Department of Electrical Engineering (ELE)

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The Department of Electrical Engineering offers graduate studies leading to the M.S. in electrical engineering. The program is designed to stimulate creativity, to provide an in-depth understanding of the basic physical phenomena involved in electrical systems, and to provide the student with the ability to use modern techniques in the analysis and design of electrical components and systems.

Admission to the graduate program in electrical engineering requires a baccalaureate degree in electrical engineering or a related area such as physics, mathematical sciences, chemistry, computer science, or other science and engineering disciplines. Undergraduate students in electrical engineering can, however, enroll in the integrated B.S./M.S. sequence after finishing 90 semester hours with a GPA of at least 3.00.

Thesis Option

All students admitted to the M.S. program are classified as thesis option students. The thesis option is designed to prepare students for graduate work at the doctoral level and concentrates on original research techniques. The graduate program of courses must include 6 semester hours of ELE 699A, Master's Thesis, on a topic approved by the student's graduate committee. The thesis must be satisfactorily defended at an oral examination. Portions of the research work required by ELE 699A may be performed in off-campus facilities if approved by the student's graduate committee.

Non-Thesis Option

Students wishing to pursue the non-thesis option are required to petition the department's graduate committee upon admission to the major. The non-thesis option is designed for practicing professionals who wish to pursue advanced study in electrical engineering culminating in the M.S. degree and who cannot pursue the traditional research experience of a thesis option. Students pursuing a M.S. degree under this option must earn a minimum of 30 semester hours of graduate credit including 3 semester hours of ELE 699B, Master's Project, which must lead to significant original work which must be defended at an oral examination and submission of a written report.

ELECTRICAL ENGINEERING COURSE LIST

520. **BIOMEDICAL INSTRUMENTATION (4).** Design and application of electrodes, biopotential amplifiers, biosensor applications, therapeutic devices. Medical imaging. Electrical safety. Measurement of ventilation, blood pressure, and flow. Three hours lecture per week and 10 lab sessions (3 hours each). PRQ: ELE 330 or consent of department.

521. **BIOMEDICAL SENSOR ENGINEERING (3).** Theory, analysis, and design of biomedical sensors. Topics include biological elements; immobilization of biological components; medical, biological, and chemical sensors; and transducers based on electrochemistry, optics, and solid-state devices. PRQ: ELE 330 and ELE 335; or MEE 390, or consent of department.

525. **BIOMEDICAL SIGNAL PROCESSING (3).** Modeling of biomedical signals and analysis of biomedical systems using both time-domain and frequency-domain techniques. Design of linear and nonlinear filters for biomedical applications and medical imaging. Practical applications in cardiac and neurological signal processing. Not available for credit to students with credit in ELE 551. PRQ: ELE 315 or consent of department.

530. **DESIGN WITH FIELD PROGRAMMABLE LOGIC DEVICES (3).** Design of high performance logic designs utilizing programmable logic gates. Design of finite state machines and introduction to latest computer-aided tools. PRQ: ELE 250 or consent of department.

531. **THEORY OF SEMICONDUCTOR DEVICES II (3).** Continuation of ELE 335 dealing with complex semiconductor devices. Theory of operation of integrated circuits, solid state lasers, switching devices, and negative conductance microwave devices. PRQ: ELE 335 or consent of department.

532. **SEMICONDUCTOR DEVICE FABRICATION LABORATORY (3).** Design and fabrication of active semiconductor devices. Laboratory exercises include artwork and pattern generation, mask making, oxidation, photolithographic processing, diffusion, metallization, and device testing. PRQ: Consent of department.

533. **DESIGN OF GALLIUM ARSENIDE INTEGRATED CIRCUITS (3).** Fundamentals of GaAs devices and logic families; fabrication processes; physical layout for VLSI circuits; interconnection and testing of high speed systems. PRQ: ELE 335 or consent of department.

534. **SEMICONDUCTOR MATERIAL AND DEVICE CHARACTERIZATION (3).** Study of fundamentals and principles of semiconductor material properties with applications to device characterization. Modern measurement techniques of semiconductor industry including electrical, optical, chemical, and physical methods. PRQ: ELE 335 or consent of department.

