

# ELECTRICAL AND COMPUTER ENGINEERING

## ECE

### Department of Electrical and Computer Engineering College of Engineering

#### 201 Circuits and Systems I

Fall, Spring, Summer. 3(3-0) P:M: ((CSE 131 or concurrently) or (CSE 231 or concurrently)) and ((MTH 234 or concurrently) or (MTH 254H or concurrently) or (LBS 119 or concurrently)) SA: ECE 200

Resistive circuits. Loop and modal analysis. Network theorems, dependent sources. Capacitor and inductor circuits. Transient analysis. Introduction to computer-aided design.

#### 202 Circuits and Systems II

Fall, Spring, Summer. 3(3-0) P:M: ECE 201 and ((MTH 235 or concurrently) or (LBS 119 or concurrently) or (MTH 255H or concurrently)) SA: ECE 360

Sinusoidal steady-state response. Laplace transforms. S-Domain circuit analysis. Frequency response. Fourier series. Mutual inductance. Power in sinusoidal steady state.

#### 230 Digital Logic Fundamentals

Fall, Spring, Summer. 3(3-0) P:M: CSE 131 or CSE 231 SA: ECE 330

Binary information. Switching algebra, combinational logic, minimization. Programmable logic devices. Sequential system fundamentals and state machines. Arithmetic operations and circuits. Memory elements and systems. Design tools. Design problems.

#### 280 Electrical Engineering Analysis

Fall, Spring. 3(3-0) P:M: MTH 234 and (ECE 201 or concurrently)

Application of linear algebra, complex numbers, vectors, probability, and random processes to elementary problems in electrical and computer engineering. Application to signals, systems, noise, electromagnetics, and reliability. Modeling using standard software packages.

#### 302 Electronic Circuits

Fall, Spring. 3(3-0) P:M: ECE 202 R: Open only to students in the Department of Electrical and Computer Engineering or Department of Computer Science and Engineering. SA: EE 302

Volt-ampere characteristics of diodes and transistors. Modeling using SPICE software. Differential, multistage, and integrated circuit amplifiers. High frequency effects.

#### 303 Electronics Laboratory

Fall, Spring. 1(0-3) P:M: ECE 202 and (ECE 302 or concurrently) R: Open only to students in the Department of Electrical and Computer Engineering or Department of Computer Science and Engineering. SA: EE 303

Electronic test equipment and measurement fundamentals.

#### 305 Electromagnetic Fields and Waves I

Fall, Spring, Summer. 4(4-0) P:M: ((MTH 235 or concurrently) or (LBS 119 or concurrently) or (MTH 255H or concurrently)) and (PHY 184 or PHY 184B or PHY 234B) R: Open only to students in the Department of Electrical and Computer Engineering. SA: EE 305

Transient and time-harmonic transmission lines. Smith charts. Two-port networks. Maxwell's equations. Force, energy, and power. Plane electromagnetic waves. Guided waves.

#### 313 Control Systems

Fall, Spring. 3(3-0) P:M: ECE 202 or ECE 345 R: Open only to juniors or seniors or graduate students in the Department of Electrical and Computer Engineering and Department of Computer Science and Engineering. SA: EE 413, ECE 413

Analysis and design of control systems using transfer functions and state variable methods.

#### 320 Energy Conversion and Power Electronics

Fall, Spring. 3(3-0) P:M: ECE 302 and ECE 303 and ECE 305 SA: EE 320

Power and energy. Magnetics and transformers. Elementary and induction machines. Power semiconductor. Controlled rectifiers and inverters. Power supplies and motor drives.

#### 331 Microprocessors and Digital Systems

Fall, Spring. 4(3-3) P:M: CSE 231 and ECE 230 R: Open only to juniors or seniors or graduate students in the Department of Electrical and Computer Engineering. SA: EE 331

Microcomputers. Microprocessor architecture. Addressing modes. Assembly language programming. Parallel and serial input and output. Interfacing. Interrupts. Peripheral device controllers. Applications, design.

#### 345 Electronic Instrumentation and Systems

Fall, Spring, Summer. 3(2-3) P:M: (MTH 235 or MTH 255H or LBS 119) and ((PHY 184 or PHY 184B or PHY 234B) and completion of Tier I writing requirement) R: Open only to students in the College of Engineering with the exception of students in the Department of Electrical and Computer Engineering. SA: EE 345

Electrical and electronic components, circuits and instruments. Circuit laws and applications, frequency response, operational amplifiers, semi-conductor devices, digital logic, counting circuits.

#### 366 Introduction to Signal Processing

Fall of even years, Spring, Summer. 3(3-0) P:M: ECE 202 R: Open only to students in the Department of Electrical and Computer Engineering. SA: ECE 360

Continuous- and discrete-time signal analysis fundamental to modern signal processing and communications technologies. Fourier and spectral analysis of signals. Elementary modulation techniques. Filtering and channel models. The z-transform. Introduction to random processes and noise in discrete time. Application examples.

#### 402 Applications of Analog Integrated Circuits

Spring. 4(3-3) P:M: ECE 302 and ECE 303 R: Open only to juniors or seniors or graduate students in the Department of Electrical and Computer Engineering. SA: EE 484, ECE 484

Circuit design using analog integrated circuits. SPICE macromodeling. Operational amplifiers, comparators, timers, regulators, multipliers and converters. Design project with hardware and software verification.

#### 405 Electromagnetic Fields and Waves II

Fall. 4(3-3) P:M: ECE 305 R: Open only to juniors or seniors or graduate students in the Electrical Engineering major and to juniors or seniors in the Computer Engineering major. SA: ECE 435

Microwave networks. Scattering parameters. Solutions to Coulomb's law, Gauss' Law and the wave equation. Planar transmission lines. Antennas. Waveguides and cavities. Measurement of the properties of antennas and microwave networks.

#### 407 Electromagnetic Compatibility

Spring. 4(3-3) P:M: ECE 202 and ECE 305 and ECE 366 R: Open only to juniors or seniors or graduate students in the Electrical Engineering major and juniors or seniors in the Computer Engineering major.

Electromagnetics for electrical systems. Signals and spectra. Regulations. Radiated and conducted emissions. Conducted and radiated immunity. Mitigation techniques.

#### 410 VLSI Design

Fall, Spring. 4(3-3) P:M: ECE 302 and ECE 303 and ECE 230 R: Open only to juniors or seniors or graduate students in the Department of Electrical and Computer Engineering or Department of Computer Science and Engineering. SA: EE 410

Digital integrated circuit design fundamentals. Design specifications: functionality, performance, reliability, manufacturability, testability, cost. Standards, silicon compilers, foundries. Design layout rules, rule checking. Circuit extraction, simulation, verification. Team-based design.

#### 411 Electronic Design Automation

Fall, Spring. 4(3-3) P:M: CSE 320 or ECE 331 R: Open only to juniors or seniors or graduate students in the Department of Electrical and Computer Engineering or Department of Computer Science and Engineering. SA: EE 411

Electronic circuit design hierarchy and the role of methodology. Application specific integrated circuits. Hardware description languages. Behavioral and structural circuit modeling. Design algorithms and design tools. Design projects.

#### 415 Computer Aided Manufacturing

Fall. 3(2-3) P:M: ECE 313 or ME 451 R: Open only to juniors or seniors in the Manufacturing Engineering major. SA: EE 415

CAD/CAM fundamentals, programmable controllers, numerical control, NC part programming, sensors, data acquisition systems.

## Electrical and Computer Engineering—ECE

- 416 Digital Control**  
Spring. 3(2-3) P:M: ECE 303 and ECE 313  
R: Open only to juniors or seniors in the Electrical Engineering major or Computer Engineering major.  
State-space models. Analysis and design of control systems using state models. Digital control. Discrete-models of sampled-data systems. Quantization effects and sample-rate selection. System identification. Simulation of nonlinear control systems. Examples of nonlinear phenomena. State of the art of control engineering. Control laboratory.
- 418 Algorithms of Circuit Design**  
Fall. 3(3-0) P:M: ECE 302 and ECE 303 and ECE 366 R: Open only to juniors or seniors or graduate students in the Department of Electrical and Computer Engineering. SA: EE 418  
Design of analog electrical circuits, filter functions, ladder synthesis, inductor simulation. Vector Newton-Raphson method. Lossy inductance and capacitance. Statistical tolerance analysis. Optimization by multi-dimensional search. Software algorithms.
- 420 Machines and Power Laboratory**  
Spring. 1(3-0) P:M: (ECE 320 or concurrently) or (ECE 423 or concurrently) R: Open only to juniors or seniors in the Department of Electrical and Computer Engineering.  
Experimental investigation of machines, power electronics and power systems. Experimental verification of material found in introductory courses on energy conversion with extension to power electronics and power systems.
- 423 Power System Analysis**  
Spring. 3(3-0) P:M: ECE 320 R: Open only to juniors or seniors in the Department of Electrical and Computer Engineering. SA: ECE 421  
Synchronous machines. Models and measurements of power components. Symmetrical components. Short-circuit analysis and equipment protection. Load flow. Voltage and frequency control. Operation and planning of power systems.
- 457 Communication Systems**  
Spring. 3(3-0) P:M: ECE 302 and ECE 366 R: Open only to juniors or seniors or graduate students in the Department of Electrical and Computer Engineering. SA: EE 457  
Representation and processing of signals in the presence of noise. System performance. Modulation, detection, and coding of information. System design applications in radar, sonar, radio, television, satellite communications, digital telephony, and wireless systems.
- 458 Communication Systems Laboratory**  
Spring. 1(0-3) P:M: ECE 303 and (ECE 457 or concurrently) SA: EE 458  
A projects laboratory in communication systems.
- 466 Digital Signal Processing and Filter Design**  
Fall. 3(3-0) P:M: ECE 366 R: Open only to seniors or graduate students in the Department of Electrical and Computer Engineering. SA: EE 466  
Discrete Fourier transforms, sampling theorem, circular convolution, Z-transforms. Design of infinite impulse resistance filters using prototypes and algorithmic methods. Design of finite impulse resistance filters by windowing, frequency sampling.
- 474 Principles of Electronic Devices**  
Fall, Spring. 3(3-0) P:M: ECE 302 and ECE 305 SA: EE 474  
Energy levels in atoms. Crystal properties, energy bands and charge carriers, semiconductors, transport properties of bulk materials. P-n junction diodes, bipolar transistors, field effect transistors.
- 476 Electro-Optics**  
Fall, Summer. 4(3-3) P:M: ECE 302 and ECE 303 and ECE 305 R: Open only to juniors or seniors in the Computer Engineering major. SA: EE 476  
Operational theory, characteristics and applications of optical components, light emitting diodes, lasers, laser diodes, photodetectors, photovoltaics, fiber optics, optical modulators and non-linear optical devices.
- 477 Microelectronic Fabrication**  
Fall. 3(2-3) P:M: ECE 474 or concurrently R: Open only to juniors or seniors in the Department of Electrical and Computer Engineering. SA: ECE 483  
Microelectronic processing fundamentals and simulations. Comparison of current microfabrication technologies and their limitations.
- 480 Senior Design**  
Fall, Spring. 5(3-6) P:M: ECE 303 and ECE 313 and ECE 320 and ECE 331 and ECE 366) or (CSE 410 and CSE 420 and completion of Tier I writing requirement. R: Open only to seniors in the Department of Electrical and Computer Engineering. SA: ECE 481, ECE 482, ECE 483  
