ELECTRICAL ENGINEERING

Engineering East Bldg. (20A), Room 200
Phone: 805.756.2781
https://ee.calpoly.edu/

Department Chair: Dale Dolan

Engineering Student Services
Engineering South (40), Room 115
Phone: 805.756.1461

Academic Programs

Program name	Program type
Computer Engineering	BS
Electrical Engineering	BS, MS

The Electrical Engineering Department offers a Bachelor of Science degree and a Master of Science degree in Electrical Engineering, and supports the Bachelor of Science degree in Computer Engineering. Both undergraduate degrees are accredited by the Engineering Accreditation Commission of ABET, http://www.abet.org.

The mission of the Electrical Engineering Department is to educate students to achieve excellence in the discipline of electrical engineering and to teach them to apply their education to solve practical problems in a socially responsible way. Students are prepared for careers of service, leadership, and distinction in a wide range of engineering and other related fields using a participatory, learn-by-doing, and “hands-on” laboratory, project, and design centered approach. Students are encouraged to participate in lifelong learning as essential in the presence of the ever-increasing pace of technological change.

Diversity in the students, faculty and staff is embraced and enhances the quality and creativity of the campus experience and environment.

The primary educational objectives of the Electrical Engineering program are to prepare graduates to:

1. Excel in the electrical engineering profession;
2. Embrace life-long learning as a necessary component to remain current in their profession; and
3. Pursue graduate degrees for enhanced skills and opportunities.

The Electrical Engineering degree programs prepare graduates for distinguished practice in professional engineering; equipping students for pursuing engineering solutions to urgent problems while being responsibly aware of all implications. To that end, the curriculum provides a sound theoretical background along with current, practical engineering knowledge. Cal Poly's "learn by doing" philosophy is emphasized by integrating design throughout the curriculum in numerous design-centered laboratories that provide students with hands-on experiences in design synthesis, analysis, characterization, and verification.

The student begins the major in the first quarter with an orientation class and laboratory; and generally has one or more major courses each quarter until graduation. The many laboratory courses provide practical experience and lead logically from demonstration of theory into design applications.

During their junior and senior years, students choose technical electives to gain additional expertise in one or more areas of specialization within electrical engineering. These courses deal with the development, design and application of circuits, electronic devices, computers, and systems for communication, controls, information processing and display, and system instrumentation. Senior courses in this area provide specialized preparation in a selected area such as active and passive network synthesis, advanced communications systems, software and hardware aspects of computer system design, microelectronic circuit engineering, microprocessor systems applications, rf and microwave engineering, photonics, biomedical engineering, integrated circuits, and solid state devices.

Other courses deal with industrial process control systems, power electronics, and with generation, distribution, control and utilization of electric power. Senior elective courses in this area provide specialized preparation in a selected area such as advanced control systems, energy conversion, power system analysis, protection and stability, and solid state motor control.

Employers recognize that students who have completed such specialized technical courses are early contributors in the workforce. Students wishing to pursue graduate work may select appropriate senior courses in keeping with this goal.

In the required senior design project, students demonstrate their understanding of engineering knowledge and their ability to apply that knowledge creatively to solve practical problems.

Involvement in faculty research is possible for graduate students and outstanding undergraduate students. Research areas include computer-aided education, autonomous systems, signal and image processing, electric vehicles, computer architecture and software systems, photonics, polymer electronics, power systems, power electronics, radio frequency electronics, communication systems, biomedical electronics, renewable energy systems, and electric power microgrid systems.

Students are encouraged to participate in professional organizations and clubs such as: Institute of Electrical and Electronics Engineers (IEEE), IEEE Computer Society (IEEE-CS), IEEE Consumer Electronics Society (IEEE-CES), IEEE Power and Energy Society (IEEE-PES), Audio Engineering Society (AES), Cal Poly Robotics, Electric Vehicle Club, Renewable Energy Club, Society of Automotive Engineers (SAE) and the Formula Electric challenge, Society of Women Engineers (SWE), Women involved in Software & Hardware (WISH), Eta Kappa Nu (HKN), Society of Photo-Optical Instrumentation Engineers (SPIE), Student Electrical Engineering Council (SEEC), and the Amateur Radio Cub. The Electric Power Institute, sponsored by the university and underwritten by major utility companies and electrical equipment manufacturers, offers advanced seminars and lectures in the electrical power field and facilitates student and faculty interaction with industry.

Undergraduate Programs

BS Computer Engineering

This program is jointly offered by the Computer Science Department and the Electrical Engineering Department. For information regarding this program, please refer to Computer Engineering (http://catalog.calpoly.edu/collegesandprograms/collegeofengineering/computerengineering/).

BS Electrical Engineering

Students are prepared for careers of service, leadership, and distinction in engineering and other related fields using a participatory, learn-by-

doing, and "hands-on" laboratory, project, and design centered approach. Students are encouraged to participate in lifelong learning in the presence of rapid technological change.

General Curriculum in Electrical Engineering or Concentrations

- General Curriculum in Electrical Engineering
- Power
- Radio Frequency - Microwaves - Photonics
- Systems

Graduate Program
MS Electrical Engineering

General Characteristics

The Master of Science program in Electrical Engineering serves students and practicing engineers seeking:

- Job-entry education for the more complex areas of engineering, such as research and development, innovative design, systems analysis and design, and managerial engineering;
- Updating and upgrading opportunities for practicing engineers;
- Graduate preparation for further study in engineering, leading to the Doctor of Engineering or Ph.D. degree;
- A base which allows graduates to maintain currency in their fields.

Prerequisites

For admission as a classified graduate student, an applicant must hold a bachelor's degree in engineering or a closely related physical science with a minimum grade point average of 3.0 in the last 90 quarter units (60 semester units) attempted. Applicants for graduate engineering programs are required to submit satisfactory scores for the General (Aptitude) Test of the Graduate Record Examination. Foreign applicants must have satisfactory scores on the TOEFL and TWE exams. An applicant who meets these standards but lacks prerequisite coursework may be admitted as a conditionally classified student and must make up any deficiencies before advancement to classified graduate standing.

Information pertaining to specific requirements for admission to graduate standing (classified or conditionally classified) may be obtained from the Graduate Coordinator, Electrical Engineering Department.

Program of Study

Graduate students in this program must file a formal study plan with their advisor, department, college and university graduate studies office by no later than the end of the second quarter in the program. The formal program of study must include a minimum of 45 units (at least 28 of which must be at the 500 level and the remainder at the 400 level).

The broad curriculum requirements for the MS in Electrical Engineering are:

1. core of 16 units;
2. a minimum of 12 units of additional electrical engineering courses;
3. at least 17 units of approved electives;
4. at least 28 units of the 45 unit program at the 500 level.

Two program options are available for MS in Electrical Engineering students: a thesis program which requires coursework, a thesis and oral defense of thesis; *or* a nonthesis option which involves additional coursework and a comprehensive examination. The thesis option is strongly encouraged for all students.

