ELECTRICAL ENGINEERING

Eric Balster, Department Chairperson

Raúl Ordoñez, Graduate Program Director

Doctor of Engineering, Electrical Engineering (ELE)

See the Doctoral Degree Requirements section on the School of Engineering page and consult with the department chair. GRE required.

Doctor of Philosophy in Engineering, Electrical Engineering (ELE)

Coursework Requirements: [1]		
ECE 500	Introduction to the Graduate Program in Electrical and Computer Engineering	0
Engineering Specialization: [3]		**9**
Choose any three graduate courses from ECE 501 through ECE 682		
Graduate Mathematics Courses: [4]		**6**
Choose any two approved graduate-level math courses		
Graduate Seminar: [5]		**3**
ECE 696		
Additional Graduate Coursework [6, 7]		**12**
Any combination of advanced graduate graded course work, Guided Research Leading to Conference Publication (ECE 695, 3 hours), and Guided Research Leading to Journal Publication (ECE 695, 6 hours)		
Dissertation Hours: [8]		**30**
ECE 699		

1. Of the 60 or more semester hours beyond the M.S., a minimum of 48 semester hours must be taken at the University of Dayton.
2. ECE 500 must be taken during the first semester of the graduate program.
3. Nine semester hours in an electrical engineering specialization area, such as Computing Systems, Sensors and Devices, Signals and Systems, or any other interdisciplinary area approved by the advisor/Chair.
4. Any graduate MTH courses. ECE 503, ECE 568, ECE 569 and ECE 642 are also approved math courses.
5. Must be taken three times over three distinct semesters for a total of three credit hours.
6. Choose graduate courses from ECE 501 through ECE 682, and at most 6 hours of non-ECE graduate courses as approved by the dissertation adviser.
7. Guided Research Leading to Conference Publication (ECE 695, 3 hours), and Guided Research Leading to Journal Publication (ECE 695, 6 hours). The guided research topic should be established by the student's main adviser or the graduate program committee chair. These courses could be taken multiple times up to twelve credit hours. They require approval from the dissertation adviser.
8. The student may not take more than 24 dissertation hours before successfully completing the candidacy exam Part 1. After successful completion of Part 1, the student may not take more than 12 dissertation hours before successful completion of Part 2.

Milestones

See https://udayton.edu/engineering/departments/electrical_and_computer/_resources/pdfs/ece-graduate-handbook.pdf for details about each of these items.

1. Preliminary Exam (PE): the student must have earned at least twelve graduate credit hours beyond the M.S. degree and completed at least four PE courses (ECE 501, 503, 504 , 505, 506, 507, 509, 511, 520, 521, 530, 531, 532, 533, 536, 547, 565, 566, 567, 572, 581, 586). The PE form must be filed at the beginning of the 2nd year, or there will be a registration hold at the 2nd year. The 1st PE needs to be finished at the beginning of the 2nd year.

2. ECE Ph.D. Candidacy Examination: the student must have a Dissertation Advisory Committee in place before the candidacy exam can be attempted. The candidacy exam can only be attempted after the student has earned at least 12 ECE graduate credit hours beyond the M.S. degree, and the PE has been passed or a waiver been granted. The candidacy exam has two parts: a. Part 1: this exam should be attempted within the 1st semester of the 2nd year the first six dissertation hours registered (after the completion of the MS degree, or equivalent), and it must be successfully completed within 24 registered credit hours. b. Part 2: it must be successfully completed within 12 dissertation hours after completion of Part 1, not within the same semester

3. Journal Paper Submission Requirement: A proof of publication or manuscript prepared for an appropriate journal and an acknowledgement of receipt by the editor must be submitted along with the dissertation. Journal paper submissions resulting from ECE 695 are only considered as coursework and do not count towards this requirement.

4. Dissertation Defense: There should be at least two full semesters (Fall, Spring or Summer) between the successful completion of Part 2 and the Dissertation Defense.

