Electrical and Computer Engineering Courses

2006-2007 Academic Year Undergraduate Bulletin

27L. Fundamentals of Electrical and Computer Engineering. How to use electrical devices and systems to interface with the physical world, transfer/transmit energy/information, extract/analyze/interpret information, and organize and store information. Topics include techniques for analyzing linear circuits, nodal and mesh analysis, energy storage, semiconductor and photonic devices, frequency representation, filtering, sampling, communications protocols, combinational and sequential logic, design concepts, and project management. In the laboratory, a robotic platform is used to design and implement solutions to realistic challenges. Prerequisites: Engineering 53 and Mathematics 32. Instructor: Gustafson, Huettel, Kim, or Ybarra. One course.

51L. Introduction to Microelectronic Devices and Circuits. Hands-on, laboratory driven introduction to microelectronic devices, sensors, and integrated circuits. Student teams of 3-4 students/team compete in a design, assembly, testing, characterization and simulation of an electronic system. Projects include microelectronic devices, sensors, and basic analog and digital circuits. Classroom portion designed to answer questions generated in laboratory about understanding operation of devices and sensors, and the performance of electronic circuits. Student evaluation based on project specification, prototyping, integration, testing, simulation and documentation. Prerequisites: Engineering 53L, and either Electrical and Computer Engineering 27L or Electrical and Computer Engineering 61L or Biomedical Engineering 153L. Instructor: Brooke or Massoud. One course.

52L. Introduction to Digital Systems. Techniques for the analysis and design of combinational and sequential networks via manual and automated methods. Introduction to hardware description languages. Introduction to simple computer systems, including their lower-level architecture, assembly language programming, and computer arithmetic. Lab stresses simulation of target circuits and physical realization with both discrete and high-complexity programmable components. Final design project. Prerequisite: Engineering 53L, and either Electrical and Computer Engineering 27L or Electrical and Computer Engineering 61L or Biomedical Engineering 153L. Instructor: Board, Dwyer, or Sorin. One course.

53L. Introduction to Electromagnetic Fields. Fundamentals and application of transmission lines and electromagnetic fields and waves, antennas, field sensing, and signal transmission. Transmission line transients and digital signal transmission; transmission lines in sinusoidal steady state, impedance transformation, and impedance matching; electrostatics and magnetostatics, including capacitance and inductance; electromagnetic waves in uniform media and their interaction with interfaces; antennas and antenna arrays. Alternating laboratories and recitations. Laboratory experiments include transmission line transients, impedance matching, static and dynamic electromagnetic fields, and antennas. Prerequisites: Engineering 53L, Mathematics 107 and either Electrical and Computer Engineering 27L or Electrical and Computer Engineering 61L or Biomedical Engineering 153L. Instructor: Carin, Cummer, Joines, Liu, or Smith. One course.

54L. Introduction to Signals and Systems. Continuous and discrete signal representation and classification; system classification and response; transfer functions. Fourier series; Fourier, Laplace, and z transforms. Applications to Integrated Sensing and Information Processing; networks, modulation, sampling, filtering, and digital signal processing. Laboratory projects using digital signal processing hardware and microcontrollers. Computational solutions of problems using Matlab and Maple. Prerequisite: Engineering 53L, and either Electrical and Computer Engineering 27L or Electrical and Computer Engineering 61L or Biomedical Engineering 153L. Instructor: Collins, Gustafson, or Huettel. One course.

61L. Introduction to Electric Circuits. Techniques for analyzing linear circuits. Nodal and mesh analysis, superposition and linearity, Thevenin and Norton equivalent circuits, operational amplifiers, energy storage, transient analysis, phasors and impedance, RMS values, AC power, frequency response, resonance, and filters. Circuit simulation using PSpice. Prerequisite: Mathematics 32. You must also enroll in ECE 61L9 when you enroll in this class. Instructor: Brooke, Brown, Gustafson, Shen, or Ybarra. One course.