535. **INTEGRATED CIRCUIT ENGINEERING (3).** Basic theory of integrated circuits including MOS processing technology. Principles of layout design, simulation, and design rule checking of large-scale integrated circuits. Introduction to design tools and techniques including utilization of available design software packages. Requirements include the design, simulation, and layout of an integrated circuit to the point of mask generation. PRQ: ELE 250 and ELE 330, or consent of department.

536. **ANALOG MOS VLSI ENGINEERING (3).** Introduction to analog MOS (nMOS and CMOS) circuits. MOS transistor as both a switch and a linear device. Different MOS circuits such as amplifiers, switches, comparators, sensors, D/A-A/D converters, multipliers, and neural networks. PRQ: ELE 330 or consent of department.

537. **HYBRID CIRCUIT DESIGN (3).** Lecture/laboratory course covering thick film processing techniques as they apply to the design and fabrication of miniature electronic circuits. Topics include minimum design rules, design of electronic components, artwork generation, screen preparation, screen printing, drying and firing profiles, and trimming. PRQ: ELE 360 or consent of department.

538. **THIN FILM ENGINEERING (3).** Lecture/laboratory course designed to demonstrate theory and principles of thin film processing including vacuum processing and deposition techniques. Topics include resistive evaporation, DC sputtering, RF sputtering, ion beam sputtering, electron beam evaporation, methods of achieving vacuum, and measurement techniques. PRQ: ELE 335 or consent of department.

540. **POWER ELECTRONICS (3).** Introduction to concepts involved with switch mode power electronic circuits. Analysis of basic circuit topologies including AC/DC, DC/DC, and DC/AC converters. Discussion of desired outputs of these circuits, as well as undesired components such as harmonies and ripple. PRQ: ELE 330 and ELE 340, or consent of department.

541. **ELECTRIC DRIVES (3).** Advanced discussion of different types of electric motors under various load conditions. Application of power electronic drives to electric motors. Topics include DC drives, AC induction motor drive, and AC synchronous motor drives. Efficiency and harmonic effects discussed for each drive system. PRQ: ELE 330 and ELE 340, or consent of department.

550. **DIGITAL DESIGN WITH HDL (3).** Design, simulation, and synthesis of digital circuits and systems using Verilog HDL or VHDL. Topics include digital design methodologies, finite state automata, behavioral models, structural design, finite state machines and datapath controllers, and algorithms and architectures for digital signal processors. Includes a term project to design, simulate, and synthesize a digital circuit/system. PRQ: ELE 250 and CSCI 240, or consent of department.

551. **DIGITAL FILTER DESIGN (3).** Difference equations, z-transform, Fourier representation of sequences, discrete-time system transfer functions, infinite impulse response discrete-time filters design. Includes implementation considerations and computer aided filter design. Practical examples and computer simulations. PRQ: ELE 315 or consent of department.

552. **REAL-TIME DIGITAL SIGNAL PROCESSING (3).** In-depth presentation of the use of single-chip programmable signal processors. Hardware design aspects of digital signal processing (DSP) systems, architectural issues, and fixed versus floating pointing representations for implementing DSP algorithms. Applications to speech processing, adaptive filtering, and telecommunications. PRQ: ELE 315 and ELE 356, or consent of department.

554. **INTRODUCTION TO DIGITAL IMAGE PROCESSING (3).** Principles, techniques, and algorithms for enhancements of degraded images, compression of pictorial information, recognition of patterns in scenes, reconstruction of a picture from projections, and descriptions of objects in a scene. PRQ: CSCI 240 and consent of department.

555. **COMPUTER SYSTEM ARCHITECTURE (3).** Register transfer and micro-operation, basic computer organization and design; central processing unit; micro-programmed control; pipeline and vector processing; computer arithmetic; input/output organization, and memory organization. PRQ: ELE 250 or consent of department.