Master of Science in Electrical Engineering (ELE)

EGR 500	Academic Integrity and Responsible Conduct of Research for Engineers	0
ECE 500	Introduction to the Graduate Program in Electrical and Computer Engineering [1]	0
Core courses: Choose any 3 ELE Core Courses below [3]		**9**
ECE 501	Contemporary Digital Systems	
ECE 503	Random Processes	
ECE 504	Power Electronics	
ECE 505	Digital Signal Processing	
ECE 506	Microelectronic Devices	
ECE 507	Electromagnetic Fields I	
ECE 509	Analysis of Linear Systems	
ECE 532	Embedded Systems	
ECE 533	Computer Design	
ECE 547	Non-Linear Systems & Control	
Engineering Specialization: [3]		**9**
Choose any three graduate courses from ECE501 through ECE 682, excluding thesis courses		
Basic Engineering Science: [3]		**6**
Choose any two graduate-level courses from Engineering, Math, or Computer Science, excluding ECE 599.		

Choose one option below: [2, 3]		**6**
Non-Thesis Option: Choose any two graduate-level courses from ECE 501 through ECE 694, excluding ECE 599.		
Thesis Option:		
ECE 599	Thesis [2]	
Total Hours		**30**

1. ECE 500 must be taken during the first semester of the graduate program.
2. Thesis Option: Six semester hours of an approved thesis. Any students employed as an RA or TA must take the thesis option.
3. Elective courses can be used to earn certificates in other programs, such as Foundations of Engineering Management, Six Sigma, Sustainability, and other offerings. A complete list of available certificates can be found in the graduate catalog: http://catalog.udayton.edu/certificatesaz/

Certificate in Aerospace Electronic Systems (AEL)

The certificate program curriculum is based on taking 12 credit hours. The student must complete four of the following courses, by taking two courses from Group 1 and two courses from Group 2.

GROUP 1 - Pick 2		
ECE 528	Avionics, Navigation and Guidance	3
ECE 576	Introduction to Radar	3
ECE 532	Embedded Systems	3
GROUP 2 - Pick 2		
ECE 523	Satellite Communications	3
ECE 531	Analog Integrated Circuit Design	3
ECE 547	Non-Linear Systems & Control	3
ECE 573	Photonic Devices & Systems	3
TOTAL HOURS:		12

Certificate in Radar Systems (RDS)

• The certificate program curriculum consists of 3 required courses for a total of 9 semester hours.

ECE 576	Introduction to Radar	3
ECE 577	Introduction to Electronic Warfare (EW)	3
ECE 578	Advanced Radar	3

Courses

ECE 500. Introduction to the Graduate Program in Electrical and Computer Engineering. 0 Hours
Introduction to ECE graduate program, research methods in ECE, technical writing, literature research, ethics, software and resources.

ECE 501. Contemporary Digital Systems. 3 Hours
An introduction to modern digital hardware logic design using a hierarchical system approach including a top-down development process. An introduction to alternative design implementation forms including hardware description languages (HDLs) for the design of simple and complex combinatorial logic circuits and sequential logic designs with finite state machines. Good HDL coding practices such as readability, reconfigurability, and efficient execution are emphasized along with the use of programmable logic circuits including Field-Programmable Gate Arrays (FPGAs). Required Background: ECE215 or equivalent. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Prerequisite: ECE 500.

ECE 503. Random Processes. 3 Hours
Random variables as applied to system theory, communications, signal processing and controls. Topics include advanced engineering probability, random variables, random vectors and an introduction to random processes. Required background: ECE 340 or equivalent.

ECE 504. Power Electronics. 3 Hours
The course introduces the characteristics of different power semiconductor devices and their application to power conversion, different types of electric power converters topologies and controls like ac-dc rectifiers, dc-dc converters, and dc-ac inverters. It will also include the applications of such power converters for renewable energy sources, hybrid electric vehicles, and power supplies. Required Background: ECE 204, ECE 316.

ECE 505. Digital Signal Processing. 3 Hours
A study of one-dimensional digital signal processing, including a review of continuous system analysis and sampling. Topics include z-transform techniques, digital filter design and analysis, and fast Fourier transform processing techniques. Required background: ECE 334 or equivalent course.

ECE 506. Microelectronic Devices. 3 Hours
Crystalline structure of matter, quantum mechanics and energy band theory; bulk properties of semiconductors; p-n and metal-semiconductor junctions; bipolar junction transistors; field-effect transistors; heterostructures; optical properties of semiconductors; devices, modeling and applications. Required background: ECE 304 or equivalent.

ECE 507. Electromagnetic Fields I. 3 Hours
Fundamental concepts, wave equation and its solutions; wave propagation, reflection and transmission; potential theory; construction of modal solutions; various electromagnetic theorems: concept of source, uniqueness, equivalence, induction and reciprocity theorems. Required background: ECE 333 or equivalent.

ECE 509. Analysis of Linear Systems. 3 Hours
State variable representation of linear systems and its relationship to the frequency domain representation using transfer functions and the Laplace transform. State transition matrix and solution of the state equation, stability, controllability, observability, state feedback, and state observers are studied. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Pre/Co-requisites: ECE 500.

ECE 510. Microwave Circuits for Communications. 3 Hours
Microwave transmission, planar transmission lines, microwave components and filters. Microwave tubes, microwave communication, radar systems, and electronic support measures. Prerequisite(s): ECE 507.

ECE 511. Antennas. 3 Hours
Fundamental principles of antennas; analysis and synthesis of arrays; resonant antennas; broadband and frequency independent antennas; aperture and reflector antennas; applications to radar and communication systems. Prerequisite(s): ECE 507 or equivalent.

ECE 520. The Internet of Things. 3 Hours
Introduction to the multi-disciplinary topic of Internet of Things (IoT), a blend of engineering and science. The course begins with a fundamental technical understanding of the IoT architecture. From this foundation, students experience hands-on labs in a team environment with theoretical justification. The applied work features environmental sensor networking with geospatial data. Each surface area in IoT is explored from sensors and embedded devices to protocols and virtual servers highlighted by current trends within IoT. Lastly, the history, software and influential people will be discussed to provide class context. Ultimately, students scaffold their knowledge through a series of labs, team challenges and supporting lectures to create a final business proposal for a real client IoT value proposition.

ECE 521. Digital Communications I. 3 Hours
Fundamentals of digital transmission of information over noisy channels; modulation schemes for binary and M-ary digital transmission; optimum receivers; coherent and noncoherent detection; signal design; intersymbol interference; error control coding; the Viberti algorithm; channel capacity and Shannon limits on reliable transmission.

ECE 523. Satellite Communications. 3 Hours
Topics related to the theory, design and orbital placement of geostationary and geosynchronous satellites and their communications applications, including transmitters and receivers in the RF, microwave and optical operational windows, the associated modulation and communication strategies, system hardware and international satellite networks. Required background: ECE 507 or permission from instructor.

ECE 528. Avionics, Navigation and Guidance. 3 Hours
Importance and Role of Avionics, Aerodynamics and Aircraft Control, Fly-by-Wire Flight Control, Inertial Sensors and Attitude Derivation, Navigation Systems, Air Data and Air Data Systems, and Avionics Systems Integration.

ECE 530. Digital Integrated Circuit Design. 3 Hours
Integrated circuit design and layout concepts, design methodology, fabrication process and limitations, MOSFET models for digital design, inverter and logic gates, interconnect and delay, combinational circuits, sequential circuits, datapath subsystems, memory circuits, digital phase lock loops. Required background ECE 304.

ECE 531. Analog Integrated Circuit Design. 3 Hours
Integrated circuit design concepts and layout; system perspective on analog design; MOS device theory and processing technology; current mirrors and biasing circuits; voltage and current references; single-stage, differential and operational amplifiers; CAD utilization to realize the design process. Required background: ECE 304 or equivalent.

ECE 532. Embedded Systems. 3 Hours
This course will introduce the student to the concept of embedded systems and the constraints imposed on hard real-time systems. Course will consist of design, development and test of selected hard-deadline hardware and software using Altera's DE2 development boards. The student will design selected hardware interfaces and develop real-time executive and application code in assembly language and C. Each student will design and implement hardware using Verilog HDL. Required Background: ECE 444 or equivalent.