122. Modern Optics I. (QID) NS One course. C-L: see Physics 185

123. Photonic and Electronic Design Projects. Photonic and electronic design problems obtained from industry are solved by teams of students. Required student response includes: formulation and written presentation of proposed problem solution, execution and evaluation of approved design solution, and written and oral presentation of final design performance, all for faculty review. Completed design must consider cost, performance, manufacturability. Students must address design solution impact on: environment, health, safety, society, and public policy as appropriate. Ethical issues as well as proper handling of intellectual property are discussed and used to guide the design process. Prerequisites: Electrical and Computer Engineering 163 and Electrical and Computer Engineering 122. Instructor: Guenther. One course.

135. Opto-Electronic Design Projects. Teams of students design an opto-electronic board-level system to a published specification. The system is built, tested, and compared to the design specifications. Optical, analog, digital, and radio frequency (RF) components are used to complete the projects. Group tasks include resource planning and management using GANTT charts, project budgeting, estimating product Bill of Materials costs, background study of the standard specification and component characteristics, testing of an evaluation board, interaction with component vendors, design of the team's board, submission of that design to a quick-turnaround board fabrication foundry, assembly of the purchased components onto the fabricated board, and board-level system test. The opto-electric board design incorporates considerations such as cost, economic viability, environmental impact, ethical issues, manufacturability, and social and political impact. Prerequisite: Electrical and Computer Engineering 163L and Junior or Senior standing in ECE or EE. Instructor: Brooke, Jokerst. One course.

141. Linear Control Systems. Analysis and design of feedback control systems. Block diagram and signal flow graph system models. Servomechanism characteristics, steady-state errors, sensitivity to parameter variations and disturbance signals. Time domain performance specifications. Stability. Root locus, Nyquist, and Bode analysis; design of compensation circuits; closed loop frequency response determination. Introduction to time domain analysis and design. Prerequisite: Electrical and Computer Engineering 54L or consent of instructor. Instructor: Gustafson. One course.

142. Introduction to Robotics and Automation. Fundamental notions in robotics, basic configurations of manipulator arm design, coordinate transformations, control functions, and robot programming. Applications of artificial intelligence, machine vision, force/torque, touch and other sensory subsystems. Design for automatic assembly concepts, tools, and techniques. Application of automated and robotic assembly costs, benefits, and economic justification. Selected laboratory and programming assignments. Prerequisites: Electrical and Computer Engineering 54L. Instructor: Janet. One course. C-L: Information Science and Information Studies

148L. Electrical Energy Systems. Electrical systems including energy distribution, static, linear, and rotary energy conversion, and control functions, linear and discrete, for energy conversion. DC and steady-state AC circuits. Transmission lines for distribution and signal transfer. Studies of static transformers, linear transducers, and rotary machines. Control theory applied to system operation. Laboratory. Prerequisites: Physics 62L and either Electrical and Computer Engineering 61L or Mathematics 107. Instructor: George. One course.

149. Electric Vehicle Project. The study of electrical components found in and the construction of an electric vehicle. Traction motors, controllers, and chargers, batteries, and metering. Project portion includes building of needed electrical devices and wiring of traction, control, lighting, and other components along with construction of adapters and devices necessary for the conversion of a vehicle to electric drive. Prerequisite: Physics 62L or Electrical and Computer Engineering 61. Instructor: George. Also taught as ME 149. One course. C-L: Mechanical Engineering and Materials Science 149

152. Introduction to Computer Architecture. Architecture and organization of digital computer systems. Processor operation, computer arithmetic, instruction set design. Assembly language programming. Selected hardware and software exercises culminating in the design, simulation, and implementation in FPGA technology of the major components of a complete computer system. Not open to students who have taken Computer Science 104. Prerequisite: Electrical and Computer Engineering 52L. Instructor: Board or Sorin. One course. C-L: Information Science and Information Studies

153. Introduction to Operating Systems. Basic concepts and principles of multiprogrammed operating systems. Processes, interprocess communication, CPU scheduling, mutual exclusion, deadlocks, memory management, I/O devices, file systems, protection mechanisms. Also taught as Computer Science 110. Prerequisites: Computer Science 100 and 104. Instructor: Chase or Ellis. One course.

