ELECTRICAL ENGINEERING

The mission of the electrical engineering program, consistent with the Missouri S&T campus mission statements, is the education of students to fully prepare them to provide leadership in the recognition and solution of society's problems in the area of electrical engineering.

The department of electrical and computer engineering offers graduate programs of study in electrical engineering that lead to graduate certificates, the M.S. degree (thesis and non-thesis options), the Ph.D. degree and the doctor of engineering degree. All of these programs can be pursued on the Rolla campus. The M.S. