Catalog Descriptions of Graduate Courses in Electrical and Computer Engineering

(Updated 3/15/2007, Yao Wang)

Changes from 3 unit courses: Most of the 3 credit courses listed here are revised from original 3 unit versions, with added content. In most cases, the old course number is used plus "3" at the end. For example, EL5013 (3 credit) is updated from EL501 (3 unit). In some special cases, the course numbers are changed to be more consistent in numbering. Specifically, EL930 is changed to EL5023, EL970 changed to EL5713. Several new courses have been added, some offered previously as special topics courses. These include EL5213, EL5553/PH5553, EL5663/PH5663, EL6183 (formerly EL912), EL6213, EL6683 (formerly EL961), EL9900.

Note: The last digit in each course number indicates the number of credits for this course. "3" means 3 credits, "1" means 1.5 credits, "x" means variable credits. "Credits: X:Y:Z:Q" means the class meets per week for X lecture periods, Y lab periods, Z recitation period, and earns Q credits. Each period is 50 minutes. For example: 3:0:0:3 means that the class meets for 2 ½ hr per week, without lab or recitation, and if successfully completed 3 credits are earned.

EL5013 Wireless Personal Communication Systems

Description:
Introduction to the underlying principles of wireless communications and practical systems. Science and technology including radio signal propagation, interference-limited communications, multiple access, radio resources management, and mobility management. Building blocks of wireless networks. Essential functions of cellular telephone systems and wireless local area networks. Details of the most important technologies including GSM, CDMA, wideband CDMA, and WiFi (IEEE802.11).

Credits: 3:0:0:3
Pre-Requisite: EE 3404 or equivalent, MA3012

EL5023 Wireless Information Systems Laboratory I

Description:
This course will include hands-on experience including a combination of laboratory experiments, lectures, and projects relating to spread spectrum code division multiple access (CDMA) wireless communication systems. Among the specific topics addressed include pseudo-noise code generation, transmitters and receivers for direct sequence and frequency hopping systems, acquisition and tracking, CDMA wireless computer

communications, UHF channel propagation characteristics including multipath time delay profiles and attenuation measurements, bit error rate measurements, phase locked loops, and spectrum sharing with existing narrowband users.

Credits: 1.5:4.5:0:3
Prerequisites: Graduate student status or EE3404
(Note: Formerly EL930)

EL5033 Wireless Information Systems Laboratory II

Description:
This course will include hands-on experience including a combination of laboratory experiments, lectures and projects relating to basic and advanced topics in wireless communications. Among the specific topics addressed include mixers, IQ modulation, phase locked loops, receiver design, PN code acquisition, smart antennas and RFID.

Credits: 1.5:4.5:0:3
Prerequisites: EL5023
(Note: formerly offered as a special topic course, EL933)

EL5123 Image Processing

Description:
Image formation and perception; image acquisition, representation and display; image sampling and resizing; contrast enhancement; two-dimensional Fourier transform and other unitary transforms; frequency domain and spatial domain linear filtering; median and morphological filtering; image smoothing, sharpening, and edge detection through linear and nonlinear filtering; color image representation and processing; lossless and lossy image coding techniques and standards, image debluring; imaging geometry, image registration and geometric transformation. C- or MATLAB implementation of selected imaging processing algorithms. Co-listed as BE6223.

Credits: 3:0:0:3
Prerequisites: Graduate student status or EE3054 and MA3012

EL5143 Multimedia Laboratory

Description:
This course provides students with hands-on experience in processing and communication of speech, audio, image and video signals. Topics include sampling and quantization, sampling rate conversion, lossless and lossy compression, basic techniques in speech, audio, image and video coding, multimedia conferencing, video-on-demand, video multicasting, multimedia document creation. Students will be exposed to popular

software and hardware for multimedia signal processing and document creation. Each week includes a lecture and a lab.

Credits: 1.5:4.5:0:3
Prerequisites: graduate status or EE3054 or equivalent

EL5213 Introduction to Systems Engineering

Description:
Introduction to fundamentals of systems engineering process. Multi-disciplinary systems methodology, design, and analysis of complex systems. Brief history of systems engineering. Mathematical models. Objective functions and constraints. Optimization tools. Topics to be covered include identification, problem definition, synthesis, analysis, and evaluation activities during conceptual and preliminary system design phases. Decision analysis and utility theory. Information flow analysis in organizations. Elements of systems management, including decision styles, human information processing, organizational decision processes, and information system design for planning and decision support. Basic economic modeling and analysis. Requirements development, life-cycle costing, scheduling, and risk analysis. Application of computer-aided systems engineering (CASE) tools.

Credits: 3:0:0:3
Prerequisites: graduate status
(Note: this is a new course for MSSE)

EL5223 Sensor Based Robotics

Description:
Robot mechanisms, robot arm kinematics (direct and inverse kinematics), robot arm dynamics (Euler-Lagrange, Newton-Euler, and Hamiltonian Formulations), six degree-of-freedom rigid body kinematics and dynamics, quaternion, nonholonomic systems, trajectory planning, various sensors and actuators for robotic applications, end-effector mechanisms, force and moment analysis, introduction to control of robotic manipulators.

Credits: 3:0:0:3
Prerequisites: graduate status. Pre/co-requisite EE3064
Co-requisites: EE3064

EL5253 Applied Matrix Theory

Description:
In-depth introduction to theory and application of linear operators and matrices in finite-dimensional vector space. Determinants, eigenvalues and eigenvectors. Theory of linear equations. Canonical forms and Jordan canonical form. Matrix analysis of differential and difference equations. Singular value decomposition. Variational principles and perturbation theory. Numerical methods.

Credits: 3:0:0:3
Prerequisites: Graduate status, MA2012, MA2132, MA2112 and MA2122

EL5363 Principles of Communication Networks

Description:
This course covers all the fundamental aspects of communications networks. Topics being discussed are: protocol architecture, data transmission and signal encoding, multiplexing, spread spectrum, data link control, local area networks, wireless LAN, circuit switching, packet switching, routing, traffic control, Internet protocol, transport layer protocol, application design and the basics of network security.

