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DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

COURSE DESCRIPTIONS

Students must refer to the Graduate School of Engineering Semester Course Offering booklets or web site to determine the courses that are actually offered in any given semester

ECEG100 Power Electronics (4SH)

Provide tools and techniques needed to analyze and design power conversion circuits that contain switches. The first part of the course emphasizes understanding and modeling of such circuits, and provides a background for engineering evaluation of power converters. The second part covers dynamics and control of this class of systems, enabling students to design controllers for a variety of power converters and motion control systems. Addresses a set of analytical and practical problems, with emphasis on a rigorous theoretical treatment of relevant questions. Designed for students with primary interests in power conditioning, control applications, and electronic circuits, but it could prove useful for designers of high-performance computers, robots, and other electronic and electromechanical (mechatronic) systems in which the dynamical properties of power supplies become important. *Prerequisite*: Knowledge of circuits, electronics, and continuous linear systems.

ECEG101 Power Systems Analysis 1 (4SH)

Covers fundamentals including phasors, single-phase and balanced three-phase circuits, complex power, and network equations; symmetrical components and sequence networks; power transformers, their equivalent circuits, per unit notation, and the sequence models; transmission line parameters including resistance, inductance, and capacitance for various configurations; steady-state operation of transmission lines including line loadability and reactive compensation techniques; power flow studies including Gauss-Speidel and Newton Raphson interactive schemes; symmetrical faults including formation of the bus impedance matrix; and unsymmetrical faults including line-to-ground, line-to-line, and double line-to-ground faults.

ECEG102 Electric Drives (4SH)

Examines all subsystems that comprise an electric drive including electric machines, power electronic converters, mechanical system requirements, feedback controller design, and intereactions with utility systems. Based on an integrative approach that requires minimal prerequisites: a junior-level course in signals and systems and some knowledge of electromagnetic field theory (possibly from physics classes), and does not require separate courses in electric machines, controls, or power electronics.

ECEG103 Classical Control Systems (4SH)

Introduces the analysis and design of classical control systems. Examines control system objectives, modeling and mathematical description, transfer function and state-variable representations, feedback control system characteristics, system responses, and stability of feedback systems. Covers compensator design based on root-locus and frequency response, and modern control system design using state-variable feedback. Also addresses advanced robust analysis and control methods pertinent to single-input, single-output systems. *Prerequisite: Permission of instructor/faculty.*

ECEG104 Electrical Machines (4SH)

Reviews phasor diagrams and three-phase circuits; the magnetic aspects including magnetic circuits and permanent magnets; transformers, their equivalent circuits, and performance; principles of electromechanical energy conversion; elementary concepts of rotating machines including rotating magnetic fields; and steady-state theory and performance of induction machines, synchronous machines, and direct current machines. *Prerequisite: Knowledge of electric circuits, electromechanical field theory.*

ECEG105 Optics for Engineers (4SH)

Provides an introductory graduate course in optics, presenting the engineering concepts necessary to understand and evaluate electro-optical systems. Begins with a brief but rigorous treatment of geometric optics including matrix methods, aberrations, and pupils and windows, with practical examples of optical instruments and electro-optical systems. Topics include polarization, interference, diffraction, and optical properties of crystals, thin films, optical resonators, guided waves, modulators, and detectors. Presents concepts with examples from modern optical systems, such as LIDAR, fiber-optical sensors, range finders, infrared systems, and optical communication systems. *Prerequisite: Bachelor of Science in engineering or physics.*

ECEG110 Digital Signal Processing (4SH)

Presents the theory and practice of modern signal processing techniques. Topics include the characteristics of discrete signals and systems, sampling, and A/D conversion; the Z-transform, the Fourier transform, and the discrete Fourier transform; fast Fourier transform algorithms; design techniques for IIR and FIR digital filters; multirate digital filters; and quantization effects in digital signal processing. *Prerequisite: Permission of instructor/faculty*

ECEG200 Linear Systems Analysis (4SH)
Covers fundamental algebraic concepts and algebraic structures. Topics include linear operators and their representations; matrices, algebraic equations, equivalence, and similarity transformations; introduction to the state-variable theory of continuous and discrete linear systems; standard canonical representations, the concept of state, and the representation of interconnected systems, linear spaces, the state equations, and their solution; stability; and introduction to the general control problem in terms of controllability and observability. *Prerequisite: Admission to Graduate School of Engineering or permission of instructor/faculty.*

ECEG201 Solid State Devices (4SH)
Covers the fundamental elements of solid-state physics and the application of these principles to developing an understanding of pn junctions, bipolar junction transistors, and MOSFETs. *Prerequisite: Graduate standing in ECE.*

ECEG202 Electromagnetic Theory 1 (4SH)
Examines the fundamental equations, their physical meaning, principal mathematical techniques, and important engineering applications. Topics include sources of the electromagnetic field, Lorentz force equation, integral form of Maxwell's equations and point relations (differential equations and boundary conditions), electromagnetic energy and power, propagation of uniform and nonuniform plane waves in homogeneous media, reflection and refraction, scalar and vector potentials, solutions in the absence of boundaries for static and dynamic problems, solutions to boundary value problems, duality, uniqueness, images, physical theory of diffraction, and general theory of metal and dielectric wave-guides and resonators for Cartesian and cylindrical systems.

ECEG203 Complex Variable Theory and Differential Equations (4SH)
Comprises the theory of functions of a complex variable. Covers Cauchy's integral and related theorems, Taylor and Laurent series, analytic continuation, and multivalued functions. Considers special functions of mathematical physics using generating functions, Taylor and Laurent expansions, and various integral representations. Reviews applications of complex variable theory drawn from optics and electromagnetic theory and from digital signal processing and digital communications. Focuses on the theory of ordinary and partial differential equations of mathematical physics. Develops series solutions of ordinary differential equations of second order using the tools of complex variable theory. Covers Sturm-Liouville theory and uses it to develop eigen function and Green function solutions of homogeneous and inhomogeneous partial differential equations. *Prerequisite: Knowledge of undergraduate advanced calculus.*

ECEG204 Applied Probability and Stochastic Processes (4SH)
Covers fundamentals of probability and stochastic processes with applications to estimation and queuing theory. Includes basic laws of probability, conditioning, and Bayes rule. Topics include random variables and their functions; PDF, PMF, and CDF notions; statistical averages; moments and characteristic functions; multiple random variables; joint and conditional PDF and PMF; multiple functions of random variables; correlation and covariance; mean squared estimation of random variables; Markov, Chebychev, and Chernov inequalities; various notions of convergence of random variable sequences; laws of large numbers; central limit theorem; and large deviation theory. As time permits, discusses basic notions of estimation and properties of estimators, unbiased and minimum variance estimation, CRLB, sufficient statistics, consistency of estimators, basic notions of discrete and continuous-time random processes, mean and autocorrelation function, WSS and cyclo-stationary processes, ergodicity of random processes, and other topics. *Prerequisite: Strong understanding of linear systems, transform techniques.*

ECEG205 Fundamentals of Computer Engineering (4SH)
Introduces fundamental techniques in computer engineering used throughout the graduate curriculum. Covers basic programming and analysis methods and the formulation and solution of a wide range of computer engineering problems, with emphasis on applications from computer-aided design, parallel computing, fault-tolerant computing, computer networks, distributed processing, computer architecture, signal processing, robotics, and coding. Also discusses the applications of algorithm analysis and complexity theory to analyzing and solving problems. *Prereq Remarks: Admission to Graduate School of Engineering.*

