

# ELECTRICAL & COMPUTER ENGR (ECE)

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## **ECE 1010. Introduction to ECE Design. 2 Credit Hours.**

An introduction to basic concepts useful for all areas of Electrical and Computer Engineering. Focus on hands-on, team-based activities using robotics.

## **ECE 1100. ECE Discovery Studio. 1 Credit Hour.**

Students will explore ECE curriculum threads and opportunities available during the undergraduate experience while navigating the early career planning process.

## **ECE 1801. Special Topics. 1 Credit Hour.**

## **ECE 1802. Special Topics. 2 Credit Hours.**

## **ECE 1803. Special Topics. 3 Credit Hours.**

## **ECE 1804. Special Topics. 4 Credit Hours.**

## **ECE 1805. Special Topics. 5 Credit Hours.**

## **ECE 1811. Special Topics. 1 Credit Hour.**

## **ECE 1812. Special Topics. 2 Credit Hours.**

## **ECE 1813. Special Topics. 3 Credit Hours.**

## **ECE 1814. Special Topics. 4 Credit Hours.**

## **ECE 1815. Special Topics. 5 Credit Hours.**

## **ECE 1871. Special Topics. 1 Credit Hour.**

Special Topics for Electrical and Computer Engineering.

## **ECE 1881. Special Topics. 1 Credit Hour.**

## **ECE 1882. Special Topics. 2 Credit Hours.**

## **ECE 1883. Special Topics. 3 Credit Hours.**

## **ECE 1884. Special Topics. 4 Credit Hours.**

## **ECE 1891. Special Topics. 1 Credit Hour.**

## **ECE 1892. Special Topics. 2 Credit Hours.**

## **ECE 1893. Special Topics. 3 Credit Hours.**

## **ECE 1894. Special Topics. 4 Credit Hours.**

## **ECE 1900. Special Problems. 1-21 Credit Hours.**

## **ECE 1901. Special Problems. 1-21 Credit Hours.**

## **ECE 1902. Special Problems. 1-21 Credit Hours.**

## **ECE 1903. Special Problems. 1-21 Credit Hours.**

## **ECE 1XXX. Electrical and Computer Engineering Elective. 1-21 Credit Hours.**

## **ECE 2001. ECE Seminar. 1 Credit Hour.**

Speakers with diverse backgrounds and representing many different industries, professions, and institutions describe their experiences, entrepreneurial ventures, and research challenges.

## **ECE 2002. ECE Seminar. 1 Credit Hour.**

Speakers with diverse backgrounds and representing many different industries, professions, and institutions describe their experiences, entrepreneurial ventures, and research challenges.

## **ECE 2003. ECE Seminar. 1 Credit Hour.**

Speakers with diverse backgrounds and representing many different industries, professions, and institutions describe their experiences, entrepreneurial ventures, and research challenges.

## **ECE 2020. Digital System Design. 3 Credit Hours.**

Computer system and digital design principles. Switch and gate design, Boolean algebra, number systems, arithmetic, storage elements. Datapath, memory organization, instruction set architecture, assembly language. Credit not allowed for both ECE 2020 and ECE 2030.

## **ECE 2025. Introduction to Signal Processing. 4 Credit Hours.**

Introduction to signal processing for discrete-time and continuous-time signals. Filtering. Frequency response. Fourier Transform. Z Transform. Laboratory emphasizes computer-based signal processing. Credit not allowed for both ECE 2025 and ECE 2026.

## **ECE 2026. Introduction to Signal Processing. 3 Credit Hours.**

Introduction to discrete-time signal processing and linear systems. Sampling theorem, filtering, frequency response, Discrete Fourier Transform, Z-Transform. Laboratory emphasizes computer-based signal processing. Credit not allowed for both ECE 2026 and ECE 2025.

## **ECE 2030. Introduction to Computer Engineering. 3 Credit Hours.**

Computer system and digital design principles. Architectural concepts, software, Boolean algebra, number systems, combinational datapath elements, sequential logic, and storage elements. Design of DRAM control and I/O bus. Credit not allowed for both ECE 2030 and ECE 2020.

## **ECE 2031. Digital Design Laboratory. 2 Credit Hours.**

Design and implementation of digital systems, including a team design project. CAD tools, project design methodologies, logic synthesis, and assembly language programming.

## **ECE 2035. Programming for Hardware/Software Systems. 4 Credit Hours.**

Creation of complex execution and storage mechanisms, based on instruction set architecture, for software design including high-level programming languages and operating systems. Programming design projects. Credit not allowed for both ECE 2035 and ECE 3035.