154. Introduction to Embedded Systems. An introduction to hardware/software codesign of embedded computer systems. Structured programming techniques for high and low level programs. Hardware interfacing strategies for sensors, actuators, and displays. Detailed study of Motorola 68HC11 and 68HC12 microcomputers as applied to embedded system development. Hardware and simulation laboratory exercises with 68HC11 and 68HC12 development boards. Major design project. Prerequisite: Electrical and Computer Engineering 152 or equivalent and consent of instructor. Instructor: Board. One course.

156. Computer Network Architecture. The architecture of computer communication networks and the hardware and software required to implement the protocols that define the architecture. Basic communication theory, transmission technology, private and common carrier facilities. International standards. Satellite communications and local area networks. Performance analysis and modeling of communication networks. Prerequisite: Electrical and Computer Engineering 52L. Instructor: Bollapragada and Retana. One course. C-L: Information Science and Information Studies

157. Computer Network Analysis and Design. Graph representation of networks. Network design problems as graph optimization problems; related graph algorithms. Elementary queuing models and formulae. Network performance issues. Modern high-speed computer-communication networks. Packet switching. Network protocols. Broadband integrated services networks (B-ISDN) and the asynchronous transfer mode (ATM). Network admission and congestion controls. Instructor: Staff. One course. C-L: Information Science and Information Studies

158. Web Technologies. Introduction to the programming languages, authoring tools, and other technologies needed to design and implement effective sites on the World Wide Web. Topics include HTML, Javascript, cgi-bin, multimedia, and security. Students lead many class sessions; course project is to design or redesign a web site of interest to the Duke or Durham communities. Pass/fail grading only. Prerequisite: knowledge of at least one programming language at level of Computer Science 1. Instructor: Board. Half course. C-L: Information Science and Information Studies

159. Discrete Mathematics. Mathematics as applied to finite and infinite collections of discrete objects, including techniques for solving engineering problems involving finite and infinite sets, permutations and combinations of elements, discrete numeric functions, finite and infinite sums. Mathematical methods needed to tackle real-world problems in computer engineering, applied mathematics, computer science, and engineering. Instructor: Staff. One course.

163L. Introduction to Electronics: Integrated Circuits. Analysis and design of electronic circuits in bipolar and MOS technologies, with emphasis on both large-signal and small-signal methods. Circuits for logic gates, latches, and memories. Single-stage and multistage amplifiers and op amps. Circuits with feedback, including stability and frequency response considerations. Analog and mixed analog/digital circuit applications. Extensive use of SPICE for circuit simulation. Prerequisite: Electrical and Computer Engineering 51L. Instructor: Derby, Dwyer, or Fair. One course.

164L. Electronic Design Projects. Electronics/photonics project laboratory in which multidisciplinary teams of students build and test custom designed circuits or electronic/photonic systems. Students gain experience in the design/build/test/demonstrate process. Requirements include: a design plan incorporating engineering standards and realistic constraints, a time line indicating project milestones, a written project report, and oral presentations to the class. The completed design must consider most of the following: cost, environmental impact, manufacturability, ethics, health and safety, social and political impact. Prerequisites: Electrical and Computer Engineering 163L (or Biomedical Engineering 154L with consent of instructor) and at least one of 52L, 141, or 180. Instructor: Brooke, George, Jokerst, Ybarra. One course.

171. Applications of Electromagnetic Fields and Waves. Solution techniques applied to static and dynamic field problems. Discussions and example applications include the following topics: waves and transmission lines, waveguides and resonators, antennas and radiation, and electromagnetic forces and energy. Prerequisite: Electrical and Computer Engineering 53L. Instructor: Carin or Joines. One course.

176. Thermal Physics. Thermal properties of matter treated using the basic concepts of entropy, temperature, chemical potential, partition function, and free energy. Topics include the laws of thermodynamics, ideal gases, thermal radiation and electrical noise, heat engines, Fermi-Dirac and Bose-Einstein distributions, semiconductor statistics, kinetic theory, and phase transformations. Also taught as Physics 176. Prerequisites: Mathematics 103 or equivalent and Physics 51L, 62L or equivalent. Instructor: Staff. One course.

