EE 5103. Engineering Programming. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Object-oriented programming for engineering design problems using C++; software development for mathematical modeling and simulation of hardware systems; extraction and reporting (e.g., text processing) using scripting languages such as Perl; and individual class projects. Differential Tuition: $165.

EE 5113. VLSI System Design. (3-1) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. VLSI Circuit Design, CMOS technology and device modeling, structured digital circuits, VLSI systems; computer-aided design tools, placement, routing, extraction, design rule checking, graphic editors, simulation, verification, minimization, silicon compilation, test pattern generation, theory for design automation, and chip design. (Formerly EE 5323 Topic 1: VLSI I. Credit cannot be earned for both EE 5113 and EE 5323 VLSI I.) Differential Tuition: $165.

EE 5123. Computer Architecture. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Description of digital computer systems, arithmetic algorithms, central processor design, memory hierarchies and virtual memory, control unit and microprogramming, input and output, coprocessors, and multiprocessing. Differential Tuition: $165.

EE 5143. Linear Systems and Control. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Advanced methods of analysis and synthesis of linear systems, continuous and discrete-time systems, analytical approach to linear control theory. Differential Tuition: $165.

EE 5153. Random Signals and Noise. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Study of probability theory, random processes, mean and autocorrelation, stationarity and ergodicity, Gaussian and Markov processes, power spectral density, noise, and linear systems. Differential Tuition: $165.

EE 5163. Digital Signal Processing. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Study of discrete-time signals and systems, including Z-transforms, fast Fourier transforms, and digital filter theory. Filter design and effects of finite register length, and applications to one-dimensional signals. Differential Tuition: $165.

EE 5183. Foundations of Communication Theory. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor; completion of EE 5153 recommended. Basis functions, orthogonalization of signals, vector representation of signals, optimal detection in noise, matched filters, pulse shaping, intersymbol interference, maximum likelihood detection, channel cutoff rates, error probabilities, bandwidth, and power-limited signaling. Differential Tuition: $165.

EE 5193. FPGA and HDL. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Fundamental digital systems principles. HDL modeling concepts and styles: structural, RTL, and behavioral; modeling for synthesis and verification; modeling combinatorial and sequential logic circuits; modeling finite state machines; testbench developments; performance estimation and improvement. (Formerly EE 5223 Topic 2: FPGA and HDL. Credit cannot be earned for both EE 5193 and EE 5223 FPGA and HDL.) Differential Tuition: $165.

EE 5223. Topics in Digital Design. (3-0) 3 Credit Hours.
Prerequisite: EE 5123 or consent of instructor. Topics may include the following: Topic 1: Graph Theory and Networking. Introduction to graphs and digraphs, applications of graphs, Eulerian and Hamiltonian graphs, connectivity, trees, planar graphs, decomposition problems, graph models for electrical and communications networks and computer architectures, communications network application examples, analysis and design. Topic 2: Microcomputer-Based Systems. 8- and 16-bit microprocessors, bus timing analysis, interfacing principles, LSI and VLSI chip interfacing, use of software development tools such as assemblers, compilers, and simulators, and hardware development tools including logic analyzer. Topic 3: PCI System Design. Understanding PCI specifications including protocol, electrical, mechanical, and timing. Study the protocol for high-speed, high-bandwidth data throughput. Designing a PCI-based system design and implementing in FPGA. May be repeated for credit as topics vary. Differential Tuition: $165.

EE 5243. Topics in Systems and Control. (3-0) 3 Credit Hours.
EE 5263. Topics in Digital Signal Processing and Digital Filtering. (3-0) 3 Credit Hours.

