent required.
Repeatable: Repeatable for up to 6.00 total credit hours. Allows multiple enrollment in term.
Additional Information: Departmental Category: General

ECEN 4841 (1-6) Independent Study
Offers an opportunity for seniors to do independent, creative work.
Repeatable: Repeatable for up to 6.00 total credit hours.

ECEN 4925 (3) Foundations of Quantum Hardware
Introduces students to the principles and operation of quantum hardware. In this course you will learn how to describe many different physical systems (trapped Ions, superconducting circuits, and optical systems) mathematically. This will allow you to model quantum sensors, communication systems and computing hardware.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 5295
Requisites: Requires prerequisite courses of ECEN 3915 OR (pre-req PHYS 3220 AND co-Req PHYS 4410) (all minimum grade C-). Restricted to College of Engineering students or Quantum Engineering minors.

ECEN 4933 (3) Engineering Genetic Circuits
Presents recent research into methods and software tools for the modeling, analysis, and design of genetic circuits that are enabling the new field of synthetic biology. Teaches both biological and engineering principles in order to enable collaborations between engineers and biologists working in the field of synthetic biology.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 5933
Recommended: Prerequisite some familiarity with genetics, cell biology, molecular biology or biochemistry or familiarity with engineering methods for modeling, analysis and design, but students are not expected to have knowledge in both.

ECEN 5005 (3) Special Topics
Examines a special topic in Electrical, Computer and Energy Engineering.
Repeatable: Repeatable for up to 9.00 total credit hours. Allows multiple enrollment in term.
Additional Information: Departmental Category: Nanostructures and Devices

ECEN 5008 (3) Special Topics
Examines a special topic in Electrical, Computer and Energy Engineering.
Repeatable: Repeatable for up to 9.00 total credit hours. Allows multiple enrollment in term.
Requisites: Restricted to graduate students only.
Additional Information: Departmental Category: Dynamical Systems and Control

ECEN 5009 (3) Special Topics
Examines a special topic in Electrical, Computer and Energy Engineering.
Repeatable: Repeatable for up to 9.00 total credit hours. Allows multiple enrollment in term.
Requisites: Restricted to graduate students only.
Additional Information: Departmental Category: VLSI CAD Methods

ECEN 5011 (1-4) Special Topics
Equivalent - Duplicate Degree Credit Not Granted: ECEN 4011
Repeatable: Repeatable for up to 9.00 total credit hours.
Requisites: Restricted to graduate students only.
Additional Information: Departmental Category: Bioengineering

ECEN 5012 (3) Special Topics
Requisites: Restricted to graduate students only.
Additional Information: Departmental Category: Digital Signal Processing Communications

ECEN 5013 (3) Special Topics
Examines a special topic in Electrical, Computer and Energy Engineering.
Repeatable: Repeatable for up to 9.00 total credit hours. Allows multiple enrollment in term.
Requisites: Campus section restricted to ECEE graduate students in Academic subplans ESE or C-EEENP or C-ECENEEEP only.
Grading Basis: Letter Grade

ECEN 5016 (3) Special Topics
Examines a special topic in Electrical, Computer and Energy Engineering.
Additional Information: Departmental Category: Optics

ECEN 5018 (1-4) Special Topics
Examines a special topic in Electrical, Computer and Energy Engineering.
Requisites: Restricted to graduate students only.
Additional Information: Departmental Category: Dynamical Systems and Control

ECEN 5021 (1-4) Special Topics
Examines a special topic in Electrical, Computer and Energy Engineering.
Repeatable: Repeatable for up to 9.00 total credit hours.
Requisites: Restricted to graduate students in Electrical Engineering (EEEN) or in Electrical/Computer Engineering (ECEN) or to Electrical or Electrical/Computer Engineering BS/MS Concurrent degree students or to Graduate Certificate Engineering (CRTGE) students.
Additional Information: Departmental Category: Bioengineering

ECEN 5023 (3) Special Topics
Examines a special topic in Electrical, Computer and Energy Engineering, Embedded Systems.
Repeatable: Repeatable for up to 9.00 total credit hours. Allows multiple enrollment in term.
Requisites: Campus section restricted to graduate students in EEEN or BS/Professional MS concurrent degree students with BS portion in EEEN or ECEN.
Additional Information: Departmental Category: Embedded Systems Engineering

ECEN 5024 (3) Special Topics
Equivalent - Duplicate Degree Credit Not Granted: ECEN 4024
Repeatable: Repeatable for up to 9.00 total credit hours.
Additional Information: Departmental Category: Electromagnetics and Remote Sensing

ECEN 5028 (3) Special Topics
Examines a special topic in Electrical, Computer and Energy Engineering.
Repeatable: Repeatable for up to 9.00 total credit hours. Allows multiple enrollment in term.
Additional Information: Departmental Category: Dynamical Systems and Control

ECEN 5032 (3) Special Topics
Additional Information: Departmental Category: Bioengineering

ECEN 5053 (3) Special Topics
Examines a special topic in Electrical, Computer and Energy Engineering - Embedded Engineering.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 4053
Repeatable: Repeatable for up to 9.00 total credit hours. Allows multiple enrollment in term.
Requisites: Campus section restricted to graduate students in Academic sub-plans ESE or C-EEENP or C-ECENEEEP.
Additional Information: Departmental Category: Embedded Systems Engineering

ECEN 5104 (3) Passive Microwave Circuits
Building on fundamentals taught in a class such as ECEN 3410 (Electromagnetic Waves), this course teaches fundamentals of microwave passive circuit analysis using scattering parameters. Design of impedance matching networks, impedance transformers, couplers, filters, dividers/combiners and other typical circuits used at microwave frequencies are covered. Using an industry-standard CAD tool, design of microstrip circuits is emphasized. Assignments include theoretical and CAD approaches to analysis and design of passive microwave transmission-line circuits.
Additional Information: Departmental Category: Electromagnetics and Remote Sensing

ECEN 5110 (1-3) Graduate Teaching Practicum
Provides training and hands-on experience in teaching of ECEE courses. Students will work with an instructor of an ECEE course to carry out teaching activities such as lecturing, leading discussion sessions, writing homework and examination problems, and relevant grading.
Repeatable: Repeatable for up to 9.00 total credit hours. Allows multiple enrollment in term.

ECEN 5111 (3) Engineering Applications in Biomedicine: Cardiovascular Devices and Systems
Application of engineering in medicine has grown dramatically in recent years. Engineers enter the clinical and experimental medical arenas with many new devices and procedures emerging as alternatives to conventional surgical and pharmacological treatments. This course, presents general principles of biomedical engineering as applied to the development of a variety of specific devices and techniques for therapy and diagnosis, with a focus on devices and systems for the cardiovascular system. This class will present relevant anatomy and physiology as part of the class discussion, which will be supplemented by a physiology reference text. Questions, exchanges of ideas, and active classroom discussion are encouraged. Biomedical engineering is an emerging field which is highly interdisciplinary- engineers and scientists from all fields are invited and encouraged to participate in this course. There are no formal prerequisites.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 4111

ECEN 5114 (3) Electromagnetic Theory
This course covers theory and applications of Maxwell's equations at the graduate level, including various electromagnetic wave types. Additionally, fundamental electromagnetic theorems such as Poynting, equivalence, duality, reciprocity and compensation, are studied through examples across the electromagnetic spectrum.
Additional Information: Departmental Category: Electromagnetics and Remote Sensing

ECEN 5122 (3) Wireless Local Area Networks
Emphasis on the IEEE P802.11 family of WLAN standards. Students learn the legacy versions of the standard (802.11DS/b), the current generation of WLAN systems (802.11a/g/n/ac), and will to analyze and critique upcoming versions (802.11ax/ba), and gain insight into proposals for new research in WLAN. Exposure to the interoperability and certification process for WLAN by the Wi-Fi Alliance, study the newest Wi-Fi Certified¿ programs, and will learn how to model and analyze WLAN traffic using industry standard tools.
Equivalent - Duplicate Degree Credit Not Granted: CSCI 5220 and CYBR 5220
Requisites: Requires prerequisite course of ECEN 3810 or APPM 3570 or MATH 4510 (minimum grade D-).
Recommended: Prerequisite CYBR 5430.
Additional Information: Departmental Category: Digital Signal Processing Communications

