Electrical and Computer Engineering

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COLLEGE OF ENGINEERING

Graduate Faculty:

Ahmadi, Reza, Assistant Professor, Ph.D., Missouri University of Science and Technology, 2013; 2013. Power electronics, electric drive systems, renewable energy harvesting, and smart grid technologies.

Ahmed, Shaikh S., Professor, Ph.D., Arizona, 2005; 2007. Nanotechnology, semiconductor devices and circuit design, simulation and characterization.

Anagnostopoulos, Iraklis, Assistant Professor, Ph.D., National Technical University of Athens, 2014; 2015. Many-core architectures, run-time resource management, embedded systems.

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

Chen, Kang, Assistant Professor, Ph.D., Clemson University, 2014; 2015. Software-defined networking (SDN), network function virtualization (NFV), vehicular networks, mobile opportunistic/ad hoc networks.

Chen, Ying (Ada), Associate Professor, Ph.D., Duke, 2007; 2007. Biomedical imaging, image reconstruction, digital tomosynthesis, image quality analysis, signal and image processing, simulation and computing.

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.

Galanos, Glafkos D., Professor, *Emeritus,* 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, Themistoklis, Associate Professor, Ph.D., University of Athens, 2008; 2013. Digital VLSI design and test, RF IC design and test, low power VLSI design, and 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, Konstantine, Professor, Ph.D., West Virginia University, 1987; 1987. Power systems modeling, simulation and control, high voltage DC transmission, power electronics, power systems transient.

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

Komaee, Arash, Assistant Professor, Ph.D., University of Maryland, College Park, 2008; 2015. Control systems, microrobotics, signal processing, estimation theory.

Lu, Chao, Assistant Professor, Ph.D., Purdue University, 2012; 2015. VLSI system design, device-circuit co-design, 3D IC.

Osborne, William, Professor, *Emeritus,* Ph. D., New Mexico State University, 1970; 2005.

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

Qin, Jun, Assistant Professor, Ph.D. Duke University, 2008;2012. Sensors and instrumentation, data acquisition, medical devices, therapeutic ultrasound, haptics.

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

Tragoudas, Spyros, Professor and *Chair,* Ph.D., University of Texas at Dallas, 1991;1999. Design and test automation for VSLI, embedded systems, computer networks.

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

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

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

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 paper based and 80 computer based. Admission to the program is granted by the Chair of the Department, upon recommendation by the faculty.

This program requires a nonrefundable $65.00 application fee that must be submitted with the application for Admissions to Graduate Study in Electrical and Computer Engineering. Applicants must pay this fee by credit card.

Requirements. The Department offers two different programs leading to the Master of Science degree, the Thesis and the Non-thesis 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) and one hour of ECE seminar (ECE 580) are required. A maximum of six hours of 400-level graduate 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 24 hours should be in 500-level courses (excluding ECE 580), thus, a maximum of six hours of 400-level graduate courses could be counted toward the degree requirements. With the approval of the Department, a maximum of three distance education hours offered by the Department, and a maximum of six hours from academic units outside the ECE Department could be applied toward the degree.

Retention. Any graduate student, thesis or non-thesis option, whose cumulative grade point average falls below 3.00 on courses that count towards the degree will be placed on departmental academic probation. Any graduate student on academic probation whose grade point average remains below 3.0 on courses that count towards the degree for two consecutive semesters in which she or he is enrolled, excluding summer sessions, will be permanently suspended from the program, unless the department grants an exception.

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://engineering.siu.edu/elec/.

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.

LAW Courses

Consult with the School of Law Associate Dean for Academic Affairs regarding the list of approved LAW courses.

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 the following areas of concentration: Biomedical, Communications, Computers, Control, Electronics, Electromagnetics, Large Scale Integration (VLSI), Networks, Optics, Power, Signal Processing.

Admission. For applicants with an M.S. degree, admission to the program requires a Master of Science degree in Electrical or Computer Engineering or a related field with a GPA of 3.25/4.0 or higher. Applications for admission must include the following: a statement of research interest, transcripts, official GRE scores, three reference letters and TOEFL/ IELTS 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.

For direct and accelerated entry into the Ph.D. program, a Bachelor of Science degree in Electrical or Computer Engineering or a related field with a GPA of 3.2/4 or higher is required. Applications for admission must include the following: A statement of research interest, transcripts, GRE scores, three reference letters and TOEFL score, as required by the Graduate School. Admission to the program is made by the Department Chair upon recommendation by the ECE Graduate Committee.