180. Fundamentals of Digital Signal Processing. An introduction to theory and applications of digital signal processing. Concepts, analytical tools and design techniques to process signals in digital form. Signal sampling and reconstruction, discrete-time transforms including the z-transform, discrete-time Fourier transform, and discrete Fourier transform. Discrete systems including the analysis and design of FIR and IIR filters. Introduction to applications of digital signal processing such as image processing, and optimal detection of signals in noise. Discrete system simulations using MATLAB. Prerequisite: Electrical and Computer Engineering 54L and Mathematics 135 or Statistics 113 or Electrical and Computer Engineering 255, or consent of instructor. Instructor: Huettel or Nolte. One course.

184. Introduction to Digital Communication Systems. Introduction to the design and analysis of modern digital communication systems. Communication channel characterization.. Baseband and passband modulation techniques. Optimal demodulation techniques with performance comparisons. Key information-theoretic concepts including entropy and channel capacity. Channel-coding techniques based on block, convolutional and Trellis codes. Equalization techniques. Applications to design of digital telephone modems, compact discs and digital wireless communication systems. Prerequisite: Electrical and Computer Engineering 54L and Mathematics 135 or Statistics 113 or Electrical and Computer Engineering 255. Instructor: Krolik. One course.

186. Wireless Communication Systems. Analog and digital cellular radio. Techniques for increasing capacity including cell division, multiple access techniques (TDMA, CDMA), speech compression, and discontinuous transmission. Direct sequence and frequency hopped spread spectrum systems. Radio wave propagation models. Intelligent antenna systems. Traffic considerations for cellular radio. Packet switched data access to the Internet and information services via wireless modems. Prerequisite: Mathematics 135 or Statistics 113 or Electrical and Computer Engineering 255. Corequisite: Electrical and Computer Engineering 184. Instructor: Ybarra. One course.

189. Digital Image and Multidimensional Processing. Introduction to the theory and methods of digital image and video sampling, denoising, coding, reconstruction, and analysis. Both linear methods (such as 2- and 3-D Fourier analysis) and non-linear methods (such as wavelet analysis). Key topics include segmentation, interpolation, registration, noise removal, edge enhancement, half toning and inverse half toning, deblurring, tomographic reconstruction, super resolution, compression, and feature extraction. While this course covers techniques used in a wide variety of contexts, it places a strong emphasis on medical imaging applications. Prerequisites: Electrical and Computer Engineering 54L and Statistics 113 or Mathematics 135 or Electrical and Computer Engineering 255 or permission of instructor. Instructor: Willett. One course. C-L: Information Science and Information Studies

191. Undergraduate Research in Electrical and Computer Engineering. For juniors only. Half course or one course each. Instructor: Staff. Variable credit.

192. Undergraduate Research in Electrical and Computer Engineering. For juniors only. Half course or one course each. Instructor: Staff. Variable credit.

193. Undergraduate Research in Electrical and Computer Engineering. For seniors only. Half course or one course each. Instructor: Staff. Variable credit.

194. Undergraduate Research in Electrical and Computer Engineering. For seniors only. Half course or one course each. Instructor: Staff. Variable credit.

195. Special Topics in Electrical and Computer Engineering. Study of selected topics in electrical engineering tailored to fit the requirements of a small group. Consent of instructor and director of undergraduate studies required. Half course or one course each. Instructor: Staff. Variable credit.

196. Special Topics in Electrical and Computer Engineering. Study of selected topics in electrical engineering tailored to fit the requirements of a small group. Consent of instructor and director of undergraduate studies required. Half course or one course each. Instructor: Staff. Variable credit.

197. Projects in Electrical and Computer Engineering. A course which may be undertaken only by seniors who are enrolled in the graduation with distinction program or who show special aptitude for individual project work. Elective for electrical and computer engineering majors. Consent of director of undergraduate studies required. Half course to two courses each. Instructor: Staff. Variable credit.

198. Projects in Electrical and Computer Engineering. A course which may be undertaken only by seniors who are enrolled in the graduation with distinction program or who show special aptitude for individual project work. Elective for electrical engineering majors. Consent of director of undergraduate studies required. Half course to two courses each. Instructor: Staff. Variable credit.

