Department of

Electrical and Computer Engineering

College of Engineering

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Degrees offered: Bachelor of Science (BS), Master of Engineering (ME), Master of Science (MS), Electrical Engineer (EE), and Doctor of Philosophy (PhD) in Electrical Engineering; BS in Computer Engineering

Graduate specializations: Communications, Computer Engineering, Control Systems, Electromagnetic Fields, Instrumentation and Optics, Microwaves, Networks and Concurrent Systems, Space Science and Engineering, Signal Processing, and VLSI Design

Undergraduate Programs

Department Mission Statement

The mission of the Electrical and Computer Engineering (ECE) Department is to develop students into outstanding electrical and computer engineers. The department is dedicated to superb teaching, research, and service.

Program Descriptions

The ECE Department offers a balanced curriculum of classwork, laboratory work, and design experiences to prepare students for careers as practicing engineers. The Bachelor of Science programs in Electrical Engineering and Computer Engineering are accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (EAC/ABET). The research program of the department, which includes undergraduates as well as graduate students, is internationally acclaimed in the fields of aerospace instrumentation and measurements, image compression, communications, electromagnetics, controls, and robotics.

Electrical Engineering

The Electrical Engineering program is dedicated to producing engineers who: (1) contribute to engineering practice, advance engineering knowledge, and contribute to the good of society; (2) are advancing their education in engineering and other professions; and (3) take a leadership role in engineering and society.

Each student is given a solid foundation in electricity, electronics, signals, and systems, with individual practical experience. Upon this basic foundation the students then build expertise in advanced areas, stressing actual design practice, to prepare them for productive engineering careers. The specialty areas can be categorized into the following: analog and digital electronics, controls, signal processing, communications, and microwave engineering.

Computer Engineering

The Computer Engineering program is dedicated to producing engineers who: (1) apply fundamental principles to solve practical engineering problems; (2) are continually engaged in professional, personal, and community development; (3) are implementing well-planned, top-down designs of complex systems; and (4) function well as team members and interact well with other professionals and nonengineers.

Building on a solid curriculum in computing hardware and software, the program begins with a strong foundation in electricity, digital logic design, and computer science, then leads into advanced software engineering and microcomputer systems. Advanced courses provide experience in formal design methods, high-performance architectures, data communications, concurrent programming, and real-time and embedded systems. Students are also required to complete advanced course sequences in computer science.

Students in the BS programs in both electrical engineering and computer engineering are permitted and encouraged to take courses in the other program. Many courses, such as controls, digital signal processing, and robotics, draw heavily on skills in both areas.

Assessment

In addition to the regular national accreditation, the ECE Department employs a number of means to assess the quality of departmental programs. The primary indicator is the success of ECE graduates in obtaining professional employment. At several intervals following graduation, the department keeps track of student placement. Other major tools include annual quantitative assessment of program objectives, semi-annual reviews of the curriculum and facilities by the ECE Industrial Advisory Board, interviews of undergraduate and graduate students upon completion of their programs, regular monitoring of faculty members by peers, and periodic surveys of ECE graduates working in industry.

Requirements

Prior to entry into the upper-division classes, the student must meet the standards for entry into the Professional Engineering Program. Additional information concerning these items is given in the College of Engineering write-up (pages 91-92). It is the responsibility of students to be aware of these rules and procedures; however, advisor assistance is available.

Bachelor of Science in Electrical Engineering. The program leading to a Bachelor of Science degree in electrical engineering is nominally a four-year program. The required program consists of a basic foundation of mathematics, science, computer science, engineering fundamentals, and laboratory and design experiences. Elective courses providing for one or more areas of technical specialization, communication skills, and University Studies complete the program and prepare students for productive and rewarding careers in the electrical engineering profession.

Bachelor of Science in Computer Engineering. The program leading to a Bachelor of Science in computer engineering is nominally a four-year program. The required program consists of a basic foundation of mathematics, science, computer science, engineering fundamentals, and laboratory and design experiences. Elective courses providing for one or more areas of technical specialization, communication skills, and University Studies complete the program and prepare students for productive and rewarding careers in the computer engineering profession.

Required Courses are shown in the accompanying paragraphs; however, because of differences in high school or transfer student preparation, it is strongly recommended that students meet with the college academic advisor to plan a detailed semester-by-semester schedule for completing the preprofessional requirements. Particular attention must be paid to course prerequisites, requiring some students to take longer than four semesters to complete the preprofessional program. Students transferring into the department should consult with the college academic advisor for transfer credit evaluation and proper placement in the curriculum.

AP and CLEP credit may be used to meet some of the required technical and University Studies courses. Details concerning courses acceptable as electives are available from the Electrical and Computer Engineering Department.

