

# Electrical Engineering (E E)

Courses primarily for undergraduates:

## E E 166. Professional Programs Orientation.

(Cross-listed with CPR E). Cr. R. F.S.

(1-0) Overview of the nature and scope of electrical engineering and computer engineering professions. Overview of portfolios. Departmental rules, advising center operations, degree requirements, program of study planning, career options, and student organizations.

## E E 185. Introduction to Electrical Engineering and Problem-Solving I.

(2-2) Cr. 3. F.S. *Prereq: Credit or enrollment in MATH 142*

Project based examples from electrical engineering. Systematic thinking process for engineering problem solving. Group problem solving. Mathematical, conceptual and computer based projects. Solving engineering problems and presenting solutions through technical reports and oral presentations. Solutions of engineering problems using computation tools and basic programming.

## E E 186. Introduction to Electrical Engineering and Problem Solving II.

(0-2) Cr. 1. S. *Prereq: E E 185*

Project based and hands on continuation of 185. Group skills needed to work effectively in teams. Individual interactive skills for small and large groups. Learning to use tools and methods for solving electrical engineering problems.

## E E 188. Bio-Electrical Engineering Fundamentals Laboratory.

(1-3) Cr. 2. *Prereq: E E 185 or equivalent*

Fundamental laboratory based course in bio-electrical engineering with an emphasis on acquiring and analyzing biomedical signals to obtain relevant information. Topics covered include an overview of basic medical terminology and anatomy, labs illustrating data acquisition from different body systems, and an introduction to statistical significance and its relationship to biological variability.

## E E 201. Electric Circuits.

(3-2) Cr. 4. F.S. *Prereq: Credit or registration in MATH 267 and PHYS 222*

Emphasis on mathematical tools. Circuit elements (resistors, inductors, capacitors) and analysis methods including power and energy relationships. Network theorems. DC, sinusoidal steady-state, and transient analysis. AC power. Frequency response. Two port models. Diodes, PSPICE. Laboratory instrumentation and experimentation. Credit for only E E 201 or 442 may be used towards graduation.

## E E 224. Signals and Systems I.

(3-3) Cr. 4. F.S. *Prereq: E E 201, MATH 267, PHYS 222*

Mathematical preliminaries. Introduction to signals and systems. Signal manipulations. System properties. LTI systems, impulse response and convolution. Fourier Series representation and properties. Continuous and discrete-time Fourier Transforms and properties. Sampling and reconstruction. Modulation and demodulation. Applications and demonstrations using Matlab.

## E E 230. Electronic Circuits and Systems.

(3-3) Cr. 4. F.S. *Prereq: E E 201, MATH 267, PHYS 222*

Frequency domain characterization of electronic circuits and systems, transfer functions, sinusoidal steady state response. Time domain models of linear and nonlinear electronic circuits, linearization, small signal analysis. Stability and feedback circuits. Operational amplifiers, device models, linear and nonlinear applications, transfer function realizations. A/D and D/A converters, sources of distortions, converter linearity and spectral characterization, applications. Design and laboratory instrumentation and measurements.

## E E 261. Transfer Orientation.

(Cross-listed with CPR E). Cr. R.

Introduction to the College of Engineering and the engineering profession specifically for transfer students. Information concerning university and college policies, procedures, and resources. Offered on a satisfactory-fail basis only.

## E E 285. Problem Solving Methods and Tools for Electrical Engineering.

(3-3) Cr. 4.

Integration of field-specific computational tools for practically solving electrical engineering problems. Methods for systematically reducing problems into sequential steps compatible with computer based tools. Structuring computer programs for efficiency and maintainability. Integration of multi-platform operating systems and multi-vendor tools for solving engineering problems. Hands-on laboratory experiences using Matlab, C, and other computational tools.

## E E 294. Program Discovery.

(Cross-listed with CPR E). Cr. R. *Prereq: CPR E 166 or E E 166*

The roles of professionals in computer and electrical engineering. Relationship of coursework to industry and academic careers. Issues relevant to today's world. Offered on a satisfactory-fail basis only.

## E E 298. Cooperative Education.

Cr. R. F.S.SS. *Prereq: Permission of department and Engineering Career Services*

First professional work period in the cooperative education program. Students must register for this course before commencing work.

## E E 303. Energy Systems and Power Electronics.

(3-0) Cr. 3. F.S. *Prereq: MATH 267, PHYS 222. Credit or registration in E E 224 and E E 230*

Structure of competitive electric energy systems. System operation and economic optimization. Mutual inductance, transformers. Synchronous generators. Balanced three-phase circuit analysis and power calculations. Network calculations and associated numerical algorithms. Two-port circuits. Voltage regulation. Resonance and power factor correction. DC and induction motors. Power electronic circuit applications to power supplies and motor drives. Nonmajor graduate credit.

## E E 311. Electromagnetic Fields and Waves.

(4-0) Cr. 4. F.S. *Prereq: E E 201, MATH 265, PHYS 222, credit or registration in MATH 267*

Fundamentals and applications of electric and magnetic fields and materials. Electrostatics and magnetostatics, potentials, capacitance and inductance, energy, force, torque. Uniform plane electromagnetic waves, Poynting vector. Transmission lines: transient and sinusoidal steady-state conditions, reflection coefficient. Nonmajor graduate credit.

## E E 314. Electromagnetics for non Electrical Engineers.

(3-0) Cr. 3. *Prereq: PHYS 222, PHYS 112, or equivalent*

Conceptual study of electromagnetism and its application in engineering and related fields. EM fundamentals, EM spectrum, radiation, radiating systems, wireless, modern concepts of physics, quantum computing, transmission lines, high speed effects, waveguides, GPS and other related phenomena will be discussed and explained with the application in mind. Nonmajor graduate credit.

## E E 321. Communication Systems I.

(3-0) Cr. 3. F. *Prereq: E E 224*

Frequency domain analysis, spectral filtering, bandwidth. Linear modulation systems. Angle modulation systems. Phase locked loop, super-heterodyne receiver. Sampling and pulse code modulation. Digital data transmission, line coding, pulse shaping, multiplexing. Nonmajor graduate credit.

## E E 322. Probabilistic Methods for Electrical Engineers.

(Cross-listed with STAT). (3-0) Cr. 3. F.S. *Prereq: E E 224*

Introduction to probability with applications to electrical engineering. Sets and events, probability space, conditional probability, total probability and Bayes' rule. Discrete and continuous random variables, cumulative distribution function, probability mass and density functions, expectation, moments, moment generating functions, multiple random variables, functions of random variables. Elements of statistics, hypothesis testing, confidence intervals, least squares. Introduction to random processes.

## E E 323. Introduction to Digital Signal Processing.

(3-3) Cr. 4. *Prereq: E E 224*

Sampling and reconstruction. Concepts and mathematical tools in discrete-time signal processing with examples from digital signal processing and communications. Discrete-time correlation and matched-filter receivers. Discrete Fourier transform (DFT). Fast Fourier algorithms. Z transforms. Design of finite impulse response (FIR) and infinite impulse response (IIR) filters. Realizations of discrete-time systems and quantization effects. Multi-rate signal processing. Laboratory experiments illustrating DSP implementations and applications. Nonmajor graduate credit.

## E E 324. Signals and Systems II.

(3-3) Cr. 4. F.S. *Prereq: E E 224*

Laplace and z-Transforms, properties and inverses. Applications to LTI systems and analog/digital filters. Feedback systems and stability. State-space representation and analysis. Nonmajor graduate credit.

## E E 325. Systems Biology for Engineering.

(Cross-listed with BIOE). (3-0) Cr. 3. *Prereq: BIOE 210, MATH 267*

Review of systems approaches for modeling. Introduction or review of methods for gene regulation in cells and how to model them. Auto regulation of gene networks. Feedforward modeling, timing considerations. Feedback mechanisms. Kinetic and rate-limiting steps.

**E E 330. Integrated Electronics.**

(Cross-listed with CPR E). (3-3) Cr. 4. *Prereq: E E 201, credit or enrollment in E E 230, CPR E 281*

Semiconductor technology for integrated circuits. Modeling of integrated devices including diodes, BJTs, and MOSFETs. Physical layout. Circuit simulation. Digital building blocks and digital circuit synthesis. Analysis and design of analog building blocks. Laboratory exercises and design projects with CAD tools and standard cells. Nonmajor graduate credit. Credit for only one of E E 330 or 331 may be counted toward graduation.

**E E 332. Semiconductor Materials and Devices.**

(Cross-listed with MAT E). (3-0) Cr. 3. S. *Prereq: PHYS 222; MAT E majors: MAT E 334; CPR E and E E majors: E E 230*

Introduction to semiconductor material and device physics. Quantum mechanics and band theory of semiconductors. Charge carrier distributions, generation/recombination, transport properties. Physical and electrical properties and fabrication of semiconductor devices such as MOSFETs, bipolar transistors, laser diodes and LED's. Nonmajor graduate credit.

**E E 336. Biomedical Instrumentation.**

(2-2) Cr. 3. *Prereq: E E 188, E E 224, E E 230*

Principles and practices of biomedical instrumentation. Topics include: the physics and measurement of biopotentials including electrocardiography (EKG), electromyography (EMG) and electro-oculography (EOG), mechanical and chemical sensors, amplifiers and filters, recording and processing biological signals from nerve cells, muscles and human body, electrode polarization, surface electrodes, power line interference, heart sound sensors, respiratory gas concentration, blood-gas sensors, noninvasive blood-gas sensors.

**E E 351. Analysis of Energy Systems.**

(3-0) Cr. 3. *Prereq: MATH 165*

Energy-scientific, engineering and economic foundations. Energy utilization-global and national. Sectoral analysis of energy consumption. Relationship of energy consumption and production to economic growth and environment. Technology for energy production. Economic evaluation of energy utilization and production. Scientific basis for global warming. Environmental impact of energy production and utilization. Renewable energy. Meets International Perspectives Requirement.

**E E 388. Sustainable Engineering and International Development.**

(Cross-listed with A E, C E, M E, MAT E, BSE). (2-2) Cr. 3. F. *Prereq: Junior classification in engineering*

Multi-disciplinary approach to sustainable engineering and international development, sustainable development, appropriate design and engineering, feasibility analysis, international aid, business development, philosophy and politics of technology, and ethics in engineering. Engineering-based projects from problem formulation through implementation. Interactions with partner community organizations or international partners such as nongovernment organizations (NGOs). Course readings, final project/design report. Meets International Perspectives Requirement.

**E E 394. Program Exploration.**

(Cross-listed with CPR E). Cr. R. *Prereq: CPR E 294 or E E 294*

Exploration of academic and career fields for electrical and computer engineers. Examination of professionalism in the context of engineering and technology with competencies based skills. Introduction to professional portfolio development and construction. Offered on a satisfactory-fail basis only.

**E E 396. Summer Internship.**

Cr. R. Repeatable. SS. *Prereq: Permission of department and Engineering Career Services*

Summer professional work period. Students must register for this course before commencing work.

**E E 397. Engineering Internship.**

Cr. R. Repeatable. F.S. *Prereq: Permission of department and Engineering Career Services*

One semester maximum per academic year professional work period. Students must register for this course before commencing work.

**E E 398. Cooperative Education.**

Cr. R. F.S.SS. *Prereq: E E 298, permission of department and Engineering Career Services*

Second professional work period in the cooperative education program. Students must register for this course before commencing work.