211. Quantum Mechanics. Discussion of wave mechanics including elementary applications, free particle dynamics, Schrödinger equation including treatment of systems with exact solutions, and approximate methods for time-dependent quantum mechanical systems with emphasis on quantum phenomena underlying solid-state electronics and physics. Prerequisite: Mathematics 107 or equivalent. Instructor: Brady, Brown, or Stiff-Roberts. One course.

214. Introduction to Solid-State Physics. Discussion of solid-state phenomena including crystalline structures, X-ray and particle diffraction in crystals, lattice dynamics, free electron theory of metals, energy bands, and superconductivity, with emphasis on understanding electrical and optical properties of solids. Prerequisite: quantum physics at the level of Physics 143L or Electrical and Computer Engineering 211. Instructor: Teitsworth. One course.

215. Semiconductor Physics. A quantitative treatment of the physical processes that underlie semiconductor device operation. Topics include band theory and conduction

phenomena; equilibrium and non equilibrium charge carrier distributions; charge generation, injection, and recombination; drift and diffusion processes. Prerequisite: Electrical and Computer Engineering 211 or consent of instructor. Instructor: Staff. One course.

216. Semiconductor Devices for Integrated Circuits. Basic semiconductor properties (energy-band structure, effective density of states, effective masses, carrier statistics, and carrier concentrations). Electron and hole behavior in semiconductors (generation, recombination, drift, diffusion, tunneling, and basic semiconductor equations). Current-voltage, capacitance-voltage, and static and dynamic models of PN Junctions, Schottky barriers, Metal/Semiconductor Contacts, Bipolar-Junction Transistors, MOS Capacitors, MOS-Gated Diodes, and MOS Field-Effect Transistors. SPICE models and model parameters. Instructor: Massoud. One course.

217. Analog Integrated Circuits. Analysis and design of bipolar and CMOS analog integrated circuits. SPICE device models and circuit macromodels. Classical operational amplifier structures, current feedback amplifiers, and building blocks for analog signal processing, including operational transconductance amplifiers and current conveyors. Biasing issues, gain and bandwidth, compensation, and noise. Influence of technology and device structure on circuit performance. Extensive use of industry-standard CAD tools, such as Analog Workbench. Prerequisite: Electrical Engineering 216. Instructor: Richards. One course.

218. Integrated Circuit Engineering. Basic processing techniques and layout technology for integrated circuits. Photolithography, diffusion, oxidation, ion implantation, and metalization. Design, fabrication, and testing of integrated circuits. Prerequisite: Electrical and Computer Engineering 216. Instructor: Fair. One course.

219. Digital Integrated Circuits. Analysis and design of digital integrated circuits. IC technology. Switching characteristics and power consumption in MOS devices, bipolar devices, and interconnects. Analysis of digital circuits implemented in NMOS, CMOS, TTL, ECL, and BiCMOS. Propagation delay modeling. Analysis of logic (inverters, gates) and memory (SRAM, DRAM) circuits. Influence of technology and device structure on performance and reliability of digital ICs. SPICE modeling. Prerequisites: Electrical and Computer Engineering 52L and 216. Instructor: Massoud. One course.

226. Optoelectronic Devices. Devices for conversion of electrons to photons and photons to electrons. Optical processes in semiconductors: absorption, spontaneous emission and stimulated emission. Light-emitting diodes (LEDs), semiconductor lasers, quantum-well emitters, photodetectors, modulators and optical fiber networks. Prerequisite: Electrical and Computer Engineering 216 or equivalent. Instructor: Stiff-Roberts. One course.

241. Linear System Theory and Optimal Control. Consideration of system theory fundamentals; observability, controllability, and realizability; stability analysis; linear feedback, linear quadratic regulators, Riccati equation, and trajectory tracking. Prerequisite: Electrical and Computer Engineering 141. Instructor: P. Wang. One course.