Electrical Engineering

Preprofessional Program

Math 1210, 1220, 2210, 2250; CS 1700, 1720; Engr 1010; ECE 2410, 2420, 2530, 2540; Phyx 2210, 2220; Engl 2010; Math/Science Elective; University Studies Breadth

Professional Program

Math 5710; ECE 3410, 3420, 3620, 3640, 3710, 3820, 3870, 4310, 4660, 4840, 4850, 5530; Electrical Engineering Electives; Technical Electives; University Studies Depth

Computer Engineering

Preprofessional Program

Math 1210, 1220, 2250, 3310; CS 1700, 1720, 2200; Engr 1010; ECE 2410, 2420, 2530, 2540; Phyx 2210, 2220; Engl 2010; Math/Science Elective; University Studies Breadth

Professional Program

Math 5710; CS 3100; ECE 3160, 3410, 3620, 3640, 3710, 3720, 3780, 3820, 4740, 4840, 4850, 5530; Computer Engineering Electives; Computer Science Electives; Technical Electives; University Studies Depth

Student Research Opportunities

Undergraduate students are extensively involved with research activities in the department. Electrical engineering majors and computer engineering majors have presented papers at research conferences and have won prizes. They have also designed satellites for deployment from the space shuttle. Electrical and Computer Engineering faculty members are dedicated to helping students and providing a challenging and interesting learning atmosphere. For additional information, see the *Research* section under *Graduate Programs* (pages 215-216).

Financial Support

Scholarships, assistantships, grants-in-aid, and work-study programs are available through the University. In addition, the department employs undergraduate and graduate students to assist in engineering research and development.

Concurrent BS/Master's Program

The concurrent BS/Master's program allows engineering students to begin taking graduate-level classes during their senior year. This permits them to complete requirements for *both* the BS degree *and* the master's degree concurrently during two years. Students in this program have a greater selection of graduate courses, since many graduate courses are taught during alternate years. In addition, the student's senior design project could be a start for a graduate design project or thesis. After completing their

BS degree, students in the program can earn a master's degree in only one additional year. Both the BS and the master's degree can generally be earned with 150 total credits, although students should note that a Plan C MS requires 3 extra credits. Finally, students with a master's degree can expect a much higher starting salary following graduation. (For more information, see *College of Engineering* section of this catalog, page 92.)

Graduate Programs

Admission Requirements

See general admission requirements on pages 72-73. Applicants with a bachelor's degree in Electrical or Computer Engineering from an ABET accredited program and having a 3.25 GPA or better can generally be admitted without restriction. Additional coursework in electrical and computer engineering fundamentals may be required in individual cases. Students must take the general GRE exam; however, the subject GRE is not required. All graduate students are expected to have a working knowledge of a computer language (preferably C).

Applications will be considered throughout the year. However, students desiring financial aid should submit application materials by December 15 to be considered for the following fall semester.

No applications will be considered until all required information arrives in the office of the School of Graduate Studies.

Degree Requirements

Specific requirements for the ME, MS, EE, and PhD degrees are outlined below; these are in addition to the general requirements of the School of Graduate Studies.

Master of Engineering (ME) and Master of Science (MS). The ME degree is based on coursework and is designed to give graduates a strong practical foundation. The MS degree requires substantial thesis or project work in a specific area and prepares students for advanced study or advanced work in that area. The MS degree has two options. Under Plan A, the student completes a thesis. Under Plan B, the student prepares an engineering project report.

If a student chooses an MS degree, changing to the ME degree is only possible by approval of the major professor, ECE graduate committee, and the department head.

The MS and ME degrees require successful completion of 30 credits of 5000-level or above coursework in a program approved by the student's supervisory committee, with the following stipulations:

Master of Science

1. At least 12 credits of ECE coursework must be completed at or above the 6000 level.

2. MS Plan A students must complete 6 credits of Thesis Research (ECE 6970).

3. MS Plan B students must complete 3 credits of Thesis Research (ECE 6970) and 3 credits of Design Project (ECE 6950).

4. MS students must have a one- to two-page, double-spaced thesis or project proposal approved by their committee when a project has been identified.

Master of Engineering

1. At least 18 credits of ECE coursework must be completed at or above the 6000 level.

2. At least two ECE courses with substantial lab components must be completed at or above the 5000 level.

All Master's Students

1. At least 3 credits of ECE coursework must be completed at the 7000 level.

2. One credit of ECE 6800 (Electrical Engineering Colloquium) must be completed as soon as possible.

3. Each master's student must form a committee and have a program of study approved by the end of his or her first semester.

4. No more than 10 credits of 5000-level coursework may be applied toward a master's degree.

5. Any exceptions to the master's requirements must be approved by the student's committee and the ECE Graduate Committee.

A course in technical and professional writing, or equivalent writing experience, is required for MS students prior to beginning the thesis. MS students may, at the discretion of their supervisors, be required to hire an editor to bring the thesis or paper into acceptable form.