ECE 533. Computer Design. 3 Hours
Design considerations of the computer; register transfer operations; hardware implementation of arithmetic processors and ALU; instruction set format and design and its effect on the internal micro engine; hardware and micro-programmed control design; comparative architectures. Required background: ECE 314 or equivalent. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Corequisites: ECE 500.

ECE 536. Microprocessor Applications. 3 Hours
Project studies, applications of microprocessors in practical implementations; logic implementation using software; memory-mapped I/O problems and interrupt structure implementation; use of compilers; study of alternate microprocessor families including industrial controllers. Required background: ECE 314 or equivalent. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Corequisites: ECE 500.

ECE 538. Object-Oriented Programming Applications. 3 Hours
A semi-formal approach to the engineering applications of object-oriented programming. Application of the concepts of classes, inheritance, polymorphism in engineering problems. Introduction to the use of class libraries. Effective integration of the concepts of application programmer interfaces, language features, and class libraries. The required background is C programming experience. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Corequisites: ECE 500.

ECE 545. Automatic Control. 3 Hours
Study of mathematical methods for control systems and analysis of performance characteristics and stability. Design topics include pole-placement, root locus, and frequency domain techniques. The student will also learn feedback loop sensitivity, basic loop shaping, performance bounds, and other introductory aspects of robust control. The required background is ECE 415 or equivalent. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Corequisites: ECE 500.

ECE 547. Non-Linear Systems & Control. 3 Hours
Introduction to nonlinear phenomena in dynamical systems. A study of the major techniques of nonlinear system analysis including phase plane analysis and Lyapunov stability theory. Application of the analytical techniques to control system design including feedback linearization, backstepping, and sliding mode control. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Corequisites: ECE 500.

ECE 549. Engineering Systems for the Common Good. 3 Hours
In this course we will mathematically examine a number of social systems and develop quantitative models describing their behavior. We will review and learn fundamental systems theory concepts, such as block diagrams, feedback loops, and continuous and discrete-time dynamics, as needed. You will apply these concepts to mathematically model and analyze social systems, and in this process, you will learn how the powerful ideal of Human Rights is understood via social system models. You will learn how to study and numerically simulate social dynamics in a methodical, mathematical manner. You will use simulation software to numerically investigate and understand social systems such as sustainability, homelessness, environmental justice, the poverty cycle, and others. For each system, we will highlight its connections to specific human rights. At the conclusion of the course, you will have achieved a deeper understanding of the connection between engineering principles and tools, human rights, and the common good. Required background: differential equations; ECE509 or ECE547 (or equivalent).

ECE 550. Artificial Neural Networks. 3 Hours
This course introduces the fundamental concepts, mathematical models, design architectures, and learning algorithms of artificial neural networks (ANNs) which learn from examples. ANNs are biologically inspired systems that mimic the structural and perceptual behavior of the human brain. Artificial neural networks are the basis and foundation of deep learning systems.

ECE 552. Visual Perception for Autonomy. 3 Hours
This course introduces the fundamental concepts and models of visual perception for autonomous systems with a practical treatment of design, development, implementation, and applications of algorithms for scene analysis and understanding. The class will briefly cover topics in visual data analysis, color perception, region localization, visual feature extraction, visual recognition, perceptual manifolds, motion perception, and visual tracking. Required Background: ECE445 or equivalent. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course.

ECE 554. Applied Robotics. 3 Hours
Within this course, focus will be on project-based learning with robotic systems. Extensive usage of student kits and industrial robotic platforms will enable hands-on learning experiences, which will encourage students to think critically and deepen their knowledge through experimentation. Using a combination of online learning content and classroom lectures, multiple comprehensive projects will be covered, such as a drawing robot, a webcam-controlled rover or industrial arm, and/or a self-balancing motorcycle. Students will use software (MATLAB, Simulink, ROS) programming to implement model-based design, control systems, image and signal processing, and more. The major learning objective is for students to get prepared for real-life environments by using the same tools as industry professionals. Students are expected to have completed a linear algebra course.

