Electrical and Computer Engineering

Electrical Engineering

The Department of Electrical and Computer Engineering serves the community, the state and the nation by educating engineers, expanding knowledge and developing new tools for solving complex technological problems. The department’s graduate programs offer students with backgrounds in electrical engineering or related areas unusual opportunities to specialize in advanced phases of electrical engineering. In addition to more than 30 full-time faculty members devoted to teaching and research, students are taught by adjunct professors from industry who offer specialty courses in their area of expertise and serve on thesis and dissertation committees.

The master's degree programs provide state-of-the-art training at advanced levels in areas of technical specialization, including faculty-supervised research. Students in the doctoral program conduct significant original research in areas of interest to department members. Students also have opportunities to conduct thesis research at industrial sites, hospitals, biomedical engineering facilities, and university centers and departments.

Master of Science in Electrical Engineering

A program for students with an undergraduate degree in engineering who wish either to specialize in an advanced phase of electrical engineering or prepare for a more advanced degree.

Admission Requirements

Applicants are expected to have undergraduate backgrounds in physics, mathematics (through differential equations and vector analysis), electrical networks and devices, electronics, analysis and design methods, transients, electromagnetic fields, and appropriate laboratory work in some of these areas. GRE scores must be submitted. International students must also achieve a minimum TOEFL score of 550 (213 computer-based). For further information, see the Admissions section in this catalog.

Graduate Certificate Program

A 12-credit graduate certificate in Telecommunications Networking is available as a step toward this degree. See Graduate Certificates in the Degree Programs section of this catalog. For further information, call the Associate Vice President of Continuing and Distance Education, Division of Continuing Professional Education, 1 (800) 624-9850 or (973) 596-3060; e-mail cpe@njit.edu

Doctor of Philosophy in Electrical Engineering

This is a program for superior students with master's degrees in electrical engineering or allied fields who wish to conduct advanced research in an area of electrical engineering.

Exceptional Candidates with a Bachelor of Science in Electrical Engineering

Highly qualified students with bachelor's degrees in electrical engineering may be accepted directly into the doctoral program. Contact the doctoral program coordinator for further information.

Admission Requirements

Applicants are expected to have a broad background in engineering, mathematics, physics, and computer science. At least half of undergraduate course work should have been in the physical sciences or similar fields. Doctoral students should have majored in electrical engineering or related field, with course work at the master's level in mathematics, physics and/or computer science. In addition, students are expected to be proficient in computer programming. A minimum master's GPA of 3.5 on a 4.0 scale, or equivalent, is required for admission. GRE scores must be submitted. International students must also achieve a minimum TOEFL score of 550 (213 computer-based).

Students who lack an appropriate background will be required to take additional courses that cannot be applied as degree credits.

Computer Engineering

Focus on interdisciplinary course work and research provides students enrolled in the M.S. and Ph.D. in Computer Engineering programs with an advanced background in both the hardware and software aspects of computing.

The master's program prepares computer engineers to successfully make the hardware-software design trade-offs inherent to computing today. The rapid development of computer hardware and software in the last decade has created a demand for engineers who are not only knowledgeable in both these areas, but who also understand their interaction. The fields of embedded computer system design and computer networks are based squarely on this knowledge.

The doctoral program is designed for superior students with a master's degree in computer engineering, computer science, electrical engineering, or other related fields, who wish to pursue advanced research in the area of computer engineering. The master's and doctoral programs emphasize computer architecture and systems, computer networking, intelligent systems, microprocessor-based systems, and VLSI system design.
Electrical and Computer Engineering

Master of Science in Computer Engineering
This program prepares its graduates to successfully handle problems requiring in-depth knowledge of both computer hardware and software, and more important, their interaction. Students may concentrate in microprocessor-based systems, parallel computing systems, computer networking, VLSI system design, or machine vision systems. All applicants must submit GRE scores. International students must achieve a minimum TOEFL score of 550 (pencil and paper) and (213 computer-based).

Admission Requirements
Applicants are expected to have an undergraduate education in engineering or computer science. Applicants with baccalaureate degrees in areas other than computer engineering may be admitted and required to complete a bridge program. Those with undergraduate degrees in other fields should consult the MSCOE Program Advisor for bridge requirements. Bridge courses do not count toward degree requirements.

Graduate Certificate Program
A 12-credit graduate certificate in Information Assurance is available as a step toward this degree. Please see Graduate Certificates in this catalog for further information. For more information about continuing and distance education, please contact the Division of Continuing Professional Education, 1-800-624-9850 or 973-596-3060; email: cpe@njit.edu.

Doctor of Philosophy in Computer Engineering
This program is intended for superior students with a master's degree in computer engineering, computer science, electrical engineering, or other related fields, who wish to pursue advanced research in computer engineering. The program emphasizes the following areas: computer architecture and systems, computer networking, intelligent systems, microprocessor-based systems, and VLSI systems design.

Admission Requirements
Applicants are expected to have a master's degree in computer engineering, computer science, electrical engineering, or other related fields. Students who lack an appropriate background may be admitted and required to take bridge courses that cannot be applied as degree credits.

Students must demonstrate superior academic background in engineering, mathematics, and physical science; skills in programming; and proficiency in major areas of computer engineering and science. A minimum master's GPA of 3.5 on a 4.0 scale, or equivalent, is required for admission. GRE scores must be submitted. International students must also achieve a minimum TOEFL score of 550 (213 computer-based).

Superior undergraduate students may apply to be admitted directly into the Ph.D. program. Such an accelerated program requires a minimum entrance GPA of 3.5 and an interview with the Electrical and Computer Engineering Department Graduate Affairs Committee.

Internet Engineering
The objective of the master of science in internet engineering program is to educate students in the field of internet engineering, with emphasis on computer internetworking and relevant applications.

Admission Requirements
Applicants should have an undergraduate degree in Computer Engineering, Electrical Engineering or other relevant discipline from an accredited institution (or its equivalent). All applicants must submit scores on the Graduate Record Examinations (GRE) verbal, quantitative, and analytical aptitude tests. International students must also achieve a minimum TOEFL score of 550 (pencil and paper) and 213 (computer-based). Applicants with undergraduate degrees in computer science, computer engineering or electrical engineering from an accredited institution are expected to have a GPA of at least 3.0 on a 4.0 scale. These students should have taken ECE 321 Random Signals and Noise, or another equivalent course; ECE 333 Signals and Systems; and proficiency in C++ programming.

Power and Energy Systems (PES)
The master of science in power and energy systems is a program for students with an undergraduate degree in engineering who wish either to specialize in an advanced phase of electrical power engineering and energy systems to prepare for a more advanced degree.

Admission Requirements
Applicants are expected to have undergraduate backgrounds in physics, mathematics (through differential equations and vector analysis), electrical networks and devices, electronics, analysis and design methods, transients, electromagnetic fields, and appropriate laboratory work in some of these areas. GRE scores must be submitted. International students must also achieve a minimum TOEFL score of 79 out 120 (or 550 in the old score system). For further information, see the Admissions section in this catalog.

Graduate Certificate Program
A 12-credit graduate certificate in Power and Energy Systems is available and can be taken as a step toward this degree. See Graduate Certificates in the Degree Programs section of this catalog. For further information, call the Associate Vice President of Continuing and Distance Education, Division of Continuing Professional Education, 1 (800) 624-9850 or (973) 596-3060; e-mail cpe@njit.edu.
Telecommunications

Telecommunications is one of the most rapidly growing fields in engineering. Telecommunications specialization also is rapidly becoming necessary in such diverse fields as banking, reservation systems, office information systems, corporate networks, and the Internet. Rapid technological progress in gigabit optical networks, multimedia communications, and wireless network access, make the future of the field very exciting.

Master of Science in Telecommunications

The objective of this program is to educate individuals in one or more telecommunication specializations.

Admission Requirements

Applicants are expected to have an undergraduate degree in computer science, computer engineering or electrical engineering from an accredited institution (or its equivalent) with a minimum GPA of 3.0 on a 4.0 scale. These students should have taken CS 333 Introduction to UNIX Operating Systems, ECE 321 Random Signals and Noise and ECE 333 Signals and Systems (or their equivalents). Students without this course work will be required to complete a bridge program. Applicants having degrees in other fields may be considered for admission on an individual basis and required to complete a bridge program. GRE scores must be submitted. International students must also achieve a minimum TOEFL score of 550 (pencil and paper) and 213 (computer-based).

Graduate Certificate Program

A 12-credit graduate certificate in Telecommunications Networking is available as a step toward this degree. See “Graduate Certificates” in this catalog. For further information about extension programs and graduate certificates, call the associate vice president of continuing and distance education, Division of Continuing Professional Education, 1 (800) 624-9850 or (973) 596-3060; e-mail cpe@njit.edu

NJIT Faculty

A
Abdi, Ali, Professor
Akansu, Ali N., Professor
Ansari, Nirwan, Professor

B
Bar-Ness, Yeheskel, Distinguished Professor Emeritus

C
Carpinelli, John D., Professor
Carr, William N., Professor Emeritus
Cornely, Roy H., Professor Emeritus

D
Dhawan, Atam P., Distinguished Professor

F
Feknous, Mohammed, University Lecturer
Frank, Joseph Associate Professor Emeritus
Friedland, Bernard, Distinguished Professor

G
Ge, Hongya, Associate Professor
Grebel, Haim, Professor

H
Haddad, Richard A., Professor Emeritus
Haimovich, Alexander M., Professor
Hou, Sui-Hoi Edwin, Associate Professor
Hubbi, Walid, Associate Professor

K
Kam, Moshe, Professor and Dean of NCE
Khreishah, Abdallah, Assistant Professor
Klapper, Jacob, Professor Emeritus
Kliwer, Joerg, Associate Professor
Ko, Dong-Kyun, Assistant Professor

L
Levkov, Serhiy P., University Lecturer
Liu, Qing, Assistant Professor
Liu, Xuan, Assistant Professor

M
Manzhura, Oksana Yu, University Lecturer
Meyer, Andrew U., Professor Emeritus
Misra, Durgamadhab, Professor

N
Nguyen, Hieu, Assistant Professor
Niver, Edip, Professor

R
Raj, Ratna, University Lecturer
Rojas-Cessa, Roberto, Associate Professor
Rosenstark, Solomon, Professor Emeritus

S
Savir, Jacob, Distinguished Professor
Shi, Yun-Qing, Professor
Simeone, Osvaldo, Associate Professor
Sohn, Kenneth S., Professor Emeritus
Sosnowski, Marek, Professor

T
Tsybeskov, Leonid, Professor and Chair

W
Wang, Cong, Assistant Professor
Whitman, Gerald, Professor

Z
Zhou, Mengchu, Distinguished Professor
Ziavras, Sotirios G., Professor

Programs
- Computer Engineering - M.S. (http://catalog.njit.edu/graduate/newark-college-engineering/electrical-computer/computer-ms)
- Electrical Engineering - M.S. (http://catalog.njit.edu/graduate/newark-college-engineering/electrical-computer/electrical-ms)
- Internet Engineering - M.S. (http://catalog.njit.edu/graduate/newark-college-engineering/electrical-computer/internet-ms)
- Power and Energy Systems - M.S. (http://catalog.njit.edu/graduate/newark-college-engineering/electrical-computer/power-energy-systems-ms)
- Telecommunications - M.S. (http://catalog.njit.edu/graduate/newark-college-engineering/electrical-computer/telecommunications-ms)

Programs
- Computer Engineering - Ph.D. (http://catalog.njit.edu/graduate/newark-college-engineering/electrical-computer/computer-phd)
- Electrical Engineering - Ph.D. (http://catalog.njit.edu/graduate/newark-college-engineering/electrical-computer/electrical-phd)

Programs
- Power Systems Engineering (http://catalog.njit.edu/graduate/newark-college-engineering/electrical-computer/power-systems-engineering-cert)

Electrical and Computer Engineering Courses

ECE 590. Graduate Co-op Work Experience I. 1 credit, 1 contact hour.
Restriction: permission from Department of Electrical and Computer Engineering and Division of Career Development Services. Cooperative education/internship providing on-the-job reinforcement of academic programs in electrical and computer engineering. Assignments and projects are developed by the co-op office in consultation with the electrical and computer engineering department. Work assignments are related to student's major and are evaluated by faculty coordinators in the ECE department. Credits for this course may not be used to fulfill any electrical or computer engineering degree requirement.

ECE 591. Graduate Co-op Work Experience II. 1 credit, 1 contact hour.
Prerequisites: ECE 590 and permission from Department of Electrical and Computer Engineering and Division of Career Development Services. See ECE 590 course description. Credits for this course may not be used to fulfill any electrical or computer engineering degree requirement.

ECE 592. Graduate Co-op Work Experience III. 1 credit, 1 contact hour.
Restriction: graduate standing and permission from Department of Electrical and Computer Engineering and Division of Career Development Services. See ECE 590 course description. Credits for this course may not be used to fulfill any electrical or computer engineering degree requirement.

ECE 593. Graduate Co-op Work Experience IV. 0 credits, 0 contact hours.
Restriction: One immediately prior 3-credit registration for graduate co-op work experience with the same employer. Requires approval of departmental co-op advisor and the Division of Career Development Services. Must have accompanying registration in a minimum of 3 credits of course work.

ECE 601. Linear Systems. 3 credits, 3 contact hours.
Methods of linear-system analysis, in both time and frequency domains, are studied. Techniques used in the study of continuous and discrete systems include state-variable representation, matrices, Fourier transforms, LaPlace transforms, inversion theorems, sampling theory, discrete and fast Fourier transforms, and Z-transforms. Computer simulation of linear systems is used, and, where feasible, computer solutions are obtained.

ECE 605. Discrete Event Dynamic Systems. 3 credits, 3 contact hours.
Corequisite: MATH 630 or ECE 601 or MNE 603 or equivalent. Covers the theory of discrete event dynamic systems with applications in modeling, control, analysis, validation, simulation, and performance evaluation of computer systems, flexible manufacturing systems, robotic systems, intelligent supervisory control systems, and communication networks. Emphasis on Petri net and automation based approaches.

ECE 610. Power System Steady-State Analysis. 3 credits, 3 contact hours.
Prerequisite: B.S. in EE or ME. Steady-state analysis of power system networks, particularly real and reactive power flows under normal conditions and current flows under faulty conditions. Symmetrical components and digital solutions are emphasized.

ECE 611. Transients in Power Systems. 3 credits, 3 contact hours.
Prerequisite: ECE 610. Transient performance of power systems with lumped properties, interruption of arcs, restriking voltage, re-ignition inertia effects, switching of rotational systems, magnetic saturation in stationary networks, harmonic oscillations, saturated systems, transient performance of synchronous machines.

ECE 612. Computer Methods Applied to Power Systems. 3 credits, 3 contact hours.
Prerequisite: undergraduate computer programming. Digital computer techniques proven successful in the solution of power system problems, particularly in the electric utility industry. Emphasis on short-circuit, load flow, and transient stability problems. Matrix sparsity is considered.

ECE 613. Protection of Power Systems. 3 credits, 3 contact hours.
Prerequisite: ECE 610 or equivalent Coils, condensers, and resistors as protective devices; fundamental principles of protective relaying; relay operating characteristics; power and current directional relays; differential relays; distance and wire pilot relays; heating and harmonic effects; and Computer-based protective device coordination.
ECE 616. Power Electronics. 3 credits, 3 contact hours.
Prerequisite: B.S. in electrical engineering. Principles of thyristor devices, dynamic characteristics of choppers, commutation, protection, voltage-fed and current-fed inverter drives, cycloconverters, pulse width modulation, phase control, and microcomputer control, with case studies.

ECE 617. Economic Control of Interconnected Power Systems. 3 credits, 3 contact hours.
Economic Control of Interconnected Power Systems: Advanced techniques for operating power systems in the most economic manner while meeting various network constraints; economic dispatch, penalty factors, optimal power flow, short-term electricity markets and locational marginal prices will be studied.

ECE 618. Renewable Energy Systems. 3 credits, 3 contact hours.
This course introduces renewable energy systems. It covers the fundamental concepts of energy and radiation with specific solar energy applications and photovoltaics, electrical energy storage systems, and thermal energy and storage. The second part covers the basic science of wind energy systems and their electrical system designs. The third part covers the bioenergy systems from resources to final products and conversion technologies. It finally introduces other promising energy sources.