Electrical Engineer. The Electrical Engineer degree is awarded for the successful completion of an advanced program of 60 credits of academic work beyond the BS, or 30 credits beyond the MS, and a comprehensive engineering report earning an additional 10 credits. The degree requirements are the same as those for the PhD listed below, except that the comprehensive examination need not be taken and the engineering report is given in lieu of the original research dissertation, reducing the total credits required for the PhD. The degree differs from the PhD by preparing the student for professional engineering work, rather than for research.

Doctor of Philosophy. The PhD is awarded for the successful completion of an advanced program of academic work and original research. A flexible program is planned individually by each candidate in consultation with his or her faculty supervisory committee.

The PhD program is expected to include 60 credits of coursework beyond the BS degree or 30 credits of coursework beyond the MS degree, plus 30 credits of dissertation research. The coursework generally represents two years of study beyond the MS degree, with up to 20 credits being taken outside the Electrical and Computer Engineering Department.

Once the student has completed at least 45 and not more than 60 graduate credits, he or she must pass a comprehensive examination based on graduate-level courses. Near the end of the program, the results of the original (publishable) research work will be presented and publicly defended as a dissertation.

Research

The department conducts extensive research through the following groups:

1. Center for Self-Organizing Intelligent Systems (CSOIS)
2. National Center for the Design of Molecular Function (NCDMF)
3. Space Dynamics Laboratory (SDL)

4. Anderson Wireless Center
5. Center of Excellence for Smart Sensors
6. Signal and Image Processing

Research activities include: robotics, control systems, digital system design, computer networks, concurrent systems, antennas, numerical modeling, faulty wire detection, space systems, image processing, digital signal processing, wireless communications, acoustics, electromagnetic compatibility, and sensors.

Financial Assistance

All applicants who are accepted academically are automatically considered for financial aid. Virtually all successful graduate students in the department do receive some level of financial aid during their degree program.

Electrical and Computer Engineering Courses (ECE)

ECE 2200. Electrical Engineering for Nonmajors. Introduction to electrical engineering, including DC circuits, electronic circuits, digital circuits, and power circuits. Not for ECE majors. Three lectures, one lab. Prerequisite: Math 1210. (4 cr) (F)

ECE 2410. Electrical Circuits. Introduction to electrical circuits and basic circuit elements. Circuit theory, analysis techniques, and introduction to design. DC analysis. First-order inductive and capacitive circuits. Operational amplifiers. AC steady-state analysis. Introduction to computer-aided design and analysis. Prerequisite: Math 1210. Corequisite: ECE 2420. (3 cr) (F,Sp)

ECE 2420. Electrical Circuits Laboratory. Introduction to measurements and use of laboratory instrumentation. Basic circuit design and analysis. Introducation to computer-aided design and analysis. Must be taken concurrently with ECE 2410. (1 cr) (F,Sp)

ECE 2530. Digital Circuits. Design of combinational and sequential logic circuits with discrete and programmable logic devices. Simulations and timing analysis. Use of CAD tools. Design of digital systems. Corequisite: ECE 2540. (3 cr) (F,Sp)

ECE 2540. Digital Circuits Laboratory. Laboratory course to accompany ECE 2530. Corequisite: ECE 2530. (1 cr) (F,Sp)

ECE 3160. Transmission Lines. High frequency effects on transmission lines: reflectors, terminations, standing waves, and matching networks. Prerequisites: ECE 2410 and Phyx 2220. (1 cr) (F)

ECE 3260 (QI, DSC). Science of Sound. Application of principles of acoustics (study of sound) to everyday life. Explores physical acoustics, psychoacoustics, musical acoustics, electroacoustics, architectural acoustics, and environmental acoustics. Uses algebra and reasoning to solve problems in acoustics. (3 cr) (F)

ECE 3410. Electronic Systems I. Fundamentals of transistors, operational amplifiers, and other integrated circuits, along with their utilization in amplifiers, switches, and other applications. Laboratory work required. Prerequisites: ECE 2410, 3620. (3 cr) (F,Sp)

ECE 3420. Electronic Systems II. Design of electronic circuits for applications in instrumentation, communication, control, and power systems. Three lectures, one lab. Prerequisite: ECE 3410. (4 cr)

ECE 3620. Circuits and Signals. Continuation of basic circuit concepts: AC power, second-order response, mutual inductance, and frequency response. Time-domain analysis of higher-order systems: impulse response and convolution. Laplace transform analysis of circuits and other systems. Some lab and computational work required. Prerequisites: Math 2250, ECE 2410, CS 1720. (3 cr) (F)

ECE 3640. Signals and Systems. Systems realizations. Time and transform domain analysis of discrete-time systems. Vector-space concepts and Fourier series. Fourier transforms in continuous and discrete time. Some lab and computational work required. Prerequisite: ECE 3620. (3 cr) (Sp)

ECE 3710. Microcomputer Hardware and Software. Synthesis of microcomputer systems, including interfacing, component analysis, signaling requirements, and programming. Covers architecture basics, including instruction sets, assembly language programming, loading, timing, and interrupts. Includes hands-on implementation. Three lectures, one lab. Prerequisites: ECE 2530 and CS 1720. (4 cr) (F,Su)