Advisement. The student must always have an advisor while in the program. However, upon arrival, the student may be advised by the department chair. The student must select a committee consisting of three members within the semester of admission. One member will serve as the student's advisor and also chair the committee. The committee will assist the student in selecting six 500-level ECE courses that define the core and in developing a plan of study. The advisor committee members must be voting ECE faculty members and must meet the requirements of the Graduate school.

Retention. Any graduate student, thesis or non-thesis option, whose cumulative grade point average falls below 3.00 on courses that count towards the degree will be placed on departmental academic probation. Any graduate student on academic probation whose grade point average remains below 3.0 on courses that count towards the degree for two consecutive semesters in which she or he is enrolled, excluding summer sessions, will be permanently suspended from the program, unless the department grants an exception.

Curriculum. For applicants with an M.S. degree, the curriculum consists of sixty-two 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 thirty-six hours of dissertation. Students who receive an MS from SIUC and have taken the seminar are exempt from one credit hour of seminar. 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.

For direct and accelerated entry into the Ph.D. program, the curriculum consists of eighty-eight hours of credit beyond the B.S. degree. Forty-four hours of 500-level ECE courses, of which nine hours must be taken from the selected core, three hours of mathematics, three hours of mathematics or science, two hours of seminar and thirty-six hours of dissertation.

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 which has two components: written exam and oral exam. Prior to taking the exam, the student must form an examining committee compromised of three voting ECE faculty members or two voting ECE faculty members and the ECE chair. The written examination covers at least three major areas of ECE and consists of questions from each member of the examining committee. The oral exam, conducted by the student's examining committee, is held within two weeks of the written exam. The student should score at least 75% in each area tested and must satisfactorily answer the questions in the oral exam. If not successful, the committee may allow the student to repeat the whole or part of the examination. The qualifying examination, in whole or in part, cannot be taken more than two times. The written exam, which is administered by the ECE Graduate Affairs Committee, is offered in the second week of February and the second week of September.

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. The dissertation supervisor must have Direct Dissertation status. A non-ECE faculty member with Direct Dissertation status may serve as a co-Supervisor along with a co-Supervisor who is a regular ECE faculty member with Direct Dissertation status.

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.

Comprehensive 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. The Dissertation must be prepared in accordance to the "Guidelines for Dissertations, Theses and Research Papers" of the Graduate School. Dissertation approval is based on successful defense of the research performed in terms of originality, relevance and presentation (written and oral). This requires approval by at least 80% of the members of the dissertation committee.

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.

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.

Graduation. The student must complete the curriculum with a minimum grade point average of 3.25 on courses that count towards degree. For entry with an M.S. degree, a dissertation approved by the committee must be completed within five years after entry.

For direct and accelerated entry, a dissertation approved by the committee must be completed within six years after entry.

The Department has established a timetable for advisement, qualifying examination, candidacy, dissertation committee formation, dissertation proposal, oral examination, and dissertation defense.

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 but only up to 6 hours.

456-3 Embedded Control and Mechatronics. Introduction to mechatronic systems, systems modeling and simulation, sensors and actuators, real-time interfacing, DSPs and microcontrollers, analysis of sampled-data systems, z-transform, digital control design techniques, emulation methods, direct method, industrial applications. Lecture and laboratory. Prerequisite: ECE 315 and 356. Lab fee: $20 to help defray cost of software licenses.

459-3 MEMS and Micro-Engineering. Introduction to micro-electro-mechanical systems (MEMS), manufacturing techniques, microsensors, microactuators, microelectronics and micro-controllers. Lecture and laboratory. Prerequisite: ECE 315 and ECE 356.

466-3 Linear Control Systems. (Same as ECE 566) Introduction to the structure and analysis of linear dynamical systems in time domain. Topics covered include linear algebra review, solutions of linear differential equations, state space representation, state transition matrix, and time varying systems. Introduction to fundamental mathematics of linear spaces and linear operator theory. Structural properties of linear systems such as controllability, oberservability, stability, realizations, and minimality. Design and synthesis of controllers and state observers for linear systems. Linear quadratic regulator theory, Kalman filter, and introduction to robust control. Prerequisites: ECE 355 and ECE 356 with a minimum grade of C.

468B-3 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. Restricted to graduate standing. Lab fee: $20 to help defray cost of software licenses.

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: ECE 375.