Electrical engineering and computer engineering senior design experience involving contemporary design tools and practices, engineering standards, ethics, cross-functional teaming, oral and written technical communication, lifelong learning.
- 490 Independent Study**  
Fall, Spring, Summer. 1 to 3 credits. A student may earn a maximum of 3 credits in all enrollments for this course. R: Approval of department. SA: EE 490  
Independent study of a topic in electrical engineering or computer engineering.
- 491 Special Topics**  
Fall, Spring, Summer. 1 to 4 credits. A student may earn a maximum of 6 credits in all enrollments for this course. R: Open only to students in the Department of Electrical and Computer Engineering. SA: EE 491  
Investigation of special topics in electrical engineering or computer engineering.
- 499 Undergraduate Research**  
Fall, Spring, Summer. 1 to 3 credits. A student may earn a maximum of 4 credits in all enrollments for this course. R: Approval of department. SA: EE 499  
Independent undergraduate research in contemporary areas of electrical engineering or computer engineering.
- 801 Independent Study**  
Fall, Spring, Summer. 1 to 3 credits. A student may earn a maximum of 3 credits in all enrollments for this course. R: Approval of department. SA: EE 801  
Independent investigation of a topic in electrical engineering compatible with the student's prerequisites, interest, and ability.
- 802 Selected Topics**  
Fall, Spring. 1 to 4 credits. A student may earn a maximum of 21 credits in all enrollments for this course. SA: EE 802  
Investigation of special topics in electrical engineering.
- 807 Computer System Performance and Measurement**  
Spring of odd years. 3(3-0) Interdepartmental with Computer Science and Engineering. Administered by Computer Science and Engineering. RB: CSE 410 and STT 441 R: Open only to Computer Science or Electrical Engineering majors. SA: CPS 807  
Queueing network modelling, general analytic techniques, workload characterization, representing specific subsystems, parameterization. Software and hardware monitors, performance measures. Case studies, software packages.
- 808 Modelling and Discrete Simulation**  
Spring of even years. 3(3-0) Interdepartmental with Computer Science and Engineering. Administered by Computer Science and Engineering. RB: CSE 232 and STT 441 R: Open only to students in the Computer Science and Engineering major or approval of department. SA: CPS 808  
Simulation examples and languages. Mathematical models, petri nets, model validation, random variate generation. Analysis of simulation data. Case studies.
- 809 Algorithms and Hardware Implementation**  
Fall. 3(3-0) Interdepartmental with Computer Science and Engineering. Administered by Electrical and Computer Engineering. SA: EE 809  
Arithmetic, signal processing, and image processing algorithms. Array structures: systolic architecture, data flow structure, neural network architecture. Performance analysis.
- 813 Advanced VLSI Design**  
Spring. 3(3-0) Interdepartmental with Computer Science and Engineering. Administered by Electrical and Computer Engineering. P:M: ECE 410 SA: EE 813  
Advanced topics in digital integrated circuit design. Design specifications: functionality, performance, reliability, manufacturability, testability, cost. Standard cells. Design-rule checking. Circuit extraction, simulation, verification. Team-based design.
- 814 Embedded Wireless RF Transceivers**  
Fall of even years. 3(3-0)  
Transceiver architecture designs. Software components. Realtime computing and synchronization on digital signal processing platforms, embedded software transceivers, receiver hardware and software considerations, signal structures and CDMA codes, real-time acquisitions and tracking, synchronization, software receivers.
- 816 Cryptography and Network Security**  
Fall. 3(3-0)  
Major security techniques, including authenticity, confidentiality, message integrity, non-repudiation, and the mechanisms to achieve them. Network security and system security practices, including authentication practice, e-mail security, IP security, Web security, and firewalls.

- 818 Robotics**  
Spring. 3(3-0) RB: ECE 313 or ME 451 R: Open only to graduate students in the College of Engineering.  
Robot modeling, kinematics, dynamics, trajectory planning, programming, sensors, controller design.
- 820 Advanced Computer Architecture**  
Fall, Spring. 3(3-0) Interdepartmental with Computer Science and Engineering. Administered by Computer Science and Engineering. RB: CSE 410 and CSE 420 R: Open only to Computer Science or Electrical Engineering majors. SA: CPS 820  
Instruction set architecture. Pipelining, vector processors, cache memory, high bandwidth memory design, virtual memory, input and output. Benchmarking techniques. New developments related to single CPU systems.
- 821 Advanced Power Electronics and Applications**  
Fall of odd years. 3(3-0)  
Power semiconductor devices, circuits, control, and applications. Converter and inverter analysis and design, DSP control and implementation. Automotive and utility applications.
- 823 Power System Stability and Control**  
Fall of even years. 3(3-0) RB: ECE 826 SA: EE 823  
Analysis and simulation of small and large disturbance stability of power systems. Generator, exciter, voltage regulator models. Design of excitation systems and power system stabilizers.
- 824 Power System Operation and Control**  
Fall of odd years. 3(3-0) RB: ECE 421 and STT 351 SA: EE 824  
Operation planning of power systems including loadflow, unit commitment, production cost methods. On line operation and control including automatic generation control, economic dispatch, security assessment, state estimation.
- 825 Alternating Current Electrical Machines and Drives**  
Spring of even years. 3(3-0) RB: ECE 320 SA: EE 825  
Analysis, modeling and design of synchronous, induction, and switched reluctance machines. Design drives for motion control and power system applications.
- 826 Linear Control Systems**  
Fall. 3(3-0) RB: (MTH 314) SA: EE 826  
Vector spaces, representation, system description, solution to the state equations, stability, controllability and observability. Adjoint of linear maps. Eigenstructure assignment. Partial and full order observers. Disturbance decoupling.
- 829 Optimal Multivariable Control**  
Spring. 3(3-0) RB: ECE 826 SA: EE 829  
Performance and robustness. Minimum time, minimum energy and regulator. Optimal control and minimum principle. LQG, Nyquist, and H-infinity design methods.
- 831 Analog Circuit Theory**  
Fall of even years. 3(3-0) SA: EE 831  
Positive real functions. Filter approximations. Passive and active network synthesis. Nullor network analysis and synthesis. Active filters. Stability. Sensitivity.
- 832 Analog Integrated Circuit Design**  
Fall of odd years. 3(3-0) SA: EE 832  
Technology. Device modeling. Circuit simulation. Integrated circuit building blocks. Amplifiers, comparators, converters. Switched-capacitor filters. Analog signal processing circuits.
- 835 Advanced Electromagnetic Fields and Waves I**  
Fall. 3(3-0) SA: EE 835  
Electrostatics, magnetostatics, electrodynamics and Maxwell's equations. Potential functions. Eigenfunction expansion. Green's functions. Radiation of EM waves. EM boundary-value problems. TEM waves. Maxwell's equations with magnetic sources.
- 836 Advanced Electromagnetic Fields and Waves II**  
Spring. 3(3-0) RB: ECE 835 SA: EE 836  
Theory of guided transmission system. Microstrip lines, metallic and dielectric waveguides. EM cavities. Excitation and discontinuities of waveguides. Surface wave and radiation modes. Integrated optics. Scattering of EM waves.
- 841 Fourier Optics**  
Spring of odd years. 3(2-3) RB: ECE 360 and (ECE 435 or ECE 835) SA: EE 841  
Scalar diffraction theory. Fourier expansion of optical fields. Spatial linear systems and information processing. Lenses. Optical imaging systems. Holography. Measurements of optical systems.
- 842 Quantum Electronics**  
Fall of even years. 3(3-0) RB: ECE 835 and ECE 874 SA: EE 842  
Quantum and electromagnetic theory of lasers. Optical resonators. Laser oscillation and amplification. Characterization of lasers. Specific laser examples.
- 850 Electrodynamics of Plasmas**  