Credits: 3:0:0:3
Prerequisites: MA3012 or instructor's permission

EL5373 Internet Architecture and Protocols

Description:
This course introduces the student to some basic local area networking technologies and protocols in a set of lectures and laboratory experiments. Link level protocols. Local area networks: CSMA/CD, Token Ring, IEEE standards and protocols. The Internet protocol suite: IP, ARP, RARP, ICMP, UDP and TCP. LAN Interconnection: bridges, routers and gateways. Application protocols: SNMP, FTP, SMTP and NFS.

Credits: 2.0:3.0:0:3
Prerequisites: EL5363 or EE136

EL5463 Introduction to RF/Microwave Integrated Circuits

Description:
The microwave circuit functions are introduced. The course starts with the concept of noise in microwave circuits and introduction of active RF components and microwave circuits. It follows with a review of microwave network analysis using signal graphs technique. The Smith chart, used for impedance match and stability analysis. Design of

amplifiers, stability analysis and examples. Oscillators and mixers. Transistor oscillators, stability, and dielectric resonator for the stability. Design considerations and examples. Introduction to microwave systems.

Credits: 3:0:0:3
Prerequisites: EE3604

EL 5473 Introduction to VLSI Design

Description:
This course will cover CMOS processing technology, MOS transistor theory, static/dynamic circuit and logic design techniques, circuit performance estimation, standard cells and gate arrays, clocking strategies, input/output structures, datapath, memory, and control logic design. Advanced VLSI CAD tools will be used for schematic capture, layout, timing analysis, and simulations for functionality and performance.

Credits: 3:0:0:3
Prerequisites: CS 2204 & EE 3114 or equivalent

EL5483 Real Time Embedded Systems

Description:
This course is designed to provide students with an overview of the unique concepts and techniques needed to design and implement computer systems having real-time response requirements in an embedded environment. It will contrast the concepts and techniques of real time and embedded systems with those of more traditional computer systems. Topics include: Basic concepts of real time and embedded systems, hardware features, programming languages, real time operating systems, synchronization techniques, performance optimization, and current trends in real time and embedded systems such as incorporating internet connectivity.

Credits: 3:0:0:3
Prerequisites: Knowledge of "C", Pascal or other programming language and a basic understanding of computer architecture.

EL5493 Advanced Computer Hardware Design

Description:
This course will show how a hardware description language (for example, VHDL) can be used for computer hardware modeling, logic synthesis, register-level synthesis and simulation. The resulting design with hundreds or thousands of gates is then ready to be downloaded to form FPGA chips or silicon cells. We plan to use programs such as QuickVHDL, modeling and simulation tools from Mentor Graphics or similar large-scale

programs. A design project is required, and students will make a written and oral presentation.

Credits: 3:0:0:3
Prerequisites: CS 1124, CS 2214 and EE 2024

EL5513 Electro-Optics I

Description:
This course describes the phenomena of and introduces the analyzing techniques for wave propagation in optical systems. Topics covered include: Review of Maxwell equations; propagation of plane waves: polarization, reflection, refraction, interfaces and multilayers; Fourier optics and diffraction; Ray and Gaussian beams; Optical cavities; Guided optical beams, optical fibers and guiding layers; Dispersion and mode distortion in fibers.

Credits: 3:0:0:3
Prerequisites: Graduate status, EE3604 or equivalent

EL5523 Electro-Optics II

Description:
This course focuses on active optical systems. Topics covered include: Resonant optical cavities; Laser oscillation and amplification; General characteristics of lasers, laser excitation; Semiconductor lasers; Detection of optical radiation.

Credits: 3:0:0:3
Prerequisites: Graduate Status, EL 5513

EL5533 Physics of Nanoelectronics

Description:

Limits to the ongoing miniaturization (Moore's Law) of the successful silicon device technology imposed by physical limitations of energy dissipation, quantum tunneling and discrete quantum electron states. Quantum physical concepts and elementary Schrodinger theory. Conductance quantum and magnetic flux quantum. Alternative physical concepts appropriate for devices of size scales of 1 to 10 nanometers, emphasizing role of power dissipation. Tunnel diode, resonant tunnel diode, electron wave transistor; spin valve, tunnel valve, magnetic disk and random access memory; single electron transistor, molecular crossbar latch, quantum cellular automata including molecular and magnetic realizations. Josephson junction and 'rapid single flux quantum' computation. Photo-

and x-ray lithographic patterning, electron beam patterning, scanning probe microscopes for observation and for fabrication; cantilever array as dense memory, use of carbon nanotubes and of DNA and related biological elements as building blocks and in self-assembly strategies. Co-listed as PH5493.

Credits: 3:0:0:3
Prerequisites: PH2004

EL5553 Physics of Quantum Computing

Description:

Limits to the performance of binary computers, traveling salesman and factorization problems, security of encryption. The concept of the quantum computer based on linear superposition of basis states. The information content of the qubit. Algorithmic improvements enabled in the hypothetical quantum computer. Isolated two-level quantum systems, the principle of linear superposition as well established. Coherence as a limit on quantum computer realization. Introduction of concepts underlying the present approaches to realizing qubits (singly and in interaction) based on physical systems. The systems in present consideration are based on light photons in fiber optic systems; electron charges in double well potentials, analogous to the hydrogen molecular ion; nuclear spins manipulated via the electron-nuclear spin interaction, and systems of ions such as Be and Cd which are trapped in linear arrays using methods of ultra-high vacuum, radiofrequency trapping and laser-based cooling and manipulation of atomic states. Summary and comparison of the several approaches. Co-listed as PH.5553.

Credits: 3:0:0:3
Prerequisites: PH2004

EL5613 Introduction to Electric Power Systems

Description:
Basic concepts: single and three-phase circuits, power triangle; transmission lines parameters: resistance, inductance, capacitance, transformers, and generators; lumped-component pi-equivalent circuit representation; per-unit normalization; symmetrical phase components; load-flow program.

Credits: 3:0:0:3
Prerequisites: EE 2024 or equivalent.

