

ELECTRICAL ENGINEERING

For the undergraduate curriculum in electrical engineering leading to the degree Bachelor of Science. The Electrical Engineering program is accredited by the Engineering Accreditation Commission of ABET, <http://www.abet.org>.

The Department of Electrical and Computer Engineering (ECpE) at Iowa State University provides undergraduate students with the opportunity to learn electrical and computer engineering fundamentals, study applications of the most recent advances in state-of-the-art technologies, and prepare for the practice of electrical engineering. The student-faculty interaction necessary to realize this opportunity occurs within an environment that is motivated by the principle that excellence in undergraduate education is enhanced by an integrated commitment to successful, long-term research and outreach programs.

The electrical engineering curriculum offers a number of emphasis areas at the undergraduate level, including control systems, electromagnetics and nondestructive evaluation, microelectronics and photonics, VLSI, electric power and energy systems, and communications and signal processing. Students are required to choose at least one course sequence that focuses on one of these areas; therefore graduates have substantial depth in specific areas to complement the breadth obtained in the required curriculum. Students also may take elective courses in computer networking, security, computer architecture, digital systems, and software.

The program objectives for the electrical engineering program describe accomplishments that graduates are expected to attain within five years after graduation. Graduates will have applied their expertise to contemporary problem solving, be engaged professionally, have continued to learn and adapt, and have contributed to their organizations through leadership and teamwork. More specifically, the objectives for expertise, engagement, learning, leadership and teamwork are defined below for each program.

The objectives of the electrical engineering program at ISU are:

- Graduates, within five years of graduation, should demonstrate peer-recognized **expertise** together with the ability to articulate that expertise and use it for contemporary problem solving in the analysis, design, and evaluation of electrical and electronic devices and systems.
- Graduates, within five years of graduation, should demonstrate **engagement** in the engineering profession, locally and globally, by contributing to the ethical, competent, and creative practice of engineering or other professional careers.
- Graduates, within five years of graduation, should demonstrate sustained **learning** and adapting to a constantly changing field through graduate work, professional development, and self study.
- Graduates, within five years of graduation, should demonstrate **leadership** and initiative to ethically advance professional and organizational goals, facilitate the achievements of others, and obtain substantive results.
- Graduates, within five years of graduation, should demonstrate a commitment to **teamwork** while working with others of diverse cultural and interdisciplinary backgrounds.

As a complement to the instructional activity, the ECpE department provides opportunities for each student to have experience with broadening activities. Through the cooperative education and internship program, students have the opportunity to gain practical industry experience.

Students have the opportunity to participate in advanced research activities, and through international exchange programs, students learn about engineering practices in other parts of the world. Well-qualified juniors and seniors in electrical engineering who are interested in graduate study may apply for concurrent enrollment in the Graduate College to simultaneously pursue both the Bachelor of Science and Master of Science, the Bachelor of Science and Master of Business Administration, or the Bachelor of Science and Master of Engineering degrees.

Students are required to prepare and to maintain a portfolio of their technical and non-technical skills. This portfolio is evaluated for student preparation during the student's curriculum planning process. Results of the evaluation are used to advise students of core strengths and weaknesses.

Courses for students who are not in the electrical engineering program: E E 442 Introduction to Circuits and Instruments, E E 448 Introduction to AC Circuits and Motors. Credit in these courses may not be counted toward a degree in either electrical engineering or computer engineering.

Curriculum in Electrical Engineering

Administered by the Department of Electrical and Computer Engineering.

Leading to the degree Bachelor of Science.

Total credits required: 128. Any transfer credit courses applied to the degree program require a grade of C or better (but will not be calculated into the ISU cumulative GPA, Basic Program GPA or Core GPA). See also Basic Program and Special Programs.

Note: Department does not allow Pass/Not Pass credits to be used to meet graduation requirements.

International Perspectives: 3 cr.¹

U.S. Diversity: 3 cr.¹

Communication Proficiency/Library requirement:

ENGL 150	Critical Thinking and Communication (Must have a C or better in this course)	3
ENGL 250	Written, Oral, Visual, and Electronic Composition (Must have a C or better in this course)	3
LIB 160	Information Literacy	1
One of the following:		3
ENGL 314	Technical Communication (C or better in this course)	
ENGL 309	Proposal and Report Writing (C or better in this course)	

General Education Electives: 15 cr.³

Complete minimum of 6 cr. from Approved General Education Component at 300 or higher level. Complete additional 9 cr. from Approved General Education Component.