**E E 414. Microwave Engineering.**

(Dual-listed with E E 514). (3-3) Cr. 4. F. *Prereq: E E 230, E E 311*

Principles, analyses, and instrumentation used in the microwave portion of the electromagnetic spectrum. Wave theory in relation to circuit parameters. S parameters, couplers, discontinuities, and microwave device equivalent circuits. RF amplifier design, microwave sources, optimum noise figure and maximum power designs. Microwave filters and oscillators. Nonmajor graduate credit.

**E E 417. Electromagnetic Radiation, Antennas, and Propagation.**

(Dual-listed with E E 517). (3-3) Cr. 4. S. *Prereq: E E 311*

Fundamental antenna concepts. Radiation from wire-and aperture-type sources. Radio transmission formulas. Wave and antenna polarization. Antenna arrays. Modern antenna topics. Practical antenna design. Antenna noise. Radiowave propagation in the presence of the earth and its atmosphere. Antenna measurements and computer aided analysis. Nonmajor graduate credit.

**E E 418. High Speed System Engineering Measurement and Testing.**

(Cross-listed with CPR E). (3-2) Cr. 4. F. *Prereq: E E 230 and CPR E 311*

Measurement of high speed systems and mixed signal systems. Measurement accuracy and error. Network analysis and spectrum analysis used in high speed measurement and testing. Test specification process and parametric measurement. Sampling and digital signal processing concepts. Design for testability. Testing equipment. Applications. Nonmajor graduate credit.

**E E 422. Communication Systems II.**

(3-0) Cr. 3. *Prereq: E E 421 and enrollment in E E 423*

Introduction to probability and random processes; Performance of analog systems with noise; Performance of digital communication with noise; optimum receivers, transmission impairments, and error rates; Introduction to information theory and coding; source coding, channel coding, channel capacity. Nonmajor graduate credit.

**E E 423. Communication Systems Laboratory.**

(0-3) Cr. 1. *Prereq: E E 421, enrollment in E E 422*

Construction and evaluation of modulators, demodulators and other components for analog and digital communications. Design, simulate, and evaluate wireless communication systems and their key components. Noise measurement. Nonmajor graduate credit.

**E E 432. Microelectronics Fabrication Techniques.**

(Dual-listed with E E 532). (Cross-listed with MAT E). (2-4) Cr. 4. *Prereq: PHYS 222, MATH 267. E E 332 or MAT E 334 recommended*

Techniques used in modern integrated circuit fabrication, including diffusion, oxidation, ion implantation, lithography, evaporation, sputtering, chemical-vapor deposition, and etching. Process integration. Process evaluation and final device testing. Extensive laboratory exercises utilizing fabrication methods to build electronic devices. Use of computer simulation tools for predicting processing outcomes. Recent advances in processing CMOS ICs and micro-electro-mechanical systems (MEMS). Nonmajor graduate credit.

**E E 435. Analog VLSI Circuit Design.**

(Cross-listed with CPR E). (3-3) Cr. 4. S. *Prereq: E E 324, E E 330, E E 332, and either E E 322 or STAT 330*

Basic analog integrated circuit and system design including design space exploration, performance enhancement strategies, operational amplifiers, references, integrated filters, and data converters. Nonmajor graduate credit.

**E E 438. Optoelectronic Devices and Applications.**

(Dual-listed with E E 538). (3-0) Cr. 3. *Prereq: E E 311, E E 332*

Transmission and reflection of electromagnetic plane waves. Propagation in dielectric and fiber optic waveguides. LED and laser operating principles and applications. Photodetectors and solar cells. Optical modulation and switching. Nonmajor graduate credit.

**E E 439. Nanoelectronics.**

(3-0) Cr. 3. S. *Prereq: E E 332/MAT E 332 or MAT E 331*

Concepts of quantum mechanics relevant to nanoelectronic devices, including quantization, tunneling, and transport; overview of some of the leading technologies for nanoelectronics, including carbon nanotubes, quantum dots, and molecular transistors; fabrication methods for building nanoelectronic devices. Nonmajor graduate credit.

**E E 442. Introduction to Circuits and Instruments.**(3-2) Cr. 2. F.S. *Prereq: PHYS 222, MATH 267*

Half-semester course. Basic circuit analysis using network theorems with time domain and Laplace transform techniques for resistive, resistive-inductive, resistive-capacitive, and resistive-inductive-capacitive circuits. Transient circuit behavior. Basic operational amplifiers and applications. Familiarization with common E E instrumentation and demonstration of basic principles. Nonmajor graduate credit. Credit for only 201 or 442 may be counted toward graduation; credit for 442 will not count toward graduation for E E or Cpr E majors.

**E E 448. Introduction to AC Circuits and Motors.**(3-2) Cr. 2. F.S. *Prereq: E E 303 or E E 441 or E E 442*

Half-semester course. Magnetic circuits. Power transformers. AC steady state and three-phase circuit analysis. Basic principles of operation and control of induction and single-phase motors. Nonmajor graduate credit.

**E E 451. Engineering Acoustics.**(2-2) Cr. 3. Alt. S., offered 2012. *Prereq: Phys 221 and Math 266 or 267*

Sound sources and propagation. Noise standards and effects of noise on people. Principles of noise and vibration control used in architectural and engineering design. Characteristics of basic noise measurement equipment. Experience in use of noise measuring equipment, sound power measurements, techniques for performing noise surveys, evaluation of various noise abatement techniques applied to common noise sources. Selected laboratory experiments. Nonmajor graduate credit.

**E E 452. Electrical Machines and Power Electronic Drives.**(2-3) Cr. 3. S. *Prereq: E E 303; E E 330 or E E 332; credit or registration in E E 324*

Basic concepts of electromagnetic energy conversion. DC motors and three-phase induction motors. Basic introduction to power electronics. Adjustable speed drives used for control of DC, induction, and AC motors. Experiments with converter topologies, DC motors, AC motors and adjustable speed drives. Nonmajor graduate credit.