EL5663 Physics of Alternative Energy

Description:

Non-petroleum sources of energy include photovoltaic cells, photocatalytic generators of hydrogen from water, and nuclear fusion reactors. The advanced physics of these emerging technical areas will be introduced in this course. Semiconductor junctions, optical absorption in semiconductors, photovoltaic effect. Energy conversion efficiency of the silicon solar cell. Single crystal, polycrystal, and thin film types of solar cells. Excitons in bulk and in confined geometries. Excitons in energy transport within an absorbing structure. Methods of making photocatalytic surfaces and structures for water splitting. Conditions for nuclear fusion. Plasmas and plasma compression. The toroidal chamber with magnetic coils as it appears in recent designs. Nuclear fusion by laser compression (inertial fusion). Small scale exploratory approaches to fusion based on liquid compression and electric field ionization of deuterium gas. Co-listed as PH5663.

Credits: 3:0:0:3
Prerequisites: PH2004

EL5673 Electronic Power Supplies

Description:
Review of power relationships. Power semiconductor switching devices. Rectifiers. Basic PWM dc-dc switching cells. Non-isolated and isolated PWM dc-dc converters. Control of PWM converters. Resonant and soft-switching converters. Low drop-out (LDO) voltage regulators. Switched-capacitor charge pumps. PWM inverters. Applications to computer equipment, portable units, distributed power systems, uninterruptible power supplies, and electric drives. Power quality and EMI issues. American and International standards.

Credits: 3:0:0:3
Prerequisites: EE3824 or equivalent

EL5683 Electric Drives Characteristics and Controls

Description:
Conversion of load (resistive) torque, inertia, mass, and force to a rotating shaft; Acceleration and deceleration times; motor power-rating selection; thermal consideration at different duty cycles; load diagram construction; four-quadrant speed control operation for DC and AC motors; Worked examples.

Credits: 3:0:0:3
Prerequisites: EE 3824 or equivalent.

EL5713 Microwave Engineering Laboratory/Project

Description:

Design, fabrication, testing of passive circuits (couplers and filters), active circuits (amplifier and oscillator) and antennas using printed circuits. Design and stimulation using microwave CAD tools (ADS, HFSS, PCAAMT), HP-8510 automated network analyzer measurement, frequency and time domain measurement, printed circuit layout and photo etching.

Credits: 1.5:4.5:0:3
Prerequisite: EE3604
Co-requisite: EL5733 or EL6713

(formerly EL970)

EL5733 RF and Microwave Systems Engineering

Description:
Review of electromagnetic theory and transmission lines. Printed transmission lines. S, Z, Y, ABCD parameters, network theory, signal flow graphs, CAD methods. Excitation of waveguides. Single and multisection impedance transformer, power divider, directional coupler, hybrid circuits. Microwave resonator: series, parallel resonators, stubs and cavities. Filter theory and designs, coupled-line filters, Kuroda identities, Chebychev and maximally flat filters.

Credits: 3:0:0:3
Prerequisites: Graduate Status or EE3604

EL5753 Introduction to Plasma Engineering

Description:
Basic plasma concepts and applications; parameters describing the plasma; motion of charged particles in electromagnetic fields; effect of particle collisions on plasma transport: diffusion and mobilities. Plasmas as dielectric media; plasma dielectric response functions for collective plasma oscillations and for electromagnetic wave propagation in plasma. Plasmas for practical applications.

Credits: 3:0:0:3
Prerequisites: EE3604

EL5813 Biomedial instrumentation

Description:
This course, intended for graduate students in the Bioengineering Program, introduces them to the principles of some of the most commonly used instruments in neuroscience research, particularly in electrophysiology and imaging. Theoretical considerations in choice of appropriate techniques as well as practical issues in choice of materials and design of experiments will be discussed. Co-listed as BE6503.

Credits: 3:0:0:3
Prerequisites: Advisor approval

EL5823 Biomedical Imaging I

Description:
This course introduces the physics, instrumentation, and signal processing methods used in X-ray imaging (projection radiography), X-ray computed tomography, nuclear medicine (SPECT/PET), ultrasound imaging, and magnetic resonance imaging. Co-listed as BE6203.

Credits: 3:0:0:3
Pre-Requisite: Multivariable calculus (MA2112, MA2122), physics (PH2004), probability (MA3012), Open to graduate students and upper level UG students.
Co-Requisite: signals and systems (EE3054, preferred but not required).
Notes: none

EL6013 Principles of Digital Communications: Modulation & Coding

Description:
Principles of M-ary communication: signal space methods, optimum detection. Fundamental parameters of digital communication systems, various modulation techniques and their performance in terms of bandwidth efficiency and error probability. Efficient signaling with coded waveforms. Block coding and convolutional coding. Joint modulation and coding. Equalization for communication over bandlimited channels. Brief overview of digital communications over fading multipath channels.

Credits: 3:0:0:3
Prerequisites: EE 3404, EL 6303

EL6023 Wireless Communications: Channel Modeling and Receiver Design

Description:
Wireless communication channel models and practical techniques for mitigating transmission impairments. **Channel Modeling Parameters**: Path loss; Fading: long-term vs. short-term fading, flat vs. frequency selective fading, and slow vs. fast fading; Multipath spread parameters: delay spread, angular spread and Doppler spread, Matrix Channel Modeling for Multiple Input and Multiple Output (MIMO) Systems. **Channel Parameter Estimation**: training sequence and blind approaches. **Mitigation:** Mitigation of path loss and fading: Diversity, handoff and power control; Mitigation of intersymbol interference: rake receiver and equalizer; Mitigation of time variation: pilot symbols and dynamic tracking. **Processing Techniques:** LS, zero forcing, MMSE, LMS, etc.

Credits: 3:0:0:3
Prerequisites: EE 3404, MA 3012

EL6033 Modern Wireless Communication Techniques and Systems

Description:
Multiple Access and Multiplexing Techniques; Spread spectrum and Code division multiple access (CDMA) techniques: Direct sequence, Frequency hopping; Multicarrier Techniques: Orthogonal frequency division (OFDM) and Multicarrier CDMA (MC-CDMA); New Wireless Communication Systems: Ultra Wideband communications, Wireless Fidelity (Wi-Fi), Radio Frequency Identification (RFID), Blue Tooth, etc.