ECEN 5126 (3) Computational Optical Imaging
Covers the fundamentals of computational optical imaging modalities, namely systems in which the hardware (optics, sensors, illumination) is designed in conjunction with algorithms (implemented optically, electronically and via software) to deliver information about a scene. Students learn the analysis and design of modern imaging systems. Covers a variety of applications including biomedical imaging, nanoscopy, photography and space imaging.
Requisites: Restricted to graduate students only.
Grading Basis: Letter Grade

ECEN 5133 (3) Fundamentals of Computer Security
Practice thinking like an attacker by exploring several modern computer security attacks and defenses through hands-on programming projects. Topics include applied cryptography (encryption, authentication), web security (XSS, CSRF, SQL Injection), network security (TLS, MITM attacks), application security (shell injection, buffer overflows), and other current events and trends (government surveillance, botnets, cryptocurrencies).
Grading Basis: Letter Grade

ECEN 5134 (3) Electromagnetic Radiation and Antennas
This course is introduction to antenna theory and antenna applications in applied electromagnetics. Elements of electromagnetic theory are first reviewed through the discussion of fundamental antenna parameters. Topics such as input impedance, radiation pattern, gain, radar cross section, near- and far-field, antenna temperature, and others are discussed first. The theory of operation of electric and magnetic dipoles, small and large dipoles, monopoles, and loops, as well as impact of different grounds on their parameters are discussed next. Other antennas such as bicones, helices, Yagi-Uda, microstrip patches, horns, reflectors, slots, spirals, log-periodics, etc. are also discussed. The fundamentals of array theory inclusive of linear, planar and circular topologies, coupling, beamforming, as well as elements of array synthesis are also discussed. Students will be exposed to the commercial software tools used to design antennas and will work individually or in teams to accomplish different project assignme
Additional Information: Departmental Category: Electromagnetics and Remote Sensing

ECEN 5138 (3) Control Systems Analysis
Analysis and design of continuous time control systems using classical and state space methods. Laplace transforms, transfer functions and block diagrams. Stability, dynamic response, and steady-state analysis. Analysis and design of control systems using root locus and frequency response methods. Computer aided design and analysis. Topics covered in this course will be investigated in more depth, require external readings, additional homework will be assigned, and the exams will be more difficult.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 4138 MCEN 4138 or MCEN 5138
Requisites: Restricted to graduate students in Electrical Engineering (EEEN) or in Electrical/Computer Engineering (ECEN) or to Electrical or Electrical/Computer Engineering BS/MS Concurrent degree students or to Graduate Certificate Engineering (CRTGE) students.
Recommended: Prerequisite ECEN 3300.
Additional Information: Departmental Category: Dynamical Systems and Control

ECEN 5139 (3) Computer-Aided Verification
Covers theoretical and practical aspects of verification of finite-state systems (hardware) and infinite-state systems (programs). Model checking: temporal logics, explicit-state and symbolic search, BDDs. Constraint solvers: SAT solvers, decision procedures. Program verification: invariants, partial vs. total correctness, abstraction. Department enforced requisite: general proficiency in discrete mathematics and programming.
Equivalent - Duplicate Degree Credit Not Granted: CSCI 5135
Requisites: Restricted to Electrical/Computer Engineering (EEEN) graduate students or Concurrent Degree students in Electrical Engineering (C-EEEN) or Electrical/Computer Engineering (C-ECENEEEN) or to Graduate Certificate Engineering (CRTGE) students.
Recommended: Prerequisite CSCI 2824.
Additional Information: Departmental Category: VLSI CAD Methods

ECEN 5154 (3) Computational Electromagnetics
This course is introduction to the frequency domain methods used in computational electromagnetics (CEM) for solving complex radio-frequency (RF) problems. The course starts with the review of electromagnetic theory and mathematical concepts used in CEM, followed by the introduction to the partial differential and integral equation based methods. Specifically, the fundamentals behind the finite difference method, finite element method, and method of moments are discussed and implemented to solve problems such as shielded microstrip line, charge distribution on metallic objects, waveguide modes, wire antennas, etc. Students will work independently and in teams to develop their own codes to solve given boundary value problems. The implementation of different methods in commercial software tools is continuously emphasized. An understanding of electrostatics and electromagnetic waves (such as covered in ECEN 3400 and ECEN 3410) is assumed.
Additional Information: Departmental Category: Electromagnetics and Remote Sensing

ECEN 5156 (3) Physical Optics
Covers the application of Maxwell's equations to optical wave propagation in free space and in media.Topics include polarization, dispersion, geometrical optics, interference, partial coherence, and diffraction.
Requisites: Restricted to graduate students only.
Recommended: Prerequisite ECEN 3410.
Additional Information: Departmental Category: Optics

ECEN 5164 (3) Electromagnetic Metamaterials
Enables students to design engineered structures to realize materials with desired electromagnetic properties that are difficult or impossible to achieve using conventional materials. Exact and approximate techniques are explored to develop an intuitive understanding of the electromagnetic response of these structures.
Recommended: Prerequisite ECEN 3410 (EM Waves and Transmissions) or equivalent course in fundamental electromagnetic theory.

ECEN 5224 (3) High Speed Digital Design
Covers fundamentals of high-speed properties of logic gates, measurement techniques, transmission lines, ground planes and layer stacking, terminations, vias, power systems, connectors, ribbon cables, clock distribution and clock oscillators.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 4224
Requisites: Restricted to graduate students only.
Additional Information: Departmental Category: Electromagnetics and Remote Sensing

ECEN 5244 (3) Stochastic / Environmental Signal Processing
Provides a baseline understanding for research and development in signal processing and analytics for environmental and other data-intensive applications. Topics include parameter estimation, transforms, linear and nonlinear estimation, data assimilation and detection. Applications include numerical weather prediction, GNSS sensing, ionospheric sounding, radar, radiometry, surveillance, target detection and tracking. Previous coursework in linear systems and electromagnetic waves recommended.
Grading Basis: Letter Grade

ECEN 5253 (3) Datacenter Scale Computing - Methods, Systems and Techniques
Covers the primary problem solving strategies, methods and tools needed for data-intensive programs using large collections of computers typically called "warehouse scale" or "data-center scale" computers. Examines methods and algorithms for processing data-intensive applications, methods for deploying and managing large collections of computers in an on-demand infrastructure and issues of large-scale computer system design.
Equivalent - Duplicate Degree Credit Not Granted: CSCI 4253 and CSPB 4253 and CSCI 5253
Requisites: Restricted to graduate students only.
Recommended: Prerequisite CSCI 5273 or ECEN 5273.

ECEN 5254 (3) Remote Sensing Signals and Systems
Examines passive and active techniques for remote sensing with emphasis on fundamental noise and detection issues from radio to optical frequencies. Emphasis is placed on electromagnetic wave detection, statistical signal and noise analysis, remote sensing system architecture, and hardware for remote sensing systems. Systems studied include radiometers, radars (real and synthetic aperture), interferometers, and lidars. Applications to detection and surveillance, Earth remote sensing, astronomy, and imaging systems are covered.
Additional Information: Departmental Category: Electromagnetics and Remote Sensing

ECEN 5264 (3) Electromagnetic Absorption, Scattering, and Propagation
Electromagnetic waves in communication, navigation, and remote sensing systems from radio to optical frequencies, including propagation in deterministic and random media. Topics include absorption and refraction by gases, discrete scattering by precipitation, clouds, and aerosols, continuous scattering by refractivity fluctuations, earth-space propagation and Faraday rotation in plasmas, and radiative transfer theory.
Recommended: Prerequisites ECEN 3400 and ECEN 3410.
Additional Information: Departmental Category: Electromagnetics and Remote Sensing

ECEN 5273 (3) Network Systems
Focuses on design and implementation of network programs and systems, including topics in network protocols, architectures, client-server computing, software-driven networking, and other contemporary network hardware-software system design and programming techniques. Familiarity with C and Unix is required.
Equivalent - Duplicate Degree Credit Not Granted: CSCI 5273
Additional Information: Departmental Category: Computer and Digital Systems

ECEN 5295 (3) Foundations of Quantum Hardware
Introduces students to the principles and operation of quantum hardware. In this course you will learn how to describe many different physical systems (trapped Ions, superconducting circuits, and optical systems) mathematically. This will allow you to model quantum sensors, communication systems and computing hardware.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 4295

ECEN 5313 (3) Concurrent Programming
Introduces the theory and practice of multicore programming. The first part of the course presents foundations of concurrent programming: mutual exclusion, wait-free and lock-free synchronization, spin locks, monitors, memory consistency models. The second part presents a sequence of concurrent data structures and techniques used in their implementations (coarse-grained, fine-grained, optimistic and lock-free synchronization).
Equivalent - Duplicate Degree Credit Not Granted: CSCI 5313 and ECEN 4313 and CSCI 4313
Requisites: Requires prerequisite courses of CSCI 2270 and ECEN 2360 or CSCI 2400 (minimum grade C). Restricted to graduate students only.
Recommended: Prerequisite ECEN 3593.