Blended BS + MS Electrical Engineering Program

A blended program provides an accelerated route to a graduate professional degree, with simultaneous conferring of both Bachelor's and Master's degrees. Students in the blended program are provided with a seamless process whereby they can progress from undergraduate to graduate status. Students are required to complete all requirements for both degrees, including senior project for the Bachelor's degree.

A blended program is available for MS Electrical Engineering.

Eligibility

Majors that are eligible for the blended program are:

- BS Computer Engineering
- BS Electrical Engineering

Participation in a blended program is based upon prior academic performance and other measures of professional promise. Refer to Graduate Education (http://catalog.calpoly.edu/graduateeducation/#graduateandpostbaccalaureateadmissionrequirements/) for more information and for the minimum criteria required to be eligible for a blended program at Cal Poly. Contact the Graduate Program Coordinator in the Electrical Engineering department for any additional eligibility criteria.

EE Courses

EE 111. Introduction to Electrical Engineering. 1 unit
Concurrent: EE 151.

A general overview of the field of electrical engineering. Preparation for successful completion of the Electrical Engineering (EE) program at Cal Poly. 1 lecture. Not required for students with transfer credit for EE 211 or EE 241.

EE 112. Electric Circuit Analysis I. 2 units
Prerequisite: MATH 142 or equivalent. Recommended: EE 111/151.

Introduction to basic circuit analysis. Resistive circuits, voltage and current sources, network theorems. Course may be offered in classroom-based or online format. 2 lectures.

EE 113. Electric Circuit Analysis I. 3 units
Prerequisite: MATH 142. Concurrent: EE 143. Recommended: EE 111, EE 151; PHYS 133.

Basic circuit analysis and basic electronics manufacturing. Resistive circuits, voltage and current sources, op-amps, network theorems. Practical electronics manufacturing expanded through concepts such as CAD/CAM design, Design for Manufacture (DFM), documentation requirements, deposition and etching processes, prototyping, and production planning. PCB design and assembly. 3 lectures.

EE 133. Digital Design. 4 units
Prerequisite: An orientation course in student's major (EE 111 and EE 151; or CPE 100) and CPE/CSC 101.

Number systems, Boolean algebra, Boolean functions, and function minimization. Analysis and design of combinational and sequential digital logic circuits. Hardware Description Language (HDL) concepts and applications digital design and synthesis in FPGAs. Course may be offered in classroom-based or online format. 3 lectures, 1 laboratory. Crosslisted as CPE/EE 133.

EE 143. Electronics Manufacturing and Circuit Analysis Laboratory. 1 unit
Prerequisite: MATH 142. Concurrent: EE 113. Recommended: EE 111, EE 151; PHYS 133.

Use of electrical and electronic test equipment. Introduction to engineering design flow (design, simulate, build, test). PCB design and manufacturing. 1 laboratory.

EE 151. Introduction to Electrical Engineering Laboratory. 1 unit
Concurrent: EE 111.

A variety of hands-on experiments and demonstrations in electrical engineering, providing background and motivation for successful completion of the Electrical Engineering (EE) program at Cal Poly. Not open to students with credit for EE 241. 1 laboratory.

EE 200. Special Problems. 1-2 units
Prerequisite: Consent of department chair.

Individual investigation, research, studies or surveys of selected problems. Total credit limited to 4 units, with a maximum of 2 units per quarter.

EE 201. Electric Circuit Theory. 3 units
Prerequisite: MATH 244, PHYS 133.

Application of fundamental circuit laws and theorems to the analysis of DC, and steady-state single-phase and three-phase circuits. Not for electrical engineering majors. Course may be offered in classroom-based or online format. 3 lectures.

EE 211. Electric Circuit Analysis II. 3 units
Prerequisite: EE 112 or EE 113. Prerequisite or Concurrent: PHYS 133, MATH 244. Concurrent: EE 241.

Continuation of basic circuit analysis. Op-amp circuits. Energy storage elements, RC and RL circuits, and AC steady state analysis. 3 lectures.

EE 212. Electric Circuit Analysis III. 3 units
Prerequisite: MATH 244, EE 211. Concurrent: EE 242.

AC power, 3-phase circuits. Mutual inductance, series and parallel resonance and two-port networks. Frequency response, including Bode plots. 3 lectures.

EE 228. Continuous-Time Signals and Systems. 4 units
Prerequisite: BMED 355; or EE 212 and EE 242. Recommended: MATH 241.

Continuous-time systems analysis, with emphasis on linear time-invariant (LTI) systems. Classifications of continuous-time systems. Convolution and its application to LTI systems. The Laplace transform, Fourier transform, and Fourier series, and their application to the analysis of LTI systems. 4 lectures.

EE 233. Computer Design and Assembly Language Programming. 4 units
Prerequisite: CPE/EE 133.

Design and implementation of digital computer circuits via CAD tools for programmable logic devices (PLDs). Basic computer design with its datapath components and control unit. Introduction to assembly language programming of an off-the-shelf RISC-based microcontroller. Not open to students with credit in CPE/EE 229. 3 lectures, 1 laboratory. Crosslisted as CPE/EE 233.

EE 241. Electric Circuit Analysis Laboratory II. 1 unit
Prerequisite: EE 112 or EE 113; EE 151 for EE students. Prerequisite or concurrent: MATH 244; PHYS 133. Concurrent: EE 211.

Use of electrical and electronic test equipment. Experimental verification of circuit analysis concepts including Kirchhoff's Laws, Thevenin's Theorem, maximum power transfer and superposition. 1 laboratory.

EE 242. Electric Circuit Analysis Laboratory III. 1 unit
Prerequisite: MATH 244, EE 241 or consent of department chair. Concurrent: EE 212.

Observation of transient and steady-state phenomena, phase-shift circuits, resonance. Use of phasor diagrams. 1 laboratory.

EE 251. Electric Circuits Laboratory. 1 unit
Concurrent: EE 201.

Techniques of measurement of DC and steady-state AC circuit parameters. Equivalent circuits, nonlinear elements, resonance. 1 laboratory.

EE 255. Energy Conversion Electromagnetics. 3 units
Prerequisite: EE 212 and EE 242; or EE 201 and EE 251. Concurrent: EE 295.

Fundamentals of electro-mechanical energy conversion. Magnetic circuits and electromagnetic devices. Theory of operation and operating characteristics of transformers, and AC induction and synchronous machines. 3 lectures.

EE 261. Intro C Programming with a Hardware Emphasis. 1 unit
Prerequisite: CPE/CSC 101. Recommended: EE 151.

Introduction to the C Programming Language with an emphasis on microprocessor implementation and applications. Not open to students with credit in CPE/CSC 357 or CPE/EE 329. 1 laboratory.

EE 262. Intro C++ Programming with a Hardware Emphasis. 1 unit
Prerequisite: CPE/CSC 101. Recommended: EE 151.