## **ECE 2036. Engineering Software Design. 4 Credit Hours.**

Object-oriented software methods for engineering applications. Numerical analysis methods; simulations and graphical presentation of simulation results; analysis of numerical precision. Programming projects. Credit not allowed for both ECE 2036 and ECE 3090.

## **ECE 2040. Circuit Analysis. 3 Credit Hours.**

Basic concepts of DC and AC circuit theory and analysis.

## **ECE 2045. Practical Skills and Design. 1 Credit Hour.**

This course teaches practical skills, such as soldering and prototyping, and introduces students to ECE design.

## **ECE 20X2. Transfer-Digital Des Lab. 2 Credit Hours.**

## **ECE 20X3. Transfer-Digital Systems. 3 Credit Hours.**

## **ECE 2698. Undergraduate Research Assistantship. 1-12 Credit Hours.**

Independent research conducted under the guidance of a faculty member.

## **ECE 2699. Undergraduate Research. 1-12 Credit Hours.**

Independent Research conducted under the guidance of a faculty member.

**ECE 2801. Special Topics. 1 Credit Hour.**

**ECE 2802. Special Topics. 2 Credit Hours.**

**ECE 2803. Special Topics. 3 Credit Hours.**

**ECE 2804. Special Topics. 4 Credit Hours.**

**ECE 2805. Special Topics. 5 Credit Hours.**

**ECE 2811. Special Topics. 1 Credit Hour.**

**ECE 2812. Special Topics. 2 Credit Hours.**

**ECE 2813. Special Topics. 3 Credit Hours.**

**ECE 2814. Special Topics. 4 Credit Hours.**

**ECE 2815. Special Topics. 5 Credit Hours.**

**ECE 2871. Special Topics. 1 Credit Hour.**

**ECE 2881. Special Topics. 1 Credit Hour.**

**ECE 2882. Special Topics. 2 Credit Hours.**

**ECE 2883. Special Topics. 3 Credit Hours.**

**ECE 2884. Special Topics. 4 Credit Hours.**

**ECE 2891. Special Topics. 1 Credit Hour.**

**ECE 2892. Special Topics. 2 Credit Hours.**

**ECE 2893. Special Topics. 3 Credit Hours.**

**ECE 2894. Special Topics. 4 Credit Hours.**

**ECE 2900. Special Problems. 1-21 Credit Hours.**

**ECE 2901. Special Problems. 1-21 Credit Hours.**

**ECE 2902. Special Problems. 1-21 Credit Hours.**

**ECE 2903. Special Problems. 1-21 Credit Hours.**

**ECE 2XXX. Electrical and Computer Engineering Elective. 1-21 Credit Hours.**

**ECE 3005. Professional and Technical Communications for ECE. 1 Credit Hour.**

Written, oral, and visual communication skills required by electrical and computer engineers. Prepares students for advanced communication tasks required in academic and professional settings.

**ECE 3006. Co-Curricular Professional Communications for ECE. 0 Credit Hours.**

This course documents student completion of ECE professional communications requirement through workshops, seminars, research projects, co/extra-curricular activities, etc.

**ECE 3011. ECE Design Fundamentals. 2 Credit Hours.**

This course teaches system-level design, including both software and hardware. Through activities and projects, students gain exposure to entrepreneurship, product lifecycle management, prototyping, and testing.

**ECE 3020. Mathematical Foundations of Computer Engineering. 3 Credit Hours.**

Fundamental concepts in discrete mathematics and their efficient realization via algorithms, data structures, computer programs, and hardware. Discussion of engineering and computational applications.

**ECE 3025. Electromagnetics. 3 Credit Hours.**

To present the laws and applications of electromagnetics.

**ECE 3030. Physical Foundations of Computer Engineering. 3 Credit Hours.**

Basic principles governing the physical realization of computing systems and their relationship to characteristics such as performance, energy, and robustness. Implementation technologies.

**ECE 3035. Mechanisms for Computing Systems. 4 Credit Hours.**

Computing system execution and storage mechanisms, starting with instruction set architecture and concluding with support for high level languages and operating systems. Credit not allowed for both ECE 3035 and ECE 2035.

**ECE 3040. Microelectronic Circuits. 4 Credit Hours.**

Basic concepts of microelectronic materials, devices, and circuits.

**ECE 3043. Measurements, Circuits, and Microelectronics Laboratory. 2 Credit Hours.**

Basic electronic test instrumentation. Elementary passive and active circuits using both discrete (diodes, bipolar junction transistors, MOSFETs) and integrated devices (operational amplifiers). Credit not allowed for both ECE 3043 and ECE 3041.

