ELECTRICAL AND COMPUTER ENGINEERING

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COLLEGE OF ENGINEERING

Botros, **Nazeih M**., Professor, Ph.D., University of Oklahoma, 1985; 1985. Digital hardware design, digital signal processing, digital instrumentation, neural networks, robot sensing, and bioeengineering.

Brown, **David P**., Professor, *Emeritus*, Ph.D., Michigan State University, 1961; 1983.

Daneshdoost, **Morteza**, Professor, Ph.D., Drexel University, 1984; 1984. Electric power systems, linear systems and circuits, control systems optimization techniques, expert systems, computer graphics, MMI.

Feiste, **Vernold**, **K**., Associate Professor, *Emeritus*, Ph.D., University of Missouri-Columbia, 1966; 1966.

Galanos, **Glafkos D**., Professor and *Chair,* Ph.D., University of Manchester, England, 1970; 1987. Power systems, HVDC transmission, power electronics systems.

Gupta, **Lalit**, Professor, Ph.D., Southern Methodist University, 1986; 1986. Computer vision, pattern recognition, digital signal processing, neural networks.

Haniotakis, T., Assistant Professor, Ph.D., University of Athens, 1998; 2001. Digital VLSI design, mixed signal VLSI design, VLSI testing, fault tolerant systems.

Harackiewicz, **Frances J**., Professor, Ph.D., University of Massachusetts-Amherst, 1990; 1989. Electromagnetics, antenna theory and design, microwaves, microstrip phased arrays and anisotropic materials.

Hatziadoniu, **Constantine**, Professor, Ph.D., West Virginia University, 1987; 1987. Power systems modeling, simulation and control, high voltage DC transmission, power electronics, power systems transient.

Hu, **Chia-Lun John**, Professor, *Emeritus*, Ph.D., University of Colorado, 1966; 1981.

Kagaris, **Dimitrios**, Associate Professor, Ph.D., Dartmouth College, 1994; 1995. VLSI design automation, digital circuit testing, communication networks.

Osborne, William P., Professor and *Dean*, Ph.D., P.E., New Mexico State University, 1970; 2005. Communications Systems Modeling and Analysis, Wireless System Design Space Based Systems, and RF Design.

Pourboghrat, **Farzad**, Professor, Ph.D., University of Iowa, 1984; 1984. Optimal control, robust and adaptive control, dynamic neural networks, robotics, embedded control systems, sensor networks.

Rawlings, **Charles A**., Professor, *Emeritus*, Ph.D., Southern Illinois University Carbondale, 1974; 1964.

Sayeh, **Mohammad R**., Professor, Ph.D., Oklahoma State University, 1985; 1986. Neural networks, optical computing, image processing, stochastic modeling, quantum electronics.

Schoen, **Alan**, Professor, *Emeritus*, Ph.D., University of Illinois, 1958; 1973.

Smith, **James G**., Professor, Ph.D., *Emeritus,* University of Missouri-Rolla, 1967; 1966.

Tragoudas, **Spyros**, Professor, Ph.D., University of Texas at Dallas, 1991, 1999. Design automation for VSLI, testing and verification of digital circuiting, computer networks.

Viswanathan, **Ramanarayanan**, Professor, Ph.D., Southern Methodist University, 1983; 1983. Detection and estimation theory, spread spectrum communication, communication theory, signal processing.

Wang, Haibo, Assistant Professor, Ph.D., University of Arizona, 2002; 2002. Mixed-signal VLSI design and testing, digital VLSI, VLSI design automation.

Weng, Ning, Assistant Professor, Ph.D., University of Massachusetts at Amherst, 2005; 2005. High performance routers, network processors, system-on-a-Chip, computer architectures.

Zhang, Wei, Assistant Professor, Ph.D., Pennsylvania State University, 2003; 2003. Computer architecture, compilers, hardware/software co-design.

Master of Science Degree in Electrical and Computer Engineering

The College of Engineering offers graduate programs leading to the Master of Science and Doctor of Philosophy degrees. The Department of Electrical and Computer Engineering offers programs of study and research leading to the Master of Science degree in Electrical and Computer Engineering and the Doctor of Philosophy in Electrical and Computer Engineering. The Department provides a rich environment for educational and professional advancement in the following areas:

Antennas, circuits and systems theory, electromagnetics, robust and adaptive control, robotics, embedded control, MEMS, plasma processing, energy conversion, power systems, power electronics, pattern recognition, image processing, biomedical engineering, neural networks, optical computing, stochastic modeling, wireless communications, detection and estimation theory, communication networks, mobile *ad hoc* networks, sensor networks, digital systems, programmable ASICs design, bioengineering, computer architecture, CMOS VLSI, fault tolerance, mixed signal testing and design, low power system design, hardware/software co-design, synthesis and verification of digital systems, physical design automation, and VLSI testing.