Introduction to the C++ Objected Oriented Programming Language with an emphasis on Microprocessor Implementation and applications. 1 laboratory.

EE 270. Selected Topics. 1-4 units
Prerequisite: Open to undergraduate students and consent of instructor.

Directed group study of selected topics. The Class Schedule will list topic selected. Total credit limited to 8 units. 1 to 4 lectures.

EE 271. Selected Laboratory. 1-2 units
Prerequisite: Consent of instructor.

Directed group laboratory study of selected topics. The Class Schedule will list topic selected. Total credit limited to 6 units. 1 to 2 laboratories.

EE 295. Energy Conversion Electromagnetics Laboratory. 1 unit
Prerequisite: EE 212 & EE 242 or EE 201 & EE 251. Concurrent: EE 255.

Single-phase and three-phase transformers. Starting of rotating machines, evaluation of characteristics of rotating machines. 1 laboratory.

EE 302. Classical Control Systems. 3 units
Prerequisite: EE 228. Concurrent: EE 342. Recommended: EE 368.

Introduction to feedback control systems. System modeling. Transfer functions. Graphical system representation. System time response, stability. Root Locus. Frequency response. Compensation. 3 lectures.

EE 306. Semiconductor Device Electronics. 3 units
Prerequisite: CHEM 124, EE 212 & EE 242, EE 143 or IME 156 or IME 458, PHYS 211. Concurrent: EE 346.

Internal operation, semiconductor physics, terminal characteristics, models and application of diodes (LEDs, solar cells, and photo-diodes) and transistors (field-effect and bipolar). 3 lectures.

EE 307. Digital Electronics and Integrated Circuits. 3 units
Prerequisite: CPE/EE 133, EE 306 and EE 346. Corequisite: CPE/EE 233. Concurrent: EE 347.

Analysis, design, application and interfacing of integrated logic circuits, including NMOS, CMOS, TTL, ECL, and other logic families. 3 lectures.

EE 308. Analog Electronics and Integrated Circuits. 3 units
Prerequisite: EE 302 & EE 342, EE 307 & EE 347. Concurrent: EE 348.

Analysis and design of integrated circuits for use in analog applications. Gain, frequency response, and feedback of linear small-signal amplifiers. 3 lectures.

EE 314. Introduction to Communication Systems. 3 units
Prerequisite: STAT 350.

Analog modulation, including: double-sideband modulation, amplitude modulation, single-sideband modulation, frequency modulation, phase modulation. Performances of such systems in the presence of white Gaussian noise. Implementations of transmitters and receivers. 3 lectures.

EE 321. Electronics. 3 units
Prerequisite: EE 201 or BRAE 216 for BRAE majors.

Semiconductor devices and circuits. Instrumentation amplifiers, power control rectifiers, feedback, pulse circuits, digital logic circuits. Not for Electrical Engineering majors. 3 lectures.

EE 322. Microcontrollers for Everyone. 4 units
2020-21 or later: Upper-Div GE Area B
2019-20 or earlier catalog: GE Area B5, B6, or B7
Prerequisite: Junior standing; completion of GE Area A with grades of C- or better; and one course in GE Area B4 with a grade of C- or better (GE Area B1 for students on the 2019-20 or earlier catalogs).

Microcontroller history and computer systems overview. Introduction to basic electrical circuits and computer programming concepts. 3 lectures, 1 laboratory. Fulfills GE Area Upper-Division B (GE Areas B5, B6, or B7 for students on the 2019-20 catalog).

EE 328. Discrete Time Signals and Systems. 3 units
Prerequisite: BMED 355 or EE 228. Concurrent: CPE/EE 368.

Discrete-time systems and analysis, with emphasis on linear time-invariant (LTI) systems. Sampling theorem. Classification of discrete-time systems. Convolution and its application to LTI systems. The z transform, discrete-time Fourier transform, and discrete Fourier transform. Introduction to digital filters. Not open to students with credit in CPE 327. 3 lectures. Crosslisted as CPE/EE 328.

EE 329. Microcontroller-Based Systems Design. 4 units
Prerequisite: EE 307 & EE 347, EE 229 & EE 269 or CPE/EE 233.

Design, implementation and testing of microcontroller-based systems. Hardware and C software for embedded systems to sense and actuate external devices. I/O common embedded systems to interface I/O devices and protocols. Analysis of power consumption. Ethics. 3 lectures, 1 laboratory. Not open to students with credit in CPE/EE 336. Crosslisted as CPE/EE 329.

EE 335. Electromagnetic Fields and Transmission. 4 units
Prerequisite: EE 201 and EE 251; or EE 212 and EE 242; and MATH 241. Concurrent: EE 375.

Maxwell's equations. Plane wave propagation in free space. Static electric and magnetic fields. Distributed-circuit concepts and transmission line parameters. Reflections and standing waves. The Smith chart and its applications. Transmission line measurements and impedance matching techniques. 4 lectures.

EE 336. Microprocessor System Design. 4 units
Prerequisite: CPE/EE 233.

Introduction to microcontrollers and integrated microprocessor systems. Hardware/software trade-offs, system economics, and functional configurations. Interface design, real-time clocks, interrupts, A/D conversion, serial and parallel communications, watch-dog timers, low power operation, event-based inter-peripheral communication, and assembly and higher-level language programming techniques. Architecture and design of sampled data and low-power systems. Not open to students with credit in CPE/EE 329. 3 lectures, 1 laboratory. Crosslisted as CPE/EE 336.

EE 342. Classical Control Systems Laboratory. 1 unit
Prerequisite: EE 228. Concurrent: EE 302. Recommended: EE 368.

Laboratory work pertaining to classical control systems, including servo control, transient and frequency responses, stability, and computer-aided analysis of control systems. 1 laboratory.

EE 346. Semiconductor Device Electronics Laboratory. 1 unit
Prerequisite: CHEM 124, EE 212 & EE 242, EE 143 or IME 156 or IME 458, PHYS 211. Concurrent: EE 306. Recommended: ENGL 134.

Experimental determination of device characteristics and models. 1 laboratory.

EE 347. Digital Electronics and Integrated Circuits Laboratory. 1 unit
Prerequisite: CPE/EE 133, EE 306 and EE 346. Corequisite: CPE/EE 233. Concurrent: EE 307.

Computer simulation and experimental investigation of the characteristics, applications and interfacing of different logic families. 1 laboratory.

EE 348. Analog Electronics and Integrated Circuits Laboratory. 1 unit
Prerequisite: EE 302 & EE 342, EE 307 & EE 347. Concurrent: EE 308.

Design, simulation, construction and testing of solid state amplifiers and sub-circuits to meet stated specifications. 1 laboratory.

EE 361. Electronics Laboratory. 1 unit
Prerequisite: EE 251 or BRAE 216 for BRAE majors. Concurrent: EE 321.