ECEN 5322 (3) Data and Network Science
The course covers the theory and design of algorithms that are used to model, analyze, and extract information from large scale datasets and networks. The course includes a project.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 4322
Requisites: Restricted to graduate students only.
Additional Information: Departmental Category: Digital Signal Processing Communications

ECEN 5341 (3) Bioelectromagnetics
Effects of electric and magnetic fields on biological systems are described with applications to therapy and safety. The complexity of biological systems is described to provide a better understanding of the distribution of fields inside the body. Risk analysis is also introduced.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 4341
Requisites: Restricted to graduate students only.
Additional Information: Departmental Category: Bioengineering

ECEN 5345 (3) Introduction to Solid State Physics
Provides an introduction to the electronic, photonic and phononic properties of solid state materials and devices. Covers optical constants, free electron gas, plasmons, energy bands, semiconductors and doping, excitons, quantum wells, phonons and electrooptical effects. Makes use of quantum mechanical methods. Department enforced prerequisite: basic quantum mechanics.
Requisites: Restricted to graduate students only.
Additional Information: Departmental Category: Nanostructures and Devices

ECEN 5355 (3) Principles of Electronic Devices 1
Relates performance and limitations of solid state devices to their structures and technology. Examines semiconductor physics and technology. Includes Pn-junction, Mos, and optoelectronic devices. For both advance circuit and device engineers.
Requisites: Restricted to graduate students only.
Recommended: Prerequisite ECEN 3320.
Additional Information: Departmental Category: Nanostructures and Devices

ECEN 5395 (3) Organic Electronic Materials and Devices
Covers the materials and physics principles of organic electronic devices, including organic light emitting diodes (OLEDs), photovoltaics (OPVs), field effect transistors (OFETs), electrochemical transistors (OECTs), and bioelectronic and neuromorphic devices. The molecular, structural, and electronic properties of organic semiconductors are introduced, and the architectures and operating principles of the devices are then taught. Assignments will require computational solutions and simulations. Previously offered as a special topics course.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 4395
Recommended: Prerequisite ECEN 5345.

ECEN 5407 (3) Renewable Energy and the Future Power Grid
This course will begin with an introduction to the power grid including planning and operations for the transmission and distribution level power grid. The course will reflect that while many of the solutions to the integration of variable generation are technical in nature, policy and economics play a large role in the changes that are occurring within the power system. After examining the technological specifications of the most important variable generation sources (wind power, solar photovoltaics, and solar thermal power), as well as traditional power generation sources, other aspects of power system planning and operations in the future power grid will be examined in detail.
Requisites: Restricted to students in College of Engineering and Applied Science (ENGR) only.
Grading Basis: Letter Grade

ECEN 5414 (3) Essential Principles of Signal Integrity
Designing a robust and cost-effective product is about following a process that helps apply your engineering intuition to balance cost and design tradeoffs specific to your product. This class introduces essential principles of signal integrity, including principles of transmission lines, reflections, inductance, ground bounce, differential pairs, losses, terminations, routing, discontinuities, impedance, PDN design and EMC with respect to optimized design.
Recommended: Prerequisite students are expected to have completed an electromagnetics course during their undergraduate curriculum; in the CU curriculum it would be ECEN3400.

ECEN 5417 (3) Power System Analysis
This course covers the basics of power system analysis techniques. Students will be introduced to the concepts behind the fundamental principles of traditional bulk power systems. The difference between single and three phase powers will be discussed. Students will learn how to model bulk power system components and the per unit system. Understanding the flow of power in the system will be examined in detail as students will learn about and apply both AC and DC powerflow formulations.
Recommended: Corequisite ECEN 5407.
Grading Basis: Letter Grade

ECEN 5423 (3) Chaotic Dynamics
Explores chaotic dynamics theoretically and through computer simulations. Covers the standard computational and analytical tools used in nonlinear dynamics and concludes with an overview of leading-edge chaos research. Topics include time and phase-space dynamics, surfaces of section, bifurcation diagrams, fractal dimension and Lyapunov exponents.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 4423 and CSCI 4446 and CSCI 5446
Additional Information: Departmental Category: Computer and Digital Systems

ECEN 5424 (3) High Speed Channel Design for Signal Integrity
Designing a robust and cost-effective product is about following a process that helps apply your engineering intuition to balance cost and design tradeoffs specific to your product. This class introduces design principles for advanced gigabit channel design. Four primary interconnect problems are identified and material and technology solutions to reduce these problems to acceptable levels are explored.
Requisites: Requies prerequisite course of ECEN 5414 (minimum grade C).

ECEN 5427 (3) Power System Planning & Operations
This course will focus on bulk power system planning and operations, with special emphasis on systems with high variable renewable energy penetrations. Electricity markets will also be presented, and the differences with vertically integrated utilities will be discussed. Students will develop an understanding of electricity market dynamics in one of the course projects by participating in an electricity market game. The application of optimization problems in bulk power system operations will be discussed and applied by the students in another course project. They will develop a production cost model to simulate bulk power system operations of a test system under different scenarios.
Requisites: Requires prerequisite course ECEN 5407 (minimum grade B-).
Recommended: Prerequisite ECEN 5417.
Grading Basis: Letter Grade

ECEN 5434 (3) S-Parameters for Signal Integrity in High Speed Digital Engineering
Designing a robust and cost-effective product is about following a process that helps apply your engineering intuition to balance cost and design tradeoffs specific to your product. This class introduces design principles obtained by understanding S-Parameter results for complex PCB structures. Single-ended and Differential Transmission lines are analyzed and four common S-Parameter patterns are identified.
Requisites: Requires prerequisite ECEN 5414 ECEN minimum grade C-.
Recommended: Prerequisite students are expected to have completed an electromagnetics course during their undergraduate curriculum; in the CU curriculum it would be ECEN 3400.

ECEN 5437 (3) Distribution System Analysis
Fundamental aspects of the analysis of power distributions systems, including the traditional distribution grid, loads, components, topologies, operational aspects, and power flow analysis. Includes how the distribution system is changing with the introduction of distributed energy resources.
Requisites: Requires corequisite course of ECEN 5407.
Recommended: Corequisite ECEN 5417.
Grading Basis: Letter Grade

ECEN 5444 (3) Electromagnetic Compatibility (EMC) for High-Speed Digital Engineering
Understanding and applying the theoretical principles of electromagnetics to high speed digital engineering with respect to electromagnetic compatibility (EMC). Faster data rates and shorter rise times make signal integrity in high-speed digital engineering (HSDE) increasingly difficult. Signal distortion has adverse effects on EMC. This course covers understanding the radiation mechanisms and susceptibility of PCB circuits in HSDE.
Recommended: Prerequisite students are expected to have completed an electromagnetics course during their undergraduate curriculum; in the CU curriculum it would be ECEN 3400.

ECEN 5447 (3) Power System Dynamics with Renewable Energy
To introduce the current and future electrical power systems dynamics coupled with inverter based renewable generators. Fundamentals of renewable generators dynamic models, power system dynamics will be introduced. Previously offered as a special topics course.
Recommended: Prerequisites ECEN 5417: Power systems analysis, ECEN 5407: Renewable Energy and the Future Power Grid, and graduate standing in the College of Engineering and Applied Science.

ECEN 5448 (3) Advanced Linear Systems
Offers a state space approach to analysis and synthesis of linear systems, state transition matrix, controllability and observability, system transformation, minimal realization, and analysis and synthesis of multi-input and multi-output systems.
Equivalent - Duplicate Degree Credit Not Granted: MCEN 5448
Requisites: Restricted to graduate students only.
Recommended: Prerequisites ECEN 3300 and ECEN 4138.
Additional Information: Departmental Category: Dynamical Systems and Control

ECEN 5457 (3) Energy Systems Optimization
Covers basic elements of power system modeling; optimization tasks at the transmission level such as economic dispatch and DC optimal power flow (OPF); and essential techniques for formulating linear, second-order cone, and semidefinite programming approximations to AC OPF problems for transmission and distribution systems. Distributed optimization approaches are covered and tied to future architectural frameworks for smart power systems. Previously offered as a special topics course.
Recommended: graduate standing in the College of Engineering and Applied Science.