**E E 455. Introduction to Energy Distribution Systems.**(3-0) Cr. 3. F. *Prereq: E E 303, credit or registration in E E 324*

Overhead and underground distribution system descriptions and characteristics, load descriptions and characteristics, overhead line and underground cable models, distribution transformers, power flow and fault analysis, overcurrent protection, power factor correction, system planning and automation, and economics in a deregulated environment. Nonmajor graduate credit.

**E E 456. Power System Analysis I.**(3-0) Cr. 3. F. *Prereq: E E 303, credit or registration in E E 324*

Power transmission lines and transformers, synchronous machine modeling, network analysis, power system representation, load flow. Nonmajor graduate credit.

**E E 457. Power System Analysis II.**(3-0) Cr. 3. S. *Prereq: E E 303, credit or registration in E E 324*

Power system protection, symmetrical components, faults, stability. Power system operations including the new utility environment. Nonmajor graduate credit.

**E E 458. Economic Systems for Electric Power Planning.**(Cross-listed with ECON). (3-0) Cr. 3. *Prereq: E E 303 or ECON 301*

Evolution of electric power industry. Power system operation and planning and related information systems. Linear and integer optimization methods. Short-term electricity markets and locational marginal prices. Risk management and financial derivatives. Basics of public good economics. Cost recovery models including tax treatment for transmission investments. Nonmajor graduate credit.

**E E 459. Electromechanical Wind Energy Conversion and Grid Integration.**(Dual-listed with E E 559). (3-0) Cr. 3. *Prereq: Credit or enrollment in E E 452, E E 456*

Summary of industry status and expected growth; power extraction from the air stream; operation and modeling of electric machines, and power electronics topologies for wind energy conversion; analysis of machine-grid power electronic circuits, controller interface, and collector (distribution) networks; treatment of harmonics, flicker, over/under-voltages, filters, low-voltage ride-through, and reactive compensation; relaying; effects on transmission expansion, planning and grid operation and coordination including variability, frequency control, reserves, and electricity markets; overview of storage technologies and hybrid configurations. Nonmajor graduate credit.

**E E 465. Digital VLSI Design.**(Cross-listed with CPR E). (3-3) Cr. 4. S. *Prereq: E E 330*

Digital design of integrated circuits employing very large scale integration (VLSI) methodologies. Technology considerations in design. High level hardware design languages, CMOS logic design styles, area-energy-delay design space characterization, datapath blocks: arithmetic and memory, architectures and systems on a chip (SOC) considerations. VLSI chip hardware design project. Nonmajor graduate credit.

**E E 466. Multidisciplinary Engineering Design.**(Cross-listed with A E, AER E, CPR E, ENGR, I E, M E, MAT E). (1-4) Cr. 3. Repeatable. F.S. *Prereq: Student must be within two semesters of graduation and receive permission of instructor*

Application of team design concepts to projects of a multidisciplinary nature. Concurrent treatment of design, manufacturing, and life cycle considerations. Application of design tools such as CAD, CAM, and FEM. Design methodologies, project scheduling, cost estimating, quality control, manufacturing processes. Development of a prototype and appropriate documentation in the form of written reports, oral presentations and computer models and engineering drawings.

**E E 467. Multidisciplinary Engineering Design II.**(Cross-listed with AER E, CPR E, ENGR, I E, MAT E, M E). (1-4) Cr. 3. Repeatable, maximum of 2 times. F.S. *Prereq: Student must be within two semesters of graduation or receive permission of instructor.*

Build and test of a conceptual design. Detail design, manufacturability, test criteria and procedures. Application of design tools such as CAD and CAM and manufacturing techniques such as rapid prototyping. Development and testing of a full-scale prototype with appropriate documentation in the form of design journals, written reports, oral presentations and computer models and engineering drawings.

**E E 475. Automatic Control Systems.**(3-0) Cr. 3. F. *Prereq: E E 324*

Stability and performance analysis of automatic control systems. The state space, root locus, and frequency response methods for control systems design. PID control and lead-lag compensation. Computer tools for control system analysis and design. Nonmajor graduate credit.

**E E 476. Control System Simulation.**(2-3) Cr. 3. S. *Prereq: E E 475*

Computer aided techniques for feedback control system design, simulation, and implementation. Nonmajor graduate credit.

**E E 488. Eddy Current Nondestructive Evaluation.**(Dual-listed with E E 588). (Cross-listed with MAT E). (3-0) Cr. 3. Alt. F., offered 2013. *Prereq: MATH 265 and (MAT E 216 or MAT E 272 or E E 311 or PHYS 364)*

Electromagnetic fields of various eddy current probes. Probe field interaction with conductors, cracks and other material defects. Ferromagnetic materials. Layered conductors. Elementary inversion of probe signals to characterize defects. Special techniques including remote-field, transient, potential drop nondestructive evaluation and the use of Hall sensors. Practical assignments using a 'virtual' eddy current instrument will demonstrate key concepts.

**E E 490. Independent Study.**Cr. arr. *Prereq: Senior classification in electrical engineering*

Investigation of an approved topic commensurate with the student's prerequisites.

**E E 490H. Independent Study: Honors.**Cr. arr. *Prereq: Senior classification in electrical engineering*

Investigation of an approved topic commensurate with the student's prerequisites.

**E E 491. Senior Design Project I and Professionalism.**(Cross-listed with CPR E). (2-3) Cr. 3. F.S. *Prereq: E E 322 or CPR E 308, completion of 24 credits in the E E core professional program or 29 credits in the Cpr E core professional program, ENGL 314*

Preparing for entry to the workplace. Selected professional topics. Use of technical writing skills in developing project plan and design report; design review presentation. First of two-semester team-oriented, project design and implementation experience.