556. **INTRODUCTION TO PATTERN RECOGNITION (3).** Theory and design of pattern recognition systems. Topics include pattern recognition and perception, non-parametric decision theoretical classification, statistical discriminant functions, Fisher's approach, unsupervised learning systems (clustering) and their performance, and neural networks for pattern recognition. PRQ: CSCI 240 or CSCI 241, ELE 250, and STAT 350 or ISYE 335, or consent of department.

557. **MICROPROCESSOR (3).** Analysis of computer logic systems. Topics include parallel and serial I/O ports, memory interface, I/O interface, and interrupt interface. PRQ: ELE 356 or consent of department.

561. **SYNTHESIS OF ACTIVE AND PASSIVE FILTERS (3).** Principles of network synthesis are introduced. Synthesis techniques are used to design active and passive filters. PRQ: ELE 360 or consent of department.

564. **SYSTEM DESIGN UTILIZING ANALOG INTEGRATED CIRCUITS (3).** Basic theory for the utilization of special purpose integrated circuit amplifiers in application specific to circuit designs, including special differential and operational amplifier circuits. PRQ: ELE 330 or consent of department.

571. **LIGHTWAVE ENGINEERING (3).** Theory, analysis, and design of opto electronic communication techniques. Multi-mode and mono-mode optical fibers examined for loss, dispersion, and practical considerations. Optical receiver, transmitter, and repeaters presented with an introduction to optical signal processing. PRQ: ELE 335, ELE 360, and ELE 370, or consent of department.

574. **TRANSMISSION LINE MEDIA AND WAVE PROPAGATION (3).** Theory and applications of various transmission line media such as two-wire, coaxial, stripline, and microstrip lines. Principles of wave propagation in freespace and waveguides. Distributed circuits and impedance matching using the Smith chart approach. PRQ: ELE 370 or consent of department.

575. **ANTENNA THEORY AND DESIGN (3).** Fundamentals of electromagnetic radiation from wire and aperture-type antennas; applications of field equivalence principles to aperture radiation; receiving antennas and noise evaluation of communication systems; antenna test equipment and measurement techniques. PRQ: ELE 370 or consent of department.

580. **CONTROL SYSTEMS II (3).** Design and compensation of feedback control systems. State-variable approach to the analysis and design of feedback control systems. Use of digital controllers in modern control systems. PRQ: ELE 380 or MEE 322, or consent of department.

581. **DIGITAL CONTROL SYSTEMS (3).** Introduction to digital and sampled-data control systems. Analysis and design of digital systems using z-transform and state-space methods. Study of the effects of quantization and sampling on stability and performance. PRQ: ELE 580 or consent of department.

597. **INDEPENDENT STUDY (1 to 3).** Independent pursuit of advanced problems in electrical engineering under faculty supervision. Written report required. May be repeated to a maximum of 3 semester hours. PRQ: Consent of department.

598. **SPECIAL TOPICS IN ELECTRICAL ENGINEERING (1 to 3).**
A. Biomedical Engineering
B. Microelectronics
C. Power Electronics
D. Computer Engineering
E. Communications Engineering
G. Electromagnetics
J. Control Systems
K. Digital Signal Processing

Advanced study of electrical engineering topics offered in a regular class format. May be repeated to a maximum of 3 semester hours in each topic, but combined semester hours taken in all 500-level courses, ELE 597, and ELE 598 may not exceed 12 semester hours. PRQ: Consent of department.

630. **ADVANCED INTEGRATED CIRCUIT ENGINEERING (3).** Design of large integrated circuits explored at transistor, gate, and register subsystem level. Mathematical abstractions related to parasitic effects and discussion of physics layout complications. PRQ: ELE 535 or consent of department.

631. **VLSI ENGINEERING: COMPUTER-AIDED DESIGN (3).** Creative use of design aids in parameter extraction, schematic capture, chip layout, channel routing, and maze routing multilevel simulation. Artwork generation and verification. PRQ: ELE 535 or consent of department.