ECEG210 Digital Control Systems (4SH)
Covers sampling and analysis tools for linear discrete-time dynamic systems. Topics include the design of digital control systems using transform techniques by discrete equivalent and direct design methods; root locus, Bode and Nyquist diagrams, and Nichols charts; controller implementation issues, such as digital filter realizations, nonlinear effects due to quantization, round off, dead band, and limit cycles; and selection of the sampling rate. *Prerequisite: ECEG103 or equivalent knowledge.*

ECEG211 Nonlinear Control (4SH)
Discusses phase plane analysis for nonlinear systems. Topics include fundamentals of Lyapunov theory; absolute stability, passivity, averaging, singular perturbation, input-output stability, and other advanced stability topics; describing functions; nonlinear control methods based on linearization, feedback linearization, sliding control, Lyapunov, and passivity and center manifold theory and bifurcations. *Prerequisite: ECEG200.*

ECEG212 Multivariable Control Systems (4SH)
Discusses mathematical preliminaries, polynomial, and polynomial matrices; representations of linear multivariable system; matrix fraction description (MFD) and polynomial matrix description (PMD); responses of linear multivariable systems; controllability, observability, and canonical forms; poles and zeros of multivariable systems; stability; realization problem;

interaction control; state feedback and observer design; compensator design, stability, and robustness; noninteraction control; and frequency domain design techniques. *Prerequisites: ECEG103 and ECEG200.*

ECEG213 System Identification and Adaptive Control (4SH)

Discusses fundamental issues of adaptive identification and control, such as stability of adaptive systems, convergence, persistent excitation, and robustness. Identification is the process of mathematically modeling a system based on measurement data that may be limited or uncertain. Adaptive control, then, is the means by which a system that is poorly modeled is controlled adequately. The purpose of the system identification portion of the course is to enhance the underlying basic ideas, which are essential for adaptive control. Emphasis is on recursive approaches, such as recursive least square algorithm, where parameter estimates are updated in real time. The adaptive control portion covers simple adaptive systems, adaptive observers, and adaptive control. Discusses in detail two major adaptive schemes, model reference adaptive control (MRAC) and self-tuning regulators (STR). *Prerequisites: ECEG110 and ECEG200.*

ECEG214 Optimal and Robust Control (4SH)

Explores state-space, time-domain techniques for analyzing and designing optimal and robust linear control systems. Introduces basic concepts of dynamic optimization and applies them to problems of short-term and long-term optimal control, path planning and stabilization, state estimation and filtering. Emphasis is given on linear quadratic optimization, H2 control, H ∞ control and μ synthesis. A brief review of pertinent linear systems concepts, connections with a geometric intuition relating quadratic optimization to projections is also discussed. *Prerequisite: ECEG200.*

ECEG220 Power Systems Analysis 2 (4SH)

Continues ECE G101. Reviews power flow studies, power system protection, power system controls, transient operation of transmission lines, transient stability, and HVDC transmission. *Prerequisite: ECEG101 or equivalent.*

ECEG221 Power Systems Operation and Control (4SH)

Provides tools and techniques needed to analyze and quantify phenomena that arise in operation and control of modern power systems. Considers problems that have a wide-ranging importance in power systems and includes analysis of steady-state and control of power systems dynamics. These problem areas share a common mathematical framework. The first part of the course covers a classical study of steady states in power systems and the solution of voltage stability problems associated with them. The goal is to present problems (and solutions) of load flow with several modifications, namely, frequency deviations and voltage-sensitive loads. The second part covers modeling, analysis, and controller design for electromechanical transients in power systems (load variations, frequency, and power transmission dynamics). Connections are established with modern robust control theory. *Prerequisite: Knowledge of controls.*

ECEG236 Special Topics in Control (4SH)

Covers aspects of controls not studied in other courses. Topics may vary from year to year. *Prerequisite: Permission of instructor/faculty.*

ECEG237 Special Topics in Power Electronics (4SH)

Covers aspects of power electronics not studied in other courses. Topics may vary from year to year. *Prerequisite: Permission of instructor/faculty.*

ECEG238 Special Topics in Electric Drives (4SH)

Covers aspects of electric drives not studied in other courses. Topics may vary from year to year. *Prerequisite: Permission of instructor/faculty.*

ECEG239 Special Topics in Power Systems (4SH)

Covers aspects of power systems not studied in other courses. Topics may vary from year to year. *Prerequisite*: *Permission of instructor/faculty.*

ECEG240 Analog Integrated Circuit Designs (4SH)

Focuses on the principles upon which the basic building blocks used in the design of analog circuits and systems are based. Topics include modeling CMOS, bipolar, and BICMOS devices; gain, impedance, and frequency response of basic amplifier structures; feedback amplifier topologies and compensation techniques; operational amplifier architectures including low-voltage, OTAs, and three-stage designs; tuned RF amplifiers; and noise sources and models. *Prerequisite: Graduate standing in ECE.*

ECEG241 Advanced Solid State Devices (4SH)

Covers state-of-the-art topics in solid-state devices including advanced MOSFET concepts like deep-submicron scaling, HBTs, HEMTs, MESFETs, and other high-frequency/high-speed semiconductor devices. P*rerequisite: ECEG201.*

ECEG242 Integrated Circuits for Communications and Analog Signal Processing (4SH)

Focuses on the design of CMOS, bipolar, and BICMOS circuits used in communication and the analog portions of mixed-signal chips. Topics include analog multipliers with applications to mixers and phase-locked loops, oscillators, clocks and waveform generators, continuous and switched-capacitor filters, and analog-to-digital and digital-to-analog converters. *Prerequisite: ECEG240.*

ECEG243 Integrated Circuit Fabrication (4SH)
Discusses the fundamental aspects of integrated circuit fabrication beginning with the scientific foundations for diffusion, oxidation, ion implantation, chemical and physical vapor deposition, etching, and lithography. Then covers state-of-the-art integrated circuit fabrication technologies in a seminar format. *Prerequisite: Graduate standing in ECE.*

ECEG244 Introduction to Microelectromechanical Systems (MEMS) (4SH)
Provides an introduction to microelectromechanical systems including principles of sensing and actuation, microfabrication technology for MEMS, noise concepts, and packaging techniques. Covers a wide range of disciplines, from electronics to mechanics, material properties, microfabrication technology, electromagnetics, and optics. Studies several classes of devices including inertial measurement devices, pressure sensors, rf components, and optical MEMS. The last third of the semester is devoted largely to design projects. These projects involve design of MEMS devices to specifications in a realistic fabrication process.

ECEG245 Microwave Circuit Design for Wireless Communication (4SH)
Covers planar microwave circuits and microwave integrated circuits. Reviews the scattering matrix and signal flow graphs before the discussion of passive structures such as microstrips, coplanar wave-guides, slot lines, and fin lines. The design of lumped elements such as inductors, capacitors, and resistors is followed by impedance matching, tuning, resonators, and filters. Also discusses active microwave circuits such as amplifiers, negative resistance oscillators, detectors, and mixers. *Prerequisite: ECEG201.*

ECEG246 Design and Analysis of Digital Integrated Circuits (4SH)
Explores the analysis and design of basic digital-integrated-circuit logic families. Focuses on CMOS and BICMOS circuits and covers emitter-coupled logic (ECL). Design considerations include propagation delay, switching speed, fan-out, and the effect of parasitics. Discusses noise, crosstalk, and interconnect issues as well as bistable circuits and clocks. Design techniques are correlated with computer simulations.