**ECE 3050. Analog Electronics. 3 Credit Hours.**

To present concepts of analysis and design of electronic circuits and systems. Biasing, small-signal analysis, frequency response, feedback amplifiers, active filters, non-linear op-amp applications, and oscillators.

**ECE 3055. Computer Architecture and Operating Systems. 4 Credit Hours.**

Core concepts of computer architecture and operating systems. Instruction set architectures (ISA), compiler/ISA relationships, pipelined datapaths. Memory hierarchy, memory management, and protection. Processes, threads, CPU scheduling, and associated techniques. Credit not allowed for both ECE 3055 and ECE 3056.

**ECE 3057. Architecture, Systems, Concurrency and Energy in Computation. 3 Credit Hours.**

Basic organizational principles of the major components of a processor - the core, memory hierarchy, I/O subsystem and basic operating system constructs that utilize them.

**ECE 3058. Architecture, Systems, Concurrency, and Energy in Computation. 4 Credit Hours.**

Basic organizational principles of the major components of a processor - the core, memory hierarchy, I/O subsystem and basic operating system constructs that utilize them.

**ECE 3060. VLSI and Advanced Digital Design. 4 Credit Hours.**

Advanced digital design issues in the context of VLSI systems. Introduction to a design methodology that encompasses the range from behavioral models to circuit simulation. Credit will not be awarded for ECE 3060 and ECE 3150.

**ECE 3065. Electromagnetic Applications. 3 Credit Hours.**

To present concepts in waveguiding and radiation, with application to microwaves, antennas, and optics. Credit will not be awarded for ECE 3065 and ECE 4350.

**ECE 3070. Electromechanical and Electromagnetic Energy Conversion. 3 Credit Hours.**

This course serves as an introduction to three-phase power systems, electromechanical energy conversion, and operating principles of electric machines.

**ECE 3071. Modern Electric Energy Systems. 3 Credit Hours.**

Non-renewable and renewable/sustainable energy sources. Processes, costs, and environmental impact of conversion into electric energy. Delivery and control of electric energy, electromechanical systems. Credit not allowed for both ECE 3071 and ECE 3072.

**ECE 3072. Electrical Energy Systems. 3 Credit Hours.**

Non-renewable and renewable/sustainable energy sources. Processes, costs, and environmental impact of conversion into electric energy. Delivery and control of electric energy, electromechanical systems. Credit not allowed for both ECE 3072 and ECE 3071.

**ECE 3075. Random Signals. 3 Credit Hours.**

Study of random variables and random processes for applications in electrical and computer engineering. Includes an introduction to statistical filtering, parameter estimation, Markov processes.

**ECE 3076. Computer Communications. 3 Credit Hours.**

Presents the basic concepts of computer communications network protocols.

**ECE 3077. Introduction to Probability and Statistics for ECE. 3 Credit Hours.**

Introduction to probability, random variables, distributions, estimation, confidence intervals, linear regression and other tools for describing and managing uncertainty in electrical and computer engineering.

**ECE 3080. Semiconductor Devices for Computer Engineering and Telecommunication Systems. 3 Credit Hours.**

To gain an understanding of the device needs for current and future computers, and fiber optic and wireless communication systems addressing the future needs of high- frequency, GHz-range, device operation.

**ECE 3084. Signals and Systems. 3 Credit Hours.**

Continuous-time linear systems and signals, their mathematical representations, and computational tools. Fourier and Laplace transforms, convolutions, input-output responses, stability.

**ECE 3085. Introduction to Systems and Controls. 3 Credit Hours.**

Theory of linear time-invariant systems for continuous and discrete time. Laplace and Z-Transforms. Transfer function and state space representations. Introduction to feedback control theory.

**ECE 3150. VLSI and Advanced Digital Design. 4 Credit Hours.**

Advanced digital design issues in the context of VLSI systems. Introduction to a design methodology that encompasses the range from architectural models to circuit simulation. Credit not awarded for ECE 3150 and ECE 3060.

**ECE 3170. Cryptographic Hardware for Embedded Systems. 4 Credit Hours.**

Introduction to cryptography and authentication from a hardware-centric perspective. Historic ciphers, symmetric and asymmetric encryption, and power analysis attacks are taught from a digital and VLSI design perspective.

**ECE 3251. Optimization for Information Systems. 3 Credit Hours.**

An introduction to the fundamentals of optimization with a focus on algorithms and applications in signal processing, control systems, machine learning, and robotics.

**ECE 3300. Electromechanical and Electromagnetic Energy Conversion. 3 Credit Hours.**

Introduction to three phase power systems, electromechanical energy conversion and operating principles of electric machines.

**ECE 3400. Analog Electronics. 3 Credit Hours.**

Analysis and design of electronic circuits and systems. Biasing, small-signal analysis, frequency response, feedback amplifiers, active filters, non-linear op-amp applications, and oscillators.