243. Pattern Classification and Recognition Technology. Theory and practice of recognition technology: pattern classification, pattern recognition, automatic computer decision-making algorithms. Applications covered include medical diseases, severe weather, industrial parts, biometrics, bioinformation, animal behavior patterns, image processing, and human visual systems. Perception as an integral component of intelligent systems. This course prepares students for advanced study of data fusion, data mining, knowledge base construction, problem-solving methodologies of "intelligent agents" and the design of intelligent control systems. Prerequisites: Mathematics 107, Statistics 113 or Mathematics 135 or Electrical and Computer Engineering 255, Computer Science 6, or consent of instructor. Instructor: Collins. One course.

245. Digital Control Systems. Review of traditional techniques used for the design of discrete-time control systems; introduction of "non classical" control problems of intelligent machines such as robots. Limitations of the assumptions required by traditional design and analysis tools used in automatic control. Consent of instructor required. Instructor: Staff. One course.

246. Optimal Control. Review of basic linear control theory and linear/nonlinear programming. Dynamic programming and the Hamilton-Jacobi-Bellman Equation. Calculus of variations. Hamiltonian and costatic equations. Pontryagin's Minimum Principle. Solution to common constrained optimization problems. This course is designed to satisfy the need of several engineering disciplines. Prerequisite: Electrical and Computer Engineering 141 or equivalent. Instructor: Staff. One course. C-L: Mechanical Engineering and Materials Science 232

251. Advanced Digital System Design. This course covers the fundamentals of advanced digital system design, and the use of a hardware description language, VHDL, for their synthesis and simulation. Examples of systems considered include the arithmetic/logic unit, memory, and microcontrollers. The course includes an appropriate capstone design project that incorporates engineering standards and realistic constraints in the outcome of the design process. Additionally, the designer must consider most of the following: Cost, environmental impact, manufacturability, health and safety, ethics, social and political impact. Each design project is executed by a team of 4 or 5 students who are responsible for generating a final written project report and making an appropriate presentation of their results to the class. Prerequisite: Electrical and Computer Engineering 52L and Senior/graduate student standing. Instructor: Marinos. One course.

252. Advanced Computer Architecture I. (M, QID) QS, R One course. C-L: see Computer Science 220

253. Parallel System Performance. Intrinsic limitations to computer performance. Amdahl's Law and its extensions. Components of computer architecture and operating systems, and their impact on the performance available to applications. Intrinsic properties of application programs and their relation to performance. Task graph models of parallel programs. Estimation of best possible execution times. Task assignment and related heuristics. Load balancing. Specific examples from computationally intensive, I/O intensive, and mixed parallel and distributed computations. Global distributed system performance. Prerequisites: Computer Science 110; Electrical and Computer Engineering 152. Instructor: Staff. One course.

254. Fault-Tolerant and Testable Computer Systems. Faults and failure mechanisms, test generation techniques and diagnostic program development for detection and location of faults in digital networks; design for testability, redundancy techniques, self-checking and fail-safe networks, fault-tolerant computer architectures. Prerequisite: Electrical and Computer Engineering 52L or equivalent. Instructor: Marinos. One course. C-L: Computer Science 225

255. Probability and Statistics. Basic concepts and techniques used in the stochastic modeling of systems. Elements of probability, statistics, queuing theory, and simulation. Also taught as Computer Science 226. Prerequisite: four semesters of college mathematics. Instructor: Trivedi. One course. C-L: Information Science and Information Studies

257. Performance and Reliability of Computer Networks. Methods for performance and reliability analysis of local area networks as well as wide area networks. Probabilistic analysis using Markov models, stochastic Petri nets, queuing networks, and hierarchical models. Statistical analysis of measured data and optimization of network structures. Prerequisites: Electrical and Computer Engineering 156 and 255. Instructor: Trivedi. One course. C-L: Information Science and Information Studies

258. Artificial Neural Networks. Elementary biophysical background for signal propagation in natural neural systems. Artificial neural networks (ANN) and the history of computing; early work of McCulloch and Pitts, of Kleene, of von Neumann and others. The McCulloch and Pitts model. The connectionist model. The random neural network model. ANN as universal computing machines. Associative memory; learning; algorithmic aspects of learning. Complexity limitations. Applications to pattern recognition, image processing and combinatorial optimization. Instructor: Cramer. One course. C-L: Information Science and Information Studies