ECE 557. Autonomous Systems. 3 Hours
At the intersection of mechanical engineering, electrical engineering, and computer science, autonomous systems involve the implementation of mechatronic technologies which operate independently (autonomously) from human intervention. This course emphasizes the practical implementation of modern control systems for the purposes of creating fully- or semi-autonomous systems. Topics include programming syntax and structure, integration of peripherals (sensors and actuators) with controllers, and data communications both within and external to the systems. Equal mix of lecture and laboratory with significant time dedicated to advanced design projects. Students are expected to have an undergraduate level background in controls and electronics.

ECE 558. Robot Modeling. 3 Hours
This course covers the fundamentals of modeling the movement of spatial systems with a focus on robots, particularly industrial robots. Topics include planar and spatial robotics, forward kinematics including the Denavit-Hartenberg formalism, inverse kinematics, manipulator velocities and the robotics-specific Jacobian, static loads in robots, and the product-of-exponentials formalism. Students are expected to have completed a linear algebra course.

ECE 560. Computational Imaging. 3 Hours
Computation imaging refers to a modality of image capture where image signals are measured not by direct means, but indirectly by a co-designed combination of image acquisition hardware and post-capture processing techniques. Hardware designs may involve modifications to conventional optics and sensor hardware, or using the optics and sensor hardware in an unusual way. Post-capture processing addresses the "inverse problems" within the computational imaging systems designed to estimate the image signal from the measured sensor data. In this class, students will learn how to design calibration experiments, will capture scenes and objects using real hardware, and will develop algorithms to recover the image signal. The class topics may include various modalities of computational imaging, including hyperspectral imaging, digital camera processing pipeline, time of flight cameras, lightfield imaging, structured light imaging, polarization imaging, neuromorphic cameras, and spherical imaging. Required background: ECE 334 (Discrete Signals & Systems) or ECE 505 (Digital Signal Processing), or equivalent.

ECE 563. Image Processing. 3 Hours
An introduction to image processing including the human visual system, image formats, two-dimensional transforms, image restoration, and image reconstruction. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Prerequisites: ECE 505. Corequisites: ECE 500.

ECE 564. 3D Computer Vision. 3 Hours
Develop the skills needed to generate synthetic images of 3D objects and to recover 3D structure from one or more views (projections) of 3D objects. Feature recognition in 2D views (images) of a scene based either on actual photographs or synthetic images (computer graphics generated). Applications in robot pose recognition and mobile robot navigation. Students should have experience with MATLAB programming and image processing. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Corequisites: ECE 500.

ECE 565. Fundamentals of Solid-State Batteries. 3 Hours
Introduction to the fundamental of solid-state, safe, durable, batteries, including working principles of a battery, state-of-the-art battery (Li-ion battery based on liquid-state electrolytes- advantages/disadvantages), battery safety, need for a safe battery system for low-high power applications (electric vehicles / unmanned-/manned aircraft, space vehicles, etc.), different design of solid-state batteries (planner-stacked, 3 dimensional, etc.), engineering the structural battery (dual functionality system that can carry the mechanical load and store energy), characterization methods to evaluate structure / electrical/ electrochemical properties of all-solid-state battery materials (cathode, anode, electrolytes), interfaces (electrodes/electrolyte), and electrical/ electrochemical testing of complete battery cells. Also, electrical test methods to evaluate solid-state Li-ion battery (including structural battery) performances, etc.), and understanding the degradation mechanism of solid-state battery systems (including structural battery) will be discussed. Required background: ECE 304 or equivalent. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Corequisites: ECE 500.

ECE 566. Fundamentals of Hybrid Electrochemical Power. 3 Hours
Introduction to the fundamentals of hybrid electrochemical power (battery + capacitor + fuel cell – integrated systems) including working principles of batteries, capacitors, lithium-ion capacitors, and fuel cells. Discussion of the advantages/disadvantages, necessity to hybridize batteries, fuel cells, capacitors. Electrical hybridization methods, electrochemical testing of hybrid power systems, degradation mechanism, and applications. Hybrid electrochemical power is highly desirable to meet requirements for a wide range of products (such as electronic gadgets, transportation vehicles, and space vehicles) requiring low to high power/energy, cycle-life, fast/slow charge/discharge, etc. Required background: ECE 304 or equivalent. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Corequisites: ECE 500.