**ECE 3450. Semiconductor Devices. 3 Credit Hours.**

Properties of semiconductor devices. Applications in current and future computers, fiber optic and wireless communication systems. Future needs of high frequency, GHz-range, device operation.

**ECE 3550. Feedback Control Systems. 3 Credit Hours.**

Analysis and design of control systems. Laplace transforms, transfer functions, and stability. Feedback systems: tracking and disturbance rejection. Graphical design techniques.

**ECE 3600. Computer Communications. 3 Credit Hours.**

Basic concepts of computer communication network protocols.

**ECE 3710. Circuits and Electronics. 2 Credit Hours.**

An introduction to electric circuit elements and electronic devices and a study of circuits containing such devices.

**ECE 3741. Instrumentation and Electronics Lab. 1 Credit Hour.**

Basic analog and digital electronic circuits and principles. Techniques of electrical and electronic measurements with laboratory instruments.

**ECE 3801. Special Topics. 1 Credit Hour.****ECE 3802. Special Topics. 2 Credit Hours.****ECE 3803. Special Topics. 3 Credit Hours.****ECE 3804. Special Topics. 4 Credit Hours.****ECE 3805. Special Topics. 5 Credit Hours.****ECE 3811. Special Topics. 1 Credit Hour.****ECE 3812. Special Topics. 2 Credit Hours.****ECE 3813. Special Topics. 3 Credit Hours.****ECE 3814. Special Topics. 4 Credit Hours.****ECE 3815. Special Topics. 5 Credit Hours.****ECE 3872. Special Topics. 2 Credit Hours.****ECE 3881. Special Topics. 1 Credit Hour.****ECE 3882. Special Topics. 2 Credit Hours.****ECE 3883. Special Topics. 3 Credit Hours.****ECE 3884. Special Topics. 4 Credit Hours.****ECE 3891. Special Topics. 1 Credit Hour.****ECE 3892. Special Topics. 2 Credit Hours.****ECE 3893. Special Topics. 3 Credit Hours.****ECE 3894. Special Topics. 4 Credit Hours.****ECE 3900. Special Problems. 1-21 Credit Hours.****ECE 3901. Special Problems. 1-21 Credit Hours.****ECE 3902. Special Problems. 1-21 Credit Hours.****ECE 3903. Special Problems. 1-21 Credit Hours.****ECE 3951. Undergraduate Research I. 1-21 Credit Hours.**

Participation in an individual or group research project under the direction of a faculty member.

**ECE 3952. Undergraduate Research II. 1-21 Credit Hours.**

Participation in an individual or group research project under the direction of a faculty member. Requires a formal research report.

**ECE 3XXX. Electrical and Computer Engineering Elective. 1-21 Credit Hours.**

**ECE 4001. Engineering Practice and Professionalism. 2 Credit Hours.** Technical tools and professional issues for engineering practice and early career development. Engineering ethics, design tools, financial and economic principles, project management, probabilistic and statistical techniques, and decision making. Credit not allowed for both ECE 4001 and ECE 4000.

**ECE 4007. ECE Culminating Design Project. 4 Credit Hours.** Team-oriented culminating design project in electrical/ computer engineering, incorporating engineering standards and realistic constraints. Requires formal reports and group presentations. Credit not allowed for both ECE 4007 and ECE 4006.

**ECE 4011. ECE Culminating Design Project I. 2 Credit Hours.** First semester of ECE culminating design sequence. Design tools, financial principles, project management, probabilistic and statistical techniques, team forming. Requires formal reports and group presentations.

**ECE 4012. ECE Culminating Design Project II. 3 Credit Hours.** Second semester of ECE culminating design sequence. Team project in ECE incorporating engineering standards and realistic constraints. Requires formal reports and group presentations.

**ECE 4013. ECE Culminating Design I. 1 Credit Hour.** First course in a culminating design sequence. Student teams design, build, test, document, demonstrate prototype system reflective of knowledge gained as an undergraduate engineering student.

**ECE 4014. ECE Culminating Design 2. 2 Credit Hours.** Second course in a culminating design sequence. Student teams design, build, test, document, demonstrate prototype system reflective of knowledge gained as an undergraduate engineering student.

**ECE 4015. ECE-Only Single-Semester Capstone Design. 3 Credit Hours.** A single-semester ECE culminating design experience forming ECE-only teams, proposing, prototyping, testing, demonstrating, formally presenting and documenting projects incorporating engineering standards and realistic constraints.

**ECE 4043. Senior Analog Electronics Laboratory. 2 Credit Hours.** Experiments in analog electronics using discrete devices and off-the-shelf integrated circuits.

**ECE 4053. Research Methods. 2 Credit Hours.** Course provides methods and practices for literature searching, reference management, and summary preparation. Coverage includes journals, conferences, theses, patents, grants, roadmaps, and companies.

**ECE 4100. Advanced Computer Architecture. 3 Credit Hours.** Comprehensive coverage of the architecture and system issues that confront the design of high-performance workstation/PC computer architectures with emphasis on quantitative evaluation. Credit is not allowed for both ECE 4100 and any of the following courses: ECE 6100, CS 4290, CS 6290.

**ECE 4110. Internetwork Programming. 4 Credit Hours.** Exploration of Internet implementation as a network of computing systems. Internetworking skills for design and implementation of hardware and software Internet products.

**ECE 4112. Internetwork Security. 3 Credit Hours.** Hands-on experimentation and evaluation of internet security theory, principles, and practices. Laboratory component involves implementing both defensive and offensive security techniques. Credit not awarded for both ECE 4112 and ECE 4115.

**ECE 4115. Introduction to Computer Security. 4 Credit Hours.** Introductory topics in computer security are presented with an emphasis on fundamental security primitives and current security challenges facing society. Credit not awarded for both ECE 4115 and ECE 4112.

**ECE 4117. Introduction to Malware Reverse Engineering. 4 Credit Hours.** This course exposes students to an immersive, hands-on experience in the dissection and analysis of the code, structure, and functionality of malicious software.

**ECE 4122. Advanced Programming Techniques for Engineering Applications. 3 Credit Hours.** Course covers a number of programming techniques for distributed and parallel computing and other advanced methods, such as multiprecision arithmetic and nonblocking I/O. Credit not awarded for ECE 4122 and ECE 6122.

**ECE 4130. Advanced VLSI Systems. 4 Credit Hours.** An advanced treatment of VLSI systems analysis, design, and testing with emphasis on complex systems and how they are incorporated into a silicon environment. Credit is not allowed for both ECE 4130 and ECE 6130.

**ECE 4147. Adv Malware Analysis. 3 Credit Hours.** This course covers advanced approaches for the analysis of malicious software and explores recent research and unsolved problems in software protection and forensics.

**ECE 4150. Cloud Computing. 3 Credit Hours.** Cloud computing technologies, computation models, and applications, design methodologies for cloud applications, use of cloud-based languages and tools in developing advanced applications.

**ECE 4156. Hardware-Oriented Security and Trust. 3 Credit Hours.** Fundamental concepts, foundation, and methodologies for the design of trustworthy circuits including protection of the hardware platform against tampering. Physical cloning of cryptographic VLSI circuits.

**ECE 4180. Embedded Systems Design. 4 Credit Hours.** Processors, chipsets, busses, and I/O devices for high-ended embedded systems. Embedded operating systems; device drivers and applications for embedded systems.

**ECE 4181. Embedded Computing Systems. 4 Credit Hours.** Algorithms and methodologies for the design of real-time, low-power embedded computing systems.

**ECE 4252. Fundamentals of Machine Learning (FunML). 3 Credit Hours.** An introduction to the fundamentals and applications of Machine Learning. Students cannot receive credit for both ECE 4252 and CS 4641.

**ECE 4258. Digital Image Processing. 3 Credit Hours.** An introduction to the Fundamentals of Image Processing.

**ECE 4260. Random Signals and Applications. 3 Credit Hours.** Introduction to random signals and processes with emphasis on applications in ECE. Includes basic estimation theory, linear prediction, and statistical modeling.

**ECE 4270. Fundamentals of Digital Signal Processing. 3 Credit Hours.** Introduction to digital signal processing. Sampling theorem, discrete-time Fourier transform. Power spectrum, discrete Fourier transform and the FFT algorithm, Z-transform, digital filter design and implementation.

**ECE 4271. Applications of Digital Signal Processing. 4 Credit Hours.** Applications of DSP in speech, image processing, radar, pattern recognition, and adaptive filtering requiring working software implementations applied to the analysis of real signals.

**ECE 4273. Design Synthesis of Application-specific Signal Processors. 3 Credit Hours.**

Fundamentals of theory and practice of DSP chip design in VHDL. Exposure to tools and environments for chip design, simulation, and verification.

**ECE 4320. Power System Analysis and Control. 3 Credit Hours.**

Introduces basic concepts in electric power generation, distribution, system control, and economic operation.

**ECE 4321. Power System Engineering. 3 Credit Hours.**

To introduce basic concepts of electric power system design, encompassing protection, stability, and control.