632. **VLSI ENGINEERING: DEVICE DESIGN (3).** Special design considerations of NMOS, COMS, and bipolar technologies. Topics include device simulation, application of graph theory to chip layout, design rules and validation techniques, and strategies for layout of microcells and macrocells. PRQ: ELE 630 or consent of department.

633. **VLSI ENGINEERING: CHIP DESIGN (3).** Complete design of integrated circuits in MOS and bipolar technologies. Designs evaluated by computer simulation with the computer results utilized in an iterative manner to optimize circuit design prior to mask generation. PRQ: ELE 632 or consent of department.

634. **INTEGRATED CIRCUIT DESIGN FOR TESTABILITY (3).** Current methodologies and techniques for design of VLSI systems are introduced. Topics include the introduction to integrated circuit design; modeling integrated circuits at functional, structural, and physical levels; fault modeling and fault detection; testing; design for testability; built-in self test; and test pattern generation. PRQ: ELE 535 or consent of department.

635. **ADVANCED ELECTRONIC DEVICES (3).** Theory, analysis, and design of advanced electronic devices such as metal semiconductor field effect transistors, modulation doped field effect transistors, heterojunction bipolar transistors, and quantum well devices. PRQ: ELE 335 or consent of department.

636. **DESIGN OF MICROSYSTEMS (3).** Theory, analysis, and design of micro-electro-mechanical systems. Topics include fabrication process of micro and nano-devices; electrical, mechanical, magnetic and thermal properties of micro and nanostructures; and analysis of newly developed nanostructures. PRQ: ELE 335 and ELE 330, or consent of department.

637. **THIN FILM RESISTIVE SENSORS (3).** Analysis and design of resistive sensors and capacitive sensors. Includes anisotropic magnetoresistors (AMR), giant magnetoresistors (GMR), thermistors, humidity sensors, and mass flow sensors. PRQ: ELE 335 and ELE 370; or consent of department.

640. **ADVANCED POWER ELECTRONICS (3).** Discussion of advanced topics involved with switch mode power electronic circuits. Topics include switching characteristics of power semiconductor devices, resonant converters, and soft-switching converters. Advanced techniques for the modeling and control of power electronic circuits. PRQ: ELE 540.

650. **DIGITAL SIGNAL PROCESSING (3).** Theory and computer realization of digital signal processing. Fourier and z-transform hardware and software implementation of digital filters. Discrete Butterworth and Chebyshev filters. FIR, IIR, and linear phase filters. Effects of finite word length in fixed and floating-point arithmetic. PRQ: ELE 315 or consent of department.

651. **RANDOM SIGNAL PROCESSING (3).** Statistical description of discrete and continuous signals in communication. Power spectrum analysis. Applications to filtering and interpolation problems. Detection and extraction of signals in noise background based on statistical decision theory. PRQ: ELE 360 or ELE 650, or consent of department.

653. **DIGITAL SPEECH PROCESSING (3).** Principles, techniques, and algorithms for speech signals. Emphasis on the representation of speech signals in digital form, the implementation of sophisticated processing techniques, and the classes of applications which rely heavily on digital processing. PRQ: ELE 651 or consent of department.

654. **ADVANCED TOPICS IN DIGITAL IMAGE PROCESSING (3).** Advanced treatment of image processing techniques; linear and nonlinear image restoration, image segmentation, image enhancement, image encoding, feature description, and image understanding; and related computer projects. PRQ: ELE 554 or consent of department.

655. **MICROPROCESSOR SYSTEM DESIGN (3).** Principles and techniques required to design a microprocessor-based electronic system by treating the microprocessor as a component of the overall system. Hardware design aspects of systems including buses, memory system design, I/O, interrupts, DMA, and memory management will be examined. PRQ: ELE 557 or consent of department.

656. **PATTERN RECOGNITION (3).** Principles of approaches currently employed in pattern recognition; nonparametric classification, clustering analysis, nonsupervised learning, dimensionality reduction, feature extraction, shape recognition, curve fitting, polygon clipping, and graphic display generation. PRQ: CSCI 230 or consent of department.