**E E 492. Senior Design Project II.**(Cross-listed with CPR E). (1-3) Cr. 2. F.S. *Prereq: CPR E 491 or E E 491*

Second semester of a team design project experience. Emphasis on the successful implementation and demonstration of the design completed in E E 491 or Cpr E 491 and the evaluation of project results. Technical writing of final project report; oral presentation of project achievements; project poster.

**E E 494. Portfolio Assessment.**

(Cross-listed with CPR E). Cr. R. *Prereq: CPR E 394 or E E 394, credit or enrollment in CPR E 491 or E E 491*

Portfolio update and evaluation. Portfolios as a tool to enhance career opportunities.

**E E 496. Modern Optics.**

(Cross-listed with PHYS). (3-0) Cr. 3. S. *Prereq: Credit or enrollment in PHYS 322, PHYS 365, and PHYS 480*

Review of wave and electromagnetic theory; topics selected from: reflection/refraction, interference, geometrical optics, Fourier analysis, dispersion, coherence, Fraunhofer and Fresnel diffraction, holography, quantum optics, nonlinear optics. Nonmajor graduate credit.

**E E 498. Cooperative Education.**

Cr. R. Repeatable. F.S.SS. *Prereq: E E 398, permission of department and Engineering Career Services*

Third and subsequent professional work periods in the cooperative education programs. Students must register for this course before commencing work.

**Courses primarily for graduate students, open to qualified undergraduates:****E E 501. Analog and Mixed-Signal VLSI Circuit Design Techniques.**

(Cross-listed with CPR E). (3-3) Cr. 4. F. *Prereq: E E 435*

Design techniques for analog and mixed-signal VLSI circuits. Amplifiers; operational amplifiers, transconductance amplifiers, finite gain amplifiers and current amplifiers. Linear building blocks; differential amplifiers, current mirrors, references, cascading and buffering. Performance characterization of linear integrated circuits; offset, noise, sensitivity and stability. Layout considerations, simulation, yield and modeling for high-performance linear integrated circuits.

**E E 504. Power Management for VLSI Systems.**

(Cross-listed with CPR E). (3-3) Cr. 4. *Prereq: E E 435, Credit or Registration for E E 501*

Theory, design and applications of power management and regulation circuits (Linear and switching regulators, battery chargers, and reference circuits) including: Architectures, Performance metrics and characterization, Noise and stability analysis, Practical implementation and on-chip integration issues, design considerations for portable, wireless, and RF SoCs.

**E E 505. CMOS and BiCMOS Data Conversion Circuits.**

(Cross-listed with CPR E). (3-3) Cr. 4. Alt. S., offered 2012. *Prereq: E E 501*

Theory, design and applications of data conversion circuits (A/D and D/A converters) including: architectures, characterization, quantization effects, conversion algorithms, spectral performance, element matching, design for yield, and practical comparators, implementation issues.

**E E 506. Design of CMOS Phase-Locked Loops.**

(Cross-listed with CPR E). (3-3) Cr. 4. *Prereq: E E 435 or E E 501 or instructor approval*

Analysis and design of phase-locked loops implemented in modern CMOS processes including: architectures, performance metrics, and characterization; noise and stability analysis; and design issues of phase-frequency detectors, charge pumps, loop filters (passive and active), voltage controlled oscillators, and frequency dividers.

**E E 507. VLSI Communication Circuits.**

(Cross-listed with CPR E). (3-3) Cr. 4. Alt. S., offered 2013. *Prereq: CPR E 330 or CPR E 501*

Radio frequency integrated circuits for wireless and wired communications with a focus on CMOS implementations. Discussions on fundamental concepts in RF design such as nonlinearity, sensitivity, and dynamic range will be followed with a detailed analysis and design of low-noise amplifiers, mixer, oscillators, and transceivers.

**E E 508. Filter Design and Applications.**

(3-3) Cr. 4. *Prereq: E E 501*

Filter design concepts. Approximation and synthesis. Transformations. Continuous-time and discrete time filters. Discrete, active and integrated synthesis techniques.

**E E 510. Topics in Electromagnetics.**

Cr. 1-3. Repeatable. *Prereq: E E 311*

**E E 511. Modern Optical Communications.**

(3-0) Cr. 3. S. *Prereq: E E 311*

Propagation in optical media. Optical fibers. Optical sources and detectors. Fiber optic communications systems. DWDM considerations.

**E E 512. Advanced Electromagnetic Field Theory I.**

(3-0) Cr. 3. F. *Prereq: E E 311*

Review of static electric and magnetic fields. Maxwell's equations. Circuit concepts and impedance elements. Propagation and reflection of plane waves in isotropic media. Guided electromagnetic wave. Characteristics of common waveguides and transmission lines. Propagation in anisotropic media. Special theorems and concepts. Radiation and scattering.

**E E 513. Advanced Electromagnetic Field Theory II.**

(3-0) Cr. 3. S. *Prereq: E E 512*

Green's functions, perturbational and variational techniques. Analysis of microstrip lines and interconnects. Spectral domain approach, waves in layered media. Integral equations and method of moments. Inverse scattering. Electromagnetic applications.

**E E 514. Microwave Engineering.**

(Dual-listed with E E 414). (3-3) Cr. 4. F. *Prereq: E E 230, E E 311*

Principles, analyses, and instrumentation used in the microwave portion of the electromagnetic spectrum. Wave theory in relation to circuit parameters. S parameters, couplers, discontinuities, and microwave device equivalent circuits. RF amplifier design, microwave sources, optimum noise figure and maximum power designs. Microwave filters and oscillators.

**E E 516. Computational Methods in Electromagnetics.**

(3-0) Cr. 3. S. *Prereq: E E 311*

Maxwell's equations. Differential equation based methods. Finite difference and finite difference time domain methods, boundary conditions. Finite element method and applications to the analysis of practical devices. Integral equation based methods. Electric and magnetic field integral equations. Matrix solvers. Fast solution methods.