**ECE 4325. Electric Power Quality. 3 Credit Hours.**

Transients and harmonics in power systems, analysis methods and mitigation practices. Causes of power quality problems and relationship to equipment susceptibility. Credit not allowed for both ECE 4325 and ECE 6340.

**ECE 4330. Power Electronics. 3 Credit Hours.**

Introduces power semiconductor devices and power electronic converters, including single-phase and three-phase ac/dc rectifiers, ac voltage controllers, dc/dc converters, and dc/ac inverters.

**ECE 4335. Electric Machinery Analysis. 3 Credit Hours.**

Advanced theory of AC machines, including AC motor winding design, finite element analysis, induction motor design, permanent magnet machine design, and synchronous machine dynamics. Credit is not allowed for both ECE 4335 and ECE 6335.

**ECE 4350. Electromagnetic and Microwave Applications. 3 Credit Hours.**

Presents concepts of electromagnetic fields applied to microwave circuit design and antenna radiation. Credit will not be awarded for ECE 4350 and ECE 3065.

**ECE 4360. RF-Microwave Measurement Laboratory. 2 Credit Hours.**

RF/microwave measurement theory and techniques. Use of state-of-the-art equipment operating into the GHz range.

**ECE 4370. Antenna Engineering. 3 Credit Hours.**

Basic theory, application, and design of a broad range of antennas.

**ECE 4371. Antenna Engineering Laboratory. 1 Credit Hour.**

Experimentation to develop a practical understanding of antennas and their properties.

**ECE 4390. Introduction to Radar and Electromagnetic Sensing. 3 Credit Hours.**

Introduces students to radar systems, including pulsed, CW, CWFM, and MTI radars. Other techniques for electromagnetic sensing such as radiometry and EM tagging are discussed.

**ECE 4391. Electromagnetic Compatibility. 3 Credit Hours.**

To study electromagnetic interference and susceptibility of electrical systems, with application to analog and digital circuits.

**ECE 4415. RF Engineering I. 3 Credit Hours.**

Fundamentals of RF engineering. Components at high frequencies, device modeling, amplifiers, lumped-element and microstrip impedance transformation networks, S-parameter-based design of RF and microwave amplifiers.

**ECE 4418. RF Engineering II. 3 Credit Hours.**

Fundamentals learned in RF-I are employed to design the elements of radio receivers, transmitters, and similar systems. Systems analysis, mixers, detectors, power amplifiers, low-noise amplifiers, and oscillators are covered.

**ECE 4420. Digital Integrated Circuits. 3 Credit Hours.**

Analysis and design of bipolar and MOS digital integrated circuit families and their applications in modern electronic systems.

**ECE 4430. Analog Integrated Circuits. 3 Credit Hours.**

Analysis and design of analog ICs using analytic techniques and CAD tools. Topics include amplifiers, current sources, output circuits, and other analog building blocks.

**ECE 4435. Operational Amplifier Design. 3 Credit Hours.**

Analysis and design techniques for utilization of integrated circuit operational amplifiers for applications in electronic systems.

**ECE 4445. Audio Engineering. 3 Credit Hours.**

Concepts of acoustics and electroacoustic modeling for the analysis and design of microphones, loudspeakers, and crossover networks. Methods of analysis and design of audio power amplifiers.

**ECE 4446. Audio Engineering Laboratory. 1 Credit Hour.**

A companion laboratory to ECE 4445. Design, analysis, construction, modeling, and testing of circuits and systems pertaining to audio engineering.

**ECE 4448. Guitar Amplification and Effects. 3 Credit Hours.**

Mathematical analysis and laboratory measurement of vibrating strings, electromagnetic pickups, vacuum tube amplifiers, solid-state distortion, and swept filter effects.

**ECE 4450. Analog Circuits for Music Synthesis. 3 Credit Hours.**

Circuits from classic analog synthesizers: nonlinear waveshapers and voltage-controlled oscillators, filters, and amplifier using operational transconductance amplifiers and the dynamic resistance of semiconductors.

**ECE 4452. IC Fabrication. 3 Credit Hours.**

Introduction to microelectronic processing technologies and CMOS. Includes a laboratory for fabrication/testing of MOS transistors, basic CMOS circuits, integrated resistors and capacitors. Credit will not be awarded for ECE 4452 and ECE 4752.

**ECE 4460. Introduction to Electronic Systems Packaging. 3 Credit Hours.**

Introduction to packaging technologies, technology drivers, electrical performance, thermal management, materials, optoelectronics, RF integration, reliability, system issues, assembly, testing.

**ECE 4470. Devices for Renewable Energy. 3 Credit Hours.**

Students study the engineering compromises, operational physics and environmental impact of a variety of devices from solar cells, batteries, thermoelectric devices and wind generators.