ECE 567. Machine Learning & Patterning. 3 Hours
This course introduces the fundamental concepts and models of machine learning with a practical treatment of design, analysis, implementation, and applications of algorithms that learn from examples. Topics include supervised and unsupervised learning, self-organization, pattern association, feed-forward, and recurrent architectures, manifold learning, dimensionality reduction, and model selection. Required background in ECE445 or Graduate Student status. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Corequisites: ECE 500.

ECE 568. Detection and Estimation. 3 Hours
This course will provide a fundamental understanding of detection, estimation, and their use in solving engineering problems. Students will be able to solve problems involving hypothesis testing, develop a discrete-time signal detector, and compute optimum parameter estimates. Students will become familiar with foundational concepts of likelihood ratio, randomized decision, sufficient statistic, Cramer-Rao bounds, and risk estimation. Students will also develop an understanding of linear least square estimation, minimum mean square estimation, minimum mean absolute error estimation, maximum a posteriori estimation, maximum likelihood estimation, minimum variance unbiased estimation, empirical Bayes estimation, and minimum risk shrinkage operator estimation, expectation-maximization algorithm. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Prerequisites: ECE 503. Corequisites: ECE 500.

ECE 569. Advanced Random Processes. 3 Hours
This course will provide students with a fundamental understanding of probability, random variables, and random processes, and their use in solving engineering problems. Students will be able to solve problems involving various noise processes and their probability distributions, describe random signals and will analyze linear systems with stochastic inputs. Some advanced topics such as Wiener filtering, Kalman filtering, and Karhunen-Loeve decomposition will be covered. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Prerequisites: ECE 503. Corequisites: ECE 500.

ECE 572. Optical Information Processing. 3 Hours
Mathematical techniques pertaining to linear systems theory; Fresnel and Fraunhoffer diffraction; Fourier transform properties of lenses; frequency analysis of optical systems, spatial filtering, applications such as optical information processing and holography. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Corequisites: ECE 500.

ECE 573. Photonic Devices & Systems. 3 Hours
Solid-state theory of optoelectronic devices; semiconductor photo emitters; LED's, optical amplifiers and semiconductor lasers; photodetectors: PIN, APD, photocells, PMT, detection, and noise; solar cells; cameras and displays; electro-optic and magneto-optic devices; integration and application of electro-optical components in systems of various types. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Prerequisites: ECE 507 or permission of department chairperson. Corequisites: ECE 500.

ECE 574. Guided Wave Optics. 3 Hours
Light propagation in slab and cylindrical waveguides; signal degradation in optical fibers; optical sources, detectors, and receivers; coupling; transmission link analysis; fiber fabrication; fiber sensor and communication systems. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Prerequisites: ECE 507 or permission of department chairperson. Corequisites: ECE 500.

ECE 576. Introduction to Radar. 3 Hours
Introduction to the radar range equation, fields and Waves, antennas and phased arrays, beamforming, targets, and clutter radar cross-section, fast time, slow time, detection processing, tracking, space-time adaptive processing, FMCW radar, SAR and ISAR, electronic warfare, transmitters, receivers, and signal processors. Required background: ECE303, ECE332, ECE340, or equivalent. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Corequisites: ECE 500.

ECE 577. Introduction to Electronic Warfare (EW). 3 Hours
Overview of the Principles of Electronic Warfare (EW). Review of radar (and radio frequency communication) systems engineering, including fields and waves, waveforms, antennas and array beamforming, target detection and image processing, tracking, space-time adaptive processing (STAP), synthetic aperture radar (SAR), Inverse SAR (ISAR). Principles of direction finding (DF), Electronic Attack (EA) of MTI (moving target indication) radar, SAR, and digital radio frequency memory (DRFM). Principles of Electronic Protection (EP) in MTI and SAR. Low Probability of Intercept (LPI) radar and communications, Electronic Intelligence and STAP, Electronic Support Measures (ESM). Required Background: ECE303, ECE332, ECE340, or equivalent. Recommended: ECE576. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Corequisites: ECE 500.

ECE 578. Advanced Radar. 3 Hours
Review of the radar range equation, fields and waves, antennas and phased arrays, beamforming, targets and clutter radar cross-section, fast time, slow time, detection processing, tracking, frequency modulated continuous wave (FMCW) radar, synthetic aperture radar (SAR) and Inverse SAR (ISAR), electronic warfare (EW), transmitters, receivers, and signal processors. Advanced space-time adaptive processing (STAP) techniques, including the Generalized Likelihood Ratio Test, Non-Homogeneity Detection, Knowledge-Based STAP, and Constant False Alarm Rate detection processing. Required Background: ECE303, ECE332, ECE340 or equivalent. Recommended: ECE576. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Corequisites: ECE 500.

ECE 580. Principles of Nanofabrication. 3 Hours
Basic principles of processes used in microelectronic and photonic device fabrication: vacuum systems, plasma processes, physical and chemical vapor deposition, properties of silicon and other substrate materials, photolithography and non-optical lithography, wet chemical, and plasma etching, thermal oxidation of silicon, semiconductor doping, ion implantation, metallization, electrical contacts, and micro-metrology. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Corequisites: ECE 500.

ECE 581. Nanoelectronics. 3 Hours
Introduction to the physics of materials on the nanoscale; quantum confinement theory; electronic and optical properties of semiconductor nanostructures; single-electron transistors (SETs); tunneling and ballistic devices; nanostructured LEDs, photodetectors, and lasers; nanophotovoltaics and nanomagnetics; quantum computing and molecular electronics; nanoelectronic fabrication, state-of-the-art, and emerging nanoscale devices and applications. Required background in ECE 506 or equivalent. Corequisites: ECE 500.

ECE 582. Smart Sensors and Automation. 3 Hours
Study of industrial internet of things (IIoT) and Industry 4.0 which refers to interconnected sensors, instruments, and other devices networked together with computers' industrial applications, including manufacturing, process, vehicular, and energy management. The course provides hands-on experience in using Programmable Logic Controllers. Prerequisite: ECE 314 or similar or Instructor Permission.

ECE 583. Advanced Photovoltaics. 3 Hours
Science and applications of photovoltaics, with special emphasis on inorganic and organic semiconductors, ferroelectrics, chalcopyrites, metamaterials, quantum structures, and photovoltaics archictecture. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Prerequisites: ECE 506 or permission of instructor. Corequisites: ECE 500.

ECE 586. Computer Networks. 3 Hours
Introduction to the fundamental of computer networks, including the Open Systems Interconnection reference model, transmission media, medium access protocol, data link protocols, routing, congestion control, applications, and network security. Required background: ECE 303 or equivalent. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Corequisites: ECE 500.

ECE 587. Wireless Security. 3 Hours
Wireless security is a very important topic and attracting more and more attention from industry, research, and academia. This course gives a comprehensive overview of the recent advances in wireless network and system security. It will cover security issues and solutions in emerging wireless access networks and systems as well as multi-hop wireless networks. Required background: ECE203 or equivalent. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Corequisites: ECE 500.

ECE 590. Biomedical Engineering and Healthcare Electronics. 3 Hours
This survey course will introduce students to the interdisciplinary field of Biomedical Engineering. Students will learn about the application of electrical and computer engineering in healthcare solutions. This course is project oriented, covering topics such as: bioethics, anatomy and physiology, biomimetics, skeletal and cardiac biomechanics, biomaterials & prosthetics, biosensors, bioinstrumentation, neuroscience and traumatic brain injury, rehabilitation engineering/assistive technology, biomedical modeling and medical additive manufacturing. Students may have the opportunity to attend industry site visits with internal and external partners in the medical field to apply knowledge learned in the classroom to real-world experiences. Required background: Introduction to Circuits (ECE 201 or EGR 203) or Introduction to Mechatronics (MEE 298 or MEE 205) or equivalent.

ECE 591. Medical Imaging. 3 Hours
This course will introduce students to the field of Medical Imaging. Students will learn about the different modalities (Ultrasound, X-ray, CT, MRI, Nuclear Medicine) utilized in healthcare and gain an understanding about which techniques are most appropriate for various medical pathology through open-ended clinical case studies. Students may have the opportunity to attend industry site visits with internal and external community partners in the medical field through collaboration with a local community hospital to apply knowledge learned in the classroom to real-world experiences. This course is project oriented, covering topics such as bioinstrumentation, medical image processing, medical additive manufacturing and sustainable healthcare solutions for developing countries. Required background: Introduction to Circuits (ECE 201 or EGR 203) or Introduction to Mechatronics (MEE 298 or MEE 205) or equivalent. Introduction to MATLAB Programming (ECE 203) or equivalent.

ECE 595. Special Problems in Electrical Engineering. 1-6 Hours
Particular assignments to be arranged and approved by the department chair. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Corequisites: ECE 500.

ECE 596. Independent Research Project in Electrical and Computer Engineering. 3 Hours
Particular assignments to be arranged and approved by the department chair. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course.

ECE 599. Thesis. 1-6 Hours
Thesis in Electrical and Computer Engineering. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Corequisites: ECE 500.

ECE 604. Advanced Power Electronics. 3 Hours
The course provides the characteristics and detailed design of power semiconductors, power conversion typologies, and controls. Passive components design and selection and optimization, advanced control strategy and typologies of DC-DC converter and DC-AC Inverters. Prerequisites: ECE 402 or 504.

ECE 633. Advanced Computer Architecture. 3 Hours
Examination of modern high-performance computing architectures, including out-of-order execution RISC multicore processors and GPGPUs. Design projects integrate the concepts learned in class. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Prerequisites: ECE 533. Corequisites: ECE 500.

ECE 642. Optimal Control & Estimation. 3 Hours
Introduction to optimal control, starting with dynamic programming for stochastic optimal control; continuous-time optimal control, including Pontryagin's Maximum Principle and its application to the linear case, leading to linear optimal control. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Prerequisites: ECE 509 or permission of instruction. Corequisites: ECE 500.

ECE 645. Adaptive Control. 3 Hours
On-line approximation based adaptive control techniques for nonlinear systems. An introduction to neural networks and fuzzy systems as part of the control loop is given, leading to a diversity of advanced methods for controlling and stabilizing nonlinear systems subject to uncertainties. Adaptive observers and adaptive output feedback are also introduced. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Prerequisites: ECE 547 or permission of instructor. Corequisites: ECE 500.

ECE 661. Statistical Signal Processing. 3 Hours
This course studies discrete methods of linear estimation theory. Topics include random vectors, linear transformations, linear estimation theory, optimal filtering, least-squares techniques, linear prediction, and spectrum estimation. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Prerequisites: ECE 503, ECE 505. Corequisites: ECE 500.

ECE 675. SILICON PHOTONICS. 3 Hours
Photonic Integrated Circuits and Components on the silicon platform, Optical fiber coupling into single mode waveguides, Power Splitting Components, Polarization Manipulation Components, Integrated Photonic Thermo-Optic, and Electro-Optic Modulators, Photonic Circuit Modeling , Silicon Photonics Foundry Fabrication, Design Project with Ansys/ Lumerical software. Prerequisites: ECE 333 or equivalent or Permission of Instructor.

ECE 695. Special Problems in Electrical and Computer Engineering. 1-6 Hours
Special topics in electrical engineering not covered in regular courses. Course sections arranged and approved by the chair of the student's doctoral advisory committee and the department chair.

ECE 696. Graduate Seminar. 0-3 Hours
Research oriented independent study course intended for doctoral level graduate students. The student will perform an in-depth research on a selected topic of mutual interest with his/her doctoral adviser, and achieve sufficient expertise to do a technical presentation about the topic in front of his/her peers. The student will prepare a report and present it in one of the graduate seminar sessions during the semester. The student is expected to attend all the seminars presented by other graduate students during the semester and to interact with them to improve the depth and breath of his/her knowledge.

ECE 699. PhD Dissertation. 1-15 Hours
Original research in electrical engineering that makes a definite contribution to technical knowledge. Results must be of sufficient importance to merit publication in a refereed journal.