**E E 517. Electromagnetic Radiation, Antennas, and Propagation.**

(Dual-listed with E E 417). (3-3) Cr. 4. S. *Prereq: E E 311*

Fundamental antenna concepts. Radiation from wire-and aperture-type sources. Radio transmission formulas. Wave and antenna polarization. Antenna arrays. Modern antenna topics. Practical antenna design. Antenna noise. Radiowave propagation in the presence of the earth and its atmosphere. Antenna measurements and computer-aided analysis.

**E E 518. Microwave Remote Sensing.**

(Cross-listed with AGRON, MTEOR). (3-0) Cr. 3. Alt. S., offered 2012. *Prereq: Math 265 or equivalent*

Microwave remote sensing of Earth's surface and atmosphere using satellite-based or ground-based instruments. Specific examples include remote sensing of atmospheric temperature and water vapor, precipitation, ocean salinity, and soil moisture.

**E E 519. Magnetism and Magnetic Materials.**

(Cross-listed with M S E). (3-0) Cr. 3. F. *Prereq: E E 311, MAT E 211 or E E 271 or E E 272 or PHYS 364*

Magnetic fields, flux density and magnetization. Magnetic materials, magnetic measurements. Magnetic properties of materials. Domains, domain walls, domain processes, magnetization curves and hysteresis. Types of magnetic order, magnetic phases and critical phenomena. Magnetic moments of electrons, theory of electron magnetism. Technological application, soft magnetic materials for electromagnets, hard magnetic materials, permanent magnets, magnetic recording technology, magnetic measurements of properties for materials evaluation.

**E E 520. Selected Topics in Communications and Signal Processing.**

(3-0) Cr. 3. Repeatable.

Space-time processing. Multiuser communications, Wireless Communications, Statistical signal processing. Pattern recognition. Coding theory. Multirate communications and signal processing. Signal processing and communications applications.

**E E 521. Advanced Communications.**

(3-0) Cr. 3. F. *Prereq: E E 422, Coreq: E E 523*

Digital communication systems overview. Characterization of communication channels. Digital modulation and demodulation design and performance analysis. Channel capacity and error-control coding concepts. Waveform design for band-limited channels. Equalization. Wireless fading channels and performance.

**E E 523. Random Processes for Communications and Signal Processing.**

(3-0) Cr. 3. Prereq: E E 322, MATH 317

Axioms of probability; Repeated trials; Functions of a random variable and multiple random variables: covariance matrix, conditional distribution, joint distribution, moments, and joint moment generating function; Mean square estimation; stochastic convergence; Some important stochastic processes: Random walk, Poisson, Wiener, and shot noise; Markov chains; Power spectral analysis; Selected applications.

**E E 524. Digital Signal Processing.**

(3-0) Cr. 3. F. Prereq: E E 322, E E 424, MATH 317

Review: sampling and reconstruction of signals; discrete-time signals, systems, and transforms. Multi-rate digital signal processing and introduction to filter banks. Optimal linear filtering and prediction. Introductions to adaptive filtering and spectral estimation. Applications.

**E E 527. Detection and Estimation Theory.**

(3-0) Cr. 3. S. Prereq: E E 422

Statistical estimation theory and performance measures: maximum likelihood estimation, Cramer-Rao bound, Bayesian estimation, optimal demodulation, signal design. Introduction to graphical models. Hidden Markov models and Kalman filter. Classical statistical decision theory, decision criteria, binary and composite hypothesis tests. Error probability and Chernoff bound. Applications.

**E E 528. Digital Image Processing.**

(3-0) Cr. 3. S. Prereq: E E 322, E E 424

Review of sampling, linear algebra and probability. Classical image processing topics such as image sampling and quantization, image transforms (2D Fourier, KLT, DCT, etc), image enhancement, restoration and filtering. Image analysis topics including edge detection, segmentation, registration and tracking (uses least squares estimation, EM, Kalman filter). Medical image reconstruction from tomographic projections (Radon transform, Fourier slice theorem and reconstruction algorithms using them) and Magnetic Resonance Imaging (MRI). Basic introduction to image and video compression methods.

**E E 530. Selected Topics in Electronics, Microelectronics and Photonics.**

(3-0) Cr. 3. Repeatable. Prereq: E E 332

**E E 532. Microelectronics Fabrication Techniques.**

(Dual-listed with E E 432). (Cross-listed with MAT E). (2-4) Cr. 4. Prereq: PHYS 222, MATH 267. E E 332 or MAT E 331 recommended

Techniques used in modern integrated circuit fabrication, including diffusion, oxidation, ion implantation, lithography, evaporation, sputtering, chemical-vapor deposition, and etching. Process integration. Process evaluation and final device testing. Extensive laboratory exercises utilizing fabrication methods to build electronic devices. Use of computer simulation tools for predicting processing outcomes. Recent advances in processing CMOS ICs and micro-electro-mechanical systems (MEMS).

**E E 535. Physics of Semiconductors.**

(Cross-listed with PHYS). (3-3) Cr. 4. Prereq: E E 311 and E E 332

Basic elements of quantum theory, Fermi statistics, motion of electrons in periodic structures, crystal structure, energy bands, equilibrium carrier concentration and doping, excess carriers and recombination, carrier transport at low and high fields, space charge limited current, photo-conductivity in solids, phonons, optical properties, amorphous semiconductors, heterostructures, and surface effects. Laboratory experiments on optical properties, carrier lifetimes, mobility, defect density, doping density, photo-conductivity, diffusion length of carriers.