ECEG269 Special Topics in Electronics, Semiconductor Devices, and Microfabrication (4SH)
Covers aspects of electronics, semiconductor devices, and microfabrication not studied in other courses. Topics may vary from year to year. *Prerequisite: Permission of instructor/faculty.*

ECEG270 Electromagnetic Theory 2 (4SH)
Continues ECE G202. Examines important electrodynamic applications by the use of advanced mathematical techniques. Topics include general theory of wave-guides and resonators with application to the cylindrical geometry; dielectric rod wave-guide; optical fibers; radiation; linear antennas; loop antenna; linear arrays; ray optics; scattering and diffraction of waves for planar, cylindrical, and spherical geometries; and effects of random media. *Prerequisite: ECEG202.*

ECEG271 Computational Methods in Electromagnetics (4SH)
Presents solutions to problems in electromagnetics using a wide variety of numerical and computational methods. Discusses in detail the finite difference approximations of partial differential equations and the finite difference time-domain method of simulating electromagnetic wave propagation and scattering. Uses moment methods to solve the integral equations related to currents and charges on wire structures. Uses finite element and higher-order finite difference methods to solve problems in electrostatics and wave propagation. Discusses efficient matrix methods, relaxation methods, the conjugate gradient technique, and multidimensional Newton's method in the context of electromagnetic field simulation. *Prerequisite: ECEG202.*

ECEG272 Radar System (4SH)
Provides emphasis on the system's aspects of radar engineering. Topics include basic theory of radar detection, measurement of range, angle, and Doppler shift; classes of radar systems; types of radar noise; components of a radar system; matched filters and correlation receivers as applied to radar systems; and fundamental ideas of radar system analysis. Also explores search radar theory, maximum likelihood estimation approach to measurement of radar target parameters, resolution and ambiguity functions applied to radar, and radar parameter uncertainty principles. *Prerequisite: ECEG204.*

ECEG273 Remote Sensing (4SH)
Introduces the theory, instruments, and techniques for remote sensing of the earth. Topics include fundamental properties of electromagnetic radiation; matter-energy interaction in the optical and microwave regions; optical imaging systems; synthetic aperture radar and side-looking airborne radar imaging systems; radar polarimetry; microwave scatterometry and radiometry; system considerations, such as temporal and spatial resolution, operating frequency and bandwidth, calibration, measurement precision, and accuracy; data acquisition and storage, such as models and techniques for retrieving geophysical parameters from remotely sensed data; and survey of current and planned airborne and spaceborne remote sensing systems and application of these sensors to measuring geophysical phenomena and monitoring global change. *Prerequisite: ECEG202 and ECEG204, or equivalent.*

ECEG274 Propagation in Artificial Structures (4SH)
Covers effective dielectric and permeability constants in composite materials at high frequencies, electromagnetic wave propagation in electrical and magnetic anisotropic media, magneto-static and magneto-elastic wave propagation in single layer, and electromagnetic wave propagation in multilayers. *Prerequisite: Knowledge of electromagnetic field theory.*

ECEG275 Antennas and Radiation (4SH)
Presents the fundamental theory and properties of antennas. Topics include equivalence, reciprocity, uniqueness, Huygen's principle, antenna impedance, and diffraction; linear, loop, array, and aperture antennas including horns, reflectors, lenses, and microstrip; transmitting and receiving antennas and transmission formulas; and numerical antenna analysis methods. *Prerequisite: ECEG202 and ECEG270.*

ECEG276 Microwave Properties of Materials (4SH)
Discusses general dielectric and magnetic properties of materials, tensor properties of dielectric and magnetic materials, special microwave properties of thin-film materials, and experimental techniques developed in the characterization of microwave materials. *Prerequisite: Knowledge of electromagnetics and materials science.*

ECEG277 Microwave Electron Devices (4SH)
Presents the fundamental principles and operation of the principal types of conventional (linear-beam and crossed-field) and novel (maser effect) devices. Topics include interactions of nonrelativistic and relativistic electron beams with electromagnetic fields, linear-beam tubes (klystron, traveling wave tube, backward-wave amplifier, and oscillator), crossed-field tubes (magnetron, forward-and-backward cross-field amplifier, and high-gain CFA), and maser-effect devices (cyclotron maser and gyrotron). *Prerequisite: ECEG202.*

ECEG280 Fourier and Binary Optics (4SH)
Examines the fundamentals of Fourier and binary optics from a theoretical and a practical viewpoint. Topics include radiation as a wave, polarization of radiation, reflection and refraction at surfaces, optical diffraction, scalar wave equation, Helmholtz and Kirchoff integral theorems, Fresnel and Fraunhoffer diffraction, Green's theorem, interferometry, division of amplitude, division of wave front, diffraction gratings, multilayer filters, interferometric instrumentation, and holography. Also discusses imaging properties of lenses and optical systems, coherent and incoherent imaging, modulation transfer function, spatial filtering, diffraction-limited optical systems, surface design of binary optical elements, miniature and micro-optics, fabrication of diffraction-limited optics, and applications of diffraction-limited optics. *Prerequisite: ECEG105.*

ECEG281 Fourier Optics (4SH)
Covers current topics of interest in Fourier optics and optical instrumentation. Discusses application of coherence phenomena to optical instrumentation including microdensitometers, microscopes, viewers, cameras, spectraphotometric, and interferometric instruments. Also considers applications of holography, optical data processing and computing, holographic memories, optical modulation, noise and its effects on data collection, synthetic aperture optics, and medical application of laser optics. *Prerequisite: ECE G280.*

ECEG282 Lasers (4SH)
Introduces basic principles of lasers. Topics include models for the interaction of electromagnetic radiation and matter, laser threshold and rate equations, resonator theory, transverse and longitudinal modes, Rigrod analysis, homogeneous and inhomogeneous broadening, Q switching, cavity dumping, and mode locking. Discusses specific laser types including gas, liquid, and solid, and the applications of lasers and laser systems. *Prerequisite: Admission to Graduate School of Engineering.*

ECEG284 Optical Properties of Matter (4SH)
Presents the formal mathematical treatment of classical crystal optics including dispersion, polarization, birefringence, metal optics, and the optics of thin films. Emphasis is on the interaction of electromagnetic waves and the crystal lattice. Classical crystal optics are extended to nonlinear effects observed with very intense electric and magnetic fields. Presents applications of nonlinear optics, such as second- and third-harmonic generation, optical mixing, optical parametric oscillation, multiple photon interaction, and linear and nonlinear scattering. Various topics in linear and nonlinear optics are applied in such areas as birefringent filters, second-harmonic generators, optical parametric oscillators, and acousto-optical beam deflectors. *Prerequisite: Bachelor of Science in engineering or physics.*