The ECE programs of study provide a balance between formal classroom instruction and research, and are tailored to the individual student's academic and professional goals. Graduates of the program enjoy excellent employment opportunities and are highly recruited worldwide in industry, government, and academia.

Admission. The program is designed for individuals holding a Bachelor of Science degree in electrical or computer engineering or related field. Qualified applicants with Bachelor of Science in other areas of engineering and science may be able to enroll in the program with additional preparation. (Approved by the Department on a case-by-case basis).

Admission to the program is based on the following factors: grade point average, class ranking, GRE scores (especially quantitative) and faculty recommendation letters. The admission requirements of the Department are higher than the minimum requirements of the Graduate School. The TOEFL score requirement for international applicants is 550 (the same as required by the Graduate School). Admission to the program is granted by the Chair of the Department, upon recommendation by the faculty.

This program requires a nonrefundable $45.00 application fee that must be submitted with the application for Admissions to Graduate Study in Electrical and Computer Engineering. Applicants may pay this fee by credit card if applying electronically. Applicants submitting a paper application must pay by personal check, cashier's check, or money order made out to SIU, and payable to a U.S. Bank.

Requirements. The Department offers two different programs leading to the Master of Science degree, the Thesis and the Non-theis program. The requirements for each of the programs are as follows:

The thesis program leading to the Master of Science degree in Electrical and Computer Engineering requires 30 semester hours of credit. Six hours of thesis (ECE 599), one hour of ECE seminar (ECE 580) and at least fifteen hours of 500-level courses are required. Thus, a maximum of eight hours of 400-level courses could be counted toward the degree requirements. With the approval of the Department, a maximum of six hours from academic units outside the ECE Department could be applied toward the degree. The degree is awarded following a comprehensive examination covering the candidate's entire program of study, including the thesis.

The non-thesis program leading to the Master of Science degree in Electrical and Computer Engineering requires 30 semester hours of credit. At least 22 hours should be in 500-level courses, thus, a maximum of eight hours of 400-level courses could be counted toward the degree requirements. With the approval of the Department, a maximum of six hours from academic units outside the ECE Department could be applied toward the degree.

Qualified individuals with exceptional credentials may apply for assistantships, fellowships, and scholarships, either at the same time they apply for admission, or at any time during the course of their studies.

Please address any correspondence to "Master of Science Program," Department of Electrical and Computer Engineering, Southern Illinois University Carbondale, Carbondale, Illinois 62901-6603. For telephone inquiries please call 618-536-2364, and refer to the Master of Science Program. The Electrical and Computer Engineering facsimile number is 618-453-7972, and the email address is ecedept@siu.edu. The Electrical and Computer Engineering home page address is http://heera.engr.siu.edu /elec/index.htm.

ECE/LAW in Electrical and Computer Engineering/Juris Doctor

Southern Illinois University Carbondale is one of the few institutions in the country to offer a concurrent degree in Electrical and Computer Engineering and Law. Students prepared for this program are expected to possess an undergraduate degree in electrical engineering, computer engineering or a related field. Students are able to tailor their program of study to focus on legal principles and policies involving the engineering profession including patent, copyright, trademark, environmental and electronic commerce laws, federal regulation of electronic media and other engineering-related areas of law.

Students must meet the requirements of admission and be admitted separately to the Master of Science program in Electrical and Computer Engineering and the School of Law. Accepted students could complete the concurrent program in as few as three years, including summers. Law students interested in this program should consult with the School of Law Associate Dean for Academic Affairs and with the Chair of the Department of Electrical and Computer Engineering.

Thesis Option

The course of study consists of the following:

- Twenty-one hours of ECE courses, including ECE 599, Master's Thesis (six hours) and ECE 592, Special Investigations (three hours).
- Eighty-one hours of LAW courses, including nine hours from an approved list of LAW courses.

The nine hours of ECE 599 and ECE 592 are applied toward the J.D. degree, for a total of 90 hours. The nine hours of LAW courses (from the approved list of LAW courses) are applied toward the M.S. degree in ECE, for a total of 30 hours.

Non-Thesis Option

The course of study consists of the following:

- Twenty-one hours of ECE courses, including ECE 593, Advanced Topics (three hours) and ECE 592, Special Investigations (three hours).
- Eighty-one hours of LAW courses, including nine hours from an approved list of LAW courses.

Nine hours of ECE courses, including ECE 592 and ECE 593 are applied toward the J.D. degree, for a total of 90 hours. The nine hours of LAW courses (from the approved list of LAW courses) are applied toward the M.S. in ECE, for a total of 30 hours.