Spring of odd years. 3(3-0) Interdepartmental with Astronomy and Astrophysics and Physics. Administered by Electrical and Computer Engineering. RB: ECE 835 or PHY 488 SA: EE 850  
Plasma kinetic and macroscopic plasma transport theory. Electromagnetic wave propagation and charged particle diffusion processes in plasma. Electromagnetic energy absorption via elastic and inelastic collisions. Dc, rf, and microwave discharges.
- 851 Linear Systems and Control**  
Fall. 3(3-0) Interdepartmental with Mechanical Engineering. Administered by Electrical and Computer Engineering. RB: Undergraduate coverage of linear algebra, differential equations and control/systems  
State models and their stability, controllability, and observability properties. Finding minimal realizations of transfer functions. Design of state and output feedback controllers. Design of state observers. LQ regulator and the Kalman filter. Time-varying systems.
- 853 Optimal Control**  
Spring of odd years. 3(3-0) Interdepartmental with Mechanical Engineering. Administered by Electrical and Computer Engineering.  
Static optimization. Nonlinear optimal control of discrete and continuous systems, with specialization to the LQ regulator and tracking. Extending the deterministic results to the Kalman filter and the LQG regulator. Dynamic programming and inequality constraints. Convex optimization and LMI's.
- 854 Robust Control**  
Spring of even years. 3(3-0) Interdepartmental with Mechanical Engineering. Administered by Mechanical Engineering. R: Open to students in the College of Engineering and approval of college.  
Linear systems and norms for signals and systems. Investigation of stability and performance of control systems. Model reduction, uncertainty, and robustness. Parameterization of stabilizing controllers, Riccati equations and related factorizations. Application to H-2, H-infinity, and L-1 control.
- 856 Adaptive Control**  
Fall of even years. 3(3-0) Interdepartmental with Mechanical Engineering. Administered by Electrical and Computer Engineering.  
Real-time parameter estimation. Design of self-tuning regulators and model reference adaptive controllers. Investigation of robustness and robust adaptive controllers. Extension to nonlinear systems.
- 859 Nonlinear Control**  
Spring. 3(3-0) Interdepartmental with Mechanical Engineering. Administered by Electrical and Computer Engineering. RB: ECE 826 and ME 857 SA: ECE 827  
Second-order systems. Fundamental properties of solutions. Lyapunov stability. Input-output stability. Passivity. Absolute stability. Linearization. Integral control. Feedback linearization. Sliding mode control. Lyapunov redesign. Passivity-based control. Recursive methods. Applications to electrical and mechanical systems.
- 859 Nonlinear Systems and Control**  
Spring. 3(3-0) Interdepartmental with Mechanical Engineering. Administered by Mechanical Engineering. RB: ECE 826 and ME 857 SA: ECE 827  
Second-order systems and fundamental properties of solutions. Lyapunov stability, input-output stability, passivity, absolute stability, and linearization. Design of feedback controllers using integral control, feedback linearization, sliding mode control, Lyapunov redesign, passivity-based control, and recursive methods. Applications to electrical and mechanical systems.
- 863 Analysis of Stochastic Systems**  
Fall. 3(3-0) RB: STT 441 SA: EE 863  
Advanced topics in random variable theory. Stochastic processes and stochastic calculus. Optimal systems for filtering and detection.
- 864 Detection and Estimation Theory**  
Spring. 3(3-0) RB: ECE 863 SA: EE 864  
Analysis and implementation of statistical estimation and detection methods used in signal processing, communications, and control applications. Bayesian, Neyman-Pearson, and minimax detection schemes. Bayesian, mean-square-error, and maximum-likelihood estimation methods.
- 865 Analog and Digital Communications**  
Fall of odd years. 3(3-0) RB: ECE 457 and ECE 863 SA: EE 865  
Optimum signal design in noisy channels, matched filters, quadrature sampling of band-pass signals in noise. Coherent and non-coherent binary modulation such as PSK, FSK, DPSK, M-ary modulation, intersymbol interference, spread spectrum.