**ECE 4500. Optical Engineering. 3 Credit Hours.**

Introduction to applications of geometric, physical optics to engineering, including optical measurements, matrix methods, instruments, interference, holography, beam optics, Fourier optics, and diffraction.

**ECE 4502. Optical Fiber Communications. 4 Credit Hours.**

Combined lecture-laboratory exploration of the technology of fiber optics, with emphasis on optical fiber communication systems. Credit will not be awarded for ECE 4502 and ECE 4501.

**ECE 4550. Control System Design. 4 Credit Hours.**

Design of control algorithms using state-space methods, microcontroller implementation of control algorithms, and laboratory projects emphasizing motion control applications.

**ECE 4560. Introduction to Automation and Robotics. 4 Credit Hours.**

Concurrent engineering principles; robotic manipulator kinematics, dynamics, and control; applications of robots in industry, medicine, and other areas; team projects and hands-on laboratory experience.

**ECE 4570. System Theory for Communication and Control. 4 Credit Hours.**

Study of the basic concepts in linear system theory and numerical linear algebra with applications to communication, computation, control, and signal processing. A unified treatment.

**ECE 4575. Numerical Methods for Optimization and Optimal Control. 3 Credit Hours.**

Algorithms for numerical optimization and optimal control, Gradient-descent techniques, linear programming, numerical linear system solvers, second-order methods of optimizing performance of dynamical systems.

**ECE 4580. Computational Computer Vision. 3 Credit Hours.**

Computational and theoretical aspects of computer vision. Application areas include robotics, autonomous vehicles, tracking, and image-guided surgery. Includes major project.

**ECE 4601. Communication Systems. 3 Credit Hours.**

To present the fundamentals of modern digital communication systems and evaluate their performance with realistic channel models.

**ECE 4605. Topics in Networks. 4 Credit Hours.**

Reviews on networking fundamentals. Latest networking technologies in wireless and wireline networks. Machine learning and data science in networks or other emerging topics. Projects included.

**ECE 4606. Wireless Communications. 3 Credit Hours.**

Cellular concept, wireless propagation modeling; types of digital modulation used in wireless systems, diversity combining, performance over fading channels, and multiple access techniques.

**ECE 4607. Mobile and Wireless Networks. 3 Credit Hours.**

Basics of mobile and wireless networking. Architectures and communication protocols for wireless sensor networks, wireless local area networks, ad-hoc networks, cellular systems, WiMAX, and Wireless Mesh Networks.

**ECE 4612. Telecommunications Systems Laboratory. 1 Credit Hour.**

Basic digital telecommunications systems are examined in a laboratory setting using electronic modules, covering concepts such as modulation, channel coding, AWGN, eye diagrams, and BER. Credit will not be awarded for ECE 4612 and ECE 4602.

**ECE 4698. Undergraduate Research Assistantship. 1-12 Credit Hours.**

Independent research conducted under the guidance of a faculty member.

**ECE 4699. Undergraduate Research. 1-12 Credit Hours.**

Independent Research conducted under the guidance of a faculty member.

**ECE 4723. Interdisciplinary Capstone Design. 3 Credit Hours.**

Seniors will work in teams to apply a systematic design process to real multi-disciplinary problems. Problems selected from a broad spectrum of interest areas, including biomedical, environmental, mechanical, industrial design, electrical and thermal/fluids. Projects must be based on the knowledge and skills acquired in earlier course work, and incorporate appropriate engineering standards and multiple realistic constraints. Emphasis is placed on the design process, the technical aspects of the design, and on reducing the proposed design to practice. The course consists of faculty and guest lectures, prototyping in design studios, and a multi-disciplinary design project.

**ECE 4751. Laser Theory and Applications. 3 Credit Hours.**

Provides an introduction to the theory and applications of laser principles and related instrumentation. Emphasis is on the fundamental principles underlying laser action. Crosslisted with PHYS 4751.

**ECE 4753. Topics in Engineering Practice. 3 Credit Hours.**

Topics of current importance offered in collaboration with an approved partner of Georgia Tech's Distance Learning Program. Crosslisted with ME 4753.

**ECE 4754. Electronics Packaging Assembly, Reliability, Thermal Management, and Test. 3 Credit Hours.**

The course provides hands-on instruction in electronics packaging, including assembly, reliability, thermal management, and test of next-generation microsystems. Crosslisted with ME and MSE 4754.

**ECE 4755. Electronic Packaging Substrate Fabrication. 3 Credit Hours.**

This course provides hands-on instruction in basic packaging substrate fabrication techniques, including interconnect design and testing, dielectric deposition, via formation, and metallization. Crosslisted with CHE 4755.