482-3 Power Converter Design and Control. (Same as ECE 582) This course covers all the steps required for designing an actual power converter or electric drive system. The power stage design considerations, gate drive circuits, isolated high voltage/current measuring circuits, and application of a Texas instrumental Digital Signal Processor (DSP) for implementing different control schemes are discussed in detail. A brief introduction about the digital control theory and implementation of digital controller transfer functions using the DSP are provided as well. Prerequisites: ECE 385, ECE 356 with a minimum grade of C. Lab fee $65 to help defray cost of software licenses and equipment.

483-3 Electric Drive Systems. (Same as ECE 583) Course content is roughly 1/3 power electronics, 1/3 applied control and 1/3 electric machinery and focuses on analysis, stimulation, and control design of electric drive based speed, torque, and position control systems. Advanced topics depending on the semester are taught. Prerequisites: ECE 385, ECE 356 with a minimum grade of C. Lab fee $65 to help defray cost of software licenses and equipment.

486-3 Clean Electric Energy. History and Future of the Energy

Resources and their use as a component of Electrical Systems. Energy Resources (Fossil, Nuclear, Hydro, Fuel Cell, Wind, Solar, Tidal, Waste, Bio-Energy, Oceanic, Renewable, etc.) Environmental and Economical Impacts of Various Energy Sources. Electric Energy Generating Plants. Renewable Energy. Special approval needed from the instructor.

489-3 Electric Power Distribution. (Same as ECE 589) Design of primary and secondary distribution networks. Load characteristics. Voltage regulation. Metering techniques and systems. Protection of distribution systems. Special topics related to power distribution. Prerequisite: ECE 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. Special approval needed from the instructor.

512-3 Wireless Networks. (Same as ECE 412) Compared to infrastructure based wireless communication systems, ad hoc wireless networks present several unique advantages. Thus, it has been widely studied as an important wireless communication paradigm. This graduate level course first introduces several widely adopted wireless communication technologies and then presents the concept, structure, and principles of ad hoc wireless networks. The course also introduces the details of several popular as hoc wireless networks including mobile ad hoc networks, delay tolerant networks, wireless sensor networks, and connected vehicle networks. Novel applications in those networks will also introduced. The course work will include paper and literature review, presentations, assignments, and a project that will enable students to be familiar with ad hoc wireless networks. NS2 will be used for student project in this course. Students can gain experience on NS2. Lab fee $10 to help defray cost of equipment.

513-3 Digital VLSI Design. (Same as ECE 423) 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 stimulation using CAD tools. CMOS design of datapath subsystems. Design of finite state machines. Examples of CMOS system designs. Laboratory experience in CMOS VLSI design. Restricted to enrollment in ECE program. Lab fee $35 to help defray cost of software licenses and equipment.

514-3 Design of Embedded Systems. (Same as ECE 424) Introduction of modern embedded system application, platform architecture and software development. Principles of embedded processor architecture, operating systems and networking connectivity. Design and optimize in terms of system power, security and performance. Rapid prototyping using Intel-Atom based platform. Lecture and laboratory. Lab fee $10 to help defray cost of equipment.

515-3 Three Dimensional Integration Systems. This course introduces the design of three dimensional VLSI integration systems, including through-silicon-via (TSV) process, characterization and modeling, 3D IC systems design, mixed signal stimulation, data management, testing, process variation, thermal and reliability challenges, as well as a review of 3D system design examples. Laboratory experience in design tools (Cadence Virtuoso and Liberate, AMS stimulator). Prerequisites: ECE 345 and ECE 423 with a grade of C or better. Restricted to enrollment in ECE program.

516-3 Implementation of VLSI Systems with HDl. (Same as ECE 426) This course is dedicated for advanced Digital VLSI architecture and system implementation for high performance and low power digital signal processing applications. Application-specific processors and architecture to support real time processing of signal processing systems will be studied. Hands-on experience of using state-of-the-art CAD tools on designing such kind of VLSI architecture and systems. Upon completion of this course students will entail large HDL-based implementation of a complete VLSI system. Prerequisite: ECE 327 with a grade of C or better. Lab fee $35 to help defray cost of software licenses and equipment.

520-3 VLSI Design and Test Automation. (Same as ECE 425) 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: ECE 329. Restricted to enrollment in ECE program. Lab fee $30 to help defray cost of software licenses and equipment.

