ELECTRICAL ENGINEERING

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

Department Chair: Dennis Derickson

College of Engineering Advising Center
Engineering South (40), Room 114
Phone: 805.756.1461

Academic Programs

<table>
<thead>
<tr>
<th>Program name</th>
<th>Program type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer Engineering</td>
<td>BS</td>
</tr>
<tr>
<td>Electrical Engineering</td>
<td>BS, MS</td>
</tr>
</tbody>
</table>

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, computer system design, microelectronic circuit engineering, microprocessor systems applications, microwave engineering, photonics, biomedical instrumentation, 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, automotive and transportation applications, 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, and electric power quality.

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-CECS), 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.

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 Honors Program

The blended program is an honors program that provides a means for academically excellent students to complete the MS Electrical Engineering, 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; embarking on their graduate coursework while they complete their undergraduate degree requirements.

Eligibility

Students majoring in BS Electrical Engineering or Computer Engineering may be eligible to pursue the blended program after completing all required EE/CPE 300-level courses. Participation in the program is based on prior academic performance and other measures of professional promise. Students are selected by the Graduate Committee. See Graduate Programs (http://catalog.calpoly.edu/graduateeducation/#generalpoliciesgoverninggraduatestudies) for the minimum university eligibility criteria; contact the EE Department for specific program eligibility criteria.

Program of Study

A unique feature of the program is to allow the use of a common project for fulfillment of both the Master’s Thesis (EE 599) and Senior Project (EE 461/EE 462 or EE 463/EE 464) degree requirement. As listed in the ABET engineering program accreditation criteria, all students must be prepared for engineering practice via a curriculum which culminates in a major design experience based on the knowledge and skills acquired in earlier coursework and incorporating engineering standards and realistic constraints. Therefore, all "Blended BS + MS program" students must have a master’s thesis that specifically includes this major design experience requirement, in order to complete their undergraduate degree. A faculty advisor serves as both the thesis committee chairperson and the senior project advisor.

The unit requirements for either the BS or MS degree are unchanged in the blended program. When all requirements are met for both the undergraduate and graduate programs, both degrees are awarded at the same time. If a student fails to complete the MS program requirements, then the BS degree may be granted when all requirements for that degree are met.

EE Courses

EE 111. Introduction to Electrical Engineering. 1 unit
Term Typically Offered: F
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
Term Typically Offered: F, W, SP
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 133. Digital Design. 4 units
Term Typically Offered: F,W,SP,SU
Prerequisite: An orientation course in student’s major (EE 111 & EE 151 for EE students, CPE 100 for CPE students), CPE/CSC 101.

Number systems, Boolean algebra, Boolean functions, and function minimization. Analysis and design of combinational and sequential logic circuits. Hardware Description Language (HDL) concepts and applications digital design and synthesis in Programmable Logic Devices (PLDs). Not open to students with credit in CPE/EE 129. Course may be offered in classroom-based or online format. 3 lectures, 1 laboratory. Crosslisted as CPE/EE 133.

EE 151. Introduction to Electrical Engineering Laboratory. 1 unit
Term Typically Offered: F
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
Term Typically Offered: F,W,SP,SU
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
Term Typically Offered: F,W,SP,SU
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
Term Typically Offered: F, W, SP
Prerequisite: EE 112. 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
Term Typically Offered: F, W, SP
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
Term Typically Offered: F, W, SP
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
Term Typically Offered: F, W, SP
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
Term Typically Offered: F, W, SP
Prerequisite: EE 112; 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
Term Typically Offered: F, W, SP
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
Term Typically Offered: F,W,SP,SU
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
Term Typically Offered: F, SP, SU
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 270. Selected Topics. 1-4 units
Term Typically Offered: TBD
Prerequisite: Open to undergraduate students and consent of instructor.

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

EE 295. Energy Conversion Electromagnetics Laboratory. 1 unit
Term Typically Offered: F, SP, SU
Prerequisite: EE 212 & EE 242 or EE 201 & EE 251. Concurrent: EE 295.

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
Term Typically Offered: W, SP
Prerequisite: EE 228. Concurrent: EE 342. Recommended: EE 368.


EE 306. Semiconductor Device Electronics. 3 units
Term Typically Offered: F, W
Prerequisite: CHEM 124, EE 212 & EE 242, IME 156 or IME 157 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
Term Typically Offered: W, SP

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
Term Typically Offered: F, SP

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
Term Typically Offered: W, SP
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
Term Typically Offered: F,W,SP,SU
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
GE Area F
Term Typically Offered: F,W,SP,SU
Prerequisite: completion of GE Area B and Junior standing. Recommended: MATH 118.

Microcontroller history and computer systems overview. Introduction to basic electrical circuits and computer programming concepts. Overview of computer peripherals such as LEDs, switches, LCD displays, timers, and ADCs; and interfacing various types of external sensors. Developing applications of microcontrollers using an integrated development environment. 3 lectures, 1 laboratory. Fulfills GE Area F.

EE 328. Discrete Time Signals and Systems. 3 units
Term Typically Offered: F, W
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. 3 lectures. Crosslisted as CPE/EE 328.

EE 329. Programmable Logic and Microprocessor-Based Systems Design. 4 units
Term Typically Offered: F, SP
Prerequisite: EE 307&347, EE 229&269 or CPE/EE 233.

Design, implementation and testing of programmable logic microprocessor-based systems. Hardware/software tradeoffs (such as timing analysis and power considerations), system economics of programmable logic and microprocessor-based system design. Interfacing hardware components (such as ADCs/DACs, sensors, transducers). 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
Term Typically Offered: F, SP
Prerequisite: EE 201 and EE 251; or EE 212 and EE 242; and MATH 241. Concurrent: EE 375.


EE 336. Microprocessor System Design. 4 units
Term Typically Offered: F, SP
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-processor 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
Term Typically Offered: W, SP
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
Term Typically Offered: F, W
Prerequisite: CHEM 124, EE 212 & EE 242, IME 156 or IME 157 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  
Term Typically Offered: W, SP  
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  
Term Typically Offered: F, SP  
Design, simulation, construction and testing of solid state amplifiers and sub-circuits to meet stated specifications. 1 laboratory.

EE 361. Electronics Laboratory. 1 unit  
Term Typically Offered: F,W,SP,SU  
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  
Term Typically Offered: F, W, SP  
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. 1 laboratory. Crosslisted as CPE/EE 368.

EE 375. Electromagnetic Fields and Transmission Laboratory. 1 unit  
Term Typically Offered: F, SP  
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 405. High Frequency Amplifier Design. 3 units  
Term Typically Offered: F  
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  
Term Typically Offered: W  
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  
Term Typically Offered: F  
Prerequisite: EE 308 & EE 348, or EE 321 and consent of instructor.  
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  
Term Typically Offered: F, W  
Prerequisite: EE 308 & EE 348 & CPE/EE 328 & CPE/EE 368; CPE/EE 329 or CPE/EE 336. Concurrent: EE 449.  

EE 410. Power Electronics I. 4 units  
Term Typically Offered: W  
Prerequisite: EE 410.  
Switching losses. Analysis, performance characterization, and design of snubber circuits and resonant converters. Operation of DC transmission lines, flexible AC transmission system (FACTS) controllers, three-phase inverters, and AC motor drives. Use of commercially available software. 3 lectures, 1 laboratory.