ECE 620. Electromagnetic Field Theory. 3 credits, 3 contact hours.
Prerequisite: undergraduate electromagnetic field theory or equivalent. Maxwell’s equations, boundary conditions and formulation of potentials. Laplace and Poisson equations for electrostatic and magnetostatic problems and the method of images. Dielectric and magnetic materials, force and energy concepts. Quasi-static and time varying fields, plane, cylindrical and spherical waves. Green’s functions, transmission lines.

ECE 622. Wave Propagation. 3 credits, 3 contact hours.
Prerequisite: ECE 620 or equivalent. Fundamentals of electromagnetics; radiation and scattering; Green’s functions; integral equations; numerical methods; ray optics and asymptotics.

ECE 624. Optical Engineering. 3 credits, 3 contact hours.
This course covers basic optical concepts, emphasizing those common to many optical instruments, such as light sources and their characteristics, polarization, coherence, and interferometry. The course introduces CAD tools for lenses, optical filters, and instrument design. The course also focuses on topics concerning optical systems, such as flat panel displays and micromechanical optical systems.

ECE 625. Fiber and Integrated Optics. 3 credits, 3 contact hours.
Prerequisite: undergraduate electromagnetic field theory and solid-state circuits. Planar dielectric waveguides, step and graded index fibers and dispersion in fibers. The p-n junction and heterostructures, light emitting diodes and semiconductor lasers, p-i-n and avalanche photodetectors, optical transmitter and receiver designs, optical fiber communication system design concepts.

ECE 626. Optoelectronics. 3 credits, 3 contact hours.

ECE 630. Microwave Engineering. 3 credits, 3 contact hours.
Prerequisite: undergraduate course in electromagnetic field theory. Review of transmission line theory and the Smith chart; scattering matrix representation, LC and microstrip matching networks; signal flow graph analysis; micro-wave transistor amplifier design, which includes power gain, stability, noise figure circles; oscillator design.

ECE 632. Antenna Theory. 3 credits, 3 contact hours.
Prerequisite: undergraduate course in electromagnetic field theory. Fundamentals of electromagnetic field theory; far field approximation, antenna characteristics (gain, impedance, pattern, etc.); elementary antenna types (dipoles, loops, etc.), antenna array theory, wire antennas; broadband antennas.

ECE 636. Computer Networking Laboratory. 3 credits, 3 contact hours.
Prerequisites: ECE 637 or CS 656. This course provides students with hands on training regarding the design, troubleshooting, modeling and evaluation of computer networks. In this course, students are going to experiment in a real test-bed networking environment, and learn about network design and troubleshooting topics and tools such as: network addressing, Address Resolution Protocol (ARP), basic troubleshooting tools (e.g. ping, ICMP), IP routing (e.g. RIP), route discovery (e.g. traceroute), TCP and UDP, IP fragmentation and many others. Student will also be introduced to the network modeling and simulation, and they will have the opportunity to build some simple networking models using the OPNET modeling tool and perform simulations that will help them evaluate their design approaches and expected network performance.

ECE 637. Internet and Higher-Layer Protocols. 3 credits, 3 contact hours.
The course introduces the protocols and standards of the TCP/IP suite that govern the functioning of the Internet. The material covered in class is a top-down approach on introduction, discussion, and analysis of protocols from the data-link layer to the application layer. Alternative protocols to the TCP/IP suite and new protocols adopted by this suite are discussed. Numerical examples related to network planning and protocol functioning are analyzed.

ECE 638. Network Management and Security. 3 credits, 3 contact hours.
Prerequisites: ECE 683 or CS 652, and ECE 637 or CS 656. Thorough introduction to current network management technology and techniques, and emerging network management standards. In-depth study of the existing network security technology and the various practical techniques that have been implemented for protecting data from disclosure, for guaranteeing authenticity of messages, and from protecting systems for network-based attacks. SNMP family of standards including SNMP, SNMPv2, and RMON (Remote Monitoring), OSI systems management. Various types of security attacks (such as intruders, viruses, and worms), Conventional Encryption and Public Key Cryptology. Various security services and standards (such as Kerberos, Digital Signature Standard, Pretty Good Privacy, SNMPv2 security facility). Same as CIS 696.
ECE 639. Principles of Broadband Networks. 3 credits, 3 contact hours.
Prerequisites: ECE 673, ECE 683 or CS 652 or equivalent. This course covers fundamental concepts of broadband networks. Topics include Broadband ISDN, Switching Techniques, ATM, SONET/SDH, Congestion Control, High-Speed Switching Architectures, Traffic Modeling of Broadband Services, Admission Control, Traffic Scheduling, IP/ATM Convergence, QoS Provisioning in IP Networks, and Optical Networks.

ECE 640. Digital Signal Processing. 3 credits, 3 contact hours.
Prerequisite: ECE 601 or equivalent. The theory of digital signals and basic processing techniques: Discrete Fourier Series, Discrete Fourier Transform and FFT, Linear and Circular Convolution, Digital Filter Design Techniques, Discrete Hilbert Transforms, Discrete Random Signals, Chirp-Z and other advanced transforms. Introduction to multivariate signal processing. The typical applications of signal processing tools are discussed and connected to the theoretical foundations.

ECE 641. Laboratory for High Performance Digital Signal Processing. 3 credits, 3 contact hours.

ECE 642. Communication Systems I. 3 credits, 3 contact hours.
Corequisite: ECE 673. Principles of communication theory applied to the representation and transmission of information. Topics include analysis of deterministic and random signals, amplitude modulation, angle modulation, sampling, quantization, PCM, DM, DPCM, geometric representation of signals, error probability, matched filter and correlation receivers and performance analysis of communication systems signal to noise ratio.