Credits: 3:0:0:3
Prerequisites: EE 3404 and EL 6303

EL6063 Information Theory

Description:
Mathematical information measures: entropy, relative entropy and mutual information. Asymptotic equipartition property, entropy rates of stochastic processes. Lossless source encoding theorems and source coding techniques. Channel capacity, differential entropy and the Gaussian channel. Lossy source coding: Rate distortion theory. Brief overview of network information theory.

Credits: 3:0:0:3
Pre-Requisite: Graduate Status, EL 6303

EL6073 Error Control Coding

Description:
General theory of linear codes. Galois fields. Coding and error correction methods. Linear block codes. Convolutional codes. Parallel and serial concatenated codes. Iterative decoding algorithms. Low density parity check codes.

Credits: 3:0:0:3
Prerequisites: EL 6303

EL6113 Signals, Systems and Transforms

Description:
Continuous and discrete linear systems, system function. Fourier transforms, periodic functions, Z transforms, discrete Fourier series, fast Fourier transforms. Magnitude Characteristics of LTI systems, All-pass Systems and Properties. Analog and digital filters, finite order system functions. Digital processing of analog signals. Sampling theorems. Co-listed as BE6403.

Credits: 3:0:0:3
Prerequisites: Graduate status

EL6123 Video Processing

Description:
Analog television systems, Fourier analysis of video signals, properties of the human visual system, video signal sampling and sampling rate conversion, motion modeling and estimation, video compression techniques and standards, stereo video processing and compression, error control in networked video applications, digital video systems. C- or Matlab implementation of selected algorithms. A project is required.

Credits: 3:0:0:3
Prerequisites: EL5123 or EL5143, EL6303

EL6183 Digital Signal Processing Laboratory

Description:
This course includes hands-on experience with a set of laboratory experiments, lectures and projects relating to real-time digital signal processing (DSP) systems using a DSP microprocessor. Students will gain experience in the implementation of common algorithms used in a variety of applications, and will learn tools and functions important for the design of DSP-based systems. Students are required to complete a project and

provide an oral presentation. This course is suitable for students interested in DSP and Embedded Systems. Co-listed as BE6483.

Credits: 1.5:4.5:0:3
Prerequisites: EL 6113 or Equivalent, C/C++

(Note: This is a new course, previously offered as a special topic course, EL912)

EL6213 System Modeling, Analysis and Design

Description:
Introduction of basic system concepts such as system state, inputs, outputs, and disturbances. Modeling methods and Computer Aided Systems Engineering (CASE) formal structures. CASE tools for solving practical systems related problems. Quantitative techniques including linear programming, network flow analysis, integer and nonlinear programming, Petri nets, basic probabilistic and stochastic tools, Markov processes, queueing theory, and Monte Carlo techniques for simulation. Fundamentals of decision and risk analysis.

Credits: 3:0:0:3
Prerequisites: EL5213

(Note: This is a new course for MSSE. EL621 is renamed to EL6243)

EL 6223 Nonlinear and Sampled-Data Control Systems

Description:
Introduction to nonlinear systems. Phase plane analysis, nonlinearities, linearization, limit cycles and averaging. Stability techniques: describing function, Lyapunov functions, Popov locus ad circle criterion. Analysis and design of sampled-data systems by Z-transforms and state variable methods. Semiglobal and global stabilization of nonlinear sampled-data systems.

Credits: 3:0:0:3
Prerequisites: graduate status and EL6253

EL6233 System Optimization Methods

Description:
Formulations of system optimization problems. Elements of functional analysis applied to system optimization. Local and global system optimization with and without constraints. Variational methods, calculus of variations, and linear, nonlinear and

dynamic programming iterative methods. Examples and applications. Newton and Lagrange multiplier algorithms, convergence analysis.
Credits: 3:0:0:3
Prerequisites: Graduate status and EL5253 or EL6253

EL6243 System Theory and Feedback Control

Description:
Design of single-input-output and multivariable systems in frequency domain. Stability of interconnected systems from component transfer functions. Matrix fractions and co-prime factorizations. Parameterization of stabilizing controllers. Introduction to optimization (Wiener-Hopf design).

Credits: 3:0:0:3
Prerequisites: Graduate status and EE3064

EL6253 Linear Systems

Description:
Basic system concepts. Equations describing continuous and discrete-time linear systems. Time domain analysis, state variables, canonical representations, transition matrix, and impulsive response. Time-variable systems. Controllability, observability and stability. SISO pole placement and observer design. Sampled data systems.

Credits: 3:0:0:3
Prerequisites: Graduate status and EE3054 or EL5253

EL6303 Probability Theory

Description:
The axiomatic definition of experiment and probability. Conditional Probability. Bayes' Theorem, Notion of independence. Repeated trials. Bernoulli trials and their limiting forms. The concept of a random variable. Probability distribution and density functions. Probability mass functions. Examples of random variables: Normal(Gaussian), Poisson, Gamma, Exponential, Laplace, Cauchy, Rayleigh, etc. Bayes' Theorem revisited. Functions of one random variable and their density functions. Expected value of a random variable: Mean, Variance, Moments, and Characteristic functions. Two random variables: Joint distribution and joint density functions of two random variables, Independence. One function of two random variables. Two functions of two random variables. Order statistics. Joint moments, Uncorrelatedness, Orthogonality, Joint characteristic function. Jointly Gaussian random variables. Conditional distribution and conditional expected values. The central limit theorem. The principle of maximum

likelihood. Elements of parameter estimation. Maximum likelihood estimation for unknown parameters. Unbiased estimators and their variances. Co-listed as BE6453.

Credits: 3:0:0:3
Prerequisites: Graduate status and MA 3012.