521-3 Fault-Tolerant Computer Design. 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. Restricted to enrollment in ECE program 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: ECE 425 or ECE 520 with a minimum grad of C, or consent of instructor. Restricted to enrollment in ECE program. Lab fee: $25 to help defray cost of software licenses.

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: ECE 423 or ECE 513 with a minimum grade of C, or consent of instructor. Restricted to enrollment in ECE program. Lab fee $35 to help defray cost of software licenses and equipment.

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: ECE 425 or ECE 520 with a minimum grade of C, or consent of instructor. Lab fee $35 to help defray cost of software licenses and equipment.

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.

Floor planning, 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: ECE 425 or ECE 520 with a minimum grade of C, or consent of instructor. Restricted to enrollment in ECE program. Lab fee $35 to help defray cost of software licenses and equipment.

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. Restricted to enrollment in ECE program or consent of the instructor.

527-3 Integrated Interconnected Networks. (Same as ECE 427) Importance of interconnection networks and networks-on-chip (NOCs). Specifications and constraints. Topology, routing, flow control, deadlock, livelock, arbitration, allocation, performance analysis, simulation. Prerequisite: ECE 329 or equivalent. Restricted to enrollment in ECE program.

528-3 Programmable ASIC Design. (Same as ECE 428) Principles and practice of designing and implementing Application-Specific Integrated Circuits (ASIC). Field Programmable Gate Arrays (FPGA). Timing analysis, timing closure and managing difference clock domains in ASIC design. Complex arithmetic circuits. Digital signal processing (DSP) circuits. FPGA microprocessors. Lab fee: $50 to help defray cost of equipment and consumable items.

529-3 Computer Systems Architecture. (Same as ECE 429) Advanced computer arithmetic, principles of performance evaluation, instruction set principles, pipeline considerations and instruction level parallelism, vector processors, memory hierarchy design. Restricted to enrollment in ECE program.

530-3 Engineering Data Acquisition. (Same as ENGR 530) Theory of data acquisition and measurement systems. Criteria for selection of data acquisition hardware and software, instruments, sensors and other components of scientific and engineering experimentation. Methods for sampled data acquisition, signal conditioning, interpretation, analysis and error estimation. Restricted to enrollment in ECE program. Project-based fee: $60 to help defray cost of software licenses and equipment.

531-3 Mixed-Signal VLSI Design. Analysis and design of mixed-signal integrated circuits. Digital to analog converter (DAC). Analog to digital converter (ADC). Sigma-delta data converters. Performance analysis of signal chains containing both analog and digital signal processing functions. Prerequisite: ECE 446 with a minimum grade of C. Restricted to enrollment in ECE program. Lab fee $60 to help defray cost of software licenses and equipment.

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 by-passing, VLIW. Prerequisite: 429. Restricted to enrollment in ECE program or consent of instructor. Lab fee $20 to help defray cost of equipment

533-3 Speech Processing. (Same as BME 533) Fundamentals of speech production system, signal analysis of speech, speech coding, linear prediction analysis, speech synthesizing, and speech recognition algorithms. Prerequisite: ECE 468B. Restricted to enrollment in ECE program or consent of instructor.

534-3 Biomedical Signal Modeling. (Same as BME 536) The nature of biomedical signals. Electricity in living tissue. Biomedical signal processing and modeling. Modeling and stimulation of biomedical systems. Prerequisite: ECE 355 with a minimum grade of C. Restricted to enrollment in ECE program or consent of instructor. Lab fee: $20 to help defray cost of software licenses.

535-3 CMOS Radio-Frequency Integrated Circuit Design. (Same as ECE 440) Introduction of RF IC, passive RLC Networks, passive IC components, MOS Transistors, distributed systems, Smith Chart and S-Parameters, introduction to Band-width estimation, biasing and voltage reference, noise in RF IC, introduction to Amplifiers, Phase-Locked Loops and Oscillators. Lecture and laboratory. Restricted to enrollment in ECE program. Lab fee $35 to help defray cost of software licenses and equipment.

536-3 Real-Time Embedded Systems. Introduction to real-time embedded systems. Topics covered include real-time schedulability theory with static and dynamic priority scheduling policies; concepts involved in the design, analysis and verification of real-time systems, including timing and cache analysis; introduction to sensor networks and poweraware scheduling. Prerequisites: ECE 321 and ECE 329. Restricted to enrollment in ECE program.