Basic Program: 27 cr.

A minimum GPA of 2.00 required for this set of courses, including any transfer courses (please note that transfer course grades will not be calculated into the Basic Program GPA). See Requirement for Entry into Professional Program in College of Engineering Overview section.

CHEM 167	General Chemistry for Engineering Students	4
or CHEM 177	General Chemistry I	
ENGL 150	Critical Thinking and Communication (Must have a C or better in this course)	3
ENGL 250	Written, Oral, Visual, and Electronic Composition (Must have a C or better in this course)	3
ENGR 101	Engineering Orientation	R
E E 185	Introduction to Electrical Engineering and Problem-Solving I ²	3
LIB 160	Information Literacy	1
MATH 165	Calculus I	4
MATH 166	Calculus II	4
PHYS 221	Introduction to Classical Physics I	5
Total Credits		27

Math and Physical Science: 16 cr.

MATH 265	Calculus III	4
MATH 267	Elementary Differential Equations and Laplace Transforms	4
MATH 207	Matrices and Linear Algebra	3

PHYS 222	Introduction to Classical Physics II	5
Total Credits		16

Electrical Engineering Core: 41 cr.

(A minimum GPA of 2.00 required for this set of courses, including any transfer courses; please note that transfer course grades will not be calculated into the Core GPA).

E E 285	Problem Solving Methods and Tools for Electrical Engineering	4
CPR E 281	Digital Logic	4
CPR E 288	Embedded Systems I: Introduction	4
E E 201	Electric Circuits	4
E E 230	Electronic Circuits and Systems	4
E E 224	Signals and Systems I	4
E E 303	Energy Systems and Power Electronics	3
E E 311	Electromagnetic Fields and Waves	4
E E 322	Probabilistic Methods for Electrical Engineers	3
Core Elective: one of the following:		7
E E 321	Communication Systems I	
E E 324	Signals and Systems II	
Core Elective: one of the following:		
E E 330	Integrated Electronics	
E E 332	Semiconductor Materials and Devices	
Total Credits		41

Note: E E 321 and E E 332 are 3-credit courses, whereas E E 324 and E E 330 are 4-credit courses. The core credit requirement (41 credits) assumes 7 credits taken for these options. Any core credit surplus or deficiency can be used as credits for E E technical electives.

Other Remaining Courses: 29 cr.

E E 491	Senior Design Project I and Professionalism	3
E E 492	Senior Design Project II	2
I E 305	Engineering Economic Analysis	3
One of the following:		3
ENGL 309	Proposal and Report Writing (C or better in this course)	
ENGL 314	Technical Communication (C or better in this course)	
E E/Cpr E Technical Electives including one approved sequence ³		12
Elective from Math, E E, Cpr E and/or non-E E/Cpr E ³		6
Total Credits		29

Seminar/Co-op/Internships:

E E 166	Professional Programs Orientation	R
E E 294	Program Discovery	R
E E 394	Program Exploration	R

E E 494	Portfolio Assessment	R
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Co-op or internship is optional

Outcomes Assessment - Students are required to prepare and to maintain a portfolio of their technical and non-technical skills. This portfolio is evaluated for student preparation during the student's curriculum planning process. Results of the evaluation are used to advise students of core strengths and weaknesses.

Transfer Credit Requirements

The degree program must include a minimum of 30 credits at the 300-level or above in professional and technical courses earned at ISU in order to receive a B.S. in electrical engineering. These 30 credits must include E E 491 Senior Design Project I and Professionalism, E E 492 Senior Design Project II, and credits in the core professional curriculum and/or in technical electives. The Electrical and Computer Engineering Department requires a grade of C or better for any transfer credit course that is applied to the degree program.

1. These university requirements will add to the minimum credits of the program unless the university-approved courses are also approved by the department to meet other course requirements within the degree program. U.S. diversity and international perspectives courses may not be taken Pass/Not Pass.
2. See Basic Program for Professional Engineering Curricula for accepted substitutions for curriculum designated courses in the Basic Program.
3. From department approved lists (<http://www.ece.iastate.edu/academics/bachelors-degree-requirements>).

See also: A 4-year plan of study grid showing course template by semester.

Note: International perspectives and U.S. diversity courses are used to meet the general education electives.