EL6313 Stochastic Processes

Description:
Random Variables, Random vectors and Random processes; Second order characterization of stochastic processes, Autocorrelation and covariance functions, Special processes: Poisson process, Wiener process and White noise process. Stationary processes, Types of stationarity: Strict sense stationary and Wide sense stationary processes, Gaussian processes, Memoryless processes. Linear Systems with random inputs, Input-output Autocorrelation relations, Input-output Stationarity properties. Ergodicity and related results. Wide sense stationary processes, Autocorrelation function and power spectra. Spectral theory for linear systems. Rational spectra, Hilbert transforms, shot noise, thermal noise. Discrete time processes, Spectral factorization, Matched filters. Integral equations and series representation of stochastic processes: Karhunen Loeve (KL) expansion. Modulation, Band limited processes and sampling theory. Mean square estimation and the orthogonality principle. Linear Prediction and its Geometric interpretation. Levinson Recursion for one step predictors. Mean square estimation and normality. Mean square error for one and multi-step predictors. Smoothing and prediction as applications of orthogonality principle.

Credits: 3:0:0:3
Prerequisites: Graduate status and EL6303.

EL6333 Detection and Estimation Theory

Description:
Detection Theory: Binary Hypothesis Testing: Bayes' Criteria; Likelihood Ratio Test; min-max test; Neyman-Pearson Tests; Receiver Operating Characteristics. Parameter Estimation Theory: Random parameter Estimation. Bayes' Procedure; Minimum Mean Square Error (MMSE) Estimator, Maximum A-Posteriori (MAP) Estimator. Nonrandom Parameter Estimation: MAP Estimator; Unbiased Estimators and Cramer-Rao(C-R) Bound; Higher Order Bhattacharya Bounds. Uniformly Minimum Variance Unbiased Estimators (UMVUE); Sufficient Statistic; Factorization Theorem; Rao-Blackwell Theorem. Multi-Parameter Estimation; Fisher Information Matrix. Composite Hypothesis Testing; Series Representation of Stochastic Processes with Rational spectra; Detection of distinct signals in white noise and colored noise; M-ary Detection and Estimation of signals in white noise and colored noise. Blind Channel Identification. Elements of signal design for white Gaussian noise. M-ary waveform design for two-dimensional signals.

Credits: 3:0:0:3
Prerequisites: Graduate status and EL 6303.

EL6373 Local and Metropolitan Area Networks

Description:
The purpose of this course is to introduce students to the fundamental design issues in wireless and wired local and metropolitan area networks, explain the state-of-the-art solutions proposed and deployed in the field by using latest standards and protocols as examples, and discuss the trends in the wireless/wired LAN/MANs. Example wireless technologies covered include the IEEE 802 family of protocols, e.g., WiFi, WiMax and Bluetooth. Example wireline technologies include those associated with Ethernet, and MAN technologies such as Resilient Packet Ring.

Credits: 3:0:0:3
Prerequisites: EL5363 or EE136 or instructor's permission

EL6383 High-Speed Networks

Description:
This course covers the basics, architectures, protocols, and technologies for high-speed networks. Topics to be included are: synchronous optical network (SONET), asynchronous transfer mode (ATM), ATM adaptation layer (AAL), 10/100/1000/10G Ethernet, Ethernet over SONET (EOS), quality of service control, packet scheduling, network processor, buffer management, flow and congestion control, TCP, high-speed TCP and XCP, Routing and IP fast rerouting, WDM networks, MPLS and GMPLS. Each student is also required to complete a project that could be reading, software design or hardware design.

Credits: 3:0:0:3
Prerequisites: Graduate status, EL 5363 or EE 136 or equivalent

EL6393 Advanced Network Security

Description:
While the recent proliferation of broadband wireline and wireless networking technologies have substantially increased the available network capacity and enabled a wide-range of feature-rich high-speed communication services, security remains a major concern. Network attacks have become common recurring events which increasing threaten the proper functioning and continual success of the communication infrastructure and services. One key aspect of mitigating such increasing threats is to develop new security/defense architectures, systems, methodologies and algorithms which can scale together with the communications infrastructure in terms of operating speed, operational

simplicity and manageability etc. The goal of the course is to understand the theoretical, architectural, system and implementation issues related to all aspects of security in high-speed networks, and study various proposed solutions. Students are required to read research papers, and complete a term project with either simulation programs to evaluate the proposed schemes, or architecture/VHDL designs for the schemes.

Credits: 3:0:0:3
Prerequisites: CS6823 or advisor approval

EL6413 Analog and High Frequency Amplifier Design

Description:
Basic semiconductor physics, small-signal low frequency models for bipolar junction transistors, biasing, and temperature compensation techniques. Physics, models, and biasing of field-effect transistors. High frequency models. Single and multistage broadband small signal amplifiers. Harmonic distortion analysis of amplifiers. Emitter follower analysis at high frequencies. Complete design and analysis of operational amplifiers (Op-Amp) analog integrated circuits. Nonlinear Op-Amp applications. Circuit design techniques to increase Op-Amp slew rate.

Credits: 3:0:0:3
Prerequisites: Graduate student status or EE3114 and EE3124

EL6423 RF Electronics for Wireless Applications

Description:
Tuned circuits and impedance transformers, narrowband nonlinear amplifiers. Tuned circuit sine wave oscillators, mixers, AM modulators and demodulators, FM modulators and demodulators, and the phase-locked loop

Credits: 3:0:0:3
Prerequisites: EL6413

EL6433 Digital Integrated Circuit Design

Description:
Analysis and design of digital integrated circuits. Circuit analysis of piecewise linear single energy storage element networks. Rules for determining states of diodes and transistors. Bipolar junction and field effect transistors as switches. Basic digital logic gates. Integrated circuit logic and building blocks (TTL, MOS, CMOS, ECL, integrated injection logic). Sweep circuits (constant current, Miller, bootstrap), monostable, astable, and bistable (Schmitt Trigger) switching circuits. Applications (pulse width modulator, triangle wave generator, FM function generator design).

Credits: 3:0:0:3
Prerequisites: EL6413

EL 6443 VLSI System and Architecture Design

Description:
A continuation of EL 5473/5474, this course covers top-down VLSI design using VHDL including structural design, modeling, algorithmic and register level design, synthesis, prototyping and implementation using FPGAs, and methods to design for test (DFT). This course provides students with a solid background and hands-on experiences with the CMOS VLSI design process where custom design techniques (covered in EL 5473) are married with HDL synthesis to produce complex systems. As part of the course requirements, students will complete a project covering design partitioning, placement and routing, automated synthesis, and standard cell design and use. The course will explore how these techniques are used in the design of ASICs, System-on-Chips (SoC), and advanced microprocessors.