ECEN 5458 (3) Sampled Data and Digital Control Systems
Provides an analysis and synthesis of discrete-time systems. Studies sampling theorem and sampling process characterization, z-transform theory and z-transferfunction, and stability theory. Involves data converters (A/D and D/A), dead-beat design, and digital controller design.
Requisites: Restricted to graduate students only.
Recommended: Prerequisites ECEN 3300 and ECEN 4138.
Additional Information: Departmental Category: Dynamical Systems and Control

ECEN 5467 (3) Data Analytics and Data-Driven Decision Making for Modern Power and Energy Systems
Focuses on modern power and energy systems with high penetration of distributed energy resources (solar, batteries, electrical vehicles). Analytical methods for inference and decision making in such systems will be covered, including state estimation, forecasting, and optimal control. The emphasis is on data-driven methods, rooted in machine-learning techniques, such as kernel-based regression and reinforcement learning.
Recommended: Prerequisite ECEN 5407 and graduate standing in the College of Engineering and Applied Science.

ECEN 5478 (3) Online Convex Optimization and Learning
Covers basics of convex optimization, online learning, time-varying optimization, online first-order methods, learning problems over networks, zeroth-order methods, bandit optimization, projection-free methods, distributed methods for online convex optimization. Application domains considered in the course include Machine Learning, Signal Processing, and Data-driven Control. Specific application examples include the Internet of Things, recommendation systems, power systems, sensor networks, and transportation systems. Previously offered as a special topics course.
Requisites: Restricted to graduate students only.
Recommended: Prerequisite ECEN 5448.

ECEN 5488 (3) Geometric Control Theory
Introduce geometric approaches to study dynamical control systems over manifolds. Cover fundamental control-theoretical results, such as controllability, observability, feedback stabilizability, symmetries and group actions, that are beyond linear control systems. Establish connections between control theory and mathematics, especially topology, differential geometry, Lie groups and Lie algebras. Final project focuses on engineering applications related to students¿ own research interests.
Equivalent - Duplicate Degree Credit Not Granted: MCEN 5488
Requisites: Restricted to graduate students only.
Recommended: Prerequisites a solid foundation in Linear Algebra and ECEN 4138/5138 and ECEN 5448.

ECEN 5498 (3) Stochastic Control Theory
Introduce a toolbox for dealing with stochastic control systems. Cover topics such as stochastic calculus, linear and nonlinear filtering, and dynamic programming. Discuss system theoretic issues and derive optimal control laws for a variety of stochastic control problems, including, e.g., the separation principle for Linear-quadratic-Gaussian problems. Final project focuses on engineering applications related to students¿ own research interests.
Equivalent - Duplicate Degree Credit Not Granted: MCEN 5498
Requisites: Restricted to graduate students only.
Recommended: Prerequisites a solid foundation in Probability Theory and ECEN 4138/5138, ECEN 5448 and ECEN 5612.

ECEN 5514 (3) Principles of Electromagnetics for High-Speed Digital Engineering
Teaches understanding and application of the theoretical principals of electromagnetics to printed circuit board design. Students learn to apply advanced concepts related to Maxwell¿s equations for SI and PI and High-Speed applications. Some topics covered include: skin effect, surface roughness, non-uniform dielectric constant, coupling, reflection, and losses; boundary conditions and boundary value problems; displacement and conduction currents.
Recommended: Prerequisite students are expected to have completed an electromagnetics course during their undergraduate curriculum; in the CU curriculum it would be ECEN 3400.

ECEN 5517 (3) Power Electronics and Photovoltaic Power Systems Laboratory
Focuses on analysis, modeling, design and testing of electrical energy processing systems in a practical laboratory setting. Studies power electronics converters for efficient utilization of available energy sources, including solar panels and utility. Experimental projects involve design, fabrication and testing of a solar power system.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 4517
Requisites: Requires prerequisite course of ECEN 5797 (minimum grade C-).
Additional Information: Departmental Category: Power

ECEN 5523 (3) Compiler Construction
Introduces the principles and techniques for compiling high-level programming languages to assembly code. Topics include parsing, instruction selection, register allocation, and compiling high-level features such as polymorphism, first-class functions, and objects. Students build a complete compiler for a simple language.
Equivalent - Duplicate Degree Credit Not Granted: CSCI 4555 and ECEN 4553 and CSCI 5525
Requisites: Restricted to Electrical/Computer Engineering (EEEN) graduate students or Concurrent Degree students in Electrical Engineering (C-EEEN) or Electrical/Computer Engineering (C-ECENEEEN) or to Graduate Certificate Engineering (CRTGE) students.
Additional Information: Departmental Category: Computer and Digital Systems

ECEN 5524 (3) Principles of Computational Electromagnetics for Signal and Power Integrity
Introduces students to practical computational electromagnetics (CEM) and numerical methods concepts necessary for solving SI/PI problems. Fundamentals behind finite difference, finite element, and method of moments are studied to solve problems like a microstrip line and others related to SI-PI applications. Students will study the concepts of accuracy, stability, convergence and boundary conditions as they apply to commercial EM tools.
Recommended: Prerequisite students are expected to have completed an electromagnetics course during their undergraduate curriculum; in the CU curriculum it would be ECEN 3400.

ECEN 5527 (3) Power Electronics Design Laboratory
Create, build, and debug an original design of a power converter to meet given a specification, project schedule, and related requirements. Lectures provide supporting information. Compliance to the specification is shown through a formal test report and demonstration to an instructor.
Requisites: Requires prerequisite courses of ECEN 5517 and ECEN 5797 (all minimum grade B-).
Grading Basis: Letter Grade

ECEN 5532 (3) Digital Signal Processing Laboratory
Develops experience in code development, debugging and testing of real-time digital signal processing algorithms using dedicated hardware. Applications include filtering, signal synthesis, audio special effects and frequency domain techniques based on the Fast Fourier Transform.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 4532
Additional Information: Departmental Category: Digital Signal Processing Communications

ECEN 5533 (3) Fundamental Concepts of Programming Languages
Considers concepts common to a variety of programming languages--how they are described (both formally and informally) and how they are implemented. Provides a firm basis for comprehending new languages and gives insight into the relationship between languages and machines.
Equivalent - Duplicate Degree Credit Not Granted: CSCI 5535
Requisites: Requires prerequisite course CSCI 3155 (minimum grade D-).
Additional Information: Departmental Category: Computer and Digital Systems

ECEN 5534 (3) Signal Integrity Measurements for High Speed Digital Engineering
Taking accurate measurements are the anchor to reality in all HSDE analysis. This course introduces the three important high speed measurement instruments; the VNA, the TDR and the high-speed oscilloscope. Measurements above 200 MHz bandwidth require special considerations. Topics covered include S-parameter analysis of interconnects, de-embedding, probing methods, measurement-simulation correlation and building circuit topology models from S-parameters.
Requisites: Requires prerequisites ECEN 5224 and ECEN 5730 (all minimum grade C-).
Recommended: Prerequisite students are expected to have completed an electromagnetics course during their undergraduate curriculum; in the CU curriculum it would be ECEN 3400.

ECEN 5544 (3) EM Signal Modeling for HSDE using Ansys HFSS and Q3D
Doing high speed digital engineering using HFSS from Ansys. This is a one semester hands-on capstone design course for the high-speed digital engineering professional master¿s program. Students will deepen their understanding of EM signal modeling for HSDE applications while learning how to correctly use HFSS to do a variety of high-speed designs for PCBs.
Requisites: Requires prerequisite course of ECEN 5524 (minimum grade C-).
Recommended: Prerequisite students are expected to have completed an electromagnetics course during their undergraduate curriculum; in the CU curriculum it would be ECEN 3400.