List of Approved LAW Courses

LAW 525 Federal Income Tax
LAW 528 Corporations
LAW 545 International Trade Law
LAW 546 Federal Business Taxation
LAW 548 Environmental Law I: Laws and Policies
LAW 559 International Business Transactions
LAW 562 Copyright Law
LAW 564 Law and Economics
LAW 565 Antitrust
LAW 567 Electronic Commerce
LAW 568 Water Law
LAW 586 Business Planning
LAW 610 Federal Regulation of Electronic Media
LAW 630 Intellectual Property
LAW 634 Trademarks and Unfair Competition
LAW 660 Food, Drug and Medical Device Law

Doctor of Philosophy in Electrical and Computer Engineering

Educational Objectives. The program is designed to achieve the following academic objectives: (a) to fulfill the obligation of the ECE Department to provide high quality education through the doctoral level as is mandated by the mission statement of the University; (b) to provide the students with the training necessary to successfully apply the fundamental concepts and methods of electrical and computer engineering to specific areas of research and development; (c) to provide the graduates with the ability to independently organize and conduct research in electrical and computer engineering; (d) to provide the graduates with the ability to concisely disseminate existing and new knowledge and to accurately present their research plans in writing.

Program Structure. The program offers two areas of concentration: (a) Electrical Engineering and (b) Computer Engineering. The concentration in Electrical Engineering offers three tracks: (1) Communications, (2) Electronics & Optics, (3) Systems. The core for each of the areas above includes six courses as follows:

ELECTRICAL ENGINEERING			COMPUTER ENGINEERING
Communications	*Electronics & Optics*	*Systems*	
ECE 551	ECE 540	ECE 551	ECE 521
ECE 552	ECE 543	ECE 564	ECE 523
ECE 558	ECE 547	ECE 565	ECE 524
ECE 564	ECE 549	ECE 584	ECE 528
ECE 568	ECE 573	ECE 587	ECE 531
ECE 577	ECE 577	ECE 588	ECE 532

Admission. Admission to the program requires a Master of Science degree in Electrical or Computer Engineering or a related field with a GPA of 3.5/4.0 or higher. Applications for admission must include the following: a statement of interest, transcripts, GRE scores, three reference letters and TOEFL score (where appropriate), as required by the Graduate School. Admission to the program is made by the Department Chair upon recommendation by the ECE Graduate Committee.

Advisement. Upon admission the Chair assigns the advisor (and chair of the student's committee) and two committee members, to assist the student in selecting the appropriate core courses and in developing a plan of study.

Curriculum. The curriculum consists of fifty hours of credit beyond the M.S. degree. Eighteen hours of 500-level ECE courses, of which nine hours must be taken from the selected core, three hours of mathematics, three additional hours of mathematics or science, two hours of seminar and twenty-four hours of dissertation. The mathematics and science courses must be approved by the student's Committee. Core courses successfully completed for the M.S. degree can be used to fulfill the core requirements, but additional courses must be taken to satisfy the requirement of eighteen hours of 500-level ECE courses beyond the M.S. degree. The objective of the

core is to provide the candidate with the foundation necessary to engage successfully in the selected research area. Thus, the core design fulfills the research tool requirement specified in the Graduate School guidelines.

Qualifying Examinations. Upon completion of the core courses the student may take the qualifying examination. This examination covers the material of the core courses selected and is administered by the student's committee. If not successful, the committee may allow the student to repeat the whole or part of the examination one more time. The qualifying examination, in whole or in part, cannot be taken more than two times.

Candidacy. Admission to candidacy requires: (a) successful completion of the qualifying examination (which satisfies the research tool requirement of the Graduate School) and (b) successful completion of twenty-four hours of credit (which satisfies the residency requirement of the Graduate School).

Dissertation Committee. Following the admission to candidacy the Department Chair in consultation with the student's advisor (dissertation supervisor) appoints the dissertation committee, which shall consist of five faculty members with at least one (but not more than two) outside the ECE Department. The student's dissertation supervisor shall be one of the five members and shall chair this committee.

Dissertation Proposal. Following the admission to candidacy and upon completion of all the coursework, the candidate will prepare and submit a formal written dissertation proposal, defining the proposed research and the proposed line of inquiry. The candidate subsequently must make an oral presentation of the dissertation proposal to the members of the dissertation committee in an open forum. A public announcement of this event must be made at least five days in advance.

Oral Examination. In the framework of the oral presentation of the dissertation proposal, the candidate is expected to address and respond to any question (by the members of the committee) related to material covered by all the courses taken during his doctoral studies or to the background necessary for the specific area of the proposed research. In addition, the candidate is expected to defend the research methodology and the proposed line of inquiry.

Dissertation Defense. Upon completion of the dissertation, which must demonstrate the ability of the candidate to conduct independent research, the committee will administer the final oral examination. The objective of the final oral examination, conducted in an open forum, will be the defense of the dissertation. Upon satisfactory completion of the dissertation and the final oral examination the committee will recommend the candidate for the doctoral degree.

Time Limits. The upper or lower time limits for completion of each of the steps in the process are the same as those specified by the Graduate School for doctoral programs.