EE 5283. Topics in Communication Systems. (3-0) 3 Credit Hours.
EE 5293. Topics in Microelectronics. (3-0) 3 Credit Hours. 
Prerequisite: EE 4313. Topics may include the following: Topic 1: Analog Integrated Circuit Design. Introduction to MOS devices and analog circuit modeling. Analog circuits: active resistors, current sources, current mirrors, current amplifiers, inverting amplifier, differential amplifier, cascade amplifier, MOS switches, and the output amplifier. Complex circuits: comparators, operational amplifiers, and other commonly used building blocks for mixed signal systems. Use of CAD tools to layout and simulate analog circuits. Topic 2: Mixed Signal Circuits and Systems. Introduction to the circuits of systems in which analog and mixed signal integrated circuit design are employed. The topics are A/D and D/A converters, including Nyquist-rate and oversampling A/D converters, switched capacitor filters, multipliers, oscillators, the PLL, and circuit design issues, testing, digital calibration and correction. May be repeated for credit as topics vary. Differential Tuition: $165.

EE 5323. Topics in VLSI Design. (3-0) 3 Credit Hours. 
Prerequisite: EE 5113 or consent of instructor. Topic 1: Advanced VLSI Design. Microelectronic systems architecture; VLSI circuit testing methods; integration of heterogeneous computer-aided design tools; wafer scale integration; advanced high-speed circuit design and integration. Engineering design of large-scale integrated circuits, systems, and applications; study of advanced design techniques, architectures, and CAD methodologies. Topic 2: Low Power VLSI Design. Hierarchy of limits of power, source of power consumption, voltage scaling approaches; circuit, logic, architecture and system level power optimization; power estimation; advanced techniques for power optimization; software design for low power. Topic 3: VLSI Testing. Digital system design verification, logic and fault simulation; testbench guidelines; functional coverage; VLSI manufacturing test; fault modeling; testability measures; Design for Testability (DFT); and Automatic Test Pattern Generation (ATPG). Topic 4: VLSI Performance Analysis and Optimization. Delay models, delay calculation, signal integrity effects, timing analysis, performance variability, performance optimization, and delay test. May be repeated for credit as topics vary. Differential Tuition: $165.

EE 5343. Intelligent Control and Robotics. (3-0) 3 Credit Hours. 

EE 5353. Topics in Multimedia Signal Processing. (3-0) 3 Credit Hours. 
Prerequisite: EE 5153 or EE 5163, or consent of instructor. Topics may include the following: Topic 1: Digital Image Processing. Study of binary image processing; histogram and point operations; algebraic and geometric image operations; 2-D digital Fourier transforms; convolution; linear and nonlinear filtering; morphological filters; image enhancement; linear image restoration (deconvolution); digital image coding and compression; and digital image analysis. (Formerly EE 5363. Credit cannot be earned for both EE 5353 Topic 1: Digital Image Processing and EE 5363.) Topic 2: Computer Vision and Application. Image perception, edge detection in the visual system, future vectors, image enhancement, shape from shading, image segmentation by textural perception in humans, chain codes, B-splines, classification (SVM and others). Topic 3: Biomedical Image Processing. This course will examine the fundamental and mathematical aspects of imaging; new algorithms and mathematical tools for the advanced processing of medical and biological images, which include fundamental methods of image reconstruction from their projections, multi-modal imaging, image analysis and visualization, image enhancement, image segmentation and gene-expression calculation, image parameter estimation and measurements, target location, texture synthesis and analysis, morphological image processing, processing of microarray images, processing of FISH stacked images, automated analysis of gene copy numbers by fluorescence in situ hybridization, image acquisition and processing in major imaging techniques, including magnetic resonance, 2-D and 3-D computed tomography, positron emission tomography, and others. Topic 4: Development of Multimedia Applications for Wireless Devices. Programming on wireless systems. Multimedia (image, audio and video) formats. Multimedia processing. Development of sample applications. May be repeated for credit as topics vary. Differential Tuition: $165.

EE 5373. Wireless Communication. (3-0) 3 Credit Hours. 
Prerequisite: Graduate standing or consent of instructor. This course offers in-depth study of wireless communication systems at the physical layer, propagation modeling for wireless systems, modulation schemes used for wireless channels, diversity techniques and multiple antenna systems, and multiple access schemes used in wireless systems. Differential Tuition: $165.