Instrumentation amplifiers, feedback, rectifiers and power control, pulse and digital logic circuits. 1 laboratory.

EE 368. Signals and Systems Laboratory. 1 unit
Prerequisite: BMED 355 or EE 228. Concurrent: CPE/EE 328.

Laboratory work pertaining to linear systems, including Fourier analysis, time and frequency responses, and system transfer function. Not open to students with credit in CPE 367. 1 laboratory. Crosslisted as CPE/EE 368.

EE 375. Electromagnetic Fields and Transmission Laboratory. 1 unit
Concurrent: EE 335.

Transmission line and passive component measurements at microwave frequencies. Response to pulse excitation using time domain techniques and sinusoidal excitation using frequency domain techniques. Application of the Smith Chart and network analyzers in transmission line characterization and impedance matching techniques. 1 laboratory.

EE 400. Special Problems. 1-5 units
Prerequisite: Consent of department chair.

Individual investigation, research, studies, or surveys of selected problems. Total credit limited to 5 units.

EE 402. Electromagnetic Waves. 4 units
Prerequisite: EE 335.

Maxwell's equations and plane wave propagation in materials. Reflection and transmission of normal and oblique incidence plane waves at planar boundaries between different media. Wave guides. Antennas. 4 lectures.

EE 403. Introduction to Photonics and Fiber Optics. 3 units
Prerequisite: EE 306 and EE 346; or PHY 323. Concurrent: EE 443.

Introduction to modern fiber optics and photonics. Lens systems, photodiodes, LEDs, laser diodes, transmitter and receiver design, diffraction, interference, optical signal processing, propagation of light in optical fibers. 3 lectures.

EE 405. High Frequency Amplifier Design. 3 units
Prerequisite: EE 308 & EE 348, EE 335. Concurrent: EE 445.

Design of modern electronic amplifiers and amplifier systems with advanced techniques. UHF and microwave small signal amplifier design utilizing microstrip transmission lines, S parameters of GaAs FET, and bipolar transistors. Low noise, broadband, and power amplifier designs. Oscillator designs. 3 lectures.

EE 406. Power Systems Analysis I. 4 units
Prerequisite: EE 335, EE 255 & EE 295.

Introduction to electric power systems. Representation of power systems and its components including transmission lines, synchronous machines, transformers and loads. One line diagrams and per unit calculations. symmetrical faults. Load flow analysis. 4 lectures.

EE 407. Power Systems Analysis II. 4 units
Prerequisite: EE 406.

Symmetrical components, unbalanced faults, power system stability, system protection, relays and relay systems, power system instrumentation and measurement techniques, economic operation. 4 lectures.

EE 409. Electronic Design. 3 units
Prerequisite: EE 308 & EE 348; CPE/EE 328 & CPE/EE 368, or CPE 327 & CPE 367; CPE/EE 329 or CPE/EE 336 or CPE 316. Concurrent: EE 449.

Design of electronic systems and subsystems using analog and digital integrated circuits. Design principles and techniques. Analysis and design of feedback amplifiers; operational amplifier applications. Design of analog/digital and digital/analog converters. Power supply design. Emphasis on IC implementation. 3 lectures.

EE 410. Power Electronics I. 4 units
Prerequisite: EE 308 and EE 348, or EE 321 and consent of instructor.

Introduction to power electronic converters and power semiconductor devices. Steady state analysis, performance study, and design of uncontrolled and controlled rectifiers, non-isolated and isolated DC-DC converters, AC voltage controllers, and single-phase inverters. Use of commercially available software. 3 lectures, 1 laboratory.

EE 411. Power Electronics II. 4 units
Prerequisite: EE 410.

Switching trajectory, switching losses, and Safe Operating Area of solid-state switches. Analysis and design of snubber circuits. Synchronous rectification. Steady-state analysis and operation of resonant DC-DC converters. Power quality and harmonics. Operation of HVDC transmission lines, introduction to flexible AC transmission system (FACTS) controllers, multilevel and three-phase inverters. Use of commercially available software. 3 lectures, 1 laboratory.

EE 412. Advanced Analog Circuits. 3 units
Prerequisite: EE 314, EE 409 & EE 449. Concurrent: EE 452.

Application of linear integrated circuits to data acquisition problems: transducer interfacing, linear and nonlinear preprocessing, phase-locked loops, and high performance quantization and recovery (A/D, D/A conversion). 3 lectures.

EE 413. Advanced Electronic Design. 4 units
Prerequisite: CSC 101, EE 409 and EE 449.

Advanced design of electronic circuits and subsystems, including sustainability and design as a process. Automated testing with GPIB instruments. Implementation of specific design projects, including team-based projects. 3 lectures, 1 laboratory.

EE 414. Robotic Systems Integration. 4 units
Prerequisite: EE/CPE 329 or EE/CPE 336 or CSC/CPE 357 or ME 305.

Integration of sensors, actuators, chassis, and Linux-based computational platforms into functioning autonomous robotic systems. Embedded Linux system programming, inter-process software communication, basic sensor fusion techniques, Pulse Width Modulation (PWM) motor actuation, and web-based interfacing for remote system way-pointing and monitoring. 3 lectures, 1 laboratory. Crosslisted as CPE/EE 414.

EE 415. Communication Systems Design. 3 units
Prerequisite: CPE 327 or EE 328.

Design of modern wireline and wireless electronic communication and telemetry systems. Emphasis: practical implementation and comparative evaluation of various communication systems. 3 lectures.

EE 416. Digital Communication Systems. 3 units
Prerequisite: EE 314; EE 328 or CPE 327.

Baseband (PCM, PAM, DM) signals and transmission. Bandpass (PSK, FSK, ASK) modulation and demodulation techniques. Digital communication signals in the presence of noise and detection of signals in Gaussian noise. Other topics such as: quantization, multiplexing and multiple access, spread spectrum techniques, coding, synchronization. 3 lectures.

EE 417. Alternating Current Machines. 4 units
Prerequisite: EE 255 & EE 295.

Alternating current machines. Generalized, operational and dynamic analysis. Steady-state and transient operation of synchronous machines and linear induction machines. 3 lectures, 1 laboratory.

EE 418. Photonic Engineering. 3 units
Prerequisite: EE 335 or PHYS 323. Concurrent: EE 458.

Modern optical design with emphasis on the use of computers to design simple optical systems and to evaluate existing optical designs. Paraxial and exact ray tracing through thin and thick lenses, mirrors, and prisms. Radiometry and photometry. Electro-optic, acousto-optic, and magneto-optic modulators and their applications. Thermal detectors, semiconductor detectors, and charge coupled device (CCD) arrays. 3 lectures.

EE 419. Digital Signal Processing. 3 units
Prerequisite: CSC 101 or CSC 231; EE 328 and EE 368, or CPE 327 and CPE 367. Concurrent: EE 459.

Review of Z-transform, convolution and discrete Fourier Transform. Digital filter design. Fast Fourier Transform. Theory and applications of digital signal processors. 3 lectures.