537-3 Integrated Photonics. Fundamentals of electromagnetic theory, waveguides, photonic structures including photonic crystals and integrated microring resonator, numerical simulations of photonic integrated circuits using the beam propagation method, finite-difference time-domain method, rate equations, and fabrication processes. Prerequisite: ECE 441. Restricted to enrollment in ECE program or consent of instructor.

538-3 Medical Instrumentation: Application and Design. (Same as ECE 438 and BME 538) Basic concept of medical instrumentation, basic sensors and principles, amplifiers, biopotential electrodes, blood pressure and sound, measurement of respiratory system, chemical biosensors, cellular measurement, nervous system measurements, magnetic resonance imaging. Prerequisite: ECE 355. Restricted to enrollment in ECE program. Project-based fee: $45 to help defray cost of software licenses and equipment.

539-3 Diagnostic Ultrasound Physics. (Same as BME 541) Propagation of ultrasonic waves in biological tissues; principles of ultrasonic measuring and imaging instrumentation; design and use of currently available tools for performance evaluation of diagnostic instrumentation; biological effects of ultrasound. Prerequisite: Modern physics, calculus & Fourier analysis. Restricted to enrollment in ECE program or consent of instructor. Lab fee $30 to help defray cost of software licenses and equipment.

540-3 CMOS Radio-Frequency Integrated Circuit Design II. High frequency amplifier design techniques, CMOS low noise amplifiers (LNA), mixers, oscillators, frequency synthesizers, power amplifiers, an overview of wireless architectures. Prerequisite: ECE 440 or ECE 535 or equivalent. Restricted to

enrollment in ECE program. Lab fee $50 to help defray cost of software licenses and equipment.

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: PHYS 320, 328; CHEM 210; or equivalent. Restricted to enrollment in ECE program.

542-3 Photonics I. (Same as ECE 441) Ray optics, wave optics, beam optics, polarization of light, statistical optics, photons and atoms. Prerequisite: ECE 375 with a grade of C or better. Lab fee: $50 to help defray cost of equipment and consumable items.

543-3 Advanced Analog Integrated Circuit Design. Analysis and design of CMOS analog integrated circuits. Circuit noise analysis. Low-voltage high-performance operational amplifiers. Voltage and current reference circuits. Integrated analog filter circuits. Prerequisites: ECE 446 or ECE 546, or consent of instructor. Lab fee $35 to help defray cost of software licenses and equipment.

544-3 Photonics II. (Same as ECE 448) Fourier optics, fiber optics, electro-optics, nonlinear optical media, acousto-optics, photonic switching, optical and interconnections and optical storage. Prerequisite: ECE 441 or consent of instructor. Lab fee: $80 to help defray cost of software licenses.

545-3 Advanced Semiconductor Devices. Technology Drivers: Moore, More Moore, and More-than-Moore. Case Study: Integrated health monitoring systems. Review of solid-state theory: electronic, magnetic, optical and thermal properties of semiconductors. Energy related devices: solid-state lighting and LEDs, single-photon emitters, OLEDs, solar cells, thermoelectric devices, piezoelectric. Energy storage and supercapacitors. Imagers and LCDs. Sensors and detectors. Thin-film transistors (TFTs). Microwave and THz devices. Prerequisites: ECE 447 or PHYS 425 or PHYS 430, or consent of instructor consent.

546-3 Analog Circuit Design. (Same as ECE 446) Analysis and design of electronic circuits, both discrete and integrated. Computer-aided circuit and analysis. Design of amplifier and filter circuits. Circuit stability analysis and frequency compensation techniques. Restricted to enrollment in ECE program. Lab fee $10 to help defray cost of equipment.

547-3 Semiconductor Devices. (Same as ECE 447) Semiconductor industry and Moore's law. Review of quantum mechanics of atoms. From atoms to crystals: energy bands, effective mass and density-of-states. Semiconductor statistics. Carrier transport phenomena. PN junctions. Schottky junctions. Bipolar junction transistors (BJTs). MOSFETs: capacitance-voltage and current-voltage characteristics, threshold voltage, scaling and short-channel effects, SPICE models. CMOS process integration. Basic optoelectronic devices: LEDs and solar cells. Lecture and Laboratory. Prerequisite: ECE 345 or equivalent. Lab fee: $25 to help defray cost of software licenses.

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: ECE 345 and 447. Restricted to enrollment in ECE program.

549-3 Fiber Optic Communications. 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: ECE 447 or 448 or consent of instructor.