Credits: 3:0:0:3
Prerequisites: EL 5473 or equivalent

EL6583 Fiber Optic Communications

Description:
This course deals with the operating principles of optical communications systems and fiber-optic communication technology. The main elements of systems will be presented in block diagrams and discussed individually. The advantages and disadvantages and the applications of Fiber Optic Communications Systems will be discussed. Topics covered include: overview of optical communication systems, review of optics, review of analog and digital communications, the characteristics of optical fibers, optical waveguides, optical sources and transmitters, optical detectors and receivers, optical amplifiers, noise and detection, impairment in optical communication systems, and optical network design issues. Upon completion of this course, students are expected to be familiar with the principles and technology of optical communication systems, and to be able to design a simple point-to-point optical communications link, including bandwidth, loss, signal to noise ratio (S/N) and bit error rate considerations.

Credits: 3:0:0:3
Prerequisites: Graduate status or EE3604

EL6603 Power Electronics

Description:
Principles of thyristor devices, GTOs, MOSFETs, IGBTs; dynamic characteristics of DC/DC converters; forced commutation circuits; switched-mode power supplies; full-wave, and half-wave rectifiers; phase controlled converters; effect of the load characteristics; pulse-width modulated inverters.

Credits: 3:0:0:3
Prerequisites: Graduate status and EE3824 or equivalent.

EL6623 Power Systems Economics and Planning

Description:
Power system economics: revenue requirements, load duration and reserve requirements. Load forecasting: econometric methods. Optimal expansion planning and methodologies: optimal generation expansion computer modeling. Decision analysis techniques. Deregulation of electric power industry.

Credits: 3:0:0:3
Prerequisites: Graduate status and EL5613 or equivalent

EL6633 Transients, Surges and Faults in Power Systems

Description:
Analysis of lumped-circuit, normal and abnormal transients in power equipment and systems. Short-circuit fault analysis and transient recovery of three-phase circuits. Analysis of traveling-wave surges on transmission lines, windings and integrated systems.

Credits: 3:0:0:3
Prerequisites: Graduate status and EL5613 or equivalent

EL6643 Relay Fault Protection

Description:
Protective relay functions and classification. Electromechanical relay types, operating principles and basic characteristics. Communication channels for relaying. Current and voltage transformers, transducers. Protection of busses, transformers, generators, motors, and other station equipment by the zone protection method. Distribution and transmission line relaying systems. Relay setting calculations. Primary and backup protection, application and philosophy with applied relay engineering examples.

Credits: 3:0:0:3
Prerequisites: Graduate status and EL5613 or equivalent

EL6653 Power System Stability

Description:
Introduction to the study of power system dynamics: mathematical modeling of prime movers, power plants, synchronous machines, field exciters transmission lines, relay loads and stabilizers.

Credits: 3:0:0:3
Prerequisites: Graduate status, EE3824, EL5613

EL6663 Distributed Generation Systems

Description:
Benefits and limitations; classification of small generating systems; principles of operation and equivalent circuits of fuel cells, solar cells, micro-turbine, reciprocating engines, wind turbines, and gas turbines; interconnection with the electric utility issues; fault condition assessment (unsymmetrical faults - open-lines); reactive power support; power quality issues.

Credits: 3:0:0:3
Prerequisites: EE 3824 and EL5613 or equivalent.

EL6683 Adjustable Speed Drives

Description:
Electric circuits and power electronics for drives. Magnetic circuits and electromechanical energy conversion. Feedback controllers for electric drives. DC motor drives. AC machines and space vectors. Permanent magnet ac and synchronous drives. Induction motors and drives. Vector control of induction drives. DQ reference frame. Reluctance machines and drives. Power quality and energy efficiency of electric drives. Matlab/Simulink mini project in a selected drive control.

Credits: 3:0:0:3
Prerequisites: Graduate status and EE 3824 or equivalent.

(Note: This is a new course, formerly a special topic course, EL961)

EL6713 Electromagnetic Theory and Applications

Description:
This course introduces Maxwell's equations, wave equation, vector potentials, boundary conditions and Poynting vector. Time-harmonic fields and phasor approach are introduced. The properties of freely propagating plane waves in uniform and layered media are derived, as well as waves guided by structures, including various transmission lines, hollow waveguides, and dielectric waveguides. A unified treatment of wave propagation is given with general theorems and examples drawn from microwaves, integrated circuits and optics.

Credits: 3:0:0:3
Prerequisites: Graduate status and EE 3604.

EL6723 Electromagnetic Radiation and Antennas

Description:
The electromagnetic fields radiated by current elements are derived from Maxwell's equations. From these results, the fields radiated by many types of antennas are derived, including various types of dipoles, arrays, aperture, and frequency independent and traveling wave antennas. Concepts such as radiation resistance and pattern, directivity, gain, effective area, reciprocity, bandwidth, noise temperature, mutual coupling and array scanning impedance are introduced.

Credits: 3:0:0:3
Prerequisites: Graduate status and EL6713, or EL3604 with grade B or better.

EL6753 UHF Propagation for Wireless Systems

Description:
UHF radio applications for cellular mobile radio telephones, wireless local area networks and personal communications networks. Propagation and reflection of plane waves and spherical waves; antennas for transmitting and receiving; path loss and link budgets; Huygens' principle; Fresnel zone and diffraction of plane and spherical waves; mathematical models of UHF propagation over a flat earth, around buildings in cities and within buildings; influence of propagation on capacity of cellular systems. (This course is based on EL 675. It includes the same topics and requirements, with additional on plane wave reflection and transmission and on propagation within buildings.)

Credits: 3:0:0:3
Prerequisites: Graduate status and undergraduate electromagnetics course.

EL6823 Biomedical Imaging II

Description:
This course introduces the mechanisms and concepts related to image acquisition and subsequent image processing and image formation in various biomedical imaging modalities. Building on material covered in Biomedical Imaging I, these courses focus on advanced topics such as functional magnetic resonance imaging (MRI), ultrasound imaging, biomagnetic imaging and optical tomographic imaging (OTI). Colisted as BE6213.