ECE 3720. Microcomputer Systems Progamming. Advanced assembly language and systems programming concerned with performance and I/O. Study of modern computer architecture issues, such as caching, pipelining, concurrent instruction execution, memory access time, and role and structure of device drivers. Prerequisite: ECE 3710. (3 cr) (Sp)

ECE 3780. Engineering Software. Methods for development of reliable engineering software. Includes experience with modern CASE tools. Prerequisite: CS 1720. (3 cr) (Sp)

ECE 3820. Design I. Students work on an engineering project as part of a multidisciplinary team. Emphasizes engineering design, project management, technical writing, technical presentations, and project documentation. Prerequisite: Professional standing. (2 cr) (Sp)

ECE 3860. Transmission Lines. Covers transmission line analysis and high frequency effects, including reflections, standing waves and interference, VSWR, crosstalk, and coupling. Intended to be taken by computer engineers. Meets simultaneously with ECE 3870 during the first five weeks of the semester. Prerequisites: ECE 2410, Phyx 2220, Math 2250. (1 cr) (F)

ECE 3870. Electromagnetics. Discussion of Maxwell's equations, electromagnetic waves, power and energy, reflection and refraction processes, transmission lines, waveguides, and antennas. Explores electrostatic and magnetostatic fields produced by charge and current distributions, as well as electromagnetic forces and materials. Laboratory work required. Prerequisites: ECE 2410, Phyx 2220. (3 cr) (F)

ECE 4250. Internship/Co-op. Planned, career-related work experience in industry. Students must register with USU Co-op Office and have program approved by the ECE co-op advisor. Written report required. Prerequisite: Professional standing. (3 cr) (F,Sp,Su) ®

ECE 4310. Control Systems I. Study of analog and computer controlled systems, classical and modern control system design methods, s-domain and z-domain transfer function models, state space, dynamics of linear systems, and frequency domain analysis and design techniques. Introduction to controllability and observability, and full-state pole placement controller design. Laboratory work required. Prerequisite: ECE 3640. (3 cr) (F)

ECE 4660. Communication Systems I. Principles of analog and digital communications theory. Signal analysis. Quantization. Amplitude and angle modulation. Survey of communication systems. Laboratory work required. Prerequisites: ECE 3640, Math 5710. (3 cr) (F)

ECE 4740. Computer and Data Communications. Systems approach to computer and data communications. Includes transmission lines, hardware controllers, computer interfaces, and protocols relating to local and wide area networks. Prerequisite: ECE 3720. (3 cr) (F)

ECE 4840 (CI). Design II. Individual or team engineering project, including design, development, and testing. Interdisciplinary projects strongly encouraged. Design reviews and written progress reports required. Prerequisite: ECE 3820. (3 cr) (Sp,Su)

ECE 4850 (CI). Design III. Individual or team engineering project, including design, development, and testing. Interdisciplinary projects strongly encouraged. Written and oral reports required, describing technical details of design project. Prerequisites: ECE 4840 and senior standing. (2 cr) (Sp,Su)

ECE 4930. Special Studies for Undergraduates. Independent or group study of engineering problems not covered in regular course offerings. (1-3 cr) (F,Sp,Su) ®

ECE 5020 (d6020).[1] Computational Methods for Electrical Engineers. Advanced computing methods for electrical engineers, such as numerical integration and differentiation, finding roots and extrema, matrix manipulations, interpolation, Fourier methods, solution of differential and partial differential equations (finite differences, finite difference time domain, finite element, method of moments). Emphasis on practical applications. Prerequisites: ECE 3870 and C/C+/C++ or MATLAB programming. (3 cr) (Sp)

ECE 5230. Spacecraft Systems Engineering. Spacecraft communications, telemetry systems, and command and data handling. Introduction to astrodynamics and orbit design. Electrical power generation and storage. Spacecraft subsystems (e.g., guidance, navigation, and control). Prerequisites: Either ECE 2200, or *both* ECE 2410 and 2530. (3 cr) (F)

ECE 5280. Electo-Acoustic Systems. Engineering analysis and design of electro-acoustic systems, including sound reinforcement and electronic music systems. Practice measuring acoustic environments and component specifications, as well as using software tools for design and analysis. Three lectures, one lab. Prerequisite: ECE 3260. (4 cr) (Sp)

ECE 5320. Control Systems II. Modern control system design, including full-state and reduced-state estimators, compensator design and the separation theorem, tracking systems, and disturbance suppression. Introduction to linear quadratic optimal controller design and real-time control system design, describing function methods for nonlinear systems. Three lectures, one lab. Prerequisite: ECE 4310. (4 cr) (Sp)

ECE 5430. Advanced Electronic Circuits. Analysis, design, and application of analog integrated circuits in electronic systems. Laboratory work required. Prerequisite: ECE 3420. (3 cr) (F)