EE 420. Sustainable Electric Energy Conversion. 4 units
Prerequisite: CHEM 124; EE 255 and EE 295.

Electrical engineering aspects of photovoltaic and wind power generation and usage, and electrochemical energy conversion. Power control, processing, and quality for grid-connected and stand-alone systems. Distribution and storage of electric energy. Hydrogen and synthetic fuels. Distributed generation. 3 lectures, 1 laboratory.

EE 422. Polymer Electronics Laboratory. 1 unit
Prerequisite: EE 347 or MATE 340 or CHEM 319 or PHYS 340.

Experimental procedures in polymer electronics. Investigation of the characteristics of a polymer electronic device. 1 laboratory. Crosslisted as EE/PHYS 422.

EE 423. Micro/Nano Fabrication. 3 units
Prerequisite: BMED 212 or MATE 210.

Fabrication science and technology for creating micro and nano scale devices. Explore basic processes such as oxidation, diffusion, ion implantation, etching, chemical and physical vapor deposition, photolithography. Develop an understanding of the science of each process and how to select the right steps for fabricating electronic, photon and micro-electro-mechanical systems devices. 3 lectures. Crosslisted as BMED 434/EE 423/MATE 430.

EE 424. Introduction to Remote Sensing. 4 units
Prerequisite: MATH 244; senior or graduate standing in engineering.

Radiation characteristics, sensor technology and platforms, satellite systems, system design tradeoffs, collection and transmission of radio-metric data, GPS, thermal remote sensing, active radar and microwave remote sensing, interpretation and exploitation of remotely sensed data for various applications. 3 lectures, 1 laboratory.

EE 425. Analog Filter Design. 3 units
Prerequisite: EE 409 & EE 449. Concurrent: EE 455.

Approximation Theory. All pole filters. Frequency transformations. Elements of passive synthesis. Time delay filters. Theory and design of active filter. Sensitivity analysis. 3 lectures.

EE 428. Computer Vision. 4 units
Prerequisite: CPE 327 or CPE/CSC 357 or EE 328 or ME 305.

Introduction to the concepts of 2D and 3D computer vision: low-level image processing methods such as filtering and edge detection; feature extraction; segmentation and clustering; stereo vision; appearance-based and model-based algorithms. 3 lectures, 1 laboratory. Crosslisted as CPE/EE 428.

EE 431. Computer-Aided Design of VLSI Devices. 4 units
Prerequisite: EE 307 and EE 347. Recommended: EE 308 and EE 348, for students interested in analog design.

Design of VLSI circuits using state-of-the-art CAD software. Design issues and algorithms related to design using CAD. Full custom design through automated design and a major multi-week chip design project in lab. 3 lectures, 1 laboratory. Crosslisted as CPE 441/EE 431.

EE 432. Digital Control Systems. 3 units
Prerequisite: EE 302 and EE 342; or CPE 327 and CPE 367. Concurrent: CPE/EE 472. Recommended: EE 328 and EE 368.

Theory and applications of digital computers in linear control systems. Analysis and design of microprocessor-based controls. Introduction of continuous and discrete transform methods for design of closed-loop dynamic systems. Applications in robotics, automotive, aircraft and industrial process control. 3 lectures. Crosslisted as CPE/EE 432.

EE 433. Introduction to Magnetic Design. 4 units
Prerequisite: EE 255 and EE 295.

Design of magnetic components. Fundamentals of magnetics, magnetic cores, design of power transformer, three-phase transformer, dc inductor, ac inductors, dc-dc converter transformer design, actuators. Use of commercially available software. 3 lectures, 1 laboratory.

EE 434. Automotive Engineering for a Sustainable Future. 4 units
Prerequisite: Junior standing in any engineering or physical science major.

Multidisciplinary investigation of automotive renewable fuels and electric/hybrid vehicles. Analyze and design related technologies and systems. Methods for complete-cycle energy and GHG analysis. Comparative emissions, efficiency, power output, and infrastructure requirements. Laboratory projects converting engines and vehicles to operate on alternative fuels or electric propulsion. 3 lectures, 1 laboratory. Crosslisted as BRAE/EE 434.

EE 435. Industrial Power Control and Automation. 1 unit
Prerequisite: EE 255, EE 295, EE 302, and EE 342.

Introduction to programmable automation controllers including custom developed functions, electrical hardware interfaces, communications networking to intelligent electronic devices, and machine operator interface terminals. Applications of industrial power control and automation systems including protection equipment, motor controllers, renewable energy, and sensors. 1 laboratory.

EE 439. Introduction to Real-Time Operating Systems. 4 units
Prerequisite: CPE/EE 329 or CPE/EE 336.

Theory, design and implementation of real-time operating system-based embedded systems. Scheduling algorithms, operating system resources, peripheral device interfacing and embedded system architecture. Resource management issues in a resource-limited (microcontroller-based) environment. 3 lectures, 1 laboratory. Crosslisted as CPE/EE 439.

EE 440. Wireless Communications. 3 units
Prerequisite: EE 335, EE 314. Concurrent: EE 480.

Wireless microwave system design and analysis. RF transmission lines, microwave networks, receiver design, modulation techniques, and mixer characterization and realizations. Noise and distortion, RF oscillators and frequency synthesizers, filter design. Radiating systems and electromagnetic wave propagation, microwave amplifier design. 3 lectures.

EE 442. Real Time Embedded Systems. 4 units
Prerequisite: CPE/EE 329 or CPE/EE 336 or CPE 316.

Theory, design and implementation of modern embedded systems. Scheduling algorithms and operating system resources. System on Chip (SoC) design issues such as interfacing with custom hardware description language (HDL) peripherals, high-performance chip interconnect standards, energy use, area, and hardware versus software performance trade-offs. 3 lectures, 1 laboratory. Crosslisted as CPE/EE 442.

EE 443. Introduction to Photonics and Fiber Optics Laboratory. 1 unit
Prerequisite: EE 306 and EE 346; or PHYS 323. Concurrent: EE 403.

Experimental study of optical fibers, optical lens systems, fiber amplifiers, light sources, and optical detectors. Simulation of a simple fiber optical network using CAD tools. Design, build, and test of fiber optic and free-space optical communication systems. 1 laboratory.

EE 444. Power Systems Laboratory. 1 unit
Prerequisite: EE 406.

Protective relaying, coordination, and relay calibration. Power control using transformers, parallel operation of generators, and computer simulation of power systems. 1 laboratory.

EE 445. High Frequency Amplifier Design Laboratory. 1 unit
Prerequisite: EE 308 & EE 348, EE 335. Corequisite: EE 405.

Experimental investigation employing advanced techniques. Design of high-frequency electronic amplifiers utilizing S-parameters of bipolar transistors, network analyzers, and computer simulation techniques. 1 laboratory.