Credits: 3:0:0:3
Pre-Requisite: BE 6203/EL5823.
Co-Requisite: none.

EL7023 Space-Time Wireless Communications

Description:
The course provides an introduction to Multiple-Input Multiple-Output (MIMO) wireless communication systems. MIMO system capacity, MIMO system design criteria. Space-time block and trellis codes. Spatial multiplexing and receiver design. Applications to MIMO OFDM systems.

Credits: 3:0:0:3
Prerequisites: EL 6303
Co-requisites: EL 6013 or EL 6023

EL7133 Digital Signal Processing

Description:
Properties and applications of the discrete Fourier transform and FFT. Frequency measurement. Properties and design of linear-phase FIR digital filters by windowing, least-squares, and minimax criterion. Spectral factorization and design of minimum-phase FIR filters. Design of recursive digital filters. Short-time Fourier transform. Finite precision effects. Multirate systems. Basic spectral estimation. Basic adaptive filtering (LMS algorithm). Computer-based exercises will be given regularly.

Credits: 3:0:0:3
Prerequisites: EL 6113 or Equivalent

EL7153 Array Signal Processing

Description:
General sonar and radar array processing concepts. Array performance considerations. Narrowband and broadband signal processors. Classical and high resolution techniques for source direction finding. Eigenstructure-based techniques and spatial smoothing techniques. Performance analysis of eigenstructure-based techniques. Asymptotic distribution of eigenparameters associated with smoothed sample covariance matrices in uncorrelated and coherent scenes. Wiener solution and adaptive algorithms. Least Mean Square (LMS), accelerated gradient search and gradient algorithms with constraints. Direct implementation by inversion of the sample covariance matrix and transient response considerations. Smart antenna design concepts for Rayleigh fading cellular communication channels. Space Time Adaptive Processing (STAP) for ground and air moving target detection.

Credits: 3:0:0:3
Prerequisites: Graduate status, EL 6113 and EL 6313
(This is a new course)

EL7163 Wavelet Transforms and Filter Banks

Description:
Orthogonal and biorthogonal wavelet bases on the real line. Scaling functions and the dilation equation. Construction of Daubechies wavelet bases. Mallat's algorithm. Digital filter banks and the discrete wavelet transform. Two-dimensional wavelet transform and applications to image processing. Wavelet-based noise reduction. Lattice and lifting structures for implementation of filter banks. Expansive (over-complete) transforms. Additional applications. Students are required to complete a project and provide an oral presentation. Regular computer-based exercises are given.

Credits: 3:0:0:3
Prerequisites: EL 7133
(Note name change)

EL7253 State Space Design for Linear Control Systems

Description:
Topics to be covered include canonical forms; control system design objectives; feedback system design by MIMO pole placement; MIMO linear observers; the separation principle; linear quadratic optimum control; random processes; Kalman filters as optimum observers; the separation theorem; Sampled-data systems; microprocessor-based digital control; robust control, and the servo-compensator problem.

Credits: 3:0:0:3
Prerequisites: Graduate status and EL6253

EL7353 Communication Networks 1: Analysis , Modeling and Performance

Description:
The purpose of this course is to introduce students to the analytical techniques used in the design and performance analysis of networks. Building on their knowledge of networking technology and applied mathematics, especially probability, students will start by learning basic queueing theory. This will be applied to the performance analysis of multiplexers, switches, and multiple access networks. Newer techniques such as the network calculus, the study of non-Poissonian long range dependent traffic sources, and applications to TCP, admission control, advanced packet switches and IEEE 802.11 networks will be introduced.

Credits: 3:0:0:3
Prerequisites: EL 5363 and EL 6303

EL7363 Communications Networks II: Design and Algorithms

Description:
Network design consists of topology design and traffic routing taking into account dynamics in network states, such as link/node failures and traffic demand variations. Efficient design models and optimization methods are crucial to simultaneously achieve good network user performance and high savings in network deployment and maintenance. This course introduces mathematical models, design problems and optimization algorithms that can be used to guide network design practice. Subjects to be covered include: Network Design Problem Modeling, Optimization Methods, Multi-Commodity Flow Routing, Location and Topological Design, Fair Networks, Resilient Network Design, Robust Network Design, Multi-Layer Networks.

Credits: 3:0:0:3
Prerequisites: Graduate Status, EL5363 or EE136

EL7373 High Performance Switches and Routers

Description:
This course addresses the basics, the theory, architectures, and technologies to implement high-performance high-speed large-scale routers and switches. The fundamental concepts and technologies of packet forwarding, classification, and switching learned in the class are useful and practical when designing IP routers, Ethernet switches, and optical switches. Topics to be included are: IP Route Lookup, Packet Classification, Packet Scheduling, Buffer Management, Basics of Packet Switching, Output-buffered Switches, Shared-memory Switches, Crosspoint-buffered Switches, Input-buffered Switches, Clos-network Switches, Multi-Stage Buffered Switches, Two-Stage Load-Balanced Switches, Optical Packet Switches, and ASIC for IP Routers..

Credits: 3:0:0:3
Prerequisites: EL5363 or advisor approval

EL8223 Applied Nonlinear Control

Description:
Stability and stabilization for nonlinear systems; Lyapunov stability and functions, input-output stability, and control Lyapunov functions. Differential geometric approaches for analysis and control of nonlinear systems: controllability, observability, feedback linearization, normal form, inverse dynamics, stabilization, tracking, and disturbance attenuation. Analytical approaches: recursive backstepping, input-to-state stability, nonlinear small-gain methods, and passivity. Output feedback designs. Various application examples for nonlinear systems including robotic and communication systems.

Credits: 3:0:0:3
Prerequisites: Graduate status and EL6253 or EL7253

EL8233 Optimal Control Theory

Description:
Optimal control problem for deterministic systems with various constraints. Solution for both continuous and discrete-time systems using the maximum principle and dynamic programming. Singular arcs. Neighboring-optimal solutions. Fuel and time optimal control problems. Computational methods.