EE 5403. Advanced Dielectric and Optoelectronic Engineering Laboratory. (2-4) 3 Credit Hours. 

EE 5413. Principles of Microfabrication. (1-6) 3 Credit Hours. 
Prerequisite: EE 3323. Photolithography, thin film deposition, doping, wet patterning, plasma etching, thin film characterization. Students will fabricate simple microstructures such as coplanar waveguides, microfluidic devices and nano-powder silica films. (Same as ME 5803. Credit cannot be earned for both EE 5413 and ME 5803.) Differential Tuition: $165.
EE 5423. Topics in Computer Architecture. (3-0) 3 Credit Hours. 

EE 5443. Discrete-Time Control Theory and Design. (3-0) 3 Credit Hours. 
Prerequisite: EE 5143. Control theory relevant to deterministic and stochastic analysis and design of computer-controlled systems using both state-space and input-output models. Differential Tuition: $165.

EE 5453. Topics in Software Engineering. (3-0) 3 Credit Hours. 
Prerequisite: EE 5123 or consent of instructor. Topic 1: Large Domain-Specific Software Architectures. Software engineering approaches; scenario-based design processes to analyze large problem domains; domain modeling and representations; creation of component-based architecture providing an object-oriented representation of system requirements; and development of large software class project. Topic 2: Embedded Software Systems Design. Dataflow models, uniprocessor and multiprocessor scheduling, hardware/software codesign, hierarchical finite state machines, synchronous languages, reactive systems, and heterogeneous systems. Topic 3: Embedded Software Testing and Quality Assurance. Systematic testing of embedded software systems; unit (module), integration and system level testing; software verification; hardware/software co-testing; code inspections; use of metrics; quality assurance; measurement and prediction of software reliability; software maintenance; software reuse and reverse engineering. Topic 4: Advanced Engineering Programming. Programming in the cloud, advanced engineering design problems and techniques using C++ and Java, advanced data structures and complexity analysis of algorithms, dynamic programming using Perl and Python, and large-scale and real-world group and individual projects. May be repeated for credit as topics vary. Differential Tuition: $165.

EE 5473. Fiber Optic Communication. (3-0) 3 Credit Hours. 
Prerequisite: Graduate standing or consent of instructor. In-depth study of fiber optic principles, performance of optical receivers, devices, digital and analog fiber optic transmission systems, wavelength division multiplexing systems, optical amplifiers, and fiber optic measurements. Differential Tuition: $165.

EE 5503. Introduction to Micro and Nanotechnology. (2-3) 3 Credit Hours. 
Prerequisite: Graduate standing or completion of or concurrent enrollment in EE 3323. Survey of micro-fabrication techniques, scaling laws, mechanical, optical and thermal transducers, micro-fluidic applications, nanostructures. (Same as ME 5883. Credit cannot be earned for both EE 5503 and ME 5883.) Differential Tuition: $165.

EE 5523. Introduction to Cloud Computing. (3-0) 3 Credit Hours. 
Prerequisite: Graduate standing or consent of instructor. Study in concepts related to cloud computing including key components of cloud computing, networking fundamentals, Python programming, resource allocation using cloud APIs, introduction to parallel programming with Python using MPI, data analytics fundamentals such as relational database theory, SQL/noSQL, and Map/Reduce. Differential Tuition: $165.

EE 5583. Topics in Digital Communication. (3-0) 3 Credit Hours. 
Prerequisite: Graduate standing or consent of instructor. Topics may include the following: Topic 1: Digital Information Theory. Entropy and mutual information; Huffman coding; source and channel coding theorems; channel capacity; block coding error bounds; random coding bounds; cutoff rate; multiuser information theory; random access channels and protocols; multiaccess coding methods. Topic 2: Digital Modulation Schemes. In-depth study of digital modulation; information sources and source coding, quantization, representation of digitally modulated signals; synchronization and timing issues in digital communications. Topic 3: Computer Communication Networks. Fundamentals of communication networks, data communication and transmission systems, peer-to-peer protocols, local/wide area networks, multiple access methods, and service integration. Topic 4: Coding and Error Correction. Algebraic Coding Theory; groups and fields, linear codes, Hamming distance, cyclic codes, minimum distance bounds, BACH codes and algebraic decoding, Reed-Solomon codes, Reed-Muller codes and maximum likelihood decoding, suboptimal decoding, and applications of coding. May be repeated for credit as topics vary. Differential Tuition: $165.