ECEG285 Opto-electronics and Fiber Optics (4SH)
Covers the fundamentals of the opto-electronic elements that interconnect to create a fiber-optic system for communication and sensing. Discusses the structure of single and multimode fibers, step and graded index fibers, modal theory of fiber propagation, ray theory of multimode fibers, fiber parameters, numerical aperture, Etendue, modal cutoff, couple mode theory, semiconductor physics, diode lasers and LED sources, photovoltaic and photoconductive detectors, coupling sources and detectors to optical fibers, noise in fiber-optic systems, active and passive components, modulators and couplers, fiber interferometry, and applications in communication and sensing. *Prerequisite: ECEG105.*

ECEG286 IR Imaging (4SH)
Covers the basic concepts necessary for understanding, designing, and evaluating electro-optical systems including modern infrared technology. Emphasis is on considering the system as a whole including radiation sources, the optical collection system, and the detection process. Performance characteristics and system limitations are derived for a variety of imaging and nonimaging systems, as well as for laser devices. Systems to be analyzed may include standard commercial television, night vision devices, laser rangers, thermal imagers, satellite imagers (LANDSAT, SPOT), optical communications, and guidance systems. *Prerequisite: Admission to Graduate School of Engineering.*

ECEG287 Optical Detection (4SH)
Covers the detector as a component of an optical system. Topics include the laws governing radiation and radiometry, properties of real radiation sources, detailed descriptions of detection devices, noise, contrast, and MTF, imaging and ranging devices, and electro-optical detector systems analysis. Also includes practical consideration in real detectors, resolution and recognition of signals, heterodyne detection, sub-nanosecond pulse detection, and calibration of electro-optical detectors. *Prerequisite: Bachelor of Science in engineering or physics.*

ECEG290 Plasma Engineering (4SH)
Overviews the basic principles and applications of plasma and gaseous discharges. Topics include gas kinetics, interaction of electrons and ions with static and rf fields, and wave propagation in plasmas. Discusses applications in material processing, space exploration, and microwave devices. *Prerequisite: ECEG202.*

ECEG291 Plasma Theory (4SH)
Introduces the basic theory of gaseous discharges. Discusses fluid and kinetic description of collisionless and collisional plasmas with and without magnetic field effects. Emphasis is on linear stability analysis, although also discusses nonlinear effects. *Prerequisite: ECEG202.*

ECEG292 Plasma Processing Seminar (4SH)
Covers the fundamental physics of plasmas in a lecture format. Students then investigate state-of-the-art plasma processing techniques used in integrated circuit fabrication, MEMS, and other materials processing applications in a seminar format. *Prerequisite: Graduate standing in ECE.*

ECEG309 Special Topics in Electromagnetics, Plasma, and Optics (4SH)
Covers aspects of electromagnetics, plasma, and optics not studied in other courses. Topics may very from year to year. *Prerequisite: Permission of instructor/faculty.*

ECEG310 Modern Signal Processing (4SH)
Theory and practice of modern signal processing techniques. Optimum Filtering: Principle of orthogonality, Wiener and Kalman filters; linear prediction, spectral factorization and cepstrum, triangular matrix factorization, autoregressive model matching and the Yule-Walker equations, maximum entropy. Applications: adaptive arrays, echo cancellation, equalization, spectrum estimation, system identification, adaptive control, and speech analysis and synthesis. Filter Realization: State-space description, realizability criteria, min/max/allpass phase systems, inverse systems; Orthogonal realizations, cascade realization for lossless two-ports; quantization and finite precision effects. Multirate signal processing: decimation and interpolation, Noble identities and polyphase representation, efficient rate conversion, complementary transfer functions and Nyquist filters, autocorrelation and spectrum in multirate systems; Maximally Decimated Filter-Banks, aliasing and distortion, perfect reconstruction, binary tree-structured filter banks, conjugate QMF and cascade (lattice) realization, filter-bank applications, speech/image coding, transmultiplexers. Spectrum Analysis: Fast Fourier transform, the short-time Fourier transform, uniform DFT filter banks; Gabor and Heisenberg representations; Fundamentals of continuous and discrete wavelet transform, connection to QMF filter banks, applications; Wigner-Ville spectrum and Cohen class, ambiguity functions and radar processing, evolutionary spectrum. *Prerequisite: ECEG204.*

ECEG311 Two Dimensional Signal and Image Processing (4SH)
Examines the fundamentals of two-dimensional signal processing, with emphasis on image processing. Topics include signals, systems, and transforms in two dimensions; design and analysis of FIR and IIR filters; DFT and FFT algorithms; generation of digital image from the source; image digitizers and display devices; image transforms; techniques for point-wise, local, and global image enhancement; statistical image restoration techniques including recursive estimation; image coding techniques in spatial and transform domain including coding for facsimile transmission; and feature analysis. *Prerequisite: Good understanding of linear systems, transform techniques, linear algebra, and random processes.*

ECEG312 Statistical and Adaptive Signal Processing (4SH)
Introduction to statistical and adaptive signal processing; FIR Wiener filter: linear mean square estimation, the orthogonality principle; the stochastic gradient approach: Least-Mean-Squares (LMS) and normalized LMS adaptive FIR filters; linear prediction and autoregressive models: Gram-Schmidt orthogonalization and triangular matrix factorization, autoregressive model matching and the Yule-Walker equations; Applications: noise cancellation, system identification, equalization, spectrum estimation, line enhancing, speech analysis and synthesis, beamforming; Estimation of signal statistics: autocorrelation estimates and their statistical properties, the deterministic least-squares approach; Recursive Least Squares (RLS) adaptive filters: conventional RLS, QR-RLS; comparative performance analysis of adaptive LMS and RLS filters: steady state error, tracking error, convergence rate and the role of orthogonalization; order-recursive estimation: forward and backward prediction, lattice filter configuration, the Levinson and Schur algorithms, fast triangular factorization; adaptive lattice filters: gradient and RLS; classification of adaptive (RLS) filters by: architecture (triangular vs. linear, transversal vs. lattice), internal scaling/implementation (quotient, error-feedback, QR-based); introduction to advanced adaptive filters: transform and subband domain, IIR (Laguerre-based), radial basis functions, back propagation in neural nets, Voltera/Laguerre models. *Prerequisite: ECEG204.*

ECEG313 Pattern Recognition (4SH)

Discusses introductory concepts, statistical classification problem, and the Bayes classifier. Covers parametric estimation and supervised learning, ML and Bayes approaches, and Bayes learning. Topics include nonparametric techniques, Parzen windows, nearest neighbor rules, convergence properties, and error bounds. Examines linear discriminant functions, linear separability, perceptrons and their training, and relaxation techniques. Discusses unsupervised learning and clustering, unsupervised Bayes learning, ML estimates, k-means algorithm, and learning vector quantization. Introduces neural network structures, feed-forward nets, ADALINE, Widrow-Hopf approach, the back propagation training algorithm, Kolmogorov's theorem, and capacity of feed-forward nets. Focuses on Hopfield model and learning, associative memory, bidirectional associative memory, stable states and convergence, and capacity of the Hopfield model. Also covers unsupervised learning, adaptive resonance theory, and self-organizing feature maps. *Prerequisite: ECEG204.*

ECEG314 Auditory Signal Processing (4SH)

Offers particular relevance to engineers interested in the processing and production of audio signals including speech, music, and audible noise. Discusses how sounds are processed and perceived in the auditory system by exploring physiological and psychological acoustics. Emphasis is on mathematical models of the auditory system. Topics include properties of acoustical stimuli; anatomy and physiology of the auditory system; electrical recordings from the auditory system; acoustic emissions from the ear; nonlinear, positive feedback model of cochlear mechanics; methods of psychophysical measurements; absolute thresholds; temporal integration; masking and auditory frequency analysis; signal detection theory applied to the auditory system; experiments on and models of auditory discrimination; temporal processing in the auditory system including gap detection thresholds and models of temporal processing; loudness; Zwicker's loudness summation model; pitch of simple and complex tones; and binaural hearing. Explores practical applications of psychoacoustics.

ECEG315 Digital Image Processing (4SH)

Focuses on generation of digital image from the source; image digitizers and display devices; image transforms; enhancement techniques, such as histogram, equalization, and edge sharpening; restoration by Wiener and Kalman filters; image coding using run-length coding; DPCM; transform coding; and feature analysis. *Prerequisite: ECEG110.*

ECEG316 Modern Spectral Analysis and Array Processing (4SH)

Describes the problem of estimating spectra from finite records of noisy data and a review of applications including communications (especially wireless communications), biomedicine, geophysics, speech, nondestructive testing, and sonar and radar. Explores common power spectrum estimation algorithms including both conventional and modern techniques. Emphasis is on the advantages and limitations of conventional, Capon's, multiple window, maximum entropy, parametric (AR, MA, and ARMA), and harmonic decomposition (Prony, Pisarenko, and SVD) methods, in terms of accuracy (bias), reliability (variance), applicability, and other criteria. Introduces higher-order and nonstationary spectrum estimation including conventional and parametric higher-order methods and sliding window (short-time Fourier transform and model-based), adaptive, time-frequency, and wavelet techniques for the nonstationary problem. Examines extensions to multichannel and multidimensional data, discusses the array processing problem from a spectrum estimation perspective, and introduces the wave-field perspective. Discusses nonparametric and parametric array processing techniques and applications, especially the use of antenna arrays for wireless communications and nontraditional wave-field processing problems. *Prerequisite: ECEG110, ECEG204, and ECEG312.*

ECEG317 Digital Filter Banks and Wavelets (4SH)

Develops the theory and applications of perfect reconstruction digital filter banks (PR filter banks) and continuous-time wavelet and wave-packet representations. The mathematical structure of the two disciplines are shown to be intimately related and the theory of both is developed from a signal processing and an abstract mathematical viewpoint. Examines applications that include signal processing and digital communications. Emphasis is on the multiresolution analysis (MRA) of discrete and continuous-time signals and to applications that make use of this paradigm. *Prerequisite: Strong understanding of DSP, modern signal processing, and linear systems/vector spaces.*

ECEG327 Special Topics in Signal Processing 1 (4SH)

Covers aspects of signal processing not studied in other courses. Topics may vary from year to year. Topics may include physics-based image restoration methods for subsurface sensing problems, fundamentals of linear and nonlinear inverse problems, wave-field signal processing, and tomographic imaging. *Prerequisite: ECEG110.*

ECEG328 Special Topics in Signal Processing 2 (4SH)

Covers aspects of signal processing not studied in other courses. Topics may vary from year to year. Topics may include physics-based image restoration methods for subsurface sensing problems, fundamentals of linear and nonlinear inverse problems, wave-field signal processing, and tomographic imaging. *Prerequisite: ECEG110.*

ECEG329 Special Topics in Signal Processing 3 (4SH)

Covers aspects of signal processing not studied in other courses. Topics may vary from year to year. Topics may include physics-based image restoration methods for subsurface sensing problems, fundamentals of linear and nonlinear inverse problems, wave-field signal processing, and tomographic imaging. *Prerequisite: ECEG110.*

ECEG330 Multi-User Detection (4SH)

Focuses on the fundamentals of joint data detection for cochannel users. Applications include magnetic recording channels and 3G base station design. Topics include the multiaccess channel, long sequences, random sequences, carrier modulation, nonantipodal modulation, matched-filter outputs, single-user matched filter, optimal receiver for the single-user channel, probability of error for asynchronous users, asymptotic multiuser efficiency and related measures, coherent single-user matched filter in Rayleigh fading, optimum coherent multiuser detection, minimum error probability in the asynchronous channel, optimum asymptotic efficiency, near-far resistance, performance analysis in Rayleigh fading, optimum noncoherent multiuser detection, decorrelating detector, truncated-window decorrelating detector, coherent decorrelator in the presence of fading, differentially coherent decorrelation, decorrelation for nonlinear modulation, nondecorrelating linear multiuser detection, mmse linear multiuser detection, linear multiuser detection, adaptive mmse linear multiuser detection, blind mmse multiuser detection, decision-driven multiuser detectors, successive cancellation, performance analysis of successive cancellation, and multistage detection. *Prerequisite: ECEG336, or permission of instructor/faculty.*

ECEG331 Network Communications and Performance Engineering (4SH)

Presents principles for the design and analysis of modern communications networks. Emphasis is on theoretical and practical concepts. Uses the concept of a layered network architecture as a framework for understanding the functions and services of reliable end-to-end communications. Analyzes different switching and multiplexing techniques within the context of network session requirements and network traffic characterization. Introduces performance modeling with intermediate-level problems in queuing theory including MG1 queues, simple queuing networks, the IPP, and the MMPP. Discusses models for transmission, encoding, and fundamental limitations of physical channels as motivation for the development of data-link-layer services. Presents correctness and performance analysis with respect to framing, error detection, and ARQ schemes. Discusses host-to-host communications as a problem of routing and addressing. Discusses routing, emphasizing correctness, stability, and performance of fundamental algorithms. Students gain insight into the problems of adapting traditional routing strategies to high-speed and wireless environments. Considers flow and congestion control strategies within the context of end-to-end session requirements and global network performance. *Prerequisite: ECEG204, working knowledge of C programming and recommended understanding of statistics, discrete-event simulation, and networking.*

ECEG332 Error Correcting Codes (4SH)

Algebra and Golois field theory is covered in detail. Linear block codes, Hamming codes, cyclic codes, their encoding and decoding algorithms, BCH and Reed-Solomon Codes, the Berlekamp-Massey decoding algorithm, Fourier transform over finite fields, codes in the frequency domain, and frequency domain decoding techniques are covered. Bounds on code performance, and burst error correcting codes are studied. Convolutional codes, their properties, Viterbi Algorithm, performance of the ML decoding, sequential decoding of convolutional codes, Zigangirov-Jelinek algorithm are studied. Concatenated codes, array codes, BCJR and SOVA algorithms, turbo codes and iterative decoding schemes are covered. Trellis coded modulation, low density parity check codes and coding for fading channels are also covered. *Prerequisite: Knowledge of probability and digital communications.*

ECEG333 Spread Spectrum Communication Systems (4SH)

Introduces the fundamental concepts of spread spectrum communication systems. Studies the basic theory of direct sequence (PN) and frequency hopping (FH) spread spectrum techniques. Topics include direct sequence code generation, acquisition, and tracking; and phase and Doppler tracking. Emphasis is on the performance of uncoded and coded spread spectrum communications in the presence of interference, jamming, and fading environments. Considers the low probability of interception/detection (LPI/LPD) characteristics of spread spectrum techniques in multiuser communication systems. Presents various practical applications of spread spectrum including IEEE 802.11b, HomeRF, and Bluetooth. *Prerequisite: ECEG336, or equivalent.*