Presentation Skills. Technical writing and oral presentation skills are important particularly for a possible academic career. During the course of study the student will be provided with opportunities to develop these skills (by attending technical writing classes and seminars). It is desirable to assign some teaching assistant duties to the candidate to gain some teaching experiences. The dissertation committee shall evaluate the candidate's skills both in technical writing and oral presentation.

Courses (ECE)

Graduate work in the Department of Electrical and Computer Engineering is offered toward a concentration for the Master of Science degree in Engineering. Safety glasses are required for some of the courses in this department. Four-hundred-level courses in this department may be taken for graduate credit unless otherwise indicated in the course description.

421-4 Synthesis with Hardware Descriptive Languages. Fundamental concepts, techniques and tools for computer-aided design of simple digital systems. Modeling and simulation of digital systems using hardware descriptive languages. Behavioral, data flow and structural modeling. Synthesis, optimization and verification. Lecture and laboratory. Prerequisite: 327.

422-4 Introduction to Data Communications Networks. Protocol architecture. Signaling and data encoding techniques. Circuit and packet switching technologies. Data link layer, routing, internet and transport protocols. Medium access control (MAC) sublayer and local area network (LAN) technologies. Cryptography. Prerequisite: 315 and 355.

423-4 Digital VLSI Design. Principles of the design and layout of Very Large Scale Integrated (VLSI) circuits concentrating on the CMOS technology. MOS transistor theory and the CMOS technology. Characterization and performance estimation of CMOS gates, CMOS gate and circuit design. Layout and simulation using CAD tools. CMOS design of datapath subsystems. Design of finite state machines. Examples of CMOS system designs. Laboratory experience in CMOS VLSI design. Lecture and Laboratory (VLSI design). Prerequisite: 327 and 345.

424-4 Microprocessor-Based System. Microprocessor technology. Design, construction and programming of microprocessor-based systems. Lecture and laboratory. Cost of parts for microprocessor-based system, approximately $80. Prerequisite: 329 or concurrent enrollment or consent of instructor.
425-4 VLSI Design and Test Automation. Principles of the automated synthesis, verification, testing and layout of Very Large Scale Integrated (VLSI) circuits concentrating on the CMOS technology. Resource allocation and scheduling in high-level synthesis. Automation of the logic synthesis for combinational and sequential logic. The physical design automation cycle and CMOS technology considerations. Fault modeling and testing. Timing analysis. Laboratory experience using commercial tools for synthesis and layout. Prerequisite: 329, 345.
428-4 Programmable ASICs Design. Introduction to theoretical concepts and experimental design and construction of Application-Specific Integrated Circuits (ASICs). Rapid prototyping of data path and control in computer systems. Field Programmable Gate Arrays (FPGAs) or similar logic. Lecture and laboratory. Laboratory fee of $10 to help defray costs of consumable items. Prerequisite: 329 or consent.
429-4 Computer Systems Architecture. Advanced computer arithmetic, principles of performance evaluation, instruction set principles, pipeline considerations and instruction level parallelism, vector processors, memory hierarchy design. Prerequisite: 329.
440-4 CMOS Radio-Frequency Integrated Circuit Design I. The basics of CMOS RFIC design, including basic concepts in RFIC design, CMOS (active and passive) microwave devices, matching networks and signal flow graph, scattering parameter microwave circuit design and analysis methods. Lecture and laboratory. Prerequisite: 345, 375; or equivalent.
441-4 Photonics I. Ray optics, wave optics, beam optics, polarization of light, statistical optics, photons and atoms. Prerequisite: 375 with a grade of *C* or better.
446-4 Electronic Circuit Design. Analysis and design of electronic circuits, both discrete and integrated. Computer-aided circuit design and analysis. Consideration of wideband, power and tuned amplifiers; switching circuits; feedback; and oscillators. Design projects. Lecture and laboratory. Laboratory fee of $10 to defray cost of consumable items. Prerequisite: 345 and 355 or concurrent enrollment.
447-4 Electronic Devices. Fundamental principles of semiconductor carrier statistics, band diagrams, pn-junction diodes, Schottky diodes, BJTs, MOS capacitors and MOSFETs for advanced VLSI technology. Lecture and laboratory. Prerequisite: 345, 375 or equivalent.
448-4 Photonics II. Fourier optics, fiber optics, electro-optics, nonlinear optical media, acousto-optics, photonic switching, optical interconnections and optical storage. Prerequisite: 441 or consent of instructor.
456-3 Embedded Control and Mechatronics. Introduction to mechatronic systems, systems modeling and simulation, sensors and actuators, real-time interfacing, DSPs and microcontrollers, analysis or sampled-data systems, z-transform, digital control design techniques, emulation methods, direct method, industrial applications. Lecture and laboratory. Prerequisite: 315 and 356.
459-4 MEMS and Micro-Engineering. Introduction to micro electro-mechanical systems (MEMS), manufacturing techniques, microsensors, microactuators, microelectronics and micro-controllers. Lecture and laboratory. Prerequisite: 315 and 356.
468-4 Digital Signal Processing. Discrete time signals and systems; z-transform; discrete Fourier transform, fast Fourier transform algorithms; digital filter design; digital filter realizations. Lecture and laboratory. Prerequisite: 355.
471-3 Wireless and Personal Communications Systems. Overview of wireless technologies, access technologies and cellular systems. Fundamentals of radio and cellular communications. Digital modulation techniques. Antennas and diversity systems. Concepts of packet radio systems. North American Cellular and PCS systems. Prerequisite: 315 and 355.
472-4 Antennas I. Analysis, design, fabrication, measurement and CAD applied to basic antenna types. Fundamental parameters. Friis transmission equation. Impedance and pattern measurements. Resonant microstrip and wire antennas. Arrays and line sources. Lecture and Laboratory. Prerequisite: 375.
476-4 Introduction to Broadband Communication Systems. Digital transmission fundamentals. Satellite, microwave, video coding and optical transmission. Prerequisite: 315, 355 and 375.
477-3 Fields and Waves I. Transmission-line for communications. Guided wave principles and resonators. Applications in electronics, optoelectronics and photonics. Principles of radiation. Solution techniques for Laplace's equation and one-dimensional wave equation. Prerequisite: 375.
478-4 Analog and Digital Communication. Amplitude, frequency, and phase modulation. Sampling theorem. Pulse code modulation. Baseband binary communication. Digital carrier systems. Optimum signal detection. Lectures and laboratory projects. Prerequisite: 315 and 355.
479-4 Microwave Engineering I. Electromagnetic theory, analysis, design, fabrication, measurement and CAD applied to passive networks at microwave frequencies. Topics include: Transmission lines, Waveguides, Impedance matching, Tuning, Resonators, Scattering parameters, the Smith Chart. Lecture and Laboratory. Prerequisite: 375.
483-4 Power Electronics. Power semiconductor devices. Line commutation: diode and thyristors rectifiers. DC choppers. Switching-mode power supplies. Forced commutation: voltage-sourced inverters. DC drives. AC drives. Prerequisite: 385.