ECE 643. Digital Image Processing I. 3 credits, 3 contact hours.
Prerequisite: ECE 601. Introductory course in digital image processing. Topics include image models, digitization and quantization, image enhancement in spatial and frequency domains, image restoration, image segmentation and analysis.

ECE 644. Wireless Communication. 3 credits, 3 contact hours.
Prerequisites: ECE 321 or MATH 333. This course is focused on the technical challenges and solutions to physical and link layer design of wireless communication systems. Course topics include characterization of the wireless channel, the cellular concept, digital modulation techniques, spread spectrum, multiple access techniques including CDMA and OFDMA, diversity techniques. Advanced techniques such as MIMO, 3G and 4G wireless technologies are introduced. Matlab is used for examples and assignments. Team projects based on advanced wireless technologies.

ECE 645. Wireless Networks. 3 credits, 3 contact hours.
Prerequisites: EE 321 or MATH 333, or equivalent (see undergraduate catalog for descriptions). Introduction to wireless network design, management, and planning stages. Topics include demand modeling, radio planning, network optimization, and information handling architecture with emphasis on resource allocation and mobility management aspects. Investigation of signaling load optimizations and internetworking problems.

ECE 650. Electronic Circuits. 3 credits, 3 contact hours.
Prerequisite: senior undergraduate level semiconductor circuits. Methods of analysis and design of linear and digital semiconductor circuits are studied. Topics include low and high frequency models, passive and active biasing techniques, I-C analysis and design, op-amp circuits, and active filters.

ECE 653. Micro/Nanotechnologies for Interacing Live Cells. 3 credits, 3 contact hours.
In this course, we will study technologies and tools available for interfacing live cells from a sub-cellular, single-cell, and multi-cellular (tissue models) approach. We will introduce key concepts of the biology of cells and tissues and will explore the technologies (micro-/nanotechnologies) and tools (sensors and actuators) available for the investigation of cell and tissue biology. Same as BME 653.

ECE 657. Semiconductor Devices. 3 credits, 3 contact hours.
Fundamental principles of solid state materials necessary for understanding semiconductor devices. Topics include crystal structure; energy bands; electron and hole generation, and transport phenomena; generation and recombination processes, and high field effects. P-N junction diode, metal semiconductor contact, and bipolar and metal oxide semiconductor transistors, including switching phenomena and circuit models. Introduction to: photonic devices--light emitting diodes, semiconductor lasers, photodetectors, and solar cells; microwave devices--tunnel and IMPATT diodes, transferred electron devices, and charge-coupled capacitors.

ECE 658. VLSI Design I. 3 credits, 3 contact hours.
Prerequisite: ECE 657 or equivalent. Analysis and design of digital integrated circuits; basic building blocks and dependence on circuit parameters of propagation delay; noise margin; fan-out; fan-in; and power dissipation for circuits of different logic families, including NMOS, CMOS and BiCMOS; subsystem designs in combinational and sequential logic; Memory Systems; HSPICE circuit simulation is used for digital characteristics evaluation. Mentor Graphics Layout design tools are used for chip design.

ECE 659. Fabrication Principles of Electronic and Optoelectronic Devices. 3 credits, 3 contact hours.
Prerequisite: ECE 657 or equivalent. Overview of all major processing steps in fabrication of integrated circuits such as crystal growth, epitaxy, oxidation, diffusion, ion implantation and etching. Formation of thin film structures along with techniques for defining submicron structures. Emphasizes silicon device technology but also includes processing of compound semiconductors such as gallium arsenide.

ECE 660. Control Systems I. 3 credits, 3 contact hours.
Prerequisites: undergraduate course equivalent to EE 333 or ME 305 (see undergraduate catalog for descriptions) and ECE 601 or equivalent or permission from instructor. Introduction to feedback control. Review of state-space analysis. Frequency-domain methods for analysis: Routh-Hurwitz stability algorithms, Root-loci; Nyquist and Bode plots; system ?type.? Controllability and observability. The separation principle and design by pole placement. Linear observers. Optimization of quadratic performance criteria. Elements of random processes. The Kalman filter as an optimum observer. Robustness considerations.
ECE 661. Control System Components. 3 credits, 3 contact hours.
Prerequisite: ECE 660. The theoretical and practical requirements for analog and digital state-of-the-art control system components are covered. Actuators, amplifiers, sensors, encoders, resolvers and other electromagnetic devices are included. A complete system is designed using current vendor catalog data. Problems affecting the system performance are analyzed using measures of functionality, reliability and cost.

ECE 664. Real-time Computer Control Systems. 3 credits, 3 contact hours.
Prerequisite: EE 486 or equivalent (see undergraduate catalog for description). Emphasizes the practical aspects of modern computer control systems. Topics include: Architecture of digital signal processors (DSP) and microcontrollers, real-time data acquisition devices and interface, programming a DSP, review of sampling theorems and properties of discrete-time systems, introduction of control systems theory, design and implementation of parameter optimized controllers, state variable controllers, and cancellation controllers. An experimental project using a TMS320C2x DSP-based data acquisition system is an integral part of this course.

ECE 667. Bio-Control Systems. 3 credits, 3 contact hours.
The course provides an introduction to dynamic and control in biological systems, with particular emphasis on engineering aspects of biological oscillators/waves which govern the basic operations of all living organisms and especially higher order life forms. A combination of theoretical and simulation tools will be applied to analyze the qualitative and quantitative properties of selected biological systems. Feedback and control mechanisms in selected biological systems will be introduced. Same as BME 667.