ECEG334 Wireless Communications (4SH)

Treats a diverse range of topics in wireless communications for applications such as cellular mobile radio, personal communication services (PCS), and wireless LANs (local area networks). Cellular system design, frequency reuse, channel assignment, handoff, power control, cell splitting, sectorization and system capacity. Radio propagation, path-loss models, log-normal shadowing, determination of coverage area, multipath and fading, statistical models for indoor and outdoor channels. Signal design principles: spectrum-efficient modulation methods (GMSK, QPSK), spread-spectrum modulation techniques (direct-sequence and frequency-hopping). Radio reception, receiver/transmitter architectures. Adaptive equalization (maximum-likelihood, linear and decision-feedback methods). Diversity techniques (selection, maximum ratio combining, equal gain combining). Bit error rate and outage probability on fading channels. Multiple access for wireless systems: frequency, time, code and space division multiple access (FDMA, TDMA, CDMA, SDMA). Wireless networking (packet-reservation multiple access, switching, mobility management for PCS). Standards for wireless systems: AMPS, IS-54, IS-95 (U.S. digital cellular based on CDMA), GSM (Global Systems Mobile) and the PCS standards. Future (third generation) systems and the International Mobile Telecommunications (IMT-2000). *Prerequisite: ECEG336.*

ECEG335 Detection and Estimation Theory (4SH)

Reviews vector space and stochastic concepts, sufficiency, unbiased estimation, Cramer-Rao bound, Rao-Blackwell theorem, Pitman efficiency, maximum likelihood estimation, Bayesian estimation, minimum mean squared error estimation, least squares estimation, and Gauss-Markov theorem. Topics include simple and composite hypotheses, Neyman-Pearson tests, uniformly most powerful tests, invariant tests, CFAR detection, Bayesian detection, minimax detection, nonparametric testing, sequential testing, and quickest detection. *Prerequisite: ECEG204, or permission of instructor/faculty.*

ECEG336 Digital Communications (4SH)

Covers fundamentals of digital communications and coding and the basic structure of a communication system. Topics include modeling of information sources; entropy; rate distortion function; lossless and lossy source coding theorems; Huffman coding; Lempel-Ziv algorithm; scalar and vector quantization; digital modulation schemes and their spectral characterization including PAM, MPSK, QAM, OQPSK, MSK, pi/4-QPSK, CPFSK, CPM, and GMSK; and orthogonal, biortogonal, and simplex signaling. Explores optimal receiver design and probability of error derivation for various systems. Covers noncoherent detection and DPSK systems and their performance. Discusses synchronization systems, analysis of PLL in the presence of noise, methods of timing recovery, channel capacity, and Shannon's noisy channel coding theorem. Studies cutoff rate and its communication system design. Other topics include coding systems, linear block codes, soft and hard decision decoding, performance of linear block codes, cyclic codes, convolutional codes, Viterbi decoding, error probability bounds, concatenated codes, MAP decoding, Trellis code modulation, communication over band-limited channels, ISI, Nyquist conditions, raised cosine signaling, partial response signaling, equalization techniques, linear adaptive equalization, decision feedback equalizers, maximum likelihood sequence detection, and communication over fading channels. *Prerequisite: ECEG204.*

ECEG337 Information Theory (4SH)

Discusses basic properties of entropy and mutual information, Shannon's fundamental theorems on data compression and data transmission in the single-user case, binning, and covering lemmas. Topics include rate distortion theory, feedback in one-way channels, Slepian-Wolf coding of correlated information sources, source coding with side information at the receiver, multiple access channel and its capacity region, and the capacity region of the Gaussian multiple access channel. Also covers broadcast channels, superposition coding, and the capacity region of the degraded broadcast channel; performance and comparison of TDMA, FDMA, and CDMA systems from a theoretical point of view; capacity issues for time-varying channels and channels with memory; relation between information theory and statistics; Stein's lemma; and large deviation theory. *Prerequisite: ECEG204.*

ECEG338 Local Area Networks and Interworking (4SH)

Presents fundamental principles on the design and analysis of local area networks (LANs) and internetworking strategies. The traditional definition of a LAN is that it provides high-speed transmission within a limited geographic scope, and ownership is associated with the organization that uses and manages it. An alternative definition is that a LAN provides the physical and link-layer access point to an internetwork. LAN technology provides electrical, physical, and signaling specifications, as well as the rules for transmission on various shared or dedicated media. Today LANs can operate at speeds in the gigabits per second and may span great distances. Internetworking imposes a higher logical-layer abstraction that provides the protocols, algorithms, and devices for interconnecting a mesh of heterogeneous LANs and intermediate networks into an Internet. Guides students through the evolution of LAN technology, from the challenges addressed by engineers designing first- and second-generation LANs to present and future advances. Emphasizes basic algorithms and protocols used for media access control and performance evaluation. Discusses internetworking concepts related to the protocols used in the present-day Internet. *Prerequisite: ECEG331 and ECEG336.*

ECEG339 Testing and Design for Testability (4SH)

Encompasses the theoretical and practical aspects of digital systems testing and the design of easily testable circuits. Topics include defect and fault models, test generation for combinational and sequential circuits, testing measures and costs, functional and parametric test methods, design for testability, built-in self-test, and concurrent testing. Provides the foundations for developing test methods for digital systems and provides the techniques necessary to practice design for testability.

ECEG340 Broadband Communications Networks (4SH)

Covers the basic principles and fundamental design issues relevant to broadband communication networks and exposes students to current research problems. Broadband networks are designed to support a variety of services and applications. Topics range from SONET and ATM switching to high-speed network control. Other topics include characterization of network traffic and its implications on network design; traffic management, flow control, and congestion control including call admissions control, scheduling, and policing; quality of service-based routing; and multicast routing. Networking technologies reflect current research areas and implementations. Focuses on high-speed wide-area-networking (WAN) technologies including frame relay (FR), asynchronous transfer mode (ATM), and next-generation Internet architecture. Includes lectures, readings from relevant literature, and student presentations.

ECEG347 Special Topics in Communications 1 (4SH)

Covers state-of-the-art advanced topics in communications. Topics are selected from the areas of interest and research of the instructor. The prerequisites are determined by the instructor. *Prerequisite: Permission of instructor/faculty.*

ECEG348 Special Topics in Communications 2 (4SH)

Covers state-of-the-art advanced topics in communications. Topics are selected from the areas of interest and research of the instructor. The prerequisites are determined by the instructor. *Prerequisite: Permission of instructor/faculty.*

ECEG349 Special Topics in Communications 3 (4SH)

Covers state-of-the-art advanced topics in communications. Topics are selected from the areas of interest and research of the instructor. The prerequisites are determined by the instructor. *Prerequisite: Permission of instructor/faculty.*

ECEG350 Software Engineering 1 (4SH)
Presents traditional methods in software engineering. Includes the various development models, requirements, specification, design, prototyping, implementation, test, and maintenance. Discusses object-oriented design principles, such as encapsulation, inheritance, and polymorphism. A software project is assigned that contrasts the differences between function-oriented and object-oriented design. *Prerequisite: Working knowledge of C programming language.*