ECE 5460. Digital VLSI System Design I. Team-oriented design of large digital systems using hardware description languages. Schematic capture and standard-cell libraries. Behavioral system modeling and simulation. Preparation of behavioral models for floor-planning, testability, and design synthesis. Extensive use of CAD tools. Design project. Prerequisite: ECE 5530. (3 cr) (F)

ECE 5470. Digital VLSI System Design II. Continuation of ECE 5460. Logic synthesis, timing analysis, and structural simulation and back annotation. Design refinement to the point of final mask artwork production. Design validation through LVS, DRC, and gate-level or device-level simulation. Formal methods of circuit verification. Extensive use of CAD tools. Design project. Prerequisite: ECE 5460. (3 cr) (Sp)

ECE 5480 (d6480). Electromagnetic Compatibility. Introduces concepts and techniques of electromagnetic compatibility to students who will be designing and working with high-speed electronic systems. (3 cr) (Sp)

ECE 5490 (d6490). Radar I. Emphasizes the system aspects of radar. After introducing the basic concepts of radar, methods for the prediction of radar performance are developed and the principles of CW, FM, MTI, and tracking radars are presented. Prerequisites: ECE 3640 and 3870 or equivalent knowledge. (3 cr) (Sp)

ECE 5530. Digital System Design. Presents modern top-down, bottom-up approach to design of digital systems, emphasizing programmable devices. Extensive use of CAD tools. Designing with ABEL, and introduction to designing with Verilog HDL. Laboratory work required. Prerequisite: ECE 2530. (3 cr) (F,Sp)

ECE 5630. Introduction to Digital Signal Processing. Theory and principles of digital signal processing, including discrete-time signals and systems, Z-Transforms, Fourier analysis, FIR and IIR digital filter design, discrete Fourier transforms, and multi-rate processing. Laboratory work required. Prerequisite: ECE 3640. (3 cr) (F)

ECE 5640. Real-Time Processors. Real-time processor architectures and methods used for digital signal processing. Includes C and assembly language programming, modern DSP architectures, tools for real-time system development, and finite word-length effects. Laboratory includes implementation of hardware-based real-time systems. Laboratory work required. Prerequisites: ECE 3640 and 3710. (3 cr) (Sp)

ECE 5660. Communication Systems II. Concepts from digital communications. Signal spaces, modulation, and performance of common digital communication constellations. Bandwidth issues. Detection and matched filtering. Synchronization and equalization. Prerequisites: ECE 4660, Math 5710. (3 cr) (Sp)

ECE 5740. Concurrent Programming. Analysis of problems associated with the use of multiple threads and processes (e.g., deadlock, livelock, and starvation) and methods for avoiding them. Proper usage of synchronization operations (mutual exclusion, critical sections, semaphores, and monitors) and communication operations (message passing, remote procedure calls, remote method invocation, and rendezvous). Extensive programming exercises in C and JAVA. Prerequisites: ECE 3720 and CS 3100 or graduate standing. (3 cr) (Sp)

ECE 5750. High-Performance Microprocessor Architecture. Modern architecture fundamentals, instruction set analysis and design, pipelined and superscalar architectures, software-hardware interaction, memory hierarchy, and virtual memory stresses processor-specific low-level code optimization. Prerequisite: ECE 3710 or equivalent. (3 cr) (Sp)

ECE 5770. Microcomputer Interfacing. Design of hardware and software interfaces to microcomputers for instrumentation and control applications. Three lectures, one lab. Prerequisite: ECE 3710. (4 cr) (Sp)

ECE 5780. Real-Time Systems. Real-time system design and implementation of basic concepts, including interrupts and controllers, context switch, concurrent processes, semaphores, message passing, rate monotonic and deadline scheduling, hardware system design and test issues, and typical engineering practice. Includes hands-on implementation. Three lectures, one lab. Prerequisite: ECE 3720. (4 cr) (F)

ECE 5810 (d6810). Microwave Engineering I. Theory of operating and design techniques for passive microwave components, transmission lines, waveguides, power dividers/combiners, and filters. Prerequisite: ECE 3870. (3 cr) (Sp)

ECE 5820 (d6820). Microwave Engineering I Laboratory. Design of a wireless local area network FSK reciever. Corequisite: ECE 5810/6810. (1 cr) (Sp)

ECE 5830 (d6830). Microwave Engineering II. Theory of operation and design techniques for active microwave components. Solid-state devices, amplifiers, oscillators, mixers, detectors, and systems. Modeling of active microwave devices. Prerequisite: ECE 5810/6810. (3 cr) (F)

ECE 5840 (d6840). Microwave Engineering II Laboratory. Students design, build, and test the active building blocks that make up microwave systems. Prerequisites: ECE 3870, 5810/6810, 5820/6820. Corequisite: ECE 5830/6830. (1 cr) (F)

ECE 5850 (d6850). Antennas I. Theory and application of electromagnetic radiation and radiating structures. Emphasis on antenna designs for modern wireless communications and radar systems. (3 cr) (F)