EE 5523. Introduction to Micro and Nanotechnology. (2-3) 3 Credit Hours. 
Prerequisite: Graduate standing or completion of or concurrent enrollment in EE 3323. Survey of micro-fabrication techniques, scaling laws, mechanical, optical and thermal transducers, micro-fluidic applications, nanostructures. (Same as ME 5883. Credit cannot be earned for both EE 5503 and ME 5883.) Differential Tuition: $165.

EE 6343. Advanced Topics in Systems and Control. (3-0) 3 Credit Hours. 
Prerequisites: Consent of Graduate Advisor of Record and Dissertation Director. Current topics in the systems and control area. May be repeated for credit as topics vary. Differential Tuition: $165.

EE 6363. Advanced Topics in Signal Processing. (3-0) 3 Credit Hours. 
Prerequisites: Consent of Graduate Advisor of Record and Dissertation Director. Current topics in the signal processing area. May be repeated for credit as topics vary. Differential Tuition: $165.

EE 6383. Advanced Topics in Communications. (3-0) 3 Credit Hours. 
Prerequisites: Consent of Graduate Advisor of Record and Dissertation Director. Current topics in the communications area. May be repeated for credit as topics vary. Differential Tuition: $165.
EE 6493. Advanced Topics in Electronic Materials and Devices. (2-3) 3 Credit Hours.
Prerequisites: EE 5693 and EE 5503 or EE 5593 or consent of instructor. Topics to be selected from advanced sensors, actuators, engineered materials, device physics, microwave applications of MEMS structures, optoelectronics and photonics, microelectronic devices and nanotechnology. May be repeated for credit as topics vary. Differential Tuition: $165.

EE 6931. Graduate Research Internship. (0-0) 1 Credit Hour.
Prerequisite: Graduate standing in electrical and computer engineering and consent of instructor. Research associated with enrollment in the Graduate Research Internship Program. The grade report for the course is either “CR” (satisfactory performance on Graduate Research Internship) or “NC” (unsatisfactory performance on Graduate Research Internship). Differential Tuition: $55.

EE 6932. Graduate Research Internship. (0-0) 2 Credit Hours.
Prerequisite: Graduate standing in electrical and computer engineering and consent of instructor. Research associated with enrollment in the Graduate Research Internship Program. The grade report for the course is either “CR” (satisfactory performance on Graduate Research Internship) or “NC” (unsatisfactory performance on Graduate Research Internship). Differential Tuition: $110.

EE 6933. Graduate Research Internship. (0-0) 3 Credit Hours.
Prerequisite: Graduate standing in electrical and computer engineering and consent of instructor. Research associated with enrollment in the Graduate Research Internship Program. The grade report for the course is either “CR” (satisfactory performance on Graduate Research Internship) or “NC” (unsatisfactory performance on Graduate Research Internship). Differential Tuition: $165.

EE 6941. Graduate Project. (0-0) 1 Credit Hour.
Prerequisites: Consent of the Graduate Advisor of Record and Project Advisor. A semester-long project with approval of a supervising faculty. Credit will be awarded upon successful submission of a written report. May be repeated for credit, but not more than 3 hours will apply to the Master's degree. Enrollment is required each term in which the project is in progress. (Formerly EE 6963.) Differential Tuition: $55.

EE 6942. Graduate Project. (0-0) 2 Credit Hours.
Prerequisites: Consent of the Graduate Advisor of Record and Project Advisor. A semester-long project with approval of a supervising faculty. Credit will be awarded upon successful submission of a written report. May be repeated for credit, but not more than 3 hours will apply to the Master's degree. Enrollment is required each term in which the project is in progress. (Formerly EE 6963.) Differential Tuition: $110.