ECEG351 Software Engineering 2 (4SH)
Continues ECEG350. Focuses on a very specific issue, modular design of software. Explores issues of stepwise-refinement and top-down design in depth and considers organizational/data-flow issues. *Prerequisite: ECEG350.*

ECEG352 Computer Architecture (4SH)
Presents many of the issues involved in the design and analysis of new and evolving computer architectures. Topics include all aspects of the system including the microprocessor, memory, I/O, and networking. Emphasizes the connection between architecture and the underlying software that drives it. Topics include pipelining, superscalar, out-of-order execution and completion, data flow, caching, prefetching, virtual memory, RAID, and ATM switching. Performance analysis is another fundamental theme of this course. A project is assigned that involves the creation of a trace-driven simulation model to study the performance of various hardware or software architectural features. Also provides a survey of the current state of the art in processor architectures and provides additional readings from recent research in the field. *Prerequisite: Working knowledge of C programming language.*

ECEG353 VLSI Design (4SH)
Covers all aspects of VLSI design and engineering including VLSI design methodology; MOS transistors and circuits; CAD tools to create, extract, simulate, and evaluate physical layouts; CMOS fabrication process; evaluation and optimization of circuit area, power consumption, and propagation delay; CAD tools to design CMOS systems with standard cells; system clocking design and evaluation; the characteristics and limitations of CAD tools, such as simulation, placement, and routing; VLSI testing, fault models, test vector generation, and design for testability; design projects going through a complete VLSI design cycle; and a research project targeting a specific area of VLSI engineering. *Prerequisite: Knowledge of electronics and digital systems design.*

ECEG354 VLSI Architecture (4SH)
Augments the physical-level VLSI design knowledge built in ECEG353 by studying how to take advantage of VLSI technologies. Provides students with the opportunity to go through the design process of VLSI architectures with two architectural-level design projects. Prior project examples include the design and evaluation of FPGAs, application specific processors, and microprocessors. Emphasizes performance and cost tradeoffs and decision making in these projects. Lectures provide theories and discussions to support these design projects that include a brief review of VLSI design methodology, pipelining and parallel processing in VLSI processors, interconnection between VLSI processing units, VLSI-oriented algorithms and applications, VLSI architecture synthesis, such special VLSI architectures as synchronous and asynchronous processor arrays and massively parallel fine-grained processor arrays, and reconfigurable VLSI architectures. *Prerequisite: ECEG353.*

ECEG355 Digital Systems Design with Hardware Description Languages (4SH)
Covers design, simulation, modeling, and implementation of complex digital systems using high-level computer hardware description languages (HDL). Begins with a description of digital system design hierarchy and abstraction. Overviews available design tools and simulation programs. Introduces HDLs, with emphasis on VHDL and AHPL. Studies using these languages for design and verification of digital systems at different levels of abstraction. Students use VHDL software for design and simulation of large digital circuits. Also addresses silicon compilation, computer-aided design, and automatic generation of hardware. *Prerequisite: ECEG352.*

ECEG356 Digital Systems Design and Interfacing with Verilog (4SH)
Covers automated design and synthesis of digital systems with the standard Verilog hardware description language, with an emphasis on CPU structures and interfacing. Demonstrates how Verilog can be used for simulation, synthesis, and test of digital systems. Discusses hardware description using predefined parts, using the bussing structure of a system, or using a mapping of inputs to outputs. After a complete presentation of the Verilog language, presents synthesizability concepts and templates for logic unit, memory unit, and state machine synthesis. Continues by using Verilog in a complete design and description of a CPU, its peripheral devices, and generation of a complete CPU board. *Prerequisite: Admission to Graduate School of Engineering.*

ECEG357 Fault-Tolerant Computers (4SH)
Overviews fault-tolerant computing and the design and evaluation of dependable systems, and provides a base for research in fault-tolerant systems. Quantitative evaluation and modeling provide the foundation for study of fault avoidance, fault detection, and fault removal from the component level to the system level. Analyzes contemporary and historical architectures. Software evaluation tools are available for the class to explore fault-tolerant design spaces.

ECEG358 Parallel Architectures for High-Performance Computing (4SH)
Introduces different models of parallel computation, network architectures used for parallel processing (ring, mesh, and hypercube, etc.), message routing mechanisms, point-to-point and collective communication primitives (one-to-all, all-to-all, scatter, gather, etc.) parallel and distributed systems performance, and scalability evaluation methods. Discusses how a sequential algorithm can be transformed systematically into a parallel computational strategy, so that it can be realized either in

hardware (using an application-specific architecture) or in software (using a network of distributed general-purpose computers). Numerical algorithms are used to highlight the key issues involved in this mapping. Case studies include high-performance scalable parallelization strategies for computationally intensive operations, such as dense and sparse linear system solvers, multidimensional data transforms, etc. which are often encountered in scientific and multimedia applications. Students learn parallel programming using intermediate level C/MPI.

ECEG359 Multiprocessor Architectures (4SH)

Presents the issues related to designing and programming tightly coupled shared-memory multiprocessor systems. Covers memory structure, snoopy and directory-based caching, memory consistency protocols, cache coherency protocols, processor interconnect strategies, and multiprocessor scalability. Covers issues related to program execution of real applications on a multiprocessor system including synchronization primitives, task scheduling, and memory allocation. *Prerequisite: Familiarity with computer architecture.*

ECEG360 Combinatorial Optimization (4SH)

Introduces combinatorial optimization, an emerging field that combines techniques from applied mathematics, operations research, and computer science to solve optimization problems over discrete structures. Emphasizes problems that arise in the areas of electrical and computer engineering including VLSI, computer-aided design, parallel computing, computer architecture, and high-performance compiling. Covers the foundations of algorithm analysis including asymptotic notation and complexity theory, and a range of optimization techniques including divide and conquer, local optimization, dynamic programming, branch and bound, simulated annealing, genetic algorithms, approximation algorithms, integer and linear programming, matroid theory, and greedy algorithms. Considers the efficient generation of optimal solutions, the development and evaluation of heuristics, and the computation of tight upper and lower bounds. *Prerequisite: Admission to Graduate School of Engineering.*

ECEG361 Digital Hardware Synthesis (4SH)

Techniques and tools for the automatic synthesis of digital systems. The course will focus on algorithms for translating a high level specification into an implementation. Topics covered will include a brief introduction to hardware description languages (HDL), automatic translation of the HDL to an intermediate format, architectural synthesis of the register transfer level implementation, automatic state machine synthesis and logic synthesis. Students will complete a research project in the automatic synthesis of digital designs. *Prerequisite*: Working knowledge of C programming language. Knowledge of digital design and VLSI design.