ECE 673. Random Signal Analysis I. 3 credits, 3 contact hours.
Fundamentals of the theory of random variables. Introduction to the theory of random processes. Topics include functions of random variables, sequences of random variables, central limit theorem, properties of random processes, correlation, spectral analysis and linear systems with random inputs.

ECE 681. High Performance Routers and Switches. 3 credits, 3 contact hours.
The course introduces the different system comprising and Internet routing including the processors for networking function and protocol compliance, switching functions and packet classification for deep-layer inspection capable routers or network appliances. This course material describe the different functions that Internet routers perform and discusses the different approaches used for improving performance of high-end routers. The content includes a discussion on switch architectures.

ECE 683. Computer Network Design and Analysis. 3 credits, 3 contact hours.
Corequisite: ECE 673. Queuing models and state-transition models are introduced to model, design and analyze computer networks. The OSI model, LANS (including token ring, token bus, and Ethernet), and useful network protocols. Emphasis on the physical, data link and network layers. ALOHA, Stop-and-Wait protocol, Go-Back-N protocol, window-flow-control, and shortest-path routing.

ECE 684. Advanced Microprocessor Systems. 3 credits, 3 contact hours.
Prerequisite: undergraduate course in computer architecture and microprocessors, and some experience in assembly language programming. Architecture of advanced microprocessors; CPU architecture, memory management and protection, interrupt and exception facilities, instruction sets, systems aspects including peripheral interfaces, communications ports, and real-time systems.

ECE 689. Computer Arithmetic Algorithms. 3 credits, 3 contact hours.
Prerequisite: undergraduate course in logic design. Data representation, integers, floating point and residue representation. Bounds on arithmetic speed, algorithms for high speed addition, multiplication, and division. Pipelined arithmetic. Hardware implementation and control issues.

ECE 690. Computer Systems Architecture. 3 credits, 3 contact hours.
Prerequisites: ECE 684 and COE 353 (see undergraduate catalog for description) or CS 650. Discusses advanced topics in modern computer systems architecture such as pipelined and superscalar processors, parallel computers (vector, SIMD, MIMD), multithreaded and dataflow architectures, cache and memory hierarchy, and system interconnect architectures. Also discusses relevant system software design issues such as shared memory and message-passing communication models, cache coherence and synchronization mechanisms, latency-hiding techniques, virtual memory management, program partitioning and scheduling. Examples are drawn from real systems.

ECE 692. Embedded Computing Systems. 3 credits, 3 contact hours.
Prerequisites: ECE 353 (COE) or ECE 684 (EE) and CS 105 (or equivalents). Introduction of the methodology for the design and implementation of embedded computing systems, and its application to real-world problems. Topics include Embedded System Design Process, UML, ARM Instruct Set Architectures, CPU's Hardware Platforms, Software Design and Analysis, Embedded Operating Systems, Real-Time Scheduling, Hardware Accelerators, Distributed Embedded Systems, and Design Methodology and Quality Assurance.

ECE 698. Selected Topics in Electrical and Computer Engineering. 3 credits, 3 contact hours.
Special area course given when suitable interest develops. Advance notice of forthcoming topics will be given.

ECE 699. Selected Topics in Electrical and Computer Engineering II. 3 credits, 3 contact hours.
See description for ECE 698 above.

ECE 700. Master's Project. 0 credits, 0 contact hours.
Prerequisite: written approval of project advisor. An extensive paper involving design, construction, and analysis, or theoretical investigation. Joint projects with industry may be acceptable. Work is carried out under the supervision of a member of the department faculty. A maximum of 3 credits may be applied to the degree.
ECE 700B. Master's Project. 3 credits, 3 contact hours.
Approval of the project advisor is required for registration. Experimental and/or theoretical investigation of a relevant topic in electrical or computer engineering. A written report must be submitted to the project advisor. The student cannot register in ECE 700B more than once and the incomplete (I) grade is not allowed.

ECE 701. Master's Thesis. 0 credits, 0 contact hours.
Prerequisite: written approval of thesis advisor. Projects involving design, construction, experimental or theoretical investigation. Joint projects with industry or governmental agencies may be acceptable. Work is carried on under the supervision of a designated member of the department faculty. Completed work in the form of a written thesis should be of a quality leading to journal publication. The completed thesis must be defended by the student in an open forum and must be approved by a committee of at least three people. A student must register for a minimum of 3 credits per semester. Only the 6 credits indicated for the thesis will be applied to the degree.

ECE 701B. Master's Thesis. 3 credits, 3 contact hours.
Approval of the thesis advisor is required for registration. Experimental and/or theoretical investigation of a relevant topic in electrical or computer engineering that can lead to a quality publication. A written thesis must be defended and approved by a committee of at least three faculty members. The student is expected to defend the thesis upon accrual of six thesis credits. Additional registration in ECE 701B, beyond six credits, is required every semester until successful thesis defense (six credits count toward degree requirements and time limits apply).

ECE 701C. Master's Thesis. 6 credits, 6 contact hours.
Approval of the thesis advisor is required for registration. Experimental and/or theoretical investigation of a relevant topic in electrical or computer engineering that can lead to a quality publication. A written thesis must be defended and approved by a committee of at least three faculty members. The student must continue registering for three thesis credits (ECE 701B) each semester until successful thesis defense (six credits count toward degree requirements and time limits apply).

ECE 725. Independent Study I. 3 credits, 3 contact hours.
Approvals of the academic advisor and course instructor are required for registration. Students working on their PhD dissertation or MS thesis cannot normally register for this course with their respective dissertation/thesis advisor. This special course covers areas of study in which one or more students may be interested but there is not sufficiently broad interest to warrant a regular course offering. Students may not register for this course more than once.