Credits: 3:0:0:3
Prerequisites: Graduate status, EL6233 and EL6253

EL8253 Large-Scale Systems and Decentralized Control

Description:
Introduction to analysis and synthesis of large-scale systems. System order reduction algorithms, interconnected system stability, series expansion and singular perturbation. Lyapunov designs. Applications to traffic networks, power systems, and transportation networks. Decentralized control: decentralized fixed-mode, LQR, frequency-shaped cost functionals and overlapping decompositions. Stability of interconnected systems and Vector Lyapunov analysis.
Credits: 3:0:0:3
Prerequisites: Graduate status and EL7253 or instructor’s permission.

EL 90x3 Selected Topics in Wireless Communication (x=1,2,…9)

Description:
Selected topics of current interest in wireless communications. (See departmental mailing for detailed description of each particular offering.)

Credits: 3:0:0:3
Pre-Requisite: Specified when offered

EL 91x3 Selected Topics in Signal Processing (x=1,2,…9)

Description:
Selected topics of current interest in signals and systems. (See departmental mailing for detailed description of each particular offering.)

Credits: 3:0:0:3
Pre-Requisite: Specified when offered

EL 92x3 Selected Topics in Control Systems (x=1,2,…9)

Description:
Topics of current interest to feedback and control system engineers. (See department mailing for detailed description of each particular offering.)

Credits: 3:0:0:3
Pre-Requisite: Specified when offered

EL 93x3 Selected Topics in Telecommunications and Networking (x=1,2,…9)

Description:
Selected topics of current interest in telecommunications and networking. (See departmental mailing for detailed description of each particular offering.)

Credits: 3:0:0:3
Pre-Requisite: Specified when offered

EL 94x3 Selected Topics in Computer Electronic Devices and Systems (x=1,2,…9)

Description:
Special topics of current interest in the field of electronic devices, circuits and systems. (See departmental mailing for detailed description of each particular offering.)

Credits: 3:0:0:3
Pre-Requisite: Specified when offered

EL 95x3 Selected Topics in Electro-Optics, Quantum Electronics and Material Science (x=1,2,…9)

Description:
Topics of current interest dealing with the interaction of matter with electromagnetic fields. (See department mailing for detailed description of each particular offering.)

Credits: 3:0:0:3
Pre-Requisite: Specified when offered

EL 96x3 Selected Topics in Power Engineering (x=1,2,…9)

Description:
Topics of current interest in electric power engineering. (See departmental mailing for detailed description of each particular offering.

Credits: 3:0:0:3
Pre-Requisite: Specified when offered

EL 97x3 Selected Topics in Electrodynamics, Wave Phenomena and Plasmas (x=1,2,…9)

Description:
Topics of current interests in plasmas, electromagnetic and acoustic wave propagation, diffraction and radiation of current interest, including wave interactions with plasmas, materials and special mathematical and numerical techniques. (See departmental mailing for detailed description of each particular offering.)

Credits: 3:0:0:3
Pre-Requisite: Specified when offered

EL 9900 Seminar in Electrical and Computer Engineering

Description:
Recent developments in electrical and computer engineering are presented through lectures given by invited speakers from industry, research and educational institutions. To receive a satisfactory grade for the semester registered, a student must attend at least two

thirds of the seminars during the semester. A Ph.D candidate must register and obtain satisfactory grade for at least four semesters to satisfy the Ph.D degree requirement.

Credits: 0
Pre-requisite: none.

(Note: This is a new course, required for PhD candidates.)

EL 9920 Graduate Internship

Description:
This course provides graduate students majoring in electrical engineering, computer engineering, electrophysics, systems engineering, telecommunication networks or wireless innovation the opportunity to gain practical training off campus. Such training will enhance and strengthen the students overall educational experience by obtaining practical experience in currently active areas in industry. Adviser approval is required.

Credits: 0
Pre-Requisite: Graduate Status and at least one semester of regular graduate course work

EL 9933 Readings in Electrical and Computer Engineering I

Description:
Reading of advanced literature in a research field relevant to electrical and computer engineering, conducted under guidance of a faculty member who is expert in the field. Oral presentation or a written report is required at the discretion of the adviser. Not more than 3 credits may be counted toward the Master's degree.

Credits: 3
Pre-Requisite: Graduate Student Status

EL 9943 Readings in Electrical and Computer Engineering II

Description:
Reading of advanced literature in a research field relevant to electrical and computer engineering, conducted under guidance of a faculty member who is expert in the field. Oral presentation or a written report is required at the discretion of the adviser. Not more than 3 credits may be counted toward the Master's degree.

Credits: 3
Pre-Requisite: Graduate Student Status.

EL 9953 Advanced Projects I

Description:
Theoretical and/or experimental projects in various research areas in electrical and computer engineering. Projects assigned on basis of specialized interest and preparation of the student and conducted under guidance of a faculty member who is expert in the chosen subject. Oral presentation or a written report is required at the discretion of the adviser.

Credits: 3
Pre-Requisite: Graduate Student Status

EL 9963 Advanced Projects II

Description:
Theoretical and/or experimental projects in various research areas in electrical and computer engineering. Projects assigned on basis of specialized interest and preparation of the student and conducted under guidance of a faculty member who is expert in the chosen subject. Oral presentation or a written report is required at the discretion of the adviser.

Credits: 3
Pre-Requisite: Graduate Student Status

EL 997x Thesis for Degree of Master of Science in Electrical Engineering, Computer Engineering, Electrophysics, or System Engineering

Description:
Independent engineering project demonstrating professional maturity, preformed under guidance of adviser. Oral thesis defense and formal, bound thesis volume required. Registration of at least 6 credits required (continuous registration required).

Credits: variable
Pre-Requisite: Graduate Student Status

EL 999x Dissertation for Degree of Doctor of Philosophy in Electrical Engineering

Description:
Original investigation of electrical engineering problem. Must demonstrate creativity and include features of originality and utility worthy of publication in recognized journals. Candidate must successfully defend dissertation orally. Registration of at least 21 credits required (continuous registration required).

Credits: variable
Pre-Requisite: Passing Ph.D qualifying examination.