ECEN 5554 (3) Designing PCB Memory Systems using Keysight ADS
Doing high speed digital engineering using ADS from Keysight. This is a one semester hands-on capstone design course for the high-speed digital engineering professional master¿s program. Students will deepen their understanding of EM signal modeling for HSDE PCB memory applications while learning how to correctly use ADS to do a variety of high-speed memory designs for PCBs.
Requisites: Requires prerequisite course of ECEN 5524 (minimum grade C-).
Recommended: Prerequisite students are expected to have completed an electromagnetics course during their undergraduate curriculum; in the CU curriculum it would be ECEN 3400.

ECEN 5555 (3) Principles of Energy Systems and Devices
Develops principles underlying electronic, optical and thermal devices, materials and nanostructures for renewable energy. Provides a foundation in statistical thermodynamics and uses it to analyze the operation and efficiency limits of devices for photovoltaics, energy storage (batteries & ultra-capacitors), chemical conversion (fuel cells and engines), solid state lighting, heat pumps, cooling and potentially harvesting zero-point energy from the vacuum.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 4555
Requisites: Restricted to students with 57-180 credits (Juniors or Seniors) or Graduate students only.
Additional Information: Departmental Category: Nanostructures and Devices

ECEN 5565 (3) Advanced Network Systems
Provides an advanced study of network architecture, across the end hosts, the network elements, and the people and systems that manage the network. The course provides the foundation for modern network systems, beyond the basic understanding of the OSI layers, and into the system which make networks work.
Requisites: Requires prerequisite of CSCI 4273 or CSCI 5273 or ECEN 5273 (minimum grade C). Restricted to graduate students in the College of Engineering.
Grading Basis: Letter Grade

ECEN 5573 (3) Advanced Operating Systems
Intended to create a foundation for operating systems research or advanced professional practice. Examines the design and implementation of a number of research and commercial operating systems and their components, system organization and structure, threads, communication and synchronization, virtual memory, distribution, file systems, security and authentication, availability and Internet services.
Equivalent - Duplicate Degree Credit Not Granted: CSCI 5573
Additional Information: Departmental Category: Computer and Digital Systems

ECEN 5590 (3) Computer Organization
Studies computer design at the microarchitecture level. Discusses instruction set architecture design, arithmetic and logic unit design, control logic, memory design and caches, simple pipelining, I/O and peripheral devices. Briefly covers aspects of modern computer architecture, such as multicore processors and hardware security.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 3593 or CSCI 3593

ECEN 5592 (3) Modern Signal Processing
Presents a mathematical tour of modern signal processing focusing on sparse signal representations and their applications. Extends classical Fourier transform and traditional digital signal processing techniques to enable various types of computational harmonic analysis. Covers time-frequency and wavelet analysis, filter banks, nonlinear approximation of functions, compression, signal restoration, compressive sensing, and convolutional neural networks.
Recommended: Prerequisites familiarity with Fourier transforms, z-transforms, filters, linear algebra, bases, norms, inner products, eigendecompositions, singular value decomposition (SVD) and MATLAB.

ECEN 5593 (3) Advanced Computer Architecture
Provides a broad-scope treatment of important concepts in the design and implementation of high-performance computer systems. Discusses important issues in the pipelining of a processor, out-of-order instruction issue and superscalar designs, design of cache memory systems and architectural features required for multicore processor designs. Also studies current and historically important computer architectures, including hardware security concepts.
Equivalent - Duplicate Degree Credit Not Granted: CSCI 5593 and ECEN 4693
Requisites: Campus section restricted to graduate students in EEEN or BS/Professional MS concurrent degree students with BS portion in EEEN or ECEN.
Recommended: Prerequisite ECEN 3593, ECEN 5090.
Additional Information: Departmental Category: Computer and Digital Systems

ECEN 5603 (3) Software Project Management
Presents topics and techniques critical to the management of software product development, including estimating, planning, quality, tracking, reporting, team organization, people management and legal issues. Gives special attention to problems unique to software projects.
Requisites: Requires prerequisite courses ECEN 4583 and ECEN 5543 and CSCI 4318 (all minimum grade D-). Restricted to graduate students only.
Additional Information: Departmental Category: Computer and Digital Systems

ECEN 5606 (3) Optics Laboratory
Provides advanced training in experimental optics. Consists of optics experiments that introduce the techniques and devices essential to modern optics, including characterization of sources, photodetectors, modulators, use of interferometers, spectrometers,and holograms and experimentation of fiber optics and Fourier optics. Department enforced prerequisite: undergraduate optics course (e.g. PHYS 4510).
Equivalent - Duplicate Degree Credit Not Granted: PHYS 5606
Additional Information: Departmental Category: Optics

ECEN 5607 (3) Power Electronics for Electrified Transportation
Covers analysis, modeling, control, simulations, and design of electric-drive vehicles and the charging infrastructure. Vehicle system architectures and dynamics are used to determine the requirements and to validate the performance of electric-vehicle drivetrain subsystems. Analysis, modeling, and design of the subsystems are addressed, including battery systems, battery management electronics, dc-dc converters, dc-ac inverters, motor drives, and chargers.
Requisites: Restricted to Electrical/Computer Engineering (EEEN) graduate students or Concurrent Degree students in Electrical Engineering (C-EEEN) or Electrical/Computer Engineering (C-ECENEEEN) or to Graduate Certificate Engineering (CRTGE) students.

ECEN 5612 (3) Random Processes for Engineers
Deals with random time-varying functions and is therefore useful in the broad range of applications where they occur. Topics include review of probability, convergence of random sequences, random vectors, minimum mean-square error estimation, basic concepts of random processes, Markov processes, Poisson processes, Gaussian processes, linear systems with random inputs, and Wiener filtering. Applications range from communications, communication networks, and signal processing to random vibration/stress analysis, mathematical finance, physics, etc.
Additional Information: Departmental Category: Digital Signal Processing Communications

ECEN 5613 (3) Embedded System Design
Introduces system hardware and firmware design for embedded applications. Students independently design and develop a hardware platform encompassing a microcontroller and peripherals. Firmware is developed in C and assembly. A significant final project is designed, developed, documented and presented. Prioritized for EEEN graduate students with ESE (Embedded Systems Engineering) sub-plan.
Additional Information: Departmental Category: Embedded Systems Engineering

ECEN 5616 (3) Optoelectric System Design
Examines optical components and electro-optic devices with the goal of integrating into well design optoelectronic systems. Sample systems include optical storage, zoom lenses and telescopes.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 4616
Requisites: Restricted to graduate students only.
Additional Information: Departmental Category: Optics

ECEN 5622 (3) Information Theory and Coding
Covers fundamental limits of data compression, reliable transmission of information and information storage. Topics include information measures, typicality, entropy rates of information sources, limits and algorithms for lossless data compression, mutual information, and limits of information transmission over noisy wired and wireless links. Optional topics include lossy data compression, limits of information transmission in multiple-access and broadcast networks, and limits and algorithms for information storage.
Requisites: Restricted to Electrical/Computer Engineering, Computer Science, Applied Math or Physics graduate students only.
Additional Information: Departmental Category: Digital Signal Processing Communications

ECEN 5623 (3) Real-Time Embedded Systems
Design and build a microprocessor-based embedded system application requiring integration of sensor/actuator devices, a real-time operating system and application firmware and software. Real-time rate monotonic theory and embedded architecture are covered. Prioritized for EEEN graduate students with ESE (Embedded Systems Engineering) sub-plan.
Additional Information: Departmental Category: Embedded Systems Engineering

ECEN 5626 (3) Active Optical Devices
Analysis of active optical devices such as semiconductor laser, detector and flat panel display by clearly defining and interconnecting the fundamental physical mechanism, device design and operating principles and device performance.
Requisites: Restricted to graduate students only.
Recommended: Prerequisite ECEN 5355.
Additional Information: Departmental Category: Optics

ECEN 5632 (3) Theory and Application of Digital Filtering
Digital signal processing and its applications are of interest to a wide variety of scientists and engineers. The course covers such topics as characterization of linear discrete-time circuits by unit pulse response, transfer functions, and difference equations, use of z-transforms and Fourier analysis, discrete Fourier transform and fast algorithms (FFT), design of finite and infinite impulse response filters, frequency transformations, study of optimized filters for deterministic signals.
Requisites: Restricted to Electrical/Computer Engineering (EEEN) graduate students or Concurrent Degree students in Electrical Engineering (C-EEEN) or Electrical/Computer Engineering (C-ECENEEEN) or to Graduate Certificate Engineering (CRTGE) students.
Additional Information: Departmental Category: Digital Signal Processing Communications

ECEN 5634 (3) Microwave and RF Laboratory
This course is a hands-on introduction to RF and microwave topics, from fundamentals including vector network analyzer (VNA) calibration and operation, power measurements, and antenna characterization, to system-level topics such as RADAR systems and superheterodyne links. Students work in small groups on weekly experiments based on both coaxial and waveguide setups. An understanding of electromagnetic waves (such as covered in ECEN 3400 and ECEN 3410) is assumed.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 4634
Requisites: Restricted to any graduate students or Electrical/Computer Engineering or Electrical Engineering Concurrent Degree majors only.
Additional Information: Departmental Category: Electromagnetics and Remote Sensing

ECEN 5638 (3) Control Systems Laboratory
Provides experience in control system design and analysis, using both real hardware and computer simulation. Covers the entire control system design cycle: modeling the system, synthesizing a controller, conducting simulations, analyzing the design to suggest modifications and improvements, and implementing the design for actual testing.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 4638, MCEN 4638, and MCEN 5638
Requisites: Requires prerequisite course of ECEN/MCEN 4138/5138 (minimum grade D-). Restricted to graduate students only.