259. Advanced Computer Architecture II. (M, QID) QS One course. C-L: see Computer Science 221

261. CMOS VLSI Design Methodologies. Emphasis on full-custom chip design. Extensive use of CAD tools for IC design, simulation, and layout verification. Techniques for designing high-speed, low-power, and easily-testable circuits. Semester design project: Groups of four students design and simulate a simple custom IC using Mentor Graphics CAD tools. Teams and project scope are multidisciplinary; each team includes students with interests in several of the following areas: analog design, digital design, computer science, computer engineering, signal processing, biomedical engineering, electronics, photonics. A formal project proposal, a written project report, and a formal project presentation are also required. The chip design incorporates considerations such as cost, economic viability, environmental impact, ethical issues, manufacturability, and social and political impact. Prerequisites: Electrical and Computer Engineering 52L and Electrical and Computer Engineering 163. Some background in computer organization is helpful but not required. Instructor: Chakrabarty. One course.

262. Analog Integrated Circuit Design. Design and layout of CMOS analog integrated circuits. Qualitative review of the theory of pn junctions, bipolar and MOS devices, and large and small signal models. Emphasis on MOS technology. Continuous time operational amplifiers. Frequency response, stability and compensation. Complex analog subsystems including phase-locked loops, A/D and D/A converters, switched capacitor simulation, layout, extraction, verification, and MATLAB modeling. Projects make extensive use of full custom VLSI CAD software. Prerequisite: Electrical and Computer Engineering 261. Instructor: Morizio. One course.

263. Multivariable Control. One course. C-L: see Civil Engineering 263; also C-L: Mechanical Engineering and Materials Science 263

266. Synthesis and Verification of VLSI Systems. Algorithms and CAD tools for VLSI synthesis and design verification, logic synthesis, multi-level logic optimization, high-level synthesis, logic simulation, timing analysis, formal verification. Prerequisite: Electrical and Computer Engineering 52L or equivalent. Instructor: Chakrabarty. One course.

269. VLSI System Testing. Fault modeling, fault simulation, test generation algorithms, testability measures, design for testability, scan design, built-in self-test, system-on-a-chip testing, memory testing. Prerequisite: Electrical and Computer Engineering 52L or equivalent. Instructor: Chakrabarty. One course.

271. Electromagnetic Theory. The classical theory of Maxwell's equations; electrostatics, magnetostatics, boundary value problems including numerical solutions, currents and their interactions, and force and energy relations. Three class sessions. Prerequisite: Electrical and Computer Engineering 53L. Instructor: Carin, Joines, Liu, or Smith. One course.

272. Electromagnetic Communication Systems. Review of fundamental laws of Maxwell, Gauss, Ampere, and Faraday. Elements of waveguide propagation and antenna radiation. Analysis of antenna arrays by images. Determination of gain, loss, and noise temperature parameters for terrestrial and satellite electromagnetic communication systems. Prerequisite: Electrical and Computer Engineering 53L or 271. Instructor: Joines. One course.

273. Optical Communication Systems. Mathematical methods, physical ideas, and device concepts of optoelectronics. Maxwell's equations, and definitions of energy density and power flow. Transmission and reflection of plane waves at interfaces. Optical resonators, waveguides, fibers, and detectors are also presented. Prerequisite: Electrical and Computer Engineering 53L or equivalent. Instructor: Joines. One course.

275. Microwave Electronic Circuits. Microwave circuit analysis and design techniques. Properties of planar transmission lines for integrated circuits. Matrix and computer-aided methods for analysis and design of circuit components. Analysis and design of input, output, and interstage networks for microwave transistor amplifiers and oscillators. Topics on stability, noise, and signal distortion. Prerequisite: Electrical and Computer Engineering 53L or equivalent. Instructor: Joines. One course.

276. Laser Physics. (QID) NS One course. C-L: see Physics 261

277. Computational Electromagnetics. Systematic discussion of useful numerical methods in computational electromagnetics including integral equation techniques and differential equation techniques, both in the frequency and time domains. Hands-on experience with numerical techniques, including the method of moments, finite element and finite-difference time-domain methods, and modern high order and spectral domain methods. Prerequisite: Electrical and Computer Engineering 271 or consent of instructor. Instructor: Carin or Liu. One course.