EE 446. Design of Fault-Tolerant Digital Systems. 4 units
Prerequisite: CPE/EE 329 or CPE/EE 336 or CPE 316. Recommended: STAT 350.

Hardware and software fault tolerance concepts: fault models, coding in computer systems, module and system level fault detection mechanisms, reconfiguration techniques for general purpose processors and ASICs, and software fault tolerance techniques such as recovery blocks, N-version programming, checkpointing, and recovery. 3 lectures, 1 laboratory. Crosslisted as CPE/EE 446.

EE 447. Stringed Musical Instrument Acoustics, Mechanics, and Transducer Design. 4 units
Prerequisite: EE/CPE 329 or EE/CPE 336 or CPE 316 or ME 305.

Acoustics, sound production, and transducer design in the context of stringed musical instruments. Introduces music theory, scales and temperament, sound radiation, structural dynamics of stringed instruments. Integrates engineering topics including frequency spectrum analysis, electromagnetics, properties of materials, digital and analog circuit design. 3 lectures, 1 laboratory. Crosslisted as CPE/EE 447.

EE 449. Electronic Design Laboratory. 1 unit
Prerequisite: EE 308 & EE 348; CPE/EE 328 & CPE/EE 368, or CPE 327 & CPE 367; CPE/EE 329 or CPE/EE 336 or CPE 316. Concurrent: EE 409.

Design of electronic systems and subsystems using integrated circuits. 1 laboratory.

EE 450. Solar Photovoltaic System Engineering. 4 units
Prerequisite: one of the following: PHYS 104; PHYS 118; PHYS 121; or PHYS 141; and junior standing.

Engineering principles, design, and installation of solar photovoltaic power systems including grid-tie and off-grid systems. Photonic energy conversion, solar module engineering, solar power electronics, photovoltaic site planning, mechanical and structural considerations, permit processes, government incentives, and analysis of financial and investment issues. Field trips required. 3 lectures, 1 laboratory. Crosslisted as BRAE/EE/HNRS 450.

EE 452. Advanced Analog Circuits Laboratory. 1 unit
Prerequisite: EE 314, EE 409 & EE 449. Concurrent: EE 412.

Advanced laboratory study of LC and VCO oscillators, phase detectors, phase-locked loop circuits, transducer interface circuits, noise sources and signal-to-noise determination, ADC and DAC for data conversion. Formal experiments and computer SPICE simulation. 1 laboratory.

EE 455. Analog Filter Design Laboratory. 1 unit
Prerequisite: EE 409 & EE 449. Concurrent: EE 425.

Advanced laboratory study of sensitivity and stability of active networks prescribed for realization of transfer functions by active network synthesis techniques. Formal experiments and individual project work. 1 laboratory.

EE 456. Digital Communication Systems Laboratory. 1 unit
Prerequisite: EE 314; EE 328 & EE 368 or CPE 327 & CPE 367.

Methods of digital modulation and demodulation. Emphasis on spectral analysis, bandwidth requirements and other practical considerations of modulation and demodulation. 1 laboratory.

EE 458. Photonic Engineering Laboratory. 1 unit
Concurrent: EE 418.

Experimental investigation of the techniques used in processing optical signals. Formal experiments on electro-optic modulation, acousto-optic modulation. Construction of an RF spectrum analyzer. Analog processing of optical signals, and charge-coupled array devices. 1 laboratory.

EE 459. Digital Signal Processing Laboratory. 1 unit
Prerequisite: CSC 101 or CSC 231; CPE 327 and CPE 367 or EE 328 and EE 368. Concurrent: EE 419.

Experiments in digital filter design and digital signal processing emphasizing various areas of application. Formal experiments and individual project work, including DSP algorithm and digital filter analysis, design and implementation using Matlab, and real-time implementations using C on an embedded DSP processor. 1 laboratory.

EE 460. Senior Project Preparation. 2 units
Prerequisite: EE 314, EE 335. Corequisite: EE 409 & EE 449.

Introduction to teamwork and team-oriented project execution. Project planning, scheduling and analysis. Usage of tools for project management including Gantt and Pert Charts. Project development, cost and time estimation using top-down and bottom-up approaches. Ethics and ethical issues as they pertain to the conduct of engineering. Development of senior project proposal. 1 lecture, 1 laboratory.

EE 461. Senior Project I. 2 units
Prerequisite: EE 409, EE 449 and EE 460.

Investigation and design of a project under faculty supervision. Projects typical of problems which graduates must solve in their fields of employment. Project results are presented in a formal report.

EE 462. Senior Project II. 2 units
Prerequisite: EE 461.

Continuation and completion of a project under faculty supervision. Projects typical of problems which graduates must solve in their fields of employment. Project results are presented in a formal report.

EE 463. Senior Project Design Laboratory I. 2 units
Prerequisite: EE 409, EE 449 and EE 460.

Investigation and design of a project under faculty supervision. Projects typical of problems which graduates must solve in their fields of employment. Project results are presented in a formal report. Not open to students with credit in EE 461. 2 laboratories.

EE 464. Senior Project Design Laboratory II. 2 units
Prerequisite: EE 463.

Continuation and completion of a project under faculty supervision. Projects typical of problems which graduates must solve in their fields of employment. Project results are presented in a formal report. Not open to students with credit in EE 462. 2 laboratories.

EE 470. Selected Advanced Topics. 1-4 units
Prerequisite: Consent of instructor.

Directed group study of selected topics for advanced students. Open to undergraduate and graduate students. The Class Schedule will list topic selected. Total credit limited to 8 units. 1 to 4 lectures.

EE 471. Selected Advanced Laboratory. 1-4 units
Prerequisite: Consent of instructor.

Directed group laboratory study of selected topics for advanced students. Open to undergraduate and graduate students. The Class Schedule will list topic selected. Total credit limited to 8 units. 1 to 4 laboratories.

EE 472. Digital Control Systems Laboratory. 1 unit
Concurrent: CPE/EE 432.

Design and programming of microprocessor-based digital controls for electro-mechanical plants. Topics include digital control laws, translation of transfer functions into algorithms, assembly language programming, real-time software design, sample rate selection, finite word-length considerations. 1 laboratory. Crosslisted as CPE/EE 472.

EE 473. Microfabrication Laboratory. 1 unit
Corequisite: BMED 434/EE 423/MATE 430.

Application of basic processes involved in microfabrication: cleanroom protocol, oxidation, diffusion, photolithography etching and sputtering. Explore process development through fabrication of electronic, photonic or microfluidic devices. Each student will be part of a team that will fabricate and test a device. 1 laboratory. Crosslisted as BMED 435/EE 473/MATE 435.

EE 475. Communication Networks and Systems Laboratory. 1 unit
Prerequisite: CPE 327 and CPE 367; or CPE/EE 328 and CPE/EE 368.

Methods of wireline and wireless communication networks and systems. Emphasis on TCP/IP wired networks and modern mobile communication standards. 1 laboratory.