ECE 726. Independent Study II. 3 credits, 3 contact hours.
Approvals of the academic advisor and course instructor are required for registration. Students working on their PhD dissertation or MS thesis cannot normally register for this course with their respective dissertation/thesis advisor. This special course covers areas of study in which one or more students may be interested but there is not sufficiently broad interest to warrant a regular course offering. Students may not register for this course more than once. Students should only register for ECE 726 if they have taken ECE 725 in a prior semester.

ECE 739. Laser Systems. 3 credits, 3 contact hours.
Prerequisite: ECE 620 or permission of instructor. Optical resonators, laser radiation and oscillation. Laser characteristics: semiconductor lasers, gas and glass lasers; mode-locking, Q-switching. Quantum-well lasers, noise; modulation and detection of laser light, optical systems for communication and computation.

ECE 740. Advanced Digital Signal Processing. 3 credits, 3 contact hours.
Prerequisites: ECE 601, ECE 640 and ECE 673. Topics in stationary discrete time stochastic processes; modeling of discrete time processes, Yule-walker equations, aspects of discrete wiener theory; principle of orthogonality, linear predictors; Levinson-Durbin recursion and algorithm, lattice predictors, method of least squares (RLS) algorithm, systolic array implementation of QRD-Ls.

ECE 742. Communication Systems II. 3 credits, 3 contact hours.
Prerequisites: ECE 642 and ECE 673 or equivalents. Principles of digital communication. Topics include fundamentals of information theory, digital modulation techniques, optimum detector receivers for digitally modulated signals, the bandlimited gaussian channel and intersymbol interference, equalization, spread spectrum, CDMA.

ECE 743. Image Data Hiding, Forensics. 3 credits, 3 contact hours.
Prerequisites: ECE 643 or CS 659 or equivalent. As we have entered digital world, information forensics and security have become critically important. With digital images as media, this course covers digital watermarking, reversible data hiding, steganography and steganalysis, forensics and counter-forensics, including image tampering detection, classification of double JPEG/MPEG compressions, camera classification from given images, classification of photographic images from computer graphic images, and so on.

ECE 744. Optimization for Communication Networks. 3 credits, 3 contact hours.
Modern communication are required to provide optimal performance in terms of quality-of-service under strict constrains on the utilization of resources, such as spectrum of power. In addition, the emerging paradigm of decentralized communication systems, such as ad hoc and sensor networks, calls for distributed, and possibly competitive, optimization techniques. This course covers the basic analytical and algorithmic tools that enable such centralized and decentralized optimization.

ECE 747. Signal Decomposition Techniques: Transforms, Sub-bands, and Wavelets. 3 credits, 3 contact hours.
Prerequisites: ECE 640 and ECE 673. Multiresolution signal decomposition techniques, transforms, sub-bands, and wavelets. Time-frequency localization properties of multiresolution algorithms. Evaluation and critique of proposed decomposition strategies from compression and performance standpoints. Applications to speech and video compression, and localized feature extraction. These are basic signal processing tools used in diverse applications such as speech and image processing and storage, seismology, machine vision.
ECE 754. Statistical Machine Learning and Pattern Recognition. 3 credits, 3 contact hours.
Prerequisites: Good knowledge of graduate probability, as in ECE 673 or equivalent, and linear algebra; or permission of instructor. This course provides a systematic introduction to machine learning and pattern recognition using information-theoretic performance criteria as guiding principles. Topics covered include linear and kernel models for classification and regression, sample complexity and VC dimension, probabilistic graphical models and approximate inference.

ECE 755. Advanced Topics in Digital Communications. 3 credits, 3 contact hours.
Prerequisites: ECE 642 and ECE 673 or equivalent. Advanced topics in digital communication systems in the presence of intersymbol interference, noise, and fading: modulation and demodulation in the presence of gaussian noise, efficient signaling with coded modulation, trellis decoding, Viterbi algorithm, digital transmission with intersymbol interference, and digital signaling over imperfect channels.

ECE 756. Advanced Topics in Semiconductor Devices. 3 credits, 3 contact hours.
Prerequisite: ECE 657 or permission of instructor. Builds on ECE 657. Covers photonic devices particularly semiconductor laser and photodetectors for optical systems; microwave and other high speed devices; scaled advanced MOS, FET, and bipolar transistors.

ECE 758. VLSI Design II. 3 credits, 3 contact hours.
Prerequisite: ECE 658 (with ECE 657 suggested). Use of CMOS, bICMOS and bipolar semiconductor technology for VLSI design. Digital techniques are emphasized with minor coverage of analog design. Application areas for full custom, gate arrays, standard cell, and compiled designs are compared. Mentor VLSI design tools running on the HP and Sun workstations are used in the course projects for each enrollee. The course attempts to provide a design environment for projects that is similar to that encountered by VLSI designers in industry.

ECE 760. Solid-State Image Sensors. 3 credits, 3 contact hours.
Prerequisites: ECE 642 and ECE 673 or equivalents. Classical theory of information developed from Shannon's theory. Information measure, Markov sources and extensions, the adjoint source, uniquely decodable and instantaneous codes and their construction, Shannon's first and second theorems, mutual information, and performance bounds on block and convolutional codes.

ECE 776. Information Theory. 3 credits, 3 contact hours.
Prerequisites: ECE 642 and ECE 673 or equivalents. Classical theory of information developed from Shannon's theory. Information measure, Markov sources and extensions, the adjoint source, uniquely decodable and instantaneous codes and their construction, Shannon's first and second theorems, mutual information, and performance bounds on block and convolutional codes.