278. Inverse Problems in Electromagnetics and Acoustics. Systematic discussion of practical inverse problems in electromagnetics and acoustics. Hands-on experience with numerical solution of inverse problems, both linear and nonlinear in nature. Comprehensive study includes: discrete linear and nonlinear inverse methods, origin and solution of non uniqueness, tomography, wave-equation based linear inverse methods, and nonlinear inverse scattering methods. Assignments are project oriented using MATLAB. Prerequisites: Graduate level acoustics or electromagnetics (Electrical and Computer Engineering 271), or consent of instructor. Instructor: Liu. One course.

281. Random Signals and Noise. Introduction to mathematical methods of describing and analyzing random signals and noise. Review of basic probability theory; joint, conditional, and marginal distributions; random processes. Time and ensemble averages, correlation, and power spectra. Optimum linear smoothing and predicting filters. Introduction to optimum signal detection, parameter estimation, and statistical signal processing. Prerequisite: Mathematics 135 or Statistics 113 or Electrical and Computer Engineering 255. Instructor: Collins or Nolte. One course.

282. Digital Signal Processing. Introduction to the fundamentals of processing signals by digital techniques with applications to practical problems. Discrete time signals and systems, elements of the Z-transform, discrete Fourier transforms, digital filter design techniques, fast Fourier transforms, and discrete random signals. Instructor: Nolte or Tantum. One course.

283. Digital Communication Systems. Digital modulation techniques. Coding theory. Transmission over bandwidth constrained channels. Signal fading and multipath effects. Spread spectrum. Optical transmission techniques. Prerequisite: Electrical and Computer Engineering 281 or consent of instructor. Instructor: Staff. One course.

284. Acoustics and Hearing. One course. C-L: see Biomedical Engineering 235

285. Signal Detection and Extraction Theory. Introduction to signal detection and information extraction theory from a statistical decision theory viewpoint. Subject areas covered within the context of a digital environment are decision theory, detection and estimation of known and random signals in noise, estimation of parameters and adaptive recursive digital filtering, and decision processes with finite memory. Applications to problems in communication theory. Prerequisite: Electrical and Computer Engineering 281 or consent of instructor. Instructor: Nolte. One course.

286. Digital Processing of Speech Signals. Detailed treatment of the theory and application of digital speech processing. Modeling of the speech production system and speech signals; speech processing methods; digital techniques applied in speech transmission, speech synthesis, speech recognition, and speaker verification. Acoustic-phonetics, digital speech modeling techniques, LPC analysis methods, speech coding techniques. Application case studies: synthesis, vocoders, DTW (dynamic time warping)/HMM (hidden Markov modeling), recognition methods, speaker verification/identification. Prerequisite: Electrical and Computer Engineering 180 or equivalent or consent of instructor. Instructor: Staff. One course.

288. Image and Array Signal Processing. Multidimensional digital signal processing with applications to practical problems in image and sensor array processing. Two-dimensional discrete signals and systems, discrete random fields, 2-D sampling theory, 2-D transforms, image enhancement, image filtering and restoration, space-time signals, beam forming, and inverse problems. Prerequisite: Electrical and Computer Engineering 282 or consent of instructor. Instructor: Krolik. One course.

289. Adaptive Filters. Adaptive digital signal processing with emphasis on the theory and design of finite-impulse response adaptive filters. Stationary discrete-time stochastic processes, Wiener filter theory, the method of steepest descent, adaptive transverse filters using gradient-vector estimation, analysis of the LMS algorithm, least-squares methods, recursive least squares and least squares lattice adaptive filters. Application examples in noise canceling, channel equalization, and array processing. Prerequisites: Electrical and Computer Engineering 281 and 282 or consent of instructor. Instructor: Krolik. One course.

299. Advanced Topics in Electrical and Computer Engineering. Opportunity for study of advanced subjects related to programs within the electrical engineering department tailored to fit the requirements of a small group. Instructor: Staff. One course.