**E E 536. Physics of Semiconductor Devices.**

(Cross-listed with PHYS). (3-0) Cr. 3. Prereq: E E 535

P-n junctions, band-bending theory, tunneling phenomena, Schottky barriers, heterojunctions, bipolar transistors, field-effect transistors, negative-resistance devices and optoelectronic devices.

**E E 538. Optoelectronic Devices and Applications.**

(Dual-listed with E E 438). (3-0) Cr. 3. Prereq: E E 311 or E E 332

Transmission and reflection of electromagnetic plane waves. Propagation in dielectric and fiber optic waveguides. Led and laser operating principles and applications. Photodetectors and solar cells. Optical modulation and switching.

**E E 539. Electronic Properties of Materials.**

(Cross-listed with M S E). (3-0) Cr. 3. Prereq: E E 332 or MAT E 331 or PHYS 322

Review of classical and quantum mechanical descriptions of electrons in solids, band theory, metallic conduction, lattice vibrations, semiconductors, semiconductor devices, dielectrics, polarization, dielectric relaxation, crystal anisotropy, ferroelectricity, piezoelectricity, superconductivity, magnetism, device applications.

**E E 545. Artificial Neural Networks.**

(3-0) Cr. 3. F. Prereq: E E 324

Introduction to the fundamentals of artificial neural networks (ANNs). Theory and practical implementation of networks. ANNs for pattern recognition, function approximation, prediction. Activation functions, neural net architectures, supervised and unsupervised learning. Various neural network methods and architectures.

**E E 547. Pattern Recognition.**

(3-0) Cr. 3. F. Prereq: E E 324

Mathematical formulation of pattern recognition problems and decision functions. Statistical approaches: Bayes classifier, probability density function estimation and expectation minimization. Clustering (supervised and unsupervised), learning, and neural network algorithms. Fuzzy recognition systems. Feature selection systems. Classifier comparison. Current applications.

**E E 553. Steady State Analysis.**

(3-0) Cr. 3. F. Prereq: E E 456, E E 457

Power flow, economic dispatch, unit commitment, electricity markets, automatic generation control, sparse matrix techniques, interconnected operation, voltage control.

**E E 554. Power System Dynamics.**

(3-0) Cr. 3. S. Prereq: E E 456, E E 457, E E 475

Dynamic performance of power systems with emphasis on stability. Modeling of system components and control equipment. Analysis of the dynamic behavior of the system in response to small and large disturbances.

**E E 555. Advanced Energy Distribution Systems.**

(3-0) Cr. 3. Prereq: E E 455

Transient models of distribution components, automated system planning and distribution automation, surge protection, reliability, power quality, power electronics and intelligent systems applications.

**E E 556. Power Electronic Systems.**

(3-0) Cr. 3. Prereq: E E 452

Converter topologies, AC/DC, DC/DC, DC/AC, AC/AC. Converter applications to do motor drives, power supplies, AC motor drives, power system utility applications (var compensators) and power quality.

**E E 559. Electromechanical Wing Energy Conversion and Grid Integration.**

(Dual-listed with E E 459). (3-0) Cr. 3. Prereq: Credit or enrollment in E E 452, E E 456

Summary of industry status and expected growth; power extraction from the air stream; operation and modeling of electric machines, and power electronics topologies for wind energy conversion; analysis of machine-grid power electronic circuits, controller interface, and collector (distribution) networks; treatment of harmonics, flicker, over/under-voltages, filters, low-voltage ride-through, and reactive compensation; relaying; effects on transmission expansion, planning and grid operation and coordination including variability, frequency control, reserves, and electricity markets; overview of storage technologies and hybrid configurations. Nonmajor graduate credit.

**E E 565. Systems Engineering and Analysis.**

(Cross-listed with AER E, I E). (3-0) Cr. 3. Prereq: Coursework in basic statistics

Introduction to organized multidisciplinary approach to designing and developing systems. Concepts, principles, and practice of systems engineering as applied to large integrated systems. Life cycle costing, scheduling, risk management, functional analysis, conceptual and detail design, test and evaluation, and systems engineering planning and organization. Not available for degrees in industrial engineering.

**E E 566. Avionics Systems Engineering.**

(Cross-listed with AER E). (3-0) Cr. 3. S. Prereq: E E 565

Avionics functions. Applications of systems engineering principles to avionics. Top down design of avionics systems. Automated design tools.

**E E 570. Systems Engineering Analysis and Design.**

(3-0) Cr. 3. Prereq: E E 475, E E 577

Selected topics in abstract algebra, linear algebra, real analysis, functional analysis, and optimization methods in electrical engineering.

**E E 571. Introduction to Convex Optimization.**

(3-0) Cr. 3.

Introduction to convex optimization problems emerging in electrical engineering. Efficiently solving convex optimization problems with the use of interior point algorithms software. Review of linear algebra, convex functions, convex sets, convex optimization problems, duality, disciplined convex programming, applications to optimal filtering, estimation, control and resources allocations, sensor network, distributed systems.

**E E 573. Random Signal Analysis and Kalman Filtering.**

(Cross-listed with AER E, MATH, M E). (3-0) Cr. 3. F. *Prereq: E E 324 or AER E 331 or M E 370 or M E 411 or MATH 341*

Elementary notions of probability. Random processes. Autocorrelation and spectral functions. Estimation of spectrum from finite data. Response of linear systems to random inputs. Discrete and continuous Kalman filter theory and applications. Smoothing and prediction. Linearization of nonlinear dynamics.

**E E 574. Optimal Control.**

(Cross-listed with AER E, MATH, M E). (3-0) Cr. 3. S. *Prereq: E E 577*

The optimal control problem. Variational approach. Pontryagin's principle, Hamilton-Jacobi equation. Dynamic programming. Time-optimal, minimum fuel, minimum energy control systems. The regulator problem. Structures and properties of optimal controls.