## Electrical and Computer Engineering—ECE

- 867 Information Theory and Coding**  
Spring. 3(3-0) P:M: ECE 863  
Shannon information measures. Uniqueness theorem and chain rules of the entropy measures. Kullback-Leibler relative-entropy. The I-measure. Asymptotic Equipartition Property (AEP) for various sources. Channel capacity; discrete-memoryless and symmetric channels. The channel coding theorem. Rate-distortion theory. Applications of coding to modern communications and compression methods such as image
- 870 Introduction to Micro-Electro-Mechanical Systems**  
Fall. 3(3-0) RB: ECE 477 and ECE 474  
Micro-electro-mechanical systems (MEMS). Fundamentals of micromachining and microfabrication techniques. Design and analysis of devices and systems in mechanical, electrical, fluidic, and thermal energy and signal domains. Sensing and transduction mechanisms, including capacitive and piezoresistive techniques. Design and analysis of miniature sensors and actuators. Examples of existing devices and their applications.
- 871 Micro-electro-mechanical Systems Fabrication**  
Spring. 3(3-0) P:M: ECE 870 or ECE 477  
Development of a complete integrated microsystem from inception to final test. Design, fabrication and testing of integrated microsystems. Development of a complete multichip microsystem containing sensors, signal processing, and an output interface. Basic MOS device and circuit processes, wafer bonding and micromachining, low power portable devices and diamond MEMS chips.
- 874 Physical Electronics**  
Fall. 3(3-0) SA: EE 874  
Applications of quantum mechanics and statistical mechanics in solids. Band theory of semiconductors. Electrical transport phenomena. Pn junctions.
- 875 Electronic Devices**  
Spring. 3(3-0) RB: ECE 874 SA: EE 875  
Operating properties of semiconductor devices including DC, AC, transient and noise models of FET, BJT, metal-semiconductor contact, heterostructure, microwave and photonic devices.
- 885 Artificial Neural Networks**  
Fall. 3(3-0) Interdepartmental with Computer Science and Engineering. Administered by Electrical and Computer Engineering. SA: EE 885  
Overview of neuro-engineering technology. Basic neural network architectures. Feedforward and feedback networks. Temporal modeling. Supervised and unsupervised learning. Implementation. Basic applications to pattern recognition.
- 899 Master's Thesis Research**  
Fall, Spring, Summer. 1 to 8 credits. A student may earn a maximum of 24 credits in all enrollments for this course. SA: EE 899  
Master's thesis research.
- 920 Selected Topics in High Performance Computer Systems**  
Spring of odd years. 3(3-0) A student may earn a maximum of 9 credits in all enrollments for this course. Interdepartmental with Computer Science and Engineering. Administered by Computer Science and Engineering. P:M: CSE 822 R: Open only to students in the Computer Science and Engineering major or approval of department. SA: CPS 920  
Design of high performance computer systems. Seminar format.
- 921 Advanced Topics in Digital Circuits and Systems**  
Fall, Spring. 3(3-0) A student may earn a maximum of 6 credits in all enrollments for this course. Interdepartmental with Computer Science and Engineering. Administered by Electrical and Computer Engineering. SA: EE 921  
Topics vary each semester.
- 921B Embedded Architectures**  
Fall of odd years, Spring of odd years. 3(3-0) Interdepartmental with Computer Science and Engineering. Administered by Electrical and Computer Engineering. RB: ECE 809 and ECE 813 SA: EE 921B  
Embedded computers and architectures for real-time computation and/or robust control. ASICs. Bit-slice architectures. Systolic arrays. Neural networks. Genetic algorithms. Implementation technologies and design issues.
- 925 Advanced Topics in Power**  
Spring. 3(3-0) A student may earn a maximum of 9 credits in all enrollments for this course. SA: EE 925  
Topics vary each semester.
- 925C Advanced Machine Drives**  
Fall of odd years, Spring of odd years. 3(3-0) RB: ECE 825 and ECE 829 SA: EE 925C  
Nonlinear drives based on state reconstruction and nonlinear and adaptive control. Sensors, implementation, special computer architectures.
- 929 Advanced Topics in Electromagnetics**  
Fall, Spring. 3 to 4 credits. A student may earn a maximum of 10 credits in all enrollments for this course. SA: EE 929  
Topics vary each semester.
- 929A Planar Waveguides and Circuits**  
Fall of odd years, Spring of odd years. 3(3-0) RB: ECE 835 SA: EE 929A  
Planar open-boundary waveguides and circuits. Surface and microstrip waveguides. Propagation-mode spectrum. Spectral analysis of layered media. Sommerfeld analysis. Integral-operator description of open waveguides and planar circuits.