484-4 Computer-Aided Circuit Analysis. Network topology. Analysis of linear and non-linear networks. Standard form of state equations. Numerical solution of state equations. Frequency domain sensitivity calculations. Lecture and projects. Prerequisite: 355.
486-3 Electric Energy Sources. Electric power generators–fossil fuel, nuclear and solar. Principles of design, operation and utilization. Direct energy conversions. Energy storage devices and systems. Cost analysis of power generation. Prerequisite: 385 or consent.
487-4 Power Systems Analysis. Introduction to analysis of electric power systems. Modeling of power system components. Transmission line calculations and modeling. Power system configuration. Per-unit quantities. Power system modeling. Introduction to load-flow analysis. Lecture and laboratory. Prerequisite: 315 and 385.
488-4 Power Systems Engineering. Power flow control. Voltage control. Economic operation of power systems. Symmetrical faults. Symmetrical components. Analysis of asymmetrical faults. Power system stability. Lecture and laboratory. Prerequisite: 356 and 487.
489-3 Electric Power Distribution. Design of primary and secondary distribution networks. Load characteristics. Voltage regulation. Metering techniques and systems. Protection of distribution systems. Technical and legal aspects, related to power distribution. Prerequisite: 385.
493-1 to 4 Special Topics in Electrical Engineering. Lectures on topics of special interest to students in various areas of electrical engineering. Designed to test new and experimental courses in electrical engineering. Prerequisite: consent of instructor.
521-3 Fault-Tolerant Computer Design. (Same as Electrical Computer Engineering 521) Concepts of error detection, location and correction in digital systems. Codes for error detection and correction. Models and simulations of faults. Design of tests for combinatorial and sequential circuits. Testability. Design of digital systems with testability. Prerequisite: 423, 425 or consent of instructor.
522-3 VLSI Circuit Testing. Theoretical and practical aspects of production testing of VLSI circuits. Relations between physical defects and fault models. Procedures for generating test inputs. Design modifications for test application and theory of built-in self-test. Prerequisite: 423, 425 or consent of instructor.
523-3 Low Power VLSI Design. Source of power dissipation, technology impact on power dissipation, low power circuit techniques, energy recovery, synthesis of low power circuits, low power components. Prerequisite: 423.
524-3 Synthesis and Verification of Digital Circuits. Binary decision diagrams, finite state machines and finite automata. Design automation concepts in logic level synthesis, optimization and verification for combinational as well as sequential logic. Technology mapping. Prerequisite: 423, 425.
525-3 Advances in Physical Design Automation. Advances in the automation of VLSI layouts with emphasis on recent developments in deep submicron, FPGA and MCM technologies. Floorplanning, placement, routing objectives in high performance designs using deep submicron technology. Timing analysis in the presence of crosstalk. FPGA architectures and design with dynamically reconfigurable FPGAs. Physical design automation for MCMs. Prerequisite: 423, 425.
526-3 Network Processing Systems Design. Protocol processing, packet processing algorithms, classification and forwarding, queuing theory, switching fabrics, network processors, network systems design tradeoffs. Prerequisite: 422 and 429 or consent of the instructor.
527-3 Switching Circuit Theory. Study of both combinational and sequential switching circuits with emphasis on sequential networks. Threshold logic. Fault detection and location in combinational circuits. Finite-state machines including: minimization, state assignment, races, state-identification. Asynchronous sequential circuits. Linear sequential machines. Prerequisite: 427.
528-3 Advanced Computer Architecture. Automation issues in architectural-level synthesis. High-level verification. Advances in ALU design, pipelining and resynthesis. Advances in memory design. Advances in parallel architecture. Performance evaluation issues at the architectural level. Prerequisite: 429.
529-3 Analog-to-Digital Conversion and Related Devices. Principles, analysis and design of analog-to-digital converters, video converters, voltage-to-frequency (V/F) and frequency-to-voltage (F/V) converters; universal synchronous/asynchronous receiver/transmitter circuits; hardware implementation of: Fourier analysis, infinite/finite impulse response (IIR/FIR) filters; microcoded systems, fixed and floating point accumulators. Two projects. Prerequisite: 428 and 465 or consent of instructor.
531-3 Mixed Signal VLSI Design. Fundamentals and practical circuit techniques of mixed-signal VLSI design, substrate coupling noise in mixed-signal ICs, D/A and A/D converters, filter circuits, techniques to partition mixed-signal circuits, prototyping and mixed-signal circuits by using FPGAs and FPAAs. Prerequisite: 423 or consent of the instructor.
532-3 Advanced Microprocessor Design. Superscalar pipeline, instruction level parallelism, out-of-order execution, register renaming, instruction/data prefetching, control speculation, data speculation, load forwarding, load bypassing, VLIW. Prerequisite: 429 or consent of instructor.
540-3 CMOS Radio-Frequency Integrated Circuit Design II. An overview of wireless transceiver architectures, high frequency amplifier design techniques, CMOS low noise amplifiers (LNA), mixers, oscillators, frequency synthesizers, power amplifiers, and CMOS RFIC testing. Prerequisite: 440 or equivalent.
541-3 Nanofabrication. Fundamentals of nanofabrication for integrated circuits, micro-electromechanical systems (MEMS), biosensors, and chemical sensors. Topics include: materials, hot processing and ion implantation,