**E E 575. Introduction to Robust Control.**

(Cross-listed with MATH, AER E, M E). (3-0) Cr. 3. *Prereq: E E 577*

Introduction to modern robust control. Model and signal uncertainty in control systems. Uncertainty description. Stability and performance robustness to uncertainty. Solutions to the H<sub>2</sub>, H<sub>∞</sub>, and I<sub>1</sub> control problems. Tools for robustness analysis and synthesis.

**E E 576. Digital Feedback Control Systems.**

(Cross-listed with AER E, MATH, M E). (3-0) Cr. 3. F. *Prereq: E E 475 or AER E 432 or M E 411 or 414 or MATH 415; and MATH 267*

Sampled data, discrete data, and the z-transform. Design of digital control systems using transform methods: root locus, frequency response and direct design methods. Design using state-space methods. Controllability, observability, pole placement, state estimators. Digital filters in control systems. Microcomputer implementation of digital filters. Finite wordlength effects. Linear quadratic optimal control in digital control systems. Simulation of digital control systems.

**E E 577. Linear Systems.**

(Cross-listed with AER E, MATH, M E). (3-0) Cr. 3. F. *Prereq: E E 324 or AER E 331 or MATH 415; and MATH 307*

Linear algebra review. Least square method and singular value decomposition. State space modeling of linear continuous-time systems. Solution of linear systems. Controllability and observability. Canonical description of linear equations. Stability of linear systems. State feedback and pole placements. Observer design for linear systems.

**E E 578. Nonlinear Systems.**

(Cross-listed with AER E, MATH, M E). (3-0) Cr. 3. S. *Prereq: E E 577*

Linear vs nonlinear systems. Phase plane analysis. Bifurcation and center manifold theory. Lyapunov stability. Absolute stability of feedback systems. Input-output stability. Passivity theory and feedback linearization. Nonlinear control design techniques.

**E E 588. Eddy Current Nondestructive Evaluation.**

(Dual-listed with E E 488). (Cross-listed with M S E). (3-0) Cr. 3. Alt. F., offered 2011. *Prereq: MATH 265 and (MAT E 216 or MAT E 272 or E E 311 or PHYS 364)*

Electromagnetic fields of various eddy current probes. Probe field interaction with conductors, cracks and other material defects. Ferromagnetic materials. Layered conductors. Elementary inversion of probe signals to characterize defects. Special techniques including remote-field, transient, potential drop nondestructive evaluation and the use of Hall sensors. Practical assignments using a 'virtual' eddy current instrument will demonstrate key concepts.

**E E 590. Special Topics.**

Cr. 1-6. Repeatable.

Formulation and solution of theoretical or practical problems in electrical engineering.

**E E 590A. Special Topics: Electromagnetic Theory.**

Cr. 1-6. Repeatable.

Formulation and solution of theoretical or practical problems in electrical engineering.

**E E 590B. Special Topics: Control Systems.**

Cr. 1-6. Repeatable.

Formulation and solution of theoretical or practical problems in electrical engineering.

**E E 590C. Special Topics: Communication Systems.**

Cr. 1-6. Repeatable.

Formulation and solution of theoretical or practical problems in electrical engineering.

**E E 590E. Special Topics: Computer Engineering.**

Cr. 1-6. Repeatable.

Formulation and solution of theoretical or practical problems in electrical engineering.

**E E 590F. Special Topics: Electric Power.**

Cr. 1-6. Repeatable.

Formulation and solution of theoretical or practical problems in electrical engineering.

**E E 590G. Special Topics: Electrical Materials.**

Cr. 1-6. Repeatable.

Formulation and solution of theoretical or practical problems in electrical engineering.

**E E 590H. Special Topics: Electronic Devices and Circuits.**

Cr. 1-6. Repeatable.

Formulation and solution of theoretical or practical problems in electrical engineering.

**E E 590I. Special Topics: Signal Processing.**

Cr. 1-6. Repeatable.

Formulation and solution of theoretical or practical problems in electrical engineering.

**E E 591. Seminar in Electronics, Microelectronics, and Photonics.**

Cr. 1-3. Repeatable.

**E E 594. Seminar in Electric Power.**

Cr. 1-3. Repeatable.

**E E 596. Seminar in Control Systems.**

Cr. 1-3. Repeatable.

**E E 597. Seminar in Communications and Signal Processing.**

Cr. 1. Repeatable.

Offered on a satisfactory-fail basis only.

**E E 599. Creative Component.**

Cr. arr. Repeatable.

**Courses for graduate students:****E E 621. Coding Theory.**

(3-0) Cr. 3. *Prereq: E E 521*

Fundamentals of error-control coding techniques: coding gain, linear block codes. Galois fields. Cyclic codes: BCH, Reed-Solomon. Convolutional codes and the Viterbi algorithm. Trellis-coded modulation. Iterative decoding. Recent developments in coding theory.

**E E 622. Information Theory.**

(3-0) Cr. 3. *Prereq: E E 521, E E 523*

Information system overview. Entropy and mutual information. Data Compression and source encoding. Discrete memoryless channel capacity. Noisy channel coding theorem. Rate distortion theory. Waveform channels. Advanced topics in information theory.

**E E 653. Advanced Topics in Electric Power System Engineering.**

(3-0) Cr. 3. Repeatable. *Prereq: Permission of instructor*

Advanced topics of current interest in electric power system engineering.

**E E 674. Advanced Topics in Systems Engineering.**

(3-0) Cr. 3. Repeatable. *Prereq: Permission of instructor*

Advanced topics of current interest in the areas of control theory, stochastic processes, digital signal processing, and image processing.

**E E 697. Engineering Internship.**

(Cross-listed with CPR E). Cr. R. Repeatable.

One semester and one summer maximum per academic year professional work period. Offered on a satisfactory-fail basis only.

**E E 699. Research.**

Cr. arr. Repeatable.