Electrical Engineering, B.S.

First Year

Fall	Credits Spring	Credits
ENGR 101	0 MATH 166	4
E E 185	3 PHYS 221	5
MATH 165	4 E E 285	4
CHEM 167	4 E E 166	0
ENGL 150	3 General Education Elective	3
LIB 160	1	
	15	16

Second Year

Fall	Credits Spring	Credits
E E 201	4 CPR E 281	4
PHYS 222	5 E E 230	4
E E 294	0 E E 224	4
MATH 267	4 MATH 265	4
ENGL 250	3	
	16	16

Third Year

Fall	Credits Spring	Credits
CPR E 288	4 EE 330 or EE 332	3-4
E E 303	3 EE 321 or EE 324	3-4
E E 311	4 E E 322	3
MATH 207	3 ENGL 314 or ENGL 309	3
E E 394	0 General Education Elective	3
General Education Elective	3	
	17	15-17

Fourth Year

Fall	Credits Spring	Credits
E E 491	3 E E 492	2
E E 494	0 Technical Electives	9
I E 305	3 General Education Electives	6
Technical Electives	9	
	15	17

Actual Total Credits: 128

Graduate Study

The department offers work for the degrees Master of Engineering, Master of Science, and Doctor of Philosophy with a major in electrical engineering and minor work to students with other majors. Minor work for electrical engineering majors is usually selected from a wide range of courses outside electrical engineering.

Master of Engineering degree is coursework only. It is recommended for off-campus students.

The degree Master of Science with thesis is recommended for students who intend to continue toward the Doctor of Philosophy degree or to undertake a career in research and development. The non-thesis Master of Science degree requires a creative component.

The department also offers a graduate certificate program in power systems engineering.

The normal prerequisite to major in graduate work in electrical engineering is the completion of undergraduate work substantially

equivalent to that required of electrical engineering students at this university. Because of the diversification in the electrical engineering graduate program, however, it is possible for a student to qualify for graduate study in certain areas of electrical engineering even though the student's undergraduate or prior graduate training has been in a discipline other than electrical engineering. Supporting work, if required, will depend on the student's background and area of research interest. Prospective students from a discipline other than electrical engineering are required to submit, with the application for admission, a statement of the proposed area of graduate study.

The department requires submission of GRE General test scores by applicants. All students whose first language is not English and who have no U.S. degree must submit TOEFL examination scores. Students pursuing the Doctor of Philosophy must complete the department qualifying process.

The Department of Electrical and Computer Engineering is a participating department in the interdepartmental graduate minor in complex adaptive systems. Students interested in this program should see the Complex Adaptive Systems section of the catalog for requirements.

The Department of Electrical and Computer Engineering is a participating department in the interdepartmental Master of Science and Doctor of Philosophy degree programs in bioinformatics and computational biology. Students interested in these programs may earn their degrees while working under an adviser in electrical and computer engineering.

Well-qualified juniors or seniors in electrical engineering who are interested in graduate study may apply for concurrent enrollment in the Graduate College to simultaneously pursue both the Bachelor of Science and Master of Science degrees, the Bachelor of Science and Master of Business Administration, or the Bachelor of Science and Master of Engineering degrees. Under concurrent enrollment, students are eligible for assistantships and simultaneously take undergraduate and graduate courses. Details are available in the Student Services Office and on the department's website.

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: MATH 143 or satisfactory scores on mathematics placement examinations; credit or enrollment in MATH 165

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

(3-3) Cr. 4. F.S.

Prereq: Credit or enrollment 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 303: Energy Systems and Power Electronics

(3-0) Cr. 3. F.S.

Prereq: MATH 267, PHYS 222; credit or enrollment in 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.

E E 311: Electromagnetic Fields and Waves

(4-0) Cr. 4. F.S.

Prereq: E E 201, MATH 265, PHYS 222, credit or enrollment 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.

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.

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.

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 engineers. 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 function, multiple random variables, functions of random variables. Elements of statistics, hypothesis testing, confidence intervals, least squares. Introduction to random processes.

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.

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.

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 317; 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.

E E 333: Electronic Systems Design

(3-3) Cr. 4. F.

Prereq: E E 230, credit or enrollment in CPR E 288

Further topics in electronic systems design: Use of sensors and actuators. High-power amplifying and switching components. Linear and switched-mode power supplies. Linear and switched-mode amplifiers. Interfacing electronic components with programmable microcontrollers. Printed circuit board technology and design tools. Laboratory exercises and design projects incorporating printed circuit technology.