ECE 5860 (d6860). Antennas I Laboratory. Students build and test antennas and antenna systems. Corequisite: ECE 5850/6850. (1 cr) (F)

ECE 5870 (d6870). Wireless Communications. System-level analysis and design of wireless communication systems. Link budget analysis. Frequency reuse and planning. Evaluation of modern communication systems. Prerequisite: ECE 3870. Corequisite or prerequisite: ECE 4660. (3 cr) (F)

ECE 5880 (d6880). Wireless Communications Laboratory. Design and testing of a CDMA communication system. Measurement and analysis of indoor and outdoor propagation effects. Corequisite: ECE 5870/6870. (1 cr) (F)

ECE 5930. Special Topics in Electrical and Computer Engineering. Independent or group study of engineering problems not covered in regular course offerings. (1-4 cr) (F,Sp,Su) ®

ECE 6010. Stochastic Processes in Electronic Systems. Introduction to stochastic processes in communications, signal processing, digital systems, and control. Topics include continuous and discrete random processes, correlation and power spectral density, optimal filtering, Markov chains, and queuing theory. Prerequisites: Math 5710 and ECE 3640. (3 cr) (F)

ECE 6020 (d5020). Computational Methods for Electrical Engineers. Advanced computing methods for electrical engineers, such as numerical integration and differentiation, finding roots and extrema, matrix manipulations, interpolation, Fourier methods, solution of differential and partial differential equations (finite differences, finite difference time domain, finite element, method of moments). Emphasis on practical applications. Prerequisites: ECE 3870 and C/C+/C++ or MATLAB programming. (3 cr) (Sp)

ECE 6030. Mathematical Methods for Signals and Systems. Signal representation using vector spaces. Linear algebraic techniques for signal modeling and estimation. Optimal detection and estimation algorithms, with applications. Prerequisite: Graduate status. Corequisite: Math 5760. (3 cr) (F)

ECE 6100. Electromagnetics Seminar. Weekly seminar or colloquium for advanced electromagnetics students. (1 cr) (Sp) ®

ECE 6240. Space Environment and Engineering. Study of space environment and models used for engineering analysis. Topics include considerations for engineering in the space environment, such as plasma interactions, debris, chemical reactions, radiation effects, and thermal issues. Also taught as Phyx 6240. (3 cr) (Sp)

ECE 6250. Graduate Internship/Co-op. Planned work experience in industry. Detailed program; must have prior approval. Written report required. (1-3 cr) (F,Sp,Su)

ECE 6290. Fundamentals of Acoustics. Principles underlying generation, transmission, and reception of acoustic waves. Applications of these principles using analytical methods to attack acoustic problems. Taught on demand. (3 cr)

ECE 6320. Linear Multivariable Control. Modeling, analysis, and design of multi-input, multi-output control systems, including both state space and transfer matrix approaches, with an emphasis on stability. Prerequisite: ECE 4310, MAE 5310, or equivalent. Also taught as MAE 6320. (3 cr) (F)

ECE 6330. Nonlinear and Adaptive Control. Methods of nonlinear and adaptive control system design and analysis. Includes qualitative and quantitative theories, graphical methods, frequency domain methods, sliding surface design, linear parameter estimation methods, and direct and indirect adaptive control techniques. Prerequisite: ECE/MAE 6320. Also taught as MAE 6330. (3 cr) (Sp)

ECE 6340. Spacecraft Attitude Control. Spacecraft attitude dynamics and controls. Spin stabilized, three axis, and dual spin modes. Attitude determination techniques. Prerequisite: ECE 5320. Also taught as MAE 6340. (3 cr) (F)

***ECE 6350. Robotics.** Fundamentals of robotic systems, including kinetics, kinematics, sensors, actuators, control algorithms, motion planning, and computer systems. Integration of critical design components to develop complete systems. Robotic manipulator analysis and design. Applications in manufacturing. Mobile robots, including wheeled, legged, and alternative locomotion robots. Prerequisite: ECE/MAE 6320 or instructor approval. Also taught as MAE 6350. (3 cr) (Sp)

ECE 6450. Device-Level Digital VLSI Design. VLSI fabrication technologies and device modeling. Layout design rules and mask artwork CAD tools. Techniques for estimating parasitic capacitance and resistance. Transistor-level circuit implementation and analysis techniques for digital circuits. Timing analysis. Modeling of submicron devices. Focus on CMOS technology. Extensive use of CAD tools. Prerequisites: ECE 2410 and 2530. Taught on demand. (3 cr)

ECE 6460. Device-Level Analog VLSI Design. Analog device characterization. Current sinks, sources, mirrors, and amplifiers. Current and voltage references, comparators, and operational amplifiers. A/D and D/A conversion. Specialized layout techniques to deal with on-chip device variance. Focus on CMOS technology. Extensive use of CAD tools. Prerequisites: ECE 5430 and 6450. Taught on demand. (3 cr)