EE 6943. Graduate Project. (0-0) 3 Credit Hours.
Prerequisites: Consent of the Graduate Advisor of Record and Project Advisor. A semester-long project with approval of a supervising faculty. Credit will be awarded upon successful submission of a written report. May be repeated for credit, but not more than 3 hours will apply to the Master's degree. Enrollment is required each term in which the project is in progress. (Formerly EE 6963.) Differential Tuition: $165.

EE 6951. Independent Study. (0-0) 1 Credit Hour.
Prerequisites: Graduate standing and permission in writing (form available) of the instructor and the Graduate Advisor of Record. Independent reading, research, discussion, and/or writing under the direction of a faculty member. For students needing specialized work not normally or not often available as part of the regular course offerings. May be repeated for credit, but not more than 6 hours, regardless of discipline, will apply to the degree. Differential Tuition: $55.

EE 6952. Independent Study. (0-0) 2 Credit Hours.
Prerequisites: Graduate standing and permission in writing (form available) of the instructor and the Graduate Advisor of Record. Independent reading, research, discussion, and/or writing under the direction of a faculty member. For students needing specialized work not normally or not often available as part of the regular course offerings. May be repeated for credit, but not more than 6 hours, regardless of discipline, will apply to the degree. Differential Tuition: $110.

EE 6953. Independent Study. (0-0) 3 Credit Hours.
Prerequisites: Graduate standing and permission in writing (form available) of the instructor and the Graduate Advisor of Record. Independent reading, research, discussion, and/or writing under the direction of a faculty member. For students needing specialized work not normally or not often available as part of the regular course offerings. May be repeated for credit, but not more than 6 hours, regardless of discipline, will apply to the degree. Differential Tuition: $165.

EE 6961. Comprehensive Examination. (0-0) 1 Credit Hour.
Prerequisites: Consent of the Graduate Advisor of Record. Independent study course for the purpose of taking the Comprehensive Examination. May be repeated for credit as many times as approved by the Graduate Studies Committee. Enrollment is required each term in which the Comprehensive Examination is taken if no other courses are being taken that term. The grade report for the course is either “CR” (satisfactory performance on the Comprehensive Examination) or “NC” (unsatisfactory performance on the Comprehensive Examination). Differential Tuition: $55.

EE 6971. Special Problems. (1-0) 1 Credit Hour.
Prerequisite: Consent of instructor. An organized course offering the opportunity for specialized study not normally or not often available as part of the regular course offerings. Special Problems courses may be repeated for credit when topics vary, but not more than 6 hours, regardless of discipline, may be applied to the degree. Differential Tuition: $55.

EE 6972. Special Problems. (2-0) 2 Credit Hours.
Prerequisite: Consent of instructor. An organized course offering the opportunity for specialized study not normally or not often available as part of the regular course offerings. Special Problems courses may be repeated for credit when topics vary, but not more than 6 hours, regardless of discipline, may be applied to the degree. Differential Tuition: $110.

EE 6973. Special Problems. (3-0) 3 Credit Hours.
Prerequisite: Consent of instructor. An organized course offering the opportunity for specialized study not normally or not often available as part of the regular course offerings. Special Problems courses may be repeated for credit when topics vary, but not more than 6 hours, regardless of discipline, may be applied to the degree. Differential Tuition: $165.

EE 6981. Master's Thesis. (0-0) 1 Credit Hour.
Prerequisites: Consent of the Graduate Advisor of Record and thesis director. Thesis research and preparation. May be repeated for credit, but not more than 6 hours will apply to the Master's degree. Credit will be awarded upon completion of the thesis. Enrollment is required each term in which the thesis is in progress. Differential Tuition: $55.