- 929B Antenna Theory**  
Fall of odd years, Spring of odd years. 4(4-0) RB: ECE 835 SA: EE 929B  
Antennas and EM scattering. Radiation by currents and surface fields. Equivalence principle. Receiving antennas. Arrays and synthesis. Integral equations. Current and impedance of wire antennas. Slot, aperture and reflector antennas. Singularity expansion method.
- 929C Geometrical Theory of Diffraction**  
Fall of odd years, Spring of odd years. 3(3-0) RB: ECE 835 SA: EE 929C  
Fourier expansion and asymptotic evaluation of two-dimensional electromagnetic fields. Scattering from half-planes, wedges and cylinders. Geometrical optics and ray-tracing. Reflection and transmission matrices. Geometrical diffraction theory.
- 931 Advanced Topics in Electronic Devices and Materials**  
Fall, Spring. 1 to 4 credits. A student may earn a maximum of 12 credits in all enrollments for this course. SA: EE 931  
Topics vary each semester.
- 931A VLSI Technology**  
Fall of odd years, Spring of odd years. 3(3-0) RB: ECE 875 SA: EE 931A  
Oxidation, doping techniques, simulation techniques, film deposition and etching, epitaxial growth, lithography, passivation, and packaging.
- 931B Microdevices and Microstructures**  
Fall of odd years, Spring of odd years. 3(3-0) RB: ECE 875 SA: EE 931B  
Technology, modeling and simulation of submicron solid state devices. Microsensors and micromachining. Diamond and superconducting devices. Vacuum microelectronic structures.
- 931C Properties of Semiconductors**  
Fall of odd years, Spring of odd years. 3(3-0) RB: ECE 874 SA: EE 931C  
Carrier scattering, single particle and collective transport, quantum effects, hot electron effects, electron-photon and electron-phonon interactions.
- 932 Advanced Topics in Analog Circuits**  
Spring of odd years. 3(3-0)  
Variable topics in advanced circuit analysis.
- 960 Advanced Topics in Control**  
Fall, Spring. 3(3-0) A student may earn a maximum of 6 credits in all enrollments for this course. RB: ECE 827 and ECE 829 SA: EE 960  
Topics vary each semester.
- 960A Adaptive Control**  
Fall of odd years, Spring of odd years. 3(3-0) RB: ECE 827 and ECE 829 SA: EE 960A  
Model reference adaptive control in continuous and discrete time. Lyapunov and hyperstability approaches, adaptive observers, self-tuning regulators, design using pole-zero assignments. Minimum variance and LQG control.
- 960B Nonlinear Control**  
Fall of odd years, Spring of odd years. 3(3-0) RB: ECE 827 and ECE 829 SA: EE 960B  
Relay control, stabilizing controllers. Design via variable structure, high gain, geometric, and Lyapunov-based methods. Feedback linearization and tracking controls.
- 963 Advanced Topics in Systems**  
Fall, Spring. 3(3-0) A student may earn a maximum of 9 credits in all enrollments for this course. SA: EE 963  
Topics vary each semester.
- 966 Advanced Topics in Signal Processing**  
Fall, Spring. 3(3-0) A student may earn a maximum of 9 credits in all enrollments for this course. SA: EE 966  
Topics vary each semester.
- 966A Discrete Time Processing of Speech Signals**  
Fall of odd years, Spring of odd years. 3(3-0) RB: ECE 466 and ECE 863 and ECE 864 SA: EE 966A  
Digital speech models. Short term temporal processing. Linear predictive and spectral analysis. Speech coding and synthesis, recognition, enhancement.
- 966B Multidimensional Signal Processing**  
Fall of odd years, Spring of odd years. 3(3-0) RB: ECE 466 and ECE 864 SA: EE 966B  
Multidimensional signals and systems concepts. Two-dimensional sampling, windowing, filter design. Fast algorithms for convolution and transforms. Sensor array processing. Interpolation.

**966C Advanced Topics in Statistical Signal Processing**

Fall of odd years, Spring of odd years. 3(3-0) RB: ECE 466 and ECE 863 and ECE 864 SA: EE 966C

Communication channels, noise models, hypothesis testing of signals by Bayesian minimax, and Neyman-Pearson criteria. Performance evaluation using ROC. Bayesian and maximum likelihood parameter estimation. Kalman-Bucy filtering.

**989 Advanced Topics in Plasma**

Fall of odd years, Spring of odd years. 3(3-0) A student may earn a maximum of 6 credits in all enrollments for this course. SA: EE 989

Topics vary each semester.

**989A Plasma Processing for IC Fabrication**

Fall of odd years, Spring of odd years. 3(3-0) RB: ECE 835 and ECE 850 SA: EE 989A

Process requirements. Plasma reactors. Etching and deposition applications. Broad ion beam processing.

**999 Doctoral Dissertation Research**

Fall, Spring, Summer. 1 to 24 credits. A student may earn a maximum of 72 credits in all enrollments for this course. SA: EE 999

Doctoral dissertation research.