ECEN 5645 (3) Introduction to Optical Electronics
Introduces lasers, Gaussian optics, modulators, nonlinear optics, optical detectors, and other related devices.
Requisites: Restricted to graduate students only.
Additional Information: Departmental Category: Nanostructures and Devices

ECEN 5652 (3) Detection and Extraction of Signals from Noise
Introduces detection, estimation, and related algorithms. Topics in detection include simple/composite hypothesis testing, repeated observations and asymptotic performance and sequential detection. Topics in estimation include Bayesian estimation including minimum mean-square estimation and non-random parameter estimation. Topics in algorithms vary. Examples include algorithms for state estimation and smoothing in Hidden Gauss-Markov models and the expectation-maximization algorithm. Applications include communications, radar/sonar/geophysical signal processing, image analysis, authentication, etc.
Requisites: Restricted to Electrical/Computer Engineering, Computer Science, Applied Math or Physics graduate students only.
Additional Information: Departmental Category: Digital Signal Processing Communications

ECEN 5672 (3) Digital Image Processing
Course objective is to present the fundamental techniques available for image representation and compression (e.g., wavelets), filtering (e.g., Wiener and nonlinear filter), and segmentation (e.g., anisotropic diffusion).
Requisites: Requires prerequisite course ECEN 5632 (minimum grade C-).
Additional Information: Departmental Category: Digital Signal Processing Communications

ECEN 5673 (3) Distributed Systems
Examines systems that span multiple autonomous computers. Topics include system structuring techniques, scalability, heterogeneity, fault tolerance, load sharing, distributed file and information systems, naming, directory services, resource discovery, resource and network management, security, privacy, ethics and social issues.
Equivalent - Duplicate Degree Credit Not Granted: CSCI 5673
Recommended: Prerequisite CSCI 5573 or a course in computer networks.
Additional Information: Departmental Category: Computer and Digital Systems

ECEN 5678 (3) Control of Multi-agent Systems
Covers basics of matrix theory and graph theory; distributed averaging and consensus methods on graphs; parallel computation of fixed points; basics of optimization; parallel and distributed optimization methods over graphs; convergence analysis. The techniques and methodologies presented in the course are introduced through application setups including Internet of Things, power and energy systems, sensor networks, transportation systems, and social networks. Previously offered as a special topics course.
Requisites: Restricted to graduate students only.
Recommended: Prerequisites ECEN 5448 and courses in convex optimization.

ECEN 5682 (3) Theory and Practice of Error Control Codes
Introduces error control coding techniques for reliable transmission of digital data over noisy channels. Topics include algebraic characterizations of cyclic codes, convolutional codes, modern graph codes, decoding algorithms for block codes, Viterbi algorithm and iterative decoding on graphs. Applications include modern digital communication and storage systems including deep space communications, satellite broadcasting, cellular networks, and optical disk storage.
Requisites: Restricted to Electrical/Computer Engineering (EEEN) graduate students or Concurrent Degree students in Electrical Engineering (C-EEEN) or Electrical/Computer Engineering (C-ECENEEEN) or to Graduate Certificate Engineering (CRTGE) students.
Additional Information: Departmental Category: Digital Signal Processing Communications

ECEN 5692 (3) Principles of Digital Communication
Introduces fundamental principles of efficient and reliable transmission of information used in wired and wireless digital communication systems including cable modems, smart phones/tablets, cellular networks, local area (wi-fi) networks, and deep-space communications. Topics include bandwidth and power constraints, digital modulation methods, optimum transmitter and receiver design principles, error rate analysis, channel coding potential in wired/wireless media, trellis coded modulation, and equalization.
Additional Information: Departmental Category: Digital Signal Processing Communications

ECEN 5696 (3) Fourier Optics
Introduces a system level approach to the analysis and design of optical systems. Topics include holography, Fourier transform properties of lenses, two-dimensional convolution and correlation functions, spatial filtering and optical computing techniques. Also covers coherent and incoherent imaging techniques, tomography, and synthetic aperture imaging.
Requisites: Restricted to graduate students only.
Recommended: Prerequisites ECEN 3300 and ECEN 3410.
Additional Information: Departmental Category: Optics

ECEN 5712 (3) Machine Learning for Engineers
Prepares students to apply/improve machine learning methods for engineering applications and to perform related research. Covers popular algorithms and theories for learning from data, e.g., supervised learning, unsupervised learning, online learning, neural networks, VC-dimension, PAC learning theory. Explores the connections with detection/estimation theory and information theory. The course project focuses on engineering applications related to students¿ majors.
Recommended: Prerequisites ECEN 5612, 5652 and 5622.

ECEN 5713 (3) Advanced Embedded Software Development
Building on fundamentals taught in ECEN 5813 PES, this course teaches more advanced programming principles for embedded systems that are implemented with the use of an embedded operating system. Topics include Linux kernel space and user programming, driver design, multi-threaded programming, and operating systems fundamentals, software design patterns, sound development methods and practices, and use of debugging and performance tools to create applications and enhance operating systems' services embedded system prototypes and products.
Requisites: Requires prerequisite course of ECEN 5813 (minimum grade D-).
Recommended: Prerequisites This course assumes students have direct coding and tool experience including C-programming Bare Metal Firmware Design, Compilation with GCC & Build Systems with GNU Make, Git, Linux command line operations, shell environment, compilation, Lab instruments, DVM, Logic Analyzer, Oscilloscope or demonstration of portable, maintainable, and testable software design.

ECEN 5720 (1) Practical Printed Circuit Board Design Accelerator
This course introduces students to the most important skills needed to convert a back-of-the-napkin circuit sketch into a working widget with first time success. Students will learn the seven steps in every board project: planning, selecting components, schematic entry, layout, assembly, bring up and debug, and documentation. This process will be exercised with a custom board design project. A commercial EDA tool widely used in the electronics industry will be used for the project. Previously offered as a special topics course.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 4730 or ECEN 5730 ECEN 4720
Recommended: Prerequisites ECEN 2250 and ECEN 2260 and ECEN 2270.

ECEN 5730 (3) Practical Printed Circuit Board Design and Manufacture
This course prepares students with all skills needed to convert a back-of-the-napkin circuit sketch into a working widget with first time success. Students will master the seven steps in every board project: planning, selecting components, schematic entry, layout, assembly, bring up and debug, and documentation. This process will be exercised with three different board design projects with increasing challenge. A commercial EDA tool widely used in the electronics industry will be used for all projects. Previously offered as a special topics course. Degree credit not offered for this course and ECEN 4720 or ECEN 5720 or ECEN 3730.
Recommended: Prerequisites ECEN 2250 and ECEN 2260 and ECEN 2270.