657. **PARALLEL PROCESSING (3).** Fundamental concepts of parallel processor organization. Development of basic algorithms suitable for such systems. Parallel sorting and interconnection networks. Applications and discussion of specific processors. PRQ: Consent of department.

658. **ARTIFICIAL INTELLIGENCE (3).** Methodology in the design of a knowledge-based system using LISP or other appropriate computer language. Subjects and strategies including information base, forward chaining, testing and debugging, and dedicated hardware. Stages from initial problem definition to system implementation will be discussed. PRQ: Consent of department.

659. **ADAPTIVE SIGNAL PROCESSING (3).** The adaptive transversal filter with least mean square algorithm introduced and compared with frequency-domain and lattice algorithms. Applications to modeling and system identification, inverse modeling, deconvolution, equalization, adaptive noise canceling, and adaptive array. Practical examples and computer simulations. PRQ: ELE 651 or consent of department.

660. **DIGITAL AND ANALOG COMMUNICATION SYSTEMS (3).** Theory of digital communication systems including digital transmission of analog systems. Digital communication in the presence of noise and the use of error correcting codes. PRQ: ELE 360 or consent of department.

661. **ERROR CONTROL CODING (3).** Fundamentals of coding theory digital communications. Topics include finite fields, linear block codes, convolutional codes, and parallel concatenated codes. Design and implementation for a digital communication system. PRQ: ELE 360 or consent of department.

662. **OPTICAL COMMUNICATION (3).** Fundamentals of the propagation of optical beams in various media. Theory and applications of optical resonators. Laser oscillation and modulation techniques of laser beams. Optical detection and noise in optical systems. Two-laser optical systems and phase conjugate optics. PRQ: ELE 335 and ELE 360, or consent of department.

664. **SPREAD SPECTRUM COMMUNICATION SYSTEMS (3).** Concepts of spread spectrum digital communication and frequency hopped communication systems, including code tracking loops, synchronization of the receiver spreading code, and binary shift register sequence. PRQ: ELE 660 or consent of department.

665. **SATELLITE COMMUNICATIONS (3).** Space vehicle overall design for communications. Orbital mechanics and the space environment presented along with station keeping, modulation methods, antenna and coding. Intended for engineers seeking entry into the satellite communications industry. PRQ: ELE 360, ELE 575, or consent of department.

670. **MICROWAVE CIRCUITS AND DEVICES (3).** Wave equation; microwave waveguides and components; solid-state devices and circuits; microwave integrated circuits; microwave test equipment and laboratory measurements. PRQ: ELE 370 or consent of department.

671. **MICROWAVE INTEGRATED CIRCUITS (3).** Analysis and design of microwave/millimeter wave integrated circuits using various transmission-line media, such as microstrips, finlines, and dielectric waveguides. "Supercompact" will be used as a design tool. PRQ: Consent of department.

672. **MICROWAVE SOLID-STATE DEVICES AND CIRCUITS (3).** Theory of operation of passive and active microwave devices including beamlead detector and mixer diodes, switching and varactor diodes, Gunn and IMPATT diodes; use of these devices in various microwave circuits, such as receiver front-ends, Gunn and IMPATT oscillators, and voltage-controlled oscillators. Design of practical microwave/millimeter wave circuits.
PRQ: Consent of department.

673. **TIME HARMONICS ELECTROMAGNETIC FIELDS (3).** Builds on advanced electromagnetic concepts to study wave propagation, resonators, and launching methods. Rigorous mathematical methods establish understanding for plane waves, cylindrical waves, and spherical waves. Body scattering, aperture principles, and perturbation methods are examined with specific focus on design, measurement, for formulation methods. PRQ: ELE 370 and ELE 575 or consent of department.