**ECE 4761. Industrial Controls and Manufacturing. 3 Credit Hours.**

Students are introduced to industrial controls and the fundamentals of manufacturing with hands-on experience based on lab projects using industry software and hardware for communications and control. Crosslisted with PTFE 4761.

**ECE 4781. Biomedical Instrumentation. 3 Credit Hours.**

A study of medical instrumentation from a systems viewpoint. Pertinent physiological and electro-physiological concepts will be covered. Credit not allowed for both ECE 4781 and (CHE 4781 or CHBE 4781 or BMED 4781 or ME 4781).

**ECE 4782. Biosystems Analysis. 3 Credit Hours.**

Analytical methods for modeling biological systems, including white-noise protocols for characterizing nonlinear systems. Crosslisted with BMED, CHE and ME 4782.

**ECE 4783. Introduction to Medical Image Processing. 3 Credit Hours.**

A study of mathematical methods used in medical acquisition and processing. Concepts, algorithms, and methods associated with acquisition, processing, and display of two- and three-dimensional medical images are studied. Crosslisted with BMED 4783.

**ECE 4784. Engineering Electrophysiology. 3 Credit Hours.**

Basic concepts of electrophysiology from an engineering perspective. Functionality of relevant organs and systems; instrumentation tools which monitor electrophysiology function. Crosslisted with BMED 4784.

**ECE 4786. Medical Imaging Systems. 3 Credit Hours.**

Introduce major biomedical and clinical imaging modalities including X-ray radiography, computed tomography (CT), nuclear medicine (SPECT and PET), magnetic resonance imaging (MRI), and ultrasound.

**ECE 4795. GPU Programming for Video Games. 3 Credit Hours.**

3-D graphics pipelines. Physically-based rendering. Game engine architectures. GPU architectures. Graphics APIs. Vertex and pixel shader programming. Post-processing effects. Deferred rendering.

**ECE 4801. Special Topics. 1 Credit Hour.**

**ECE 4802. Special Topics. 2 Credit Hours.**

**ECE 4803. Special Topics. 3 Credit Hours.**

**ECE 4804. Special Topics. 4 Credit Hours.**

**ECE 4805. Special Topics. 5 Credit Hours.**

**ECE 4811. Special Topics. 1 Credit Hour.**

**ECE 4812. Special Topics. 2 Credit Hours.**

**ECE 4813. Special Topics. 3 Credit Hours.**

**ECE 4814. Special Topics. 4 Credit Hours.**

**ECE 4815. Special Topics. 5 Credit Hours.**

**ECE 4816. Special Topics. 6 Credit Hours.**

**ECE 4823. Special Topics. 3 Credit Hours.**

**ECE 4824. Special Topics. 4 Credit Hours.**

special topics.

**ECE 4833. Special Topics. 3 Credit Hours.**

**ECE 4853. ECE Single-Semester Create-X Capstone Design. 3 Credit Hours.**

A single-semester ECE culminating design experience in which interdisciplinary teams propose, prototype, test, demonstrate, formally present, and document projects incorporating engineering standards and realistic constraints.

**ECE 4863. Special Topics. 3 Credit Hours.**

Special Topics in ECE.

**ECE 4871. Special Topics. 1 Credit Hour.**

**ECE 4872. Special Topics. 2 Credit Hours.**

Special Topics in ECE.

**ECE 4873. Special Topics. 3 Credit Hours.**

**ECE 4881. Special Topics. 1 Credit Hour.**

**ECE 4882. Special Topics. 2 Credit Hours.**

**ECE 4883. Special Topics. 3 Credit Hours.**

**ECE 4884. Special Topics. 4 Credit Hours.**

**ECE 4891. Special Topics. 1 Credit Hour.**

**ECE 4892. Special Topics. 2 Credit Hours.**

**ECE 4893. Special Topics. 3 Credit Hours.**

**ECE 4894. Special Topics. 4 Credit Hours.**

**ECE 4900. Special Problems. 1-21 Credit Hours.**

**ECE 4901. Special Problems. 1-21 Credit Hours.**

**ECE 4902. Special Problems. 1-21 Credit Hours.**

**ECE 4903. Special Problems. 1-21 Credit Hours.**

**ECE 4951. Undergraduate Research I. 1-21 Credit Hours.**

Participation in an individual or group research project under the direction of a faculty member.

**ECE 4952. Undergraduate Research II. 1-21 Credit Hours.**

Participation in an individual or group research project under the direction of a faculty member.

**ECE 4XXX. Electrical and Computer Engineering Elective. 1-21 Credit Hours.**