pattern transfer, thin films, and process integration. Prerequisite: Physics 320, 328; Chemistry 210; or equivalent.

542-3 Optical Information Processing. Fraunhofer and Fresnel diffraction, the reciprocity theorem, Kirchoff's integral. General aspects of mutual coherence. Basic properties of recording materials. Phase transformation of thin lenses, Fourier transform properties of lenses, coherent optical information processing systems and applications. Introduction to holography and its applications. Prerequisite: 355.

543-3 Analog VLSI. Integrated circuit processing steps; NMOS, CMOS, and Bipolar processes. Model for MOS and Bipolar transistors. Computer-aided circuit analysis; SPICE. Basic analog building blocks. Inverter. CAD tools for layout. Participation in the MOSIS fabrication program.

545-3 Advanced Semiconductor Devices. Physical principles and operational characteristics of solid-state devices. p-n junction devices, Interface and thin-film devices, optoelectronic devices, and bulk-effect devices. Fabrication and circuit model of devices. Prerequisite: 447 or consent of instructor.

546-3 Gaseous Electronics. Basic science of gas discharges and plasmas. Electrode phenomenon and plasma oscillations. Application of gas discharges to dry etching, plasma-assisted chemical vapor deposition, and sputtering. Prerequisite: consent of instructor.

547-3 Solid-State Theory of Electronic Materials. Electronic properties of materials and their application to practical devices. Quantum and statistical mechanics. Semiconductor principles and devices. Thermo-electric phenomena. Magnetic materials. Quantum electronics and lasers. Prerequisite: consent of instructor.

548-3 Advanced Electronic Devices. A study of techniques in fabricating microelectronic and discrete electronic devices and influences on device design. Thick-film hybrid, thin-film hybrid, monolithic bipolar, and monolithic MOS technologies will be examined. Prerequisite: 447 and Engineering 345.

549-3 Fiber Optics Communication. Fundamentals of step index and graded index fiber waveguides using geometrical optics and Maxwell's equations. Other topics include design criteria, practical coupling techniques, discussion of optical sources and detectors used in light-wave communications, system examples, characterization and measurement techniques. Prerequisite: 447 or 448 or consent of instructor.