EE 480. Wireless Communications Laboratory. 1 unit
Prerequisite: EE 335, EE 314. Concurrent: EE 440.

Wireless microwave system design and analysis. RF transmission lines, microwave networks, receiver design, modulation techniques, and mixer characterization and realizations. Noise and distortion, RF oscillators and frequency synthesizers, filter design. Radiating systems and electromagnetic wave propagation, microwave amplifier design. 1 laboratory.

EE 493. Cooperative Education Experience. 1-2 units
CR/NC
Prerequisite: Sophomore standing.

Part-time work experience in business, industry, government, and other areas of student career interest. Positions are paid and usually require relocation and registration in course for two consecutive quarters. Formal report and evaluation by work supervisor required. No major credit allowed; total credit limited to 6 units. Credit/No Credit grading only.

EE 494. Cooperative Education Experience. 6-12 units
CR/NC
Prerequisite: Sophomore standing and consent of instructor.

Full-time work experience in business, industry, government, and other areas of student career interest. Positions are paid and usually require relocation and registration in course for two consecutive quarters. Evaluation by work supervisor required. Credit/No Credit grading only. No major credit allowed; total credit limited to 24 units.

EE 495. Cooperative Education Experience. 6-12 units
Prerequisite: Two consecutive quarters of EE 494 immediately preceding EE 495; sophomore standing and consent of instructor.

Full-time work experience in business, industry, government, and other areas of student career interest. Positions are paid and usually require relocation and registration in course for two consecutive quarters. Formal report and evaluation by work supervisor required. Major credit limited to 4 units; total credit limited to 12 units.

EE 500. Individual Study. 1-3 units
Prerequisite: Consent of department chair, graduate advisor, and supervising faculty member.

Advanced study planned and completed under the direction of a member of the department faculty. Open only to graduate students who have demonstrated ability to do independent work. Enrollment by petition. Total credit limit at discretion of graduate advisor, not to exceed 9 units.

EE 502. Microwave Component and System Engineering. 4 units
Prerequisite: Graduate standing; or EE 306, EE 346, EE 335, and EE 375.

Passive and active microwave/millimeter wave system theory, design and project construction. Microwave components such as power splitters, filters, mixers, detectors, oscillators, modulators, and amplifiers are designed, fabricated and tested. Components are combined for system-level functionality projects. 3 lectures, 1 laboratory.

EE 504. Software Defined Radio. 4 units
Prerequisite: EE 314; and EE 328 or CPE 327; or graduate standing.

Introduction to software defined radios, including architectures of software defined radio receivers and transmitters, design principles and trade-offs, signal processing techniques, and applications of the technologies. 3 seminars, 1 laboratory.

EE 509. Computational Intelligence. 4 units
Prerequisite: Senior or graduate standing.

Theory, design, and applications of biologically inspired computational paradigms, including artificial neural networks, evolutionary computation, swarm intelligence, and hybrid intelligent systems. 4 seminars.

EE 511. Electric Machines Theory. 4 units
Prerequisite: EE 255 or equivalent, and graduate standing or consent of instructor.

Advanced topics in electric machines theory. Introduction to Park's transformation. Analysis of electric machines using Kron's generalized concept. Vector control of induction machines. 4 seminars.

EE 513. Control Systems Theory. 4 units
Prerequisite: EE 302 or equivalent, and graduate standing or consent of instructor.

State representation of dynamic systems. Mathematical models of physical devices, controllability and observability. Design of closed-loop systems. Optimal control theory. 4 seminars.

EE 514. Advanced Topics in Automatic Control. 4 units
Prerequisite: EE 513 or equivalent, EE 328 or similar course on discrete-time linear systems.

Summary course covering five selected graduate-level topics in automatic control theory and practice; implementation issues in digital control, nonlinear control theory and design, LQ and time optimal control, variable structure control, and fuzzy logic/model-free control. 4 seminars.

EE 515. Discrete Time Filters. 4 units
Prerequisite: EE 314 or equivalent, and graduate standing or consent of instructor.

Advanced topics in filter design and implementation. Emphasis placed on current applications and on the processing of real signals. Topics may include signal analysis via spectral estimation, short time Fourier transforms, and spectrograms. Effects of coefficient quantization, and limits of practical filters. State space realization. Optimal and adaptive filters for signal prediction, system identification, and noise cancellation. Techniques implemented in programming assignments. 4 seminars.

EE 516. Pattern Recognition. 4 units
Prerequisite: STAT 312 or STAT 350.

Fundamental topics in statistical pattern recognition including Bayesian decision theory, Maximum-likelihood and Bayesian estimation, non-parametric density estimation, feature selection, dimension reduction, and clustering, with application to image pattern recognition. 3 seminars, 1 laboratory.

EE 518. Power System Protection. 4 units
Prerequisite: EE 406 and graduate standing.

Unsymmetrical faults. Protection fundamentals. Instrument transformers. Power system grounding. Generator protection, transformer protection, busbar protection, line and motor protection. 3 seminars, 1 laboratory.

EE 519. Advanced Analysis of Power Systems. 4 units
Prerequisite: EE 406 or equivalent, and graduate standing or consent of instructor.

Advanced power system stability analysis, numerical methods in power system analysis. 4 seminars.

EE 520. Advanced Solar-Photovoltaic Systems Design. 4 units
Prerequisite: Graduate standing or consent of instructor.

Solar radiation and insolation variability. Solar cell theory. Photovoltaic module and array design. Interfacing PV generators with various kinds of loads. Power processing circuits and systems. Energy storage options. Stand-alone and grid-connected systems. Life Cycle Assessment and Recycling of Solar PV equipment. Economic, policy and sustainability issues. 4 seminars.

EE 521. Computer Systems. 4 units
Prerequisite: CPE/EE 329 or CPE/EE 336, or equivalent, and graduate standing or consent of instructor.

Organization of modern general purpose, high speed digital computer systems. Design of arithmetic units, control units, memories and memory subsystems. Cost, power and speed trade-offs in the design of such systems. 3 seminars, 1 laboratory. Crosslisted as CPE/EE 521.

EE 522. Advanced Real-Time Operating Systems Design. 4 units
Prerequisite: CPE/EE 439.

Define and implement a microcontroller-based Real-Time Operating System (RTOS). Advanced real-time concepts, kernel structure, task and time management, various intertask communication constructs including semaphores, queues and mailboxes. Scheduler design, memory management and shared resource management in a resource-constrained microcontroller environment. 3 seminars, 1 laboratory. Crosslisted as CPE/EE 522.

EE 523. Digital Systems Design. 4 units
Prerequisite: CPE/EE 329 or CPE/EE 336, and graduate standing.

Full-custom design and analysis of digital circuits using full CMOS, pass-transistor and dynamic circuit topologies. Transistor sizing for minimizing power consumption, delay and other design criteria. 3 seminars, 1 laboratory. Crosslisted as CPE/EE 523.