ECEG362 Network Computing (4SH)

Studies the theory and practice of analysis and design of network-based computing systems. Programs can be executed adaptively in a changeable computing environment, such as clusters of workstations or PCs. Topics include distributed shared memory, cache coherence, snooping, locking, atomic exchange, deadlock, message passing interface (MPI-1 and MPI-2), point-to-point communication, collective communications, and groups, contexts, and communicators. Also studies process topologies (virtual topologies), network of workstations (NOW), protocols and programming, scalable coherent interface (SCI) using point-to-point connection of distributed shared memory (DSM) machine, SCIs, cache coherence protocol, clusters of workstations based on SCI, scalable networks for data processing topologies, wormhole routing, deadlock avoidance, scalability, message format, fault tolerance, arbitration policies, and performance evaluation of network-based computing systems. Case studies include ServerNet, myrinet, and clusters of advanced workstations. *Prerequisites: ECEG352 and ECEG363.*

ECEG363 Interconnection Networks for Multicomputers (4SH)

Covers static interconnection networks, topological properties of static interconnection networks, dynamic networks, routing in multicomputer networks, path setup, path selection (deterministic and adaptive), network flow control (store and forward, virtual cut-through, and wormhole), deadlocks in routine (virtual networks), multicasting and broadcasting in static networks (one-to-all, all-to-all broadcasting, and spanning graphs), fault tolerance and reliability of interconnection networks, and performance metrics for different topologies (through-put, message latency, max delivery time, saturation point, hot spots, stable state, average link usage, and dynamic hot spots identification). Also studies modules for a realization of interconnection networks, Node's architecture and organization, based on 32- and 64-bits CPU. Case studies include different topologies and routine strategies. *Prerequisite: ECEG352.*

ECEG364 Mobile and Wireless Networking (4SH)

Introduces the fundamental techniques and protocols in first- and second-generation, and emerging third-generation, wireless systems. Examines how mobility affects networks, systems, and applications. Mobility of devices and end-users has behavioral implications at all layers of the Internet protocol stack, from the MAC layer up through the application layer. Handling mobility efficiently requires more information sharing between network layers than is typically considered. Topics include cellular system, medium access control protocols for wireless systems, mobility management and signaling within mobile networks, common air interfaces (AMPS, IS-136, IS-95, or GSM), wireless data networking (CDPD), ad hoc networks, Bluetooth, Mobile IP, and PCS systems. Also introduces students to the problems and current research in the provision of quality of service (QoS) in wireless networks. Methodology includes lectures, textbooks, and emphasis on readings from relevant literature.

ECEG365 Distributed Systems (4SH)

Covers fundamentals of distributed systems, distributed computing models, client-server computing, remote procedure calls, distributed file and directory services, distributed systems design and implementation issues, reliability and availability,

security, overview of computer networks, and case studies in distributed systems. *Prerequisite: Knowledge of operating systems.*

ECEG366 Special Topics in Computer Engineering 1 (4SH)
Covers topics in computer engineering not studied in other courses. Subject matter may change from year to year. Topics may include computer architecture, design automation, parallel computing, VLSI, networks, compilers, algorithm design, fault-tolerance, and testing.

ECEG367 Robotics and Automation Systems (4SH)
Explores methods of operation of general-purpose and industrial manipulator systems, kinematic and dynamic models of mechanical arms, joint solutions and motion characteristics, trajectory planning, arm control through coordinate transformations, classical feedback methods and modern closed-loop control techniques, and real-time control of robotic systems. *Prerequisite: ECEG200.*

ECEG387 Special Topics in Computer Networks (4SH)
Covers current aspects of computer communications networks not covered in previous courses. Subject matter may change from year to year. Topics may include wireless ad hoc networks, quality of service in wireless networks, network and Internet security, modeling and analysis of network traffic and mobility, and advanced queuing.

ECEG388 Special Topics in Computer Engineering 2 (4SH)
Covers topics in computer engineering not studied in other courses. Subject matter may change from year to year. Topics may include computer architecture, design automation, parallel computing, VLSI, networks, compilers, algorithm design, fault tolerance, and testing.

ECEG389 Robot Vision and Sensors (4SH)
Examines methods of acquisition, representation, and processing of real-world information for robot control. Focuses on the different aspects of robot vision. Topics include projection, lens distortion, image noise reduction, texture, edge-based systems, region-based systems, Hough space, matched filtering, object modeling, stereo vision, motion, and optical flow. Robot sensors covers a variety of sensor types including force/torque, proximity, and tactile sensors. *Prerequisite: ECEG367.*

ECEG391 Special Problems in Electrical Engineering (1SH)
Offers theoretical or experimental work under individual faculty supervision. *Prerequisite: Permission of the department.*

ECEG392 Special Problems in Electrical Engineering (2SH)
Offers theoretical or experimental work under individual faculty supervision. *Prerequisite: Permission of the department.*

ECEG393 Special Problems in Electrical Engineering (3SH)
Offers theoretical or experimental work under individual faculty supervision. *Prerequisite: Permission of the department.*

ECEG394 Special Problems in Electrical Engineering (4SH)
Offers theoretical or experimental work under individual faculty supervision. *Prerequisite: Permission of the department.*

ECEG398 Special Topics (4SH)
Covers topics of interest to the faculty member conducting this class for advanced study. *Prerequisite: Permission of the department.*

ECEG399 Advanced Seminar (4SH)
Offers treatment of advanced topics of research to include theoretical as well as experimental aspects. Requires reports and discussion of selected technical articles in professional journals and symposia.

ECEG664 Master's Research (4SH)
Offers investigation of master's research topic under supervision of individual faculty member.

ECEG668 Master's Research (4SH)
Offers investigation of master's research topic under supervision of individual faculty member.

ECEG674 Master of Science Project (4SH)
Offers analytical and/or experimental work leading to a written report and a final exam consisting of a poster session together with a five-minute presentation. The student is required to select an adviser, who will be responsible for the grade, and one other ECE faculty member. All MS projects shall be presented at one poster session together with five-minute presentations scheduled the Friday before final exam week. *Prerequisite: Permission of the Graduate Committee.*

ECEG681 Thesis (1SH)
Offers analytical and/or experimental work conducted under the auspices of the department. *Prerequisite: Bachelor of Science in engineering or science and permission of the department.*

ECEG682 Thesis (2SH)
Offers analytical and/or experimental work conducted under the auspices of the department. *Prerequisite: Bachelor of Science in engineering or science.*

ECEG684 Thesis (4SH)
Offers analytical and/or experimental work conducted under the auspices of the department. *Prerequisite: Bachelor of Science in engineering or science.*

ECEG688 Thesis (8SH)
Offers analytical and/or experimental work conducted under the auspices of the department. *Prerequisite*: Bachelor of Science in engineering or science.

ECEG699 Thesis Continuation (0SH)
Offers analytical and/or experimental work conducted under the auspices of the department. *Prerequisite: Bachelor of Science in engineering or science and permission of the department*

ECEG803 PhD Seminar (0SH)
Requires the student to present a seminar to the Department of Electrical Engineering on a subject related to his/her PhD thesis. The thesis supervisor coordinates the seminar.

ECEG860 PhD Reading (0SH)
Approved material by the candidate's adviser (only S or F grades will be assigned for this course). *Prerequisite: Passing of PhD qualifying exam.*

ECEG864 PhD Research
Investigates doctoral research topic under supervision of individual faculty member. *Prerequisite: Passing of PhD qualifying exam.*

ECEG868 PhD Research (8SH)
Investigates doctoral research topic under supervision of individual faculty member. *Prerequisite: Passing of PhD qualifying exam.*

ECEG890 Dissertation (0SH)
Offers theoretical and/or experimental work conducted under the auspices of the department. *Prerequisite: Passing of PhD qualifying exam.*

ECEG899 Dissertation Continuation (0SH)
Offers continuing dissertation supervision under individual faculty supervision. *Prerequisite: Passing of PhD qualifying exam.*