ECE 6470. Semiconductor Device Physics. Semiconductor materials, and their physical and electronic properties. Detailed device models for metal-semiconductor contacts, p-n junctions, bipolar transistors, and field-effect transistors. Introduction to fabrication technology, including crystal growth and doping, diffusion, exitaxy, ion-implantation, and lithography. Prerequisite: ECE 6450. Taught on demand. (3 cr)

ECE 6480 (d5480). Electromagnetic Compatibility. Introduces concepts and techniques of electromagnetic compatibility to students who will be designing and working with high-speed electronic systems. (3 cr) (Sp)

ECE 6490 (d5490). Radar I. Emphasizes the system aspects of radar. After introducing the basic concepts of radar, methods for the prediction of radar performance are developed and the principles of CW, FM, MTI, and tracking radars are presented. Prerequisites: ECE 3640 and 3870 or equivalent knowledge. (3 cr) (Sp)

ECE 6600. Computer Networking I. Topics include network topology, flow, capacity and queuing analysis, detailed description of the standard layers, and specific networking systems, including local area networks. Some lab work included. (3 cr) (F)

ECE 6620. Introduction to Digital Image Processing. Digital processing theory and techniques for two-dimensional signals. Topics include two-dimensional transforms, image perception, sampling, modeling, enhancement, and data compression. Prerequisites: ECE 5630 and 6010. (3 cr) (Sp)

***ECE 6750. Concurrent Systems Engineering I.** Reliable and efficient software design for multiprocessor and multithreaded applications on real-time or embedded systems. Use of CASE tools to develop substantial concurrent programs for single and multiprocessor systems. Prerequisite: BS degree in Electrical and Computer Engineering or Computer Science. (3 cr) (F)

****ECE 6760. Fault-tolerant Systems.** Methods for design and implementation of fault-tolerant computer systems, emphasizing small real-time and embedded applications. Detection, assessment, confinement, and treatment of faults. Checkpointing, rollback, and secure protocols. Fault-tolerance on distributed systems. Prerequisite: BS degree in Electrical and Computer Engineering or Computer Science. (3 cr) (F)

ECE 6770. Real-Time Operating Systems. Both low- and high-level design and implementation of real-time operating systems. Provides hands-on experience with embedded real-time operating system. Introduction to scheduling tradeoffs. Survey of current commercial real-time operating systems. Prerequisite: ECE 5780. Taught on demand. (3 cr)

ECE 6780. Device Drivers. Design and implementation of UNIX and Windows device drivers. Includes hardware/software design tradeoffs in light of modern operating systems. Students implement working device drivers. Prerequisite: ECE 5780. Taught on demand. (3 cr)

ECE 6800. Electrical Engineering Colloquium. Weekly seminars or colloquia. Students are normally required to enroll for two semesters. (0.5 cr) (F,Sp) ®

ECE 6810 (d5810). Microwave Engineering I. Theory of operating and design techniques for passive microwave components, transmission lines, waveguides, power dividers/combiners, and filters. Prerequisite: ECE 3870. (3 cr) (Sp)

ECE 6820 (d5820). Microwave Engineering I Laboratory. Design of a wireless local area network FSK reciever. Corequisite: ECE 6810/5810. (1 cr) (Sp)

ECE 6830 (d5830). Microwave Engineering II. Theory of operation and design techniques for active microwave components. Solid-state devices, amplifiers, oscillators, mixers, detectors, and systems. Modeling of active microwave devices. Prerequisite: ECE 6810/5810. (3 cr) (F)

ECE 6840 (d5840). Microwave Engineering II Laboratory. Students design, build, and test the active building blocks that make up microwave systems. Prerequisites: ECE 3870, 6810/5810, 6820/5820. Corequisite: ECE 6830/5830. (1 cr) (F)

ECE 6850 (d5850). Antennas I. Theory and application of electromagnetic radiation and radiating structures. Emphasis on antenna designs for modern wireless communications and radar systems. (3 cr) (F)

ECE 6860 (d5860). Antennas I Laboratory. Students build and test antennas and antenna systems. Corequisite: ECE 6850/5850. (1 cr) (F)

ECE 6870 (d5870). Wireless Communications. System-level analysis and design of wireless communication systems. Link budget analysis. Frequency reuse and planning. Evaluation of modern communication systems. Prerequisite: ECE 3870. Corequisite or prerequisite: ECE 4660. (3 cr) (F)

ECE 6880 (d5880). Wireless Communications Laboratory. Design and testing of a CDMA communication system. Measurement and analysis of indoor and outdoor propagation effects. Corequisite: ECE 6870/5870. (1 cr) (F)

ECE 6930. Special Topics in Electrical Engineering. Independent or group study in electrical engineering topics, such as automated systems, optics and laser engineering, electro-acoustics, solid-state materials, devices, and intelligent systems engineering. (1-6 cr) (F,Sp,Su) ®