EE 524. Solid State Electronics. 3 units
Prerequisite: PHYS 412 or equivalent, and graduate standing or consent of instructor.

Physical theory of solid-state devices. Properties of metal-semiconductor junctions and p-n junctions. Derivation of properties of diodes, transistors, and four-layer devices from basic physical and mathematical considerations. 3 seminars.

EE 525. Stochastic Processes. 4 units
Prerequisite: STAT 350 or equivalent, and graduate standing or consent of instructor.

Probability and stochastic processes used in random signal analysis. Response of linear systems to random inputs. Auto-correlation and power spectral densities. Applications in signal processing using the discrete Kalman filter. 4 seminars.

EE 526. Advanced Digital Communications. 4 units
Prerequisite: EE 314, EE 416, and graduate standing.

Modern digital communication systems. M-ary signals. Vector space representation of signals. Optimum receiver principles. Common signal sets. Signal space dimensionality versus time-bandwidth product. 4 seminars.

EE 527. Advanced Topics in Power Electronics. 4 units
Prerequisite: EE 410 or equivalent, and graduate standing or consent of instructor.

Selected advanced topics in power electronics such as dc-dc converters, phase-controlled rectifiers, switched-mode inverters, ac and dc drives, HVDC transmission, or utility applications of power electronics. 4 seminars.

EE 528. Digital Image Processing. 4 units
Prerequisite: CPE 327 or EE 328; EE 525; and graduate standing.

Processing and interpretation of images by computer. Emphasis on current applications with real images used in programming assignments. Topics may include histogram equalization, 2-D convolution, correlation, frequency-domain processing, median filtering, compression, Hough transform, segmentation and region growing, morphological operations, texture description, shape description, Bayes classifier. 4 seminars.

EE 529. Microwave Device Electronics. 4 units
Prerequisite: EE 306 or graduate standing.

Emphasis on device theory of operation, fabrication techniques and circuit principles of active microwave solid-state devices, their noise aspects and systems applications. 3 lectures, 1 laboratory.

EE 530. Fourier Optics. 4 units
Prerequisite: EE 402 or equivalent, EE 314 or equivalent, and graduate standing or consent of instructor.

Approach to the design and analysis of optical systems using linear communication theory, including Fourier analysis. Analysis of two-dimensional signals and systems, foundations of scalar diffraction theory. Fresnel and Fraunhofer diffraction. Wave-optics analysis of coherent optical systems, frequency analysis of optical imaging systems, holo-graphy.4 seminars.

EE 531. Advanced VLSI Design. 4 units
Prerequisite: CPE 441/EE 431.

Advanced Very Large Scale Integrated (VLSI) design using state-of-the-art software. Advanced topics in digital, analog and mixed signal circuit design to enable a quarter-long design project culminating in a tapeout-ready integrated circuit design. 3 lectures, 1 laboratory. Crosslisted as CPE 541/EE 531.

EE 532. VLSI Circuit Testing. 1 unit
Prerequisite: EE 531/CPE 541.

Characterization, testing and documentation of custom-fabricated Very Large Scale Integrated (VLSI) circuits. Use of specialized test equipment. 1 laboratory. Crosslisted as CPE/EE 532.

EE 533. Antennas. 4 units
Prerequisite: EE 402 or equivalent.

Principles of antenna theory. Antenna parameters, radiation integrals. Duality and reciprocity theorems. Wire antennas. Antenna arrays. Traveling wave antennas. Broadband and frequency independent antennas. Aperture and reflector antennas. Microstrip antennas. Antenna design. 4 seminars.

EE 534. Advanced Photonic Systems. 4 units
Prerequisite: EE 335 or graduate standing. Recommended: EE 403 and EE 443.

Design, implementation, and characterization of advanced photonic systems including optical sensors, holography, optical coherence tomography (OCT), and light detection and ranging (LIDAR) systems. 3 lectures, 1 laboratory.

EE 541. Advanced Microwave Laboratory. 2 units
Prerequisite: EE 402 or equivalent and graduate standing.

Experimental measurement in waveguide and microstrip circuits employing the advanced Network Analyzer. Design of both passive and active microwave circuits using microstrip. Graphical and analytical design techniques as well as the use of computer-aided design codes. 2 laboratories.

EE 542. Advanced Real Time Embedded Systems. 4 units
Prerequisite: CPE/EE 442.

Advanced study and application of modern embedded systems. Memory bandwidth matching, clock-domain crossing, IP creation and verification, and student-led lectures on modern System on Chip (SoC) design topics. Building a prototype embedded system. 3 lectures, 1 laboratory. Crosslisted as CPE/EE 542.

EE 544. Solid-state Electronics and VLSI Laboratory. 1 unit
Prerequisite: Graduate standing; EE 431 or EE 524 (EE 524 may be taken concurrently).

Experimental procedures in solid-state electronics and integrated circuits. Investigation and improvement of the characteristics of solid-state electronic devices and integrated circuits. 1 laboratory.

EE 563. Graduate Seminar. 1 unit
CR/NC
Current developments in the fields of electrical and electronic engineering. Participation by students, faculty and guest lecturers. Open to graduate students with a background in electrical or electronic engineering. Credit/No Credit grading only. Total credit limited to 3 units. 1 seminar.

EE 570. Selected Advanced Topics. 1-4 units
Prerequisite: Graduate standing or consent of instructor.

Directed group study of selected topics for advanced students. Open to graduate students and selected seniors with electrical and electronic engineering background. The Class Schedule will list topic selected. Total credit limited to 8 units. 1 to 4 seminars.

EE 571. Selected Advanced Laboratory. 1-4 units
Prerequisite: Graduate standing or consent of instructor.

Directed group laboratory study of selected topics for advanced students. Open to undergraduate and graduate students. The Class Schedule will list topic selected. Total credit limited to 8 units. 1 to 4 laboratories.

EE 594. Cooperative Education Experience. 6-12 units
CR/NC
Prerequisite: Graduate standing and consent of instructor.

Advanced study analysis and full-time work experience in student's career field; current innovations, practices, and problems in administration, supervision, and organization of business, industry, and government. Must have demonstrated ability to do independent work and research in career field. Credit/No Credit grading only. Total credit limited to 24 units.

EE 595. Cooperative Education Experience. 6-12 units
CR/NC
Prerequisite: Graduate standing and consent of instructor.

Advanced study analysis and full-time work experience in student's career field; current innovations, practices, and problems in administration, supervision, and organization of business, industry, and government. Must have demonstrated ability to do independent work and research in career field. A fully-developed formal report and evaluation by work supervisor required. Total credit limited to 12 units.

EE 599. Design Project (Thesis). 1-9 units
Prerequisite: Graduate standing and consent of instructor.

Each individual or group will select, with faculty guidance and approval, a topic for independent research or investigation resulting in a thesis or project to be used to satisfy the requirement for the degree. An appropriate experimental or analytical thesis or project may be accepted.