EE 411. Power Electronics II. 4 units  
Term Typically Offered: W  
Prerequisite: EE 410.  
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 430. Fiber Optic Communication. 3 units  
Term Typically Offered: F  
Prerequisite: EE 335 or PHYS 323. Concurrent: EE 443.  
Propagation of light in optical fibers, attenuation and bandwidth. LED and Laser Diode sources for use with optical fibers. Optical sources, detectors, and receivers. Design of optical communication systems with applications in telecommunications and local area networks (LANs). 3 lectures.
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
<th>Term Typically Offered</th>
<th>Prerequisites</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>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.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EE 413</td>
<td>Advanced Electronic Design</td>
<td>4</td>
<td>SP</td>
<td>CSC 101, EE 409 and EE 449.</td>
</tr>
<tr>
<td></td>
<td>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.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EE 415</td>
<td>Communication Systems Design</td>
<td>3</td>
<td>F</td>
<td>EE 314, EE 409 and EE 449.</td>
</tr>
<tr>
<td></td>
<td>Design of modern electronic communication and telemetry systems. Emphasis: practical implementation and comparative evaluation of various communication systems. 3 lectures.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EE 416</td>
<td>Digital Communication Systems</td>
<td>3</td>
<td>F</td>
<td>EE 314, EE 328.</td>
</tr>
<tr>
<td></td>
<td>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.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EE 417</td>
<td>Alternating Current Machines</td>
<td>4</td>
<td>F</td>
<td>EE 255 &amp; EE 295.</td>
</tr>
<tr>
<td></td>
<td>Alternating current machines. Generalized, operational and dynamic analysis. Steady-state and transient operation of synchronous machines and linear induction machines. 3 lectures, 1 laboratory.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EE 418</td>
<td>Photonic Engineering</td>
<td>3</td>
<td>F</td>
<td>EE 335 or PHYS 323.</td>
</tr>
<tr>
<td></td>
<td>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.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EE 419</td>
<td>Digital Signal Processing</td>
<td>3</td>
<td>W</td>
<td>CSC 101 or CSC 231; EE 328 and EE 368. Concurrent: EE 459.</td>
</tr>
<tr>
<td>EE 420</td>
<td>Sustainable Electric Energy Conversion</td>
<td>4</td>
<td>W</td>
<td>CHEM 124; EE 255 and EE 295.</td>
</tr>
<tr>
<td></td>
<td>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.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EE 422</td>
<td>Polymer Electronics Laboratory</td>
<td>1</td>
<td>F, W</td>
<td>EE 347 or MATE 340 or CHEM 319 or PHYS 340.</td>
</tr>
<tr>
<td></td>
<td>Experimental procedures in polymer electronics. Investigation of the characteristics of a polymer electronic device. 1 laboratory. Crosslisted as EE/PHYS 422.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EE 423</td>
<td>Micro/Nano Fabrication</td>
<td>3</td>
<td>F</td>
<td>BMED 212 or MATE 210.</td>
</tr>
<tr>
<td></td>
<td>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.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EE 424</td>
<td>Introduction to Remote Sensing</td>
<td>4</td>
<td>W</td>
<td>CPE/CSC 357 or EE 409 or ME 305.</td>
</tr>
<tr>
<td></td>
<td>Radiation characteristics, sensor technology and platforms, satellite systems, system design tradeoffs, collection and transmission of radiometric 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.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EE 425</td>
<td>Analog Filter Design</td>
<td>3</td>
<td>W</td>
<td>EE 409 &amp; EE 449.</td>
</tr>
<tr>
<td>EE 428</td>
<td>Computer Vision</td>
<td>4</td>
<td>SP</td>
<td>CPE/CSC 357 or EE 328 or ME 305.</td>
</tr>
<tr>
<td></td>
<td>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.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
EE 431. Computer-Aided Design of VLSI Devices. 4 units
Term Typically Offered: F
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
Term Typically Offered: F
Prerequisite: EE 302 & EE 342. Concurrent: CPE/EE 472. Recommended: Prior background in discrete time systems, for example EE 328, EE 368.

Theory and applications of digital computers in linear control systems. Discrete time methods are used in analysis and design studies. Digital control systems are synthesized. 3 lectures. Crosslisted as CPE/EE 432.

EE 433. Introduction to Magnetic Design. 4 units
Term Typically Offered: SP
Prerequisite: EE 255 and EE 295.

Design of magnetic components. Fundamentals of magnets, 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
Term Typically Offered: W
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 BARE/EE 434.

EE 439. Introduction to Real-Time Operating Systems. 4 units
Term Typically Offered: F
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 BARE/EE 439.

EE 440. Wireless Communications. 3 units
Term Typically Offered: W
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 443. Fiber Optics Laboratory. 1 unit
Term Typically Offered: F
Prerequisite: EE 335 or PHYS 323. Concurrent: EE 403.

Experimental investigation of the properties of optical fibers, sources, and detectors. Measurement of fiber physical characteristics, attenuation, losses, and bandwidth. Evaluation of an analog and digital fiber optic data link. 1 laboratory.