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: PHYS 222

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 B E, C E). (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 391: Open Laboratory and Design Studio

(2-2) Cr. 2.

Prereq: E E 224

Studio-based activity (guided problem-based learning and design) focusing on elements of design, measurement, data capture, and data interpretation. Team building, engineering professionalism, engineering process of review and critique, and presentation. Open design activities that may include working with other studios.

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

Professional work period of at least 10 weeks during the summer.

Students must register for this course prior to commencing work. Offered on a satisfactory-fail basis only.

E E 398: Cooperative Education (Co-op)

Cr. R. Repeatable. F.S.

Prereq: Permission of department and Engineering Career Services

Professional work period. One semester per academic or calendar year. Students must register for this course before commencing work. Offered on a satisfactory-fail basis only.

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.

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.

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 E 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.

E E 419: Magnetism and Magnetic Materials

(Dual-listed with E E 519). (Cross-listed with MAT E). (3-0) Cr. 3. F.

Prereq: E E 311 or MAT E 317 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 422: Communication Systems II

(3-0) Cr. 3.

Prereq: E E 321, E E 322, 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.

E E 423: Communication Systems Laboratory

(0-3) Cr. 1.

Prereq: E E 321, 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.

E E 424: 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.

E E 432: Microelectronics Fabrication Techniques

(Dual-listed with E E 532). (Cross-listed with MAT E). (2-4) Cr. 4.

Prereq: credit or enrollment in E E 332

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 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.

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.

E E 439: Nanoelectronics

(3-0) Cr. 3. S.

Prereq: E E 332 or M A T E 334

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.

E E 442: Introduction to Circuits and Instruments

(3-2) Cr. 2. F.S.

Prereq: P H Y S 222, M A T H 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. 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 442

Half-semester course. Basics of DC machines, stepper motors, AC induction motors, and synchronous generators. AC steady state analysis, transformers, and three-phase circuit analysis.

E E 450: Biosensing

(Cross-listed with B M E). (3-0) Cr. 3.

Prereq: B M E 220

Overview of biosensors and bioanalytical challenges; designing for performance including various analytical problems, ion-selective membranes, characteristics of enzymes and basics of bioaffinity sensing; fundamentals of bioselective layers including depositing films and membranes, surfaces for immobilization and bioselective agents; survey of different biosensing technologies including electroanalytical, biomembrane, optical, and acoustic-wave based sensors.

E E 450L: Biosensing Laboratory

(Cross-listed with B M E). (0-3) Cr. 1.

Prereq: B M E 220, concurrent enrollment in B M E 450

Laboratory course accompanying B M E 450. Design, fabrication, and characterization of various electrical, chemical, polymer, optical and acoustic sensors.

E E 451: Engineering Acoustics

(Cross-listed with E M, M E). (2-2) Cr. 3. Alt. S., offered even-numbered years.

Prereq: P H Y S 221 and M A T H 266 or M A T H 267

The basics of acoustic wave propagation in fluids with an emphasis on sound propagation in air. Topics include transmission and reflection of sound at a boundary; role of acoustic sources in directing sound fields; diffraction of sound around solid objects; reverberation of sound in a room; and the measurement of sound fields.

E E 452: Electrical Machines and Power Electronic Drives

(2-3) Cr. 3. S.

Prereq: E E 303, 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.

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.

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.

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.

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.

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.

E E 465: Digital VLSI Design

(Cross-listed with CPR E). (3-3) Cr. 4. F.

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.

E E 466: Multidisciplinary Engineering Design

(Cross-listed with A B E, AER E, B M 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; 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, M E, MAT E). (1-4) Cr. 3.

Repeatable, maximum of 2 times. Alt. F., offered irregularly. Alt. S., offered irregularly.

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.

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.

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 odd-numbered years.

Prereq: MATH 265 and (MAT E 216 or MAT E 273 or MAT E 392 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 489: Survey of Remote Sensing Technologies

(Dual-listed with E E 589). (Cross-listed with GEOL, MTEOR, NREM). (3-0) Cr. 3. F.

Prereq: Four courses in physical or biological sciences or engineering

Electromagnetic-radiation principles, active and passive sensors, multispectral and hyperspectral sensors, imaging radar, SAR, thermal imaging, lidar. Examples of applications. Also offered online S.