ECE 777. Statistical Decision Theory in Communications. 3 credits, 3 contact hours.
Prerequisite: ECE 642 or equivalent. Relation between detection theory and statistical hypothesis testing problem. Use of Bayes decision criteria, Neyman-Pearson, and mini-max tests; receiver operating characteristics. Representation of signals in signal space, probability of error calculations. Estimation of random and non-random signal parameters, Cramer-Rao Inequality. The general Gaussian problem and the use of covariance matrices.

ECE 783. Computer Communication Networks. 3 credits, 3 contact hours.
Prerequisites: ECE 673 and ECE 683. Data link control and communication channels. Delay models in data networks. Queueing analysis techniques are taught in detail. Multi-access communication techniques. Routing in computer communication networks.

ECE 788. Selected Topics in Electrical and Computer Engineering. 3 credits, 3 contact hours.
Special-area course given when suitable interest develops. Advance notice of forthcoming topics will be given.

ECE 789. Selected Topics in Electrical and Computer Engineering II. 3 credits, 3 contact hours.
See description for ECE 788.

ECE 790. Doctrl Dissrtn & Research. 0 credits, 0 contact hours.
Required of all students working toward the Ph.D. in Computer Engineering or in Electrical Engineering. A minimum of 36 credits is required. The student must register for at least 6 credits of dissertation per semester; registration for additional credits may be permitted beyond the 6, with the approval of the advisor, up to a maximum of 12 credits per semester. If the student is still actively engaged in the research after completion of 36 credits, continued registration of 3 credits per semester is required.

ECE 790A. Doctrl Dissrtn & Research. 1 credit, 1 contact hour.
Co-requisite: ECE 791. Approval of the dissertation advisor is required for registration. Experimental and/or theoretical investigation of a relevant topic in electrical or computer engineering. For PhD students who have successfully defended their dissertation proposal. The student must register in ECE 790A every semester until successful dissertation defense. A written dissertation must be defended and approved by a committee of at least five members. Students enrolled in the PhD program before 2015 Fall must accumulate a minimum number of credits in Doctoral Dissertation Research and Pre-Doctoral Research (see graduate catalog for program-specific details; the same requirement may apply to joint PhD programs with other universities).

ECE 790B. Doctrl Dissrtn & Research. 3 credits, 3 contact hours.
Co-requisite: ECE 791. Since the ECE 790A course should normally be taken instead, approvals of academic and dissertation advisors are required for registration. Experimental and/or theoretical investigation of a relevant topic in electrical or computer engineering. For PhD students who have successfully defended their dissertation proposal. Students enrolled in the PhD program before 2015 Fall must accumulate a minimum number of credits in Doctoral Dissertation Research and Pre-Doctoral Research (see graduate catalog for program-specific details; the same requirement may apply to joint programs with other universities).
ECE 790C. Doctor Dissertation & Resrch. 6 credits, 6 contact hours.
Co-requisite: ECE 791. Since the ECE 790A course should normally be taken instead, approvals of academic and dissertation advisors are required for registration. For PhD students who have successfully defended their dissertation proposal. Experimental and/or theoretical investigation of a relevant topic in electrical or computer engineering. Students enrolled in the PhD program before 2015 Fall must accumulate a minimum number of credits in Doctoral Dissertation Research and Pre-Doctoral Research (see graduate catalog for program-specific details; the same requirement may apply to some joint programs with other universities).

ECE 790D. Doctor Dissertation & Resrch. 9 credits, 3 contact hours.
Required of all students working toward the Ph.D. in Computer Engineering or in Electrical Engineering. A minimum of 36 credits is required. The student must register for at least 6 credits of dissertation per semester; registration for additional credits may be permitted beyond the 6, with the approval of the advisor, up to a maximum of 12 credits per semester. If the student is still actively engaged in the research after completion of 36 credits, continued registration of 3 credits per semester is required.

ECE 790E. Doctor Dissertation & Resrch. 12 credits, 3 contact hours.
Required of all students working toward the Ph.D. in Computer Engineering or in Electrical Engineering. A minimum of 36 credits is required. The student must register for at least 6 credits of dissertation per semester; registration for additional credits may be permitted beyond the 6, with the approval of the advisor, up to a maximum of 12 credits per semester. If the student is still actively engaged in the research after completion of 36 credits, continued registration of 3 credits per semester is required.

ECE 790F. Doctor Dissertation & Resrch. 15 credits, 3 contact hours.
Required of all students working toward the Ph.D. in Computer Engineering or in Electrical Engineering. A minimum of 36 credits is required. The student must register for at least 6 credits of dissertation per semester; registration for additional credits may be permitted beyond the 6, with the approval of the advisor, up to a maximum of 12 credits per semester. If the student is still actively engaged in the research after completion of 36 credits, continued registration of 3 credits per semester is required.

ECE 790G. Doctor Dissertation & Resrch. 18 credits, 3 contact hours.

ECE 791. Graduate Seminar. 0 credits, 0.5 contact hours.
All master's and doctoral students must register for two semesters and six semesters of ECE 791 Graduate Seminar, respectively. To receive a satisfactory grade, students must attend at least five seminars during the semester, as approved by the seminar supervisor.

ECE 792B. Pre-Doctoral Research. 3 credits, 3 contact hours.
Co-requisite: ECE 791. Approval of the dissertation advisor is required for registration. Preliminary experimental and/or theoretical investigation of a relevant topic in electrical or computer engineering. For students who have passed the qualifying examination but have not defended the dissertation proposal. Permission is needed of the academic advisor as well for students who have completed the required coursework but have not passed the qualifying examination.

ECE 792C. Pre-Doctoral Research. 6 credits, 3 contact hours.