EE 444. Power Systems Laboratory. 1 unit
Term Typically Offered: SP
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
Term Typically Offered: F
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 449. Electronic Design Laboratory. 1 unit
Term Typically Offered: F, W
Prerequisite: EE 308 & EE 348; CPE/EE 328 & CPE/EE 368; CPE/EE 329 or CPE/EE 336. Concurrent: EE 409.

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

EE 450. Solar Photovoltaic System Engineering. 4 units
Term Typically Offered: W
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 BARE/EE/HNRS 450.

EE 452. Advanced Analog Circuits Laboratory. 1 unit
Term Typically Offered: W
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
Term Typically Offered: SP

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
Term Typically Offered: F
Prerequisite: EE 314, EE 328 and EE 368.
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
Term Typically Offered: SP
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
Term Typically Offered: W
Prerequisite: CSC 101 or CSC 231; 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
Term Typically Offered: F, W
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
Term Typically Offered: F, W, SP, SU
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
Term Typically Offered: F, W, SP, SU
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
Term Typically Offered: F, W, SP, SU
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
Term Typically Offered: F, W, SP, SU
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
Term Typically Offered: TBD
Prerequisite: Consent of instructor.
Directed group study of selected topics for advanced students. Open to undergraduate and graduate students. Class Schedule will list topic selected. Total credit limited to 8 units. 1-4 lectures.

EE 471. Selected Advanced Laboratory. 1-4 units
Term Typically Offered: TBD
Prerequisite: Consent of instructor.
Directed group laboratory study of selected topics for advanced students. Open to undergraduate and graduate students. Class Schedule will list topic selected. Total credit limited to 8 units. 1-4 laboratories.

EE 472. Digital Control Systems Laboratory. 1 unit
Term Typically Offered: SP, SU
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 480. Wireless Communications Laboratory. 1 unit
Term Typically Offered: W
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 494. Cooperative Education Experience. 6-12 units
CR/NC
Term Typically Offered: F, W, SP, SU
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
Term Typically Offered: F,W,SP,SU
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
Term Typically Offered: F,W,SP,SU
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 Engineering. 4 units
Term Typically Offered: W
Prerequisite: EE 402 or equivalent.


EE 504. Software Defined Radio. 4 units
Term Typically Offered: SP
Prerequisite: EE 314 and EE 328; 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
Term Typically Offered: SP
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
Term Typically Offered: W
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
Term Typically Offered: W
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
Term Typically Offered: SP
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
Term Typically Offered: F
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
Term Typically Offered: SP
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
Term Typically Offered: SP
Prerequisite: EE 406 or equivalent, and graduate standing or consent of instructor.


EE 519. Advanced Analysis of Power Systems. 4 units
Term Typically Offered: SP
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. Solar-Photovoltaic Systems Design. 4 units
Term Typically Offered: SP
Prerequisite: Graduate standing or consent of instructor.


EE 521. Computer Systems. 4 units
Term Typically Offered: SP
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
Term Typically Offered: W
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
Term Typically Offered: F
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
Term Typically Offered: SP
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
Term Typically Offered: F
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
Term Typically Offered: W
Prerequisite: EE 314, EE 416, and graduate standing.


EE 527. Advanced Topics in Power Electronics. 4 units
Term Typically Offered: SP
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
Term Typically Offered: F
Prerequisite: EE 314 or equivalent, EE 525, and graduate standing or consent of instructor.

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. 3 units
Term Typically Offered: W
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 seminars.

EE 530. Fourier Optics. 4 units
Term Typically Offered: W
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 533. Antennas. 4 units
Term Typically Offered: SP
Prerequisite: EE 402 or equivalent.

EE 541. Advanced Microwave Laboratory. 2 units  
Term Typically Offered: W  
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 544. Solid-state Electronics and VLSI Laboratory. 1 unit  
Term Typically Offered: TBD  
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  
Term Typically Offered: F, W, SP  
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  
Term Typically Offered: TBD  
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. Class Schedule will list topic selected. Total credit limited to 8 units. 1-4 seminars.

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

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

EE 594. Cooperative Education Experience. 6-12 units  
CR/NC  
Term Typically Offered: F, W, SP, SU  
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  
Term Typically Offered: F, W, SP, SU  
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.