551-3 Probability and Stochastic Processes for Engineers. (Same as Electrical Computer Engineering 521) Axioms of probability, random variables and vectors, joint distributions, correlation, conditional statistics, sequences of random variables, stochastic convergence, central limit theorem, stochastic processes, stationarity, ergodicity, spectral analysis, and Markov processes. Prerequisite: graduate student status.

552-3 Detection Theory. Signal detection in white and colored noise. Random waveforms. Matched filtering. Mary signal detection, nonparametric detection, sequential hypothesis testing, decision theoretic schemes. Applications in communication and radar signal processing. Prerequisite: 551 or consent of instructor.

553-3 Data Communications Network. High-speed data networks. TCP/IP and ATM platforms. Analysis of protocols. Congestion Control and Traffic Management. Performance Modeling. Queuing theory. Routing Algorithms. Data Compression. Prerequisite: 422 or consent of instructor.

554-3 Spread Spectrum Communication. Concepts of spread spectrum systems, frequency hopping, and direct sequence systems. Anti-jamming performance analysis, synchronization schemes, and systems with forward error correction. Prerequisite: 552 or consent of instructor.

555-3 Information Theory. Introduce the foundations of information theory as related to data compression and transmission of information. Contents: Entropy, block encoding, Huffman code, universal code, capacity, channel coding, Ergodic Theorem, Shannon-McMillan Theorem, rate-distortion theory, quantization, predictive coding, multiterminal information networks. Prerequisite: 551 or Mathematics 480 or consent of instructor.

556-3 Digital Communications. Bandpass signals and systems characterization. Optimum receivers for detecting modulation signals in additive white Gaussian noise, block and convolutional code, communication through bandlimited channels. Prerequisite: 551 and Engineering 521 or consent of the instructor.

558-3 Digital Image Processing I. Basic concepts, scope and examples of digital image processing, digital image fundamentals, image sampling and quantization, an image model, relationship between pixels, enhancement in the spatial domain, enhancement in the frequency domain, image segmentation, basics of color image processing. Prerequisite: consent of instructor.

563-3 Estimation Theory and Filtering. Parameter estimation for deterministic systems: least-squares, projection and persistent excitation methods. State and parameter estimation of stochastic systems. Bayesian estimation theory, maximum likelihood and maximum a-posterior estimation. Optimal filtering. The Kalman recursive filter. Nonlinear estimation. Estimation bounds. Applications to communications and control. Prerequisite: 551 or consent of instructor.

564-3 Optimal Control. Optimization techniques for linear and nonlinear systems. Variational calculus. Dynamic programming. Pontryagin's maximum principle. Hamilton-Jacobi theory. Linear regulator. Bang Bang control, minimum time control, singular control. Discrete variational calculus. Combined estimation and control. Computational methods in optimal control. Prerequisite: 456 or consent of instructor.

565-3 Nonlinear Systems Analysis. Nonlinear systems, autonomous systems. Analytical approximation methods. Nonlinear differential equations. Stability of time-varying and nonlinear systems. Liapunov's method, input-output stability. Nonlinear discrete systems. Prerequisite: 456 or consent of instructor.

566-3 Adaptive Control. Adaptive systems and adaptation mechanisms. Error system models, direct and indirect adaptive control methods, self-tuning control, model reference adaptive control, variable structure adaptive

control, robust control, learning control. Design techniques and applications. Prerequisite: 456 or consent of instructor.

568-3 Pattern Classification. Classification models, discriminant functions, decision surfaces, generalized linear discriminant functions, parameter estimation, problems of dimensionality, component analysis, Fisher discriminant analysis, hidden Markov models, nearest neighbor rules, classification trees, string matching, resampling for classifier design and evaluation, clustering algorithms, projects. Prerequisite: consent of instructor.

571-3 Wireless and Personal Communications Systems. Overview of wireless technologies, access technologies and cellular systems. Fundamentals of radio and cellular communications. Digital modulation techniques. Antennas and diversity systems. Concepts of packet radio systems. North American Cellular and PCS systems. Prerequisite: 551 or Mathematics 480 or 483 or consent of instructor.

572-3 Neural Networks. Anatomy and physiology of the cerebral cortex. Feed-forward Networks, Linear Associator, Multilayer Perceptrons. Feedback Networks, Hopfield Networks, ART. Applications to pattern recognition, robotics and speech processing. Optical and electronic implementations. Prerequisite: Mathematics 305 or consent of instructor.

573-3 Field and Waves II. Time-harmonic electromagnetic fields in dielectric and lossy media, transmission lines, antennas and resonators. Techniques include duality, image theory, reciprocity and integral equations. Boundary value problems solved for several frequently encountered symmetries. Prerequisite: 477.