ECE 6950. Design Project. (3 cr) (F,Sp,Su) ®

ECE 6970. Thesis Research, MS. (1-6 cr) (F,Sp,Su) ®

ECE 6990. Continuing Graduate Advisement. (1-6 cr) (F,Sp,Su) ®

ECE 7210. Spacecraft Instrumentation. Theory, engineering, and data reduction techniques of spacecraft instrumentation for space science and spacecraft systems. Taught on demand. Also taught as Phyx 7210. (3 cr)

***ECE 7350. Intelligent Control Systems.** Intelligent control strategies, including neural network, fuzzy logic, associated memory networks, and rule-based control systems. Prerequisite: ECE/MAE 6320 or instructor approval. Also taught as MAE 7350. (3 cr) (F)

****ECE 7360. Optimal and Robust Control.** Advanced methods of control system analysis and design. Operator approaches to optimal control, including LQR, LQG, and L1 optimization techniques. Robust control theory, including QFT, H-infinity, and interval polynomial approaches. Prerequisite: ECE/MAE 6320 or instructor approval. Also taught as MAE 7360. (3 cr) (Sp)

ECE 7610. Computer Networking II. Advanced TCP/IP protocols, routing strategies, major applications. Details of Unix systems for advanced use of BSD sockets and TLI/Streams. Prerequisite: ECE 6600. (4 cr) (Sp)

***ECE 7620. Advanced Digital Image Processing.** Advanced digital processing theory and techniques. Topics include image restoration, image reconstruction from projections (computed tomography), and data compression. Prerequisite: ECE 6620. (3 cr) (F)

****ECE 7630. Advanced Digital Signal Processing.** Advanced digital signal processing theory and methods. Topics include optimal filter design (Wiener and Kalman filters), adaptive filtering, spectral estimation, and beamforming. Prerequisites: ECE 5630, 6010. (3 cr) (F)

***ECE 7670. Coding Theory and Practice in Communication.** Examination of codes employed in digital communications, including discussion of error correction codes over finite fields. Reed-Solomon, convolutional, and trellis coding. Advanced coding techniques. Prerequisite: ECE 6030. Corequisite: ECE 5660. (3 cr) (Sp)

****ECE 7680. Information Theory.** Topics related to information theory, including source coding theorem with examples of data compression, channel coding, and rate distortion theory. Prerequisite: ECE 6030. Corequisite: ECE 5660. (3 cr) (Sp)

***ECE 7710. Concurrent Systems Engineering II.** Advanced work on the development of reliable and correct concurrent systems, including those with time constraints. Substantial experience with CASE tools and application development. Prerequisite: ECE 6750. (3 cr) (Sp)

ECE 7740. Real-Time Scheduling. Classic real-time scheduling from a mathematical basis. Includes rate monotonic, deadline, value-based, slack-based, and job shop flow scheduling problems. Advanced research topics in real-time scheduling, including adaptive, multi-processor, and stochastic techniques. Prerequisites: ECE 5780, 6010. Taught on demand. (3 cr)

ECE 7750. Distributed Control Systems. Design and implementation issues concerning distributed control systems. Real-time processing, distributed stability methods, network techniques and standards, system development and management, smart sensors, and control actuators. Survey of current literature. Prerequisites: ECE 4310 and 5780. Taught on demand. (3 cr)

ECE 7760. Advanced Topics in Distributed Systems. Advanced topics in parallel and distributed computing, emphasizing small-scale real-time and embedded systems. Prerequisite: ECE 6750. Taught on demand. (3 cr)

ECE 7770. Advanced Topics in Real-Time Systems. Survey of current real-time systems research. Covers topics such as scheduling, multiprocessor systems, fault tolerance, diagnostic systems, use of artificial intelligence techniques, and user interfaces. Prerequisite: ECE 5780. Taught on demand. (3 cr)

ECE 7850. Antennas II. Advanced topics, such as antenna arrays, smart antennas, fields in matter, radar cross section, and computational methods. Prerequisite: ECE 6850/5850 or instructor's approval. (3 cr) (Sp)

ECE 7860. Computational Electromagnetics. Topics selected from advanced numerical methods, high-frequency methods, finite elements, finite difference time domain, and other current electromagnetic modeling tools. (3 cr) (Sp)

ECE 7930. Special Topics in Electrical Engineering. Independent or group study in electrical engineering topics, such as automated systems, laser engineering, electroacoustics, solid-state materials, devices, and intelligent systems engineering. (1-6 cr) (F,Sp,Su) ®

ECE 7970. Dissertation Research. (1-6 cr) (F,Sp,Su) ®

ECE 7990. Continuing Graduate Advisement. (1-9 cr) (F,Sp,Su) ®

® Repeatable for credit. Check with major department for limitations on number of credits that can be counted for graduation.

[1]Parenthetical numbers preceded by *d* indicate a *dual* listing.

*Taught 2002-2003.

**Taught 2003-2004.

***This course is taught alternating years. Check with department for information about when course will be taught.