ECEN 5737 (3) Adjustable-Speed AC Drives
Presents unified treatment of complete electrical drive systems: mechanical load, electrical machine, power converter, and control equipment. Emphasizes induction, synchronous, and permanent-magnet drives. Uses simulation programs (e.g., SPICE, Finite Element/Difference Program) to simulate drive system components (e.g., gating, inverter, electric machine).
Requisites: Restricted to Electrical/Computer Engineering (EEEN) graduate students or Concurrent Degree students in Electrical Engineering (C-EEEN) or Electrical/Computer Engineering (C-ECENEEEN) or to Graduate Certificate Engineering (CRTGE) students.
Recommended: Prerequisite ECEN 3170.
Additional Information: Departmental Category: Power

ECEN 5738 (3) Nonlinear Control Systems
Nonlinear systems and control. Introduction to nonlinear phenomena: multiple equilibria, limit cycles, bifurcations, complex dynamical behavior. Planar dynamical systems, analysis using phase plane techniques. Input-output analysis and stability. Passivity. Lyapunov stability theory. Feedback linearization. Exploration of examples and applications. Formerly ECEN 7438.
Equivalent - Duplicate Degree Credit Not Granted: MCEN 5738
Requisites: Requires prerequisite course of ECEN 5448 (minimum grade C-). Restricted to graduate students only.
Recommended: Prerequisite knowledge in differential equations.
Additional Information: Departmental Category: Dynamical Systems and Control

ECEN 5752 (3) Communication Laboratory
Analysis and design of realistic communication signals in a modern digital signal processing environment. Covers both analog and digital communication signals with and without noise and distortion. Pulse amplitude modulation is used initially at baseband and then combined with amplitude and phase/frequency modulation to produce the kind of bandpass signals that are used in cell phones and wireless data networks.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 4752
Requisites: Requires prerequisite course of ECEN 4242 (minimum grade C-). Restricted to College of Engineering majors only.

ECEN 5753 (3) Computer Performance Modeling
Presents a broad range of system modeling techniques, emphasizing applications to computer systems. Covers stochastic processes, queuing network models, stochastic Petri nets and simulation (including parallel processing techniques). Also requires second-semester calculus.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 4753 and CSCI 4753 and CSCI 5753
Additional Information: Departmental Category: Computer and Digital Systems

ECEN 5763 (3) Embedded Computer Vision
Introduces students to machine vision and machine learning methods used in automation, autopilots and security and inspection systems. Embedded and automation topics include implementation of algorithms with FPGA or GP-GPU embedded real time co-processing for autopilots (intelligent transportation), general automation and security including methods for detection, classification, recognition of targets for inspection, surveillance, search and rescue, and machine vision navigation applications.
Requisites: Campus section restricted to graduate students in Academic sub-plans ESE or C-EEENP or C-ECENEEEP.
Grading Basis: Letter Grade
Additional Information: Departmental Category: Embedded Systems Engineering

ECEN 5773 (3) Developing the Industrial Internet of Things
This course goes beyond consumer IoT hype to emphasize a much greater space for potential embedded system applications and growth: The Industrial Internet of Things (IIoT), also known as Industry 4.0. Cisco¿s CEO stated: ¿IoT overall is a $19 Trillion market. IIoT is a significant subset including digital oilfield, advanced manufacturing, power grid automation, and smart cities¿. The course examines emerging markets, technology trends, applications and skills required for exploring career opportunities in this space.
Requisites: Restricted to students with an Embedded Systems Engineering (ESE) subplan or Electrical Engr-Prof Degree (C-EEENP) or Elec Cmp Elec Eng-Prof Degree (C-ECENEEENP) only.
Recommended: Prerequisites ECEN 5613, ECEN 5823, ECEN 5053, and ECEN 5133.

ECEN 5783 (3) Embedded Interface Design
This course deeply explores interface design approaches and architectures for creating embedded system prototypes and products. For both machine and user interfaces, we will examine best practices for the interface design process, including considerations of characteristics of the information to be transferred between devices or between a device and a user. Projects leverage the now standard Raspberry Pi 3 single-board computer (SBC), providing a strong foundation for exploring many elements of interface design.
Requisites: Restricted to students with an Embedded Systems Engineering (ESE) subplan or Electrical Engr-Prof Degree (C-EEENP) or Elec Cmp Elec Eng-Prof Degree (C-ECENEEENP) only.
Recommended: Prerequisites knowledge of programming, particularly Python, ECEN 2120, ECEN 2350, ECEN 1030, ECEN 1310, CSCI 1300.

ECEN 5793 (3) Secure Computer Architecture
Explore cutting-edge secure architectures that look to protect the system from the hardware up. This course covers advanced topics in security with an emphasis on computer architecture on both the attack and defense sides. Discussion oriented classes will deepen understanding of weekly technical reading assignments, enhance the ability to analyze technical papers, and help carry out a semester long research project.
Requisites: Requires prerequisite or corequisite course of ECEN 5593 (minimum grade D-).

ECEN 5797 (3) Introduction to Power Electronics
An introduction to switched-mode converters. Includes steady-state converter modeling and analysis, switch realization, discontinuous conduction mode and transformer-isolated converters. Ac modeling of converters using averaged methods, small-signal transfer functions, feedback loop design and transformer design.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 4797
Requisites: Restricted to Electrical/Computer Engineering (EEEN) graduate students or Concurrent Degree students in Electrical Engineering (C-EEEN) or Electrical/Computer Engineering (C-ECENEEEN) or to Graduate Certificate Engineering (CRTGE) students.
Additional Information: Departmental Category: Power

ECEN 5803 (3) Mastering Embedded Systems Architecture
Acquire an understanding of embedded systems architectures for the purpose of creating prototypes or products for a variety of applications. The salient issues in the decision making process will be examines, including trade-offs between hardware and software implementations, processor and operating system selection and IP creation or acquisition. Projects will involve the latest software development and tools and hardware platforms.
Grading Basis: Letter Grade
Additional Information: Departmental Category: Embedded Systems Engineering

ECEN 5807 (3) Modeling and Control of Power Electronic Systems
Studies modeling and control topics in power electronics. Averaged switch modeling of converters, computer simulation, ac modeling of the discontinuous conduction mode, the current programmed mode, nulldouble injection techniques in linear circuits, input filter design, and low-harmonic rectifiers.
Requisites: Requires prerequisite course of ECEN 5797 (minimum grade C-).
Additional Information: Departmental Category: Power

ECEN 5813 (3) Principles of Embedded Software
Introduces principles around embedded software elements and software development needed for the Embedded Systems Engineering core curriculum. Student will write C program applications hat employ efficient, high performance and robust software design techniques. Topics include bare-metal firmware, c-programming optimization and introductions to underlying embedded architecture. Sound testing and debug practices will be instilled and utilized in several application projects.
Grading Basis: Letter Grade
Additional Information: Departmental Category: Embedded Systems Engineering

ECEN 5817 (3) Resonant and Soft-Switching Techniques in Power Electronics
Covers resonant converters and inverters, and soft switching; sinusoidal approximations in analysis of series, parallel, LCC, and other resonant dc-dc and dc-ac converters; state-plane analysis of resonant circuits; switching transitions in hand-switched and soft-switched PWM converters; zero-voltage switching techniques, including resonant, quasi resonant, zero voltage transition, and auxiliary switch circuits.
Requisites: Requires prerequisite course of ECEN 5797 (minimum grade C-).
Additional Information: Departmental Category: Power

ECEN 5823 (3) Internet of Things Embedded Firmware
Acquire firmware development skills to meet low energy and internet connectivity demands of embedded systems. Event-driven firmware techniques will be explored through programming assignments, transitioning to programming an Internet of Things RF Network Protocol such as Bluetooth Low Energy or Thread. The coursework will align with the latest industry firmware and embedded wireless protocol trends.
Grading Basis: Letter Grade
Additional Information: Departmental Category: Embedded Systems Engineering

ECEN 5827 (3) Analog IC Design
Covers the fundamentals of transistor-level analog integrated circuit design. Starting with motivations from application circuits, the course develops principles of dc biasing, device models, amplifier stages, frequency response analysis and feedback and compensation techniques for multi-stage operational amplifiers.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 4827
Requisites: Restricted to Electrical/Computer Engineering (EEEN) graduate students or Concurrent Degree students in Electrical Engineering (C-EEEN) or Electrical/Computer Engineering (C-ECENEEEN) or to Graduate Certificate Engineering (CRTGE) students.
Additional Information: Departmental Category: Power

ECEN 5828 (3) Hybrid Dynamical Systems: Theory and Applications
Students will study the basic properties of differential and difference equations and inclusions including: existence of solutions, uniqueness, invariance principles; introduction to basic hybrid systems that combine continuous-time and discrete-time dynamics: automata, switched systems, etc.; Lyapunov theory for hybrid systems; and examples and applications in the areas of optimization, feedback control, machine learning, energy systems, social networks, multi-agent systems, and asynchronous systems. Previously offered as a special topics course.
Requisites: Restricted to graduate students only.