E E 489L: Satellite Remote Sensing Laboratory

(Dual-listed with E E 589L). (Cross-listed with GEOL, MTEOR, NREM). (0-3)

Cr. 1. F.

Prereq: Completion or concurrent enrollment in MTEOR/GEOL/NREM/EE 489/589

Processing and analysis of satellite sensor data (optical and radar).

Provides practical applications in an environmental context.

E E 490: Independent Study

Cr. arr. Repeatable.

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.

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 even-numbered years.

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 odd-numbered years.

Prereq: E E 435 or E E 501

Phase-locked loops, frequency synthesizers, clock and data recovery circuits, theory and implementation of adaptive filters, low-noise amplifiers, mixers, power amplifiers, transmitter and receiver architectures.

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 509: Mixed-Signal IC Testing and Built In Self Test

(3-0) Cr. 3.

Prereq: E E 424 or equivalent and E E 435 or E E 501

Introduction to mixed-signal IC testing; measurement uncertainty and test validity; IEEE standard test algorithms; high performance test and built-in self test challenges; new mixed-signal test algorithms and techniques to reduce data acquisition to relax instrumentation requirements, to simplify test setup, to improve test validity, and/or to enable co-testing of heterogeneous functions.

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 even-numbered years.

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

(Dual-listed with E E 419). (Cross-listed with M S E). (3-0) Cr. 3. F.

Prereq: E E 311 or MAT E 317 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.

E E 521: Advanced Communications

(3-0) Cr. 3. F.

Prereq: E E 422, credit or enrollment in 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 522: Cognitive Radio Networks

(Cross-listed with CPR E). (3-0) Cr. 3. Alt. F., offered irregularly.

Prereq: Permission of instructor

Topics on cognitive radio networks: Cognitive Radio Networks Architecture; Software Defined Radio Architecture; Spectrum Sensing; Spectrum Management; Spectrum Sharing; Spectrum Mobility; Applications of Cognitive Radio Networks.

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 529: Data Analytics in Electrical and Computer Engineering

(Cross-listed with CPR E). (3-0) Cr. 3. S.

Prereq: E E 322 or equivalent

Introduces a variety of data analytics techniques # particularly those relevant for electrical and computer engineers # from a foundational perspective. Topics to be covered include techniques for classification, visualization, and parameter estimation, with applications to signals, images, matrices, and graphs. Emphasis will be placed on rigorous analysis as well as principled design of such techniques.

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 M S E). (2-4) Cr. 4.

Prereq: credit or enrollment in E E 332

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, 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 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 552: Energy System Planning

(3-0) Cr. 3.

Prereq: E E 456, E E 457 or equivalent

Characteristics of bulk energy conversion, storage, and transport technologies. Environmental legislation. Modeling of electricity markets. Evaluation of sustainability and resiliency. Types of planning analyses: economic, multi-sector, long-term, national. Planning tools and associated optimization methods.

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 Wind 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.

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, 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, 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, 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 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 H₂, H_∞, and I₁ control problems. Tools for robustness analysis and synthesis.

E E 576: Digital Feedback Control Systems

(Cross-listed with AER E, M E). (3-0) Cr. 3. F.

Prereq: E E 475 or AER E 432 or M E 411 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, M E, MATH). (3-0) Cr. 3. F.

Prereq: E E 324 or AER E 331 or MATH 415; and MATH 207

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, M E, MATH). (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 odd-numbered years.

Prereq: MATH 265 and (MAT E 216 or MAT E 273 or MAT E 392 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 589: Survey of Remote Sensing Technologies

(Dual-listed with E E 489). (Cross-listed with GEOL, MTEOR, NREM). (3-0)

Cr. 3. F.

Prereq: Four courses in physical or biological sciences or engineering

Electromagnetic-radiation principles, active and passive sensors, multispectral and hyperspectral sensors, imaging radar, SAR, thermal imaging, lidar. Examples of applications. Also offered online S.

E E 589L: Satellite Remote Sensing Laboratory

(Dual-listed with E E 489L). (Cross-listed with GEOL, MTEOR, NREM). (0-3)

Cr. 1. F.

Prereq: Completion or concurrent enrollment in MTEOR/GEOL/NREM/EE 489/589

Processing and analysis of satellite sensor data (optical and radar). Provides practical applications in an environmental context.

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.