574-3 Nonlinear Optics. Coupled-mode-analysis applied to nonlinear wave interactions, harmonic generation, parametric amplification, backward wave amplifiers, backward oscillation in laser systems, phase conjugation and multiple-wave mixing systems, Pockel and Kerr effects, and electro-optical modulations in optical communication systems. Prerequisite: 375 or consent of instructor.

576-3 Numerical Electromagnetics. Numerical solution of electromagnetic problems by methods that include finite element, integral equation, moment, spectral domain and finite difference. Examination of electromagnetic problems and their solutions in current literature. Prerequisite: 573.

577-3 Antenna II. Analysis, design and CAD of antennas. Numerical methods. Broadband, traveling-wave, frequency independent, electrically-small, aperture and microstrip antenna types. Prerequisite: 472.

578-3 Digital Image Processing II. Full-color image processing, image noise and degradation models, image restoration, inverse filtering, Wiener filtering, geometric transformations, image compression models, error-free compression, lossy compression, compression standards, dilation and erosion, opening and closing operations, morphological filtering, boundary descriptors, regional descriptors, principal components, vision-based pattern recognition. Prerequisite: 558.

579-3 Microwave Engineering II. Analysis and design of passive and active devices at microwave frequencies. Topics include: power dividers, couplers, filters, ferrite devices, noise, noise effects in detectors, mixers, modulators, amplifier and oscillator design, and an introduction to microwave systems. Prerequisite: 479.

580-1 Seminar. Study and formal presentation by student of selected research in electrical engineering. Prerequisite: enrollment in program leading to Master of Science in Electrical Engineering.

582-3 HVDC Transmission. Development of HVDC technology. Static power conversion. Harmonic elimination. Control of HVDC systems. Interaction between AC and DC systems. Fault development and protection. HVDC systems based on the voltage sourced inverter. Prerequisite: 487 or consent of the instructor.

583-3 Advanced Applications of Power Electronic System. Device properties, electrical and thermal protection design. HVDC transmission using line communtation. Harmonic control, multi-pulse structures, design of harmonic filters. Phase control and AC control circuits. Multi-level inverters. Utility applications of inverters, Flexible AC Transmission Systems. Prerequisite: 483 or consent of instructor.

584-3 Linear and Non-Linear Networks. Device modeling convex and concave elements. Network graphs graph matrices, formulation of circuit equations. Multi-port networks. State equations of non-linear circuit computer formulation. Advanced techniques for the numerical integration of the state equations. Transient properties of linear and non-linear circuits. Network functions. Sparse matrices. Numerical techniques applied to matrices. Prerequisite: 484 or consent of the instructor.

585-3 Power Systems Stability and Control. Fundamentals of power system stability, synchronous machine modeling and simulation, transient and small signal stability, control and protection, power system stabilizers, voltage stability, voltage collapse, concepts and devices of flexible ac transmission, mid-term and long-term stability. Prerequisite: 487.

586-3 Power Systems Analysis II. Techniques for solving power system problems. Network reduction. Loadflow, short-circuit, and transient-stability studies. Utilization of digital and analog computers. Prerequisite: 487.

587-3 Power System Operation and Control. Advanced mathematical and operations research methods applied to power systems such as economic dispatch, unit commitment, transmission losses, control of generation, power pools and power system security. Prerequisite: 488 or consent of instructor.

588-3 Advanced Electrical Network Theory. Graph theory. Steady-state solution of linear and nonlinear networks. Transfer function techniques. Sensitivity analysis for networks. Prerequisite: 484 or consent of instructor.

589-3 Planning and Automation of EL PWR DSTRB. Analysis and design of distribution networks. Economic planning. Distribution substations-substation planning. Optimum operation of distribution feeders. Distribution network automation. Control and protection. Distribution. Distribution system reliability. Prerequisite: 489 or consent of the instructor.

592-1 to 3 Special Investigations in Electrical Engineering. Individual advanced projects and problems selected by student or instructor. Prerequisite: graduate standing and consent of instructor.
593-1 to 3 Advanced Topics in Electrical Engineering. Lectures on advanced topics of special interest to students in various areas of electrical engineering. This course is designed to offer and test new experimental courses in electrical engineering. Prerequisite: consent of instructor.
599-1 to 6 Thesis.
600-1 to 24 (1 to 16 per semester) Doctoral Dissertation. Dissertation research. Hours and credit to be arranged by director of graduate studies. Graded S/U only. Prerequisite: Admission to PhD program in Electrical and Computer Engineering.
601-1 per semester Continuing Enrollment. For those graduate students who have not finished their degree programs and who are in the process of working on their dissertation, thesis, or research paper. The student must have completed a minimum of 24 hours of dissertation research, or the minimum thesis, or research hours before being eligible to register for this course. Concurrent enrollment in any other course is not permitted. Graded *S / U* or *DEF* only.