674. **MICROWAVE MEASUREMENT AND BEAM INSTRUMENTATION LABORATORY (3).** Topics include (1) Microwave measurements in the time and frequency domains, basics of spectrum analyzers, vector signal analyzers, and time domain reflectometers; (2) Transmission lines, complex impedance, reflection coefficients; (3) Microwave measurements with a vector network analyzer; basics of vector network analyzers; (4) Microwave components and devices, splitters, circulators, directional couplers, filters, etc.; (5) Beam signals for circular accelerators, beam spectrums, power spectral density, betatron and synchrotron signals; (6) Signals, noise and dynamic range, basic noise performance of devices and systems; (7) Impedance matching, basics of matching devices; (8) RF cavity measurements, cavity basics, bead pull, coupling, cavity bandwidth. PRQ: ELE 561 or consent of department.

677. **ADVANCED MICROWAVE AND MILLIMETER WAVE ENGINEERING (3).** Analysis of various transmission-line media, including rectangular and circular waveguides, dielectric waveguides, finlines, and microstrip transmission lines; microwave/millimeter wave passive and active components; theory and design of integrated circuits, such as receiver front-ends; application of microwave systems and measurement techniques. PRQ: ELE 370 or consent of department.

680. **MICROPROCESSOR SENSORS AND CONTROL SYSTEMS (3).** Application of microprocessors to various sensors including temperature, pressure, flow, and moisture measurements. Development of microprocessor based control systems. Includes laboratory experiments in microprocessor interface techniques. PRQ: ELE 380 or MEE 322, or consent of department.

681. **STATE SPACE ANALYSIS (3).** Study of linear systems emphasizing state space analysis. Topics include signals and signal representation, mathematic description of continuous and discrete systems, matrices and linear spaces, state variables and linear continuous systems, state variables and linear discrete systems, system controllability and observability, and introduction to stability theory. PRQ: ELE 580 or consent of department.

682. **NONLINEAR CONTROL SYSTEMS (3).** Study of the methods used for the analysis and design of nonlinear feedback control systems. Emphasis on the phase-plane method, numerical techniques, describing functions, and the methods of Lyapunov. PRQ: ELE 580 or consent of department.

683. **COMPUTERIZED CONTROL AND MODELING OF AUTOMATED SYSTEMS (3).** Study of computerized control in automated systems for industries, emphasizing digital controllers and linear quadratic controllers (LQC). Topics include introduction to computer control, digital controller design, command generation for process control, process modeling, optimal design methods, finite-wordlength effects, and case studies. PRQ: ELE 580 or consent of department.

684. **OPTIMUM CONTROL SYSTEMS (3).** Introduction to the basic theory and methods for the optimization of control system problems. Topics include matrix calculus, optimization with and without constraints, calculus of variations, dynamic programming with applications, optimal control of continuous and discrete systems, state estimation, and Kalman filters with electrical engineering applications. PRQ: ELE 581 or consent of department.

685. **CONTROL LAWS AND STRATEGIES FOR MULTI-LINK MANIPULATORS (3).** Study of servo control for manipulators, emphasizing various control schemes currently active in the robotic field. Topics include single-link control, kinematics and dynamics of multi-link manipulators, computed torque technique, variable-structure control, nonlinear feedback control, resolved motion control, adaptive control, and force control. PRQ: ELE 580 or consent of department.

687. **FUZZY LOGIC IN ENGINEERING (3).** Study of fuzzy logic with emphasis on its engineering applications. Topics include classical and fuzzy sets, classical and fuzzy relations, membership functions, fuzzy-to-crisp conversions, fuzzy arithmetic, classical and fuzzy logic, fuzzy rule-based systems, fuzzy control systems, and other engineering applications. PRQ: Consent of department.

689. **INTRODUCTION TO NEURAL NETWORKS (3).** Study of neural networks with an engineering application emphasis. Topics include feedforward neural networks, single layer feedback neural networks, supervised and unsupervised learning, and associative memories, as well as topics related to intelligent systems such as genetic algorithms.

699A. **MASTER'S THESIS (1 to 9).** May be taken every semester of enrollment, but only 6 semester hours will count towards the degree. PRQ: Consent of department.

699B. **MASTER'S PROJECT (1 to 3).** May be repeated to a maximum of 3 semester hours. PRQ: Consent of department.