550-3 Nanoelectronic Devices. Principles of semiconductor materials or devices. Nanotransistors: Charge-based devices-MOSFETs, non-ideal and quantum effects in nanoscale MOSFETs, advanced MOSFETs: trigate FETs, FinFETs, ETSOI, SiGE, Ge and III-Vs, carbon nanotubes and graphene ribbons, 2-D monolayers, nonowires, high electron mobility transistors (HEMTs), compact and SPICE models for advanced MOS devices. VLSI interconnects, parasitic elements, and reliability issues. Non-charge based devices- spinFET. Quantum devices- resonant tunnel diodes, tunnel FETs, single electron transistors (SETs). Nanomemory: EEPROM and Flash, phase change memory, electrolyte, magnetic and ferroelectric RAM, spin-torque devices, DRAM and ZRAM. Prerequisites: ECE 447 or PHYS 425 or PHYS 430 or instructor consent. Lab fee: $25 to help defray cost of software licenses.

551-3 Probability and Stochastic Processes for Engineers. (Same as ENGR 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. Restricted to graduate student status. Restricted to enrollment in ECE program. Lab fee: $20 to help defray cost of software licenses.

552-3 Signal Detection and Estimation. Estimation theory: parameter estimation, minimum variance unbiased estimators, sufficient statistics, Cramer-Rao lower bound, best linear unbiased estimators, maximum likelihood estimators, least squares, Bayesian estimation, maximum a posteriori estimators, minimum mean square error estimators, linear minimum mean square error estimators, Wiener filtering. Detection theory: hypothesis testing, likelihood ratios, Neyman-Pearson detection, Bayesian hypothesis testing, matched filtering, multiple hypothesis testing, sequential detection, composite hypothesis testing, uniformly most powerful tests, generalized likelihood-ratio tests. Prerequisite: ECE 551. Restricted to enrollment in ECE program.

553-3 Computer Network System Architecture. (Same as ECE 422) Principles of Computer Networks. Protocols and system level implementations. Socket programming, router and switching fabric architecture, security and packet classification techniques, multimedia networking and QoS. Lab fee $10 to help defray cost of equipment.

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: ECE 552. Restricted to enrollment in ECE program or consent of instructor.

555-3 Introduction to Information Theory and Channel Coding. (Same as ECE 476) Entropy and Mutual Information. Channel Capacity. Gaussian Channel. Linear Block Codes. Convolutional Codes. Advance Channel Coding Techniques. Restricted to enrollment in ECE program.

556-3 Digital Communications. Digital communication signals and systems characterization. Deterministic receiver design. Probabillistic receiver design. Error control coding. Communication over band limited channels. Prerequisite: ECE 551. Restricted to enrollment in ECE program.

557-3 Computational Electronics. (Same as ECE 457) Elements of computational science/engineering. High-performance clusters and software tools for HPCs. Essential numerical methods. Fundamental physics and modeling of charge transport phenomena. Numerical solution of carrier continuity equations and terminal currents in semiconductor devices. Numerical solution of the Schrodinger equation. Electronic bandstructure calculations using tight-binding formalism. Phonon (heat) transport and thermoelectrics. Fundamentals of optical processes. Commercial and noncommercial semiconductor device modeling tools. Prerequisite: ECE 345 or PHYS 425 or instructor consent. Lab fee: $25 to help defray cost of software licenses.

558-3 Digital Image Processing I. (Same as ECE 458) 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. Restricted to enrollment in ECE program or special approval needed from the instructor.

560-3 Semiconductor Materials and Device Characterization. (Same as ECE 449) Materials for modern ICs: semiconductor crystals, tubular and monolayer materials, organic materials, heterostructures, wafers and notations. Nanoscale fabrication processes: IC production flow, selective doping, nanolithography, etching, contacts and interconnects, spontaneous formations and ordering of nanostructures, fabrication of MEMS/NEMS systems, IC assembly and packaging. MOS device characterization: electrical CV and IV profiling, defect characterization using DLTS, carrier mobility and lifetime measurements, optical microscopy and spectroscopy, particle beam and X-ray techniques. Reliability of devices and ICs: harsh environments, hot carriers, NBTI, electromigration, electrostatic discharge, IC power dissipation and cooling. Prerequisite: ECE 447 or ECE 423 or instructor consent.

562-3 Microwave Engineering I. (Same as ECE 479) 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: ECE 375. Restricted to enrollment in ECE program. Lab fee: $100 to help defray cost of software licenses.

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: ECE 456. Restricted to enrollment in ECE program or consent of instructor.