ECEN 5830 (3) Special Topics
Examines a special topic in Electrical, Computer and Energy Engineering.
Repeatable: Repeatable for up to 9.00 total credit hours. Allows multiple enrollment in term.
Additional Information: Departmental Category: General

ECEN 5833 (3) Low Power Embedded Design Techniques
The course explores through weekly quizzes, assignments, and a course project, low energy hardware design concepts, selecting components to meet reliability goals, radio implementation, power supply design, product design, and system bring up. The programming of the microcontroller or SoC will most likely be ¿coding to the metal¿ to control individual microcontroller peripherals and utilizing them in the most energy efficient ways.
Requisites: Restricted to students with an Embedded Systems Engineering (ESE) subplan or Electrical Engr-Prof Degree (C-EEENP) or Elec Cmp Elec Eng-Prof Degree (C-ECENEEENP) only.
Recommended: Requisites Students should have knowledge of assembly and C programming, digital logic design, and embedded computer architecture, and have had at least one course in each of these subjects, such as ECEN 5813 or ECEN 5823, students should also have experience using a microcontroller Integrated Development Environment (IDE) and its associated tools including its debugger and register views.

ECEN 5837 (3) Mixed-Signal IC Design Lab
Software laboratory course extends the concepts developed in ECEN 5827 to full design and layout of mixed analog and digital custom integrated circuits. Assignments explore implementation of analog to digital and digital to analog converters, and final project developes a full custom IC for a target application.
Requisites: Requires prerequisite course of ECEN 5827 (minimum grade C-).
Additional Information: Departmental Category: Power

ECEN 5840 (1-6) Independent Study
Offers an opportunity for students to do independent, creative work at the master's level. Numbered ECEN 5840-5849. Department consent required.
Repeatable: Repeatable for up to 6.00 total credit hours.
Additional Information: Departmental Category: General

ECEN 5853 (3) Embedding Sensors and Motors
Introduces students to the design of sensors and motors, and methods that integrate them into embedded systems used in consumer and industrial products. Students will learn about sensor technologies and motors through lectures, recorded and online videos, online reading, and through laboratory experiments. Students will build systems that take sensor inputs, and sort, filter and evaluate the resulting data. They will also learn how to use sensor input to measure properties of motors.
Requisites: Restricted to students with an Embedded Systems Engineering (ESE) subplan or Electrical Engr-Prof Degree (C-EEENP) or Elec Cmp Elec Eng-Prof Degree (C-ECENEEENP) only.
Recommended: Prerequisites ECEN 1400, ECEN 2250, ECEN 2260 and ECEN 2440 or equivalent coursework.

ECEN 5857 (3) Digital Control for Power Electronics
Focuses on analysis, modeling and design of digitally controlled power converters. Covers the dynamical discrete-time analysis of power converters, digital compensator design and main nonlinear phenomena due to quantization effects. Addresses the basics of controller autotuning.
Requisites: Requires prerequisite course of ECEN 5797 (minimum grade C-).

ECEN 5863 (3) Programmable Logic Embedded System Design
Learn to design programmable systems on a chip for the purpose of creating prototypes or products for a variety of applications. Explore complexities, capabilities and trends of Field Programmable Gate Arrays (FPGA) and Complex Programmable Logic Devices (CPLD). Implement synchronization and timing closure in these devices. Projects will involve the latest software and FPGA development tools and hardware platforms.
Grading Basis: Letter Grade
Additional Information: Departmental Category: Embedded Systems Engineering

ECEN 5907 (3) Special Topics
Special topics class.
Repeatable: Repeatable for up to 9.00 total credit hours. Allows multiple enrollment in term.

ECEN 5915 (3) Foundations of Quantum Engineering
Introduces engineers to quantum theory. In this course you will learn how to describe many different physical systems (such as atoms, electrons, light, mechanical oscillators, and tops) mathematically. It also explores different notions of quantumness such as entanglement and non-contextuality. The foundations obtained in this course are important for further study of quantum hardware (sensors), communication, and computing.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 3915

ECEN 5925 (3) Foundations of Quantum Hardware
Introduces students to the principles and operation of quantum hardware. In this course you will learn how to describe many different physical systems (trapped Ions, superconducting circuits, and optical systems) mathematically. This will allow you to model quantum sensors, communication systems and computing hardware.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 4295

ECEN 5930 (1-3) Industry Internship
This class provides a structure for ECEE graduate students to receive academic credit for internships with industry partners that have an academic component to them suitable for graduate-level work. Participation in the program will consist of an internship agreement between a student and an industry partner who will employ the student in a role that supports the academic goals of the internship. Instructor participation will include facilitation of mid-term and final assessments of student performance as well as support for any academic-related issues that may arise during the internship period. May be taken during any term following initial enrollment and participation in ECEE graduate programs.
Repeatable: Repeatable for up to 3.00 total credit hours.
Grading Basis: Letter Grade

ECEN 5933 (3) Engineering Genetic Circuits
Presents recent research into methods and software tools for the modeling, analysis, and design of genetic circuits that are enabling the new field of synthetic biology. Teaches both biological and engineering principles in order to enable collaborations between engineers and biologists working in the field of synthetic biology.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 4933
Recommended: Prerequisite some familiarity with genetics, cell biology, molecular biology, or biochemistry or familiarity with engineering methods for modeling, analysis and design, but students are not expected to have knowledge in both.

ECEN 6016 (1-3) Special Topics
Additional Information: Departmental Category: Optics

ECEN 6106 (3) Numerical Methods in Photonics
Teaches students how to create and use their own computational techniques to explore optical physics, devices and systems. Learning is project-based, that is no traditional homework or exams are used. Instead, students write their own series of different numerical tools such as finite difference time domain and Fourier beam propagation. Previously offered as a special topics course.
Requisites: Restricted to graduate students only.
Recommended: Prerequisite ECEN 5696 Fourier Optics or equivalent and some familiarity with a numerical programming language such as Matlab is strongly recommended.

ECEN 6139 (3) Logic Synthesis of VLSI Systems
Studies synthesis and optimization of sequential circuits, including retiming transformations and don't care sequences. Gives attention to hardware description languages and their application to finite state systems. Also includes synthesis for testability and performance, algorithms for test generation, formal verification of sequential systems, and synthesis of asynchronous circuits.
Recommended: Prerequisites ECEN 5139 and CSCI 5454.
Additional Information: Departmental Category: VLSI CAD Methods

ECEN 6144 (3) Electromagnetic Boundary Problems
Provides mathematical and physical fundamentals necessary for the systematic analysis of electromagnetic fields problems. Covers basic properties of Maxwell's equations, potentials and jump conditions; scattering and diffraction by canonical structures; Green's functions, integral equations and approximate methods. Requires some maturity in electromagnetics.
Requisites: Requires prereq course of ECEN 5114 or 5134 (minimum grade C-). Restricted to graduate students in Electrical Engr (EEEN) or Electrical/Computer Engr (ECEN) or Electrical Engr Concurrent or Electrical/Computer Engr Concurrent Degree students only.
Additional Information: Departmental Category: Electromagnetics and Remote Sensing

ECEN 6800 (3) Master of Engineering Report
Additional Information: Departmental Category: General

ECEN 6940 (1) Master's Candidate for Degree
Registration intended for students preparing for a thesis defense, final examination, culminating activity, or completion of degree.
Additional Information: Departmental Category: General

ECEN 6950 (1-6) Master's Thesis
Repeatable: Repeatable for up to 6.00 total credit hours. Allows multiple enrollment in term.
Additional Information: Departmental Category: General

ECEN 6960 (3) Master of Engineering Project
Additional Information: Departmental Category: General

ECEN 7840 (1-6) Independent Study
Offers an opportunity for students to do independent, creative work at the doctoral level. Department consent required.
Repeatable: Repeatable for up to 6.00 total credit hours.
Additional Information: Departmental Category: General

ECEN 7849 (1-6) Independent Study
Offers an opportunity for students to do independent, creative work at the doctoral level. Department consent required.
Repeatable: Repeatable for up to 6.00 total credit hours.
Additional Information: Departmental Category: VLSI CAD Methods

ECEN 8990 (1-10) Doctoral Dissertation
Repeatable: Repeatable for up to 10.00 total credit hours.
Additional Information: Departmental Category: General