EE 6982. Master's Thesis. (0-0) 2 Credit Hours.
Prerequisites: Consent of the Graduate Advisor of Record and thesis director. Thesis research and preparation. May be repeated for credit, but not more than 6 hours will apply to the Master's degree. Credit will be awarded upon completion of the thesis. Enrollment is required each term in which the thesis is in progress. Differential Tuition: $110.
EE 6983. Master’s Thesis. (0-0) 3 Credit Hours.
Prerequisites: Consent of the Graduate Advisor of Record and thesis director. Thesis research and preparation. May be repeated for credit, but not more than 6 hours will apply to the Master’s degree. Credit will be awarded upon completion of the thesis. Enrollment is required each term in which the thesis is in progress. Differential Tuition: $165.

EE 6991. Research Seminar. (1-0) 1 Credit Hour.
Organized research lectures and seminar presentations. The grade report for this course is either “CR” (satisfactory participation in the seminar) or “NC” (unsatisfactory participation in the seminar). This course may include a written component. May be repeated for credit, but not more than 1 hour will apply to the Master’s degree, regardless of discipline. Differential Tuition: $55.

EE 7443. Nonlinear Control Systems. (3-0) 3 Credit Hours.
Prerequisite: EE 5143. Principles of nonlinear systems modeling and analysis: Lyapunov stability, input-output stability, and homogeneous theory. Control of nonlinear systems: integrator backstepping, feedback domination, Lyapunov-based design, small control technique, output feedback design, and applications to physical systems. Differential Tuition: $165.

EE 7931. Doctoral Research Seminar. (1-0) 1 Credit Hour.
Organized research lectures and seminar presentations. This course may include a written component. The grade report for this course is either “CR” (satisfactory participation in the seminar) or “NC” (unsatisfactory participation in the seminar). May be repeated for credit, but not more than 3 hours will apply to the doctoral degree. Differential Tuition: $55.

EE 7932. Doctoral Research Seminar. (2-0) 2 Credit Hours.
Organized research lectures and seminar presentations. This course may include a written component. The grade report for this course is either “CR” (satisfactory participation in the seminar) or “NC” (unsatisfactory participation in the seminar). May be repeated for credit, but not more than 3 hours will apply to the doctoral degree. Differential Tuition: $110.

EE 7933. Doctoral Research Seminar. (3-0) 3 Credit Hours.
Organized research lectures and seminar presentations. This course may include a written component. The grade report for this course is either “CR” (satisfactory participation in the seminar) or “NC” (unsatisfactory participation in the seminar). May be repeated for credit, but not more than 3 hours will apply to the doctoral degree. Differential Tuition: $165.

EE 7951. Doctoral Research. (0-0) 1 Credit Hour.
Prerequisites: Ph.D. student standing and consent of instructor and the Graduate Advisor of Record. May be repeated for a maximum credit of 18 hours. Differential Tuition: $55.

EE 7952. Doctoral Research. (0-0) 2 Credit Hours.
Prerequisites: Ph.D. student standing and consent of instructor and the Graduate Advisor of Record. May be repeated for a maximum credit of 18 hours. Differential Tuition: $110.

EE 7953. Doctoral Research. (0-0) 3 Credit Hours.
Prerequisites: Ph.D. student standing and consent of instructor and the Graduate Advisor of Record. May be repeated for a maximum credit of 18 hours. Differential Tuition: $165.

EE 7991. Doctoral Dissertation. (0-0) 1 Credit Hour.
Prerequisites: Consent of the Doctoral Advisor of Record and Dissertation Advisor. May be repeated for a maximum credit of 18 hours. Differential Tuition: $55.

EE 7992. Doctoral Dissertation. (0-0) 2 Credit Hours.
Prerequisites: Consent of the Doctoral Advisor of Record and Dissertation Advisor. May be repeated for a maximum credit of 18 hours. Differential Tuition: $110.

EE 7993. Doctoral Dissertation. (0-0) 3 Credit Hours.
Prerequisites: Consent of the Doctoral Advisor of Record and Dissertation Advisor. May be repeated for a maximum credit of 18 hours. Differential Tuition: $165.