565-3 Nonlinear Systems Analysis. Analysis and design of nonlinear dynamical systems. Topics include: nonlinear differential equations, stability, Lyapunov stability analysis, stability of perturbed systems, linearization, and central manifold theorem. Stabilization, feedback linearization, and controller design methods such as backstepping and sliding mode control.

566-3 Linear Control Systems. (Same as ECE 466) Introduction to the structure and analysis of linear dynamical systems in time domain. Topics covered include linear algebra review, solutions of linear differential equations, state space representations, state transition matrix, and time varying systems. Introduction to fundamental mathematics of linear spaces and linear operator theory. Structural properties of linear systems such as controllability, observability, stability, realizations, and minimality. Design and synthesis of controllers and state observers for linear systems. Linear quadratic regulator theory, Kalman filter, and introduction to robust control.

567-3 Modern Biomedical Imaging. (Same as ECE 467 and BME 532) Modern biomedical imaging. Diagnostic x-ray projection imaging. Tomographic imaging. Ultrasound imaging and therapy. Magnetic resonance imaging (MRI). Signal and noise characteristics. Image quality evaluation. Three-dimensional image reconstruction algorithms. Prerequisite: ECE 355. Restricted to enrollment in ECE program or consent of instructor. Project-based fee: $30 to help defray cost of software licenses and equipment.

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. Restricted to enrollment in ECE program or pecial approval needed from the instructor.

569-3 Biomedical Instrumentation. (Same as BME 538) Basic concept of Medical instrumentation, basic sensors and principles, amplifiers, biopotential electrodes, blood pressure and sound, measurement of respiratory system, chemical biosensors, Cellular measurements, Nervous system measurements, magnetic resonance imaging. Prerequisites: PHSL 410A or CHEM 444. Restricted to enrollment in ECE program or consent of instructor.

570-3 Principles of Communication Systems. (Same as ECE 478) Amplitude, frequency, and phase modulation. Sampling theorem. Pulse code modulation. Digital carrier systems. Optimum signal detection. Lectures and laboratory projects. Prerequisite: ECE 315 and ECE 355. Restricted to enrollment in ECE program.

571-3 Wireless and Personal Communications Systems. (Same as ECE 471) Introduction to cellular systems. Propagation modeling. Modulation techniques. Digital signaling on fading channels. Diversity and MIMO. OFDM and CDMA. Prerequisite: ECE 315 and ECE 335. Restricted to enrollment in ECE program. Lab fee: $20 to help defray cost of software licenses.

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: MATH 305. Restricted to enrollment in ECE program 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: ECE 477. Restricted to enrollment in ECE program.

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 electrooptical modulations in optical communication systems. Prerequisite: ECE 375. Restricted to enrollment in ECE program or consent of instructor.

575-3 Antennas I. (Same as ECE 472) 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: ECE 375. Restricted to enrollment in ECE program. Lab fee: $120 to help defray cost of software licenses.

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: ECE 573. Restricted to enrollment in ECE program.

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: ECE 472. Restricted to enrollment in ECE program.

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: ECE 558. Restricted to enrollment in ECE program.

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. Restricted to enrollment in ECE program.

580-1 Seminar. Study and formal presentation by students of selected research in electrical and computer engineering. Restricted to students in the graduate program in Electrical and Computer Engineering. Special approval needed from the instructor.

581-3 Wind and Solar Energy Power Systems. (Same as ECE 481) This course introduces students to wind and solar energy power systems. Planning of wind generation; design and operation of wind generators, mechanical and electrical design, power conditioning, control and protection. Planning, operation and design of electric solar plants; power conditioning, control and protection. Restricted to enrollment in ECE program.

582-3 Power Converter Design and Control. (Same as ECE 482) This course covers all the steps required for designing an actual power converter or electric drive system. The power stage design considerations, gate drive circuits, isolated high voltage/current measuring circuits, and application of a Texas Instrument Digital Signal Processor (DSP) for implementing different control schemes are discussed in detail. A brief introduction about the digital control theory and implementation of digital controller transfer functions using the DSP are provided as well. Lab fee $65 to help defray cost of software licenses and equipment.

583-3 Electric Drive Systems. (Same as ECE 483) Course content is roughly 1/3 power electronics, 1/3 applied control and 1/3 electric machinery and focuses on analysis, simulation, and control design of electric drive based speed, torque, and position control systems. Advanced topics depending on the semester are taught. Lab fee $65 to help defray cost of software licenses and equipment.

584-3 Electric and Hybrid Vehicles. (Same as ECE 484) This course covers an entire range of topics related to analysis, design, control, and optimization of electric, hybrid, and plug-in hybrid power trains including automotive applications of adjustable speed motor drives, energy storage systems, and advanced power converters. Prerequisite: ECE 385. Restricted to enrollment in ECE program or consent of the instructor. Lab fee $65 to help defray cost of software licenses and equipment.

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: ECE 487. Restricted to enrollment in ECE program.

586-3 Computational Methods in Power Systems. The course covers advanced methods for the computation and analysis of power systems. Topics: circuit graph theory and network matrices, computation of electromagnetic transients, computation of system stability, stochastic methods in power systems, load forecasting, state estimation, unit dispatch. The course uses power system software. Lecture. Restricted to enrollment in ECE program.

587-3 Advanced Power Electronic Systems. The purpose of this course is to cover selected areas of power electronics in greater depth. The topics covered include small signal analysis of power converters, voltage- and current- mode control, embedded control of power electronic systems, soft switching techniques, power factor correctors, multi-level converters, advanced motor drives, and PWM techniques. Restricted to enrollment in ECE program. Lab fee $65 to help defray cost of software licenses and equipment.

588-3 Power System Engineering (Same as ECE 488) The course covers topics involving the design and operation of a power system. Topics: symmetrical and unsymmetrical power system faults, power system protection design, transient stability of power generators, power system economic operation,

power system control, transient operation of transmission lines. The course uses power system software. Lecture restricted to enrollment in the ECE program.

589-3 Electric Power Distribution. (Same as ECE 489) Design of primary and secondary distribution networks. Load characteristics. Voltage regulation. Metering techniques and systems. Protecting of distribution systems. Special topics related to power distribution. Prerequisite: ECE 385 or equivalent. Restricted to enrollment in ECE program.

592-1 to 3 Special Investigations in Electrical Engineering. Individual advanced projects and problems selected by student or instructor. Restricted to graduate standing. Restricted to enrollment in ECE program or special approval needed from the instructor.

593-1 to 3 Advanced Topics in Electrical Engineering. Lectures on advanced topics of special interest to students in various areas of Electrical & Computer Engineering. This course is designed to offer and test new experimental courses in electrical engineering. **(a)** Antennas and Propagation, **(b)** ASIC Design, **(c)** Communications, **(d)** Computer Architecture, **(e)** Control Systems, **(f)** Design Automation **(g)** Digital Design **(h)** Digital Testing and Verification **(i)** electromagnetic fields and waves **(j)** Embedded Systems **(k)** Medical Imaging **(l)** Mixed-signal testing and design **(m)** nanotechnology **(n)** Network systems **(o)** photonics **(p)** Physical Design automation **(q)** Power Electronic Converters and Drive Systems **(r)** Power Quality **(s)** Power System control and protection **(t)** Renewable Energy **(u)** RF and Microwave Systems **(v)** Signal Processing **(w)** Software Engineering **(x)** Wireless Systems. Restricted to enrollment in ECE program or special approval needed from the instructor.

595-3 Communication Skills for Engineering Graduate Students. This course prepares graduate engineering students to communicate technical information to various audiences and for various purposes. Principles and strategies are applied to theses, dissertations, scholarly presentations, and other engineering documents such as lab reports, user manuals, business correspondences, job application materials, and engineering ethics. Research tools and software programs prepare students to deliver oral presentations on current engineering topics. Restricted to graduate standing. Does not count toward the hours required for graduation in the ECE program. Restricted to enrollment in ECE program.

596-1 Introduction to Biomedical Engineering. (Same as BME 596) Introduction and orientation to the biomedical engineering program. Topics to be discussed include: History and scope of the Program, curriculum, required courses, elective courses, thesis and non-thesis options, graduate committee formation, research areas, monitoring academic progress, financial assistance and discussion of BME-related topics that involve math, chemistry, biology, and engineering. Restricted to: Enrollment in BME or ECE program or instructor consent. Does not count toward the hours required for graduation.

597-1 Biomedical Research Ethics. (Same as BME 597) Series of lectures from distinguished speakers, from academia, industry and government, regarding ethical issues associated with biomedical research and development. Graded *S/U* or *DEF* only. Restricted to: Enrollment in BME or ECE program. Does not count toward the hours required for graduation in the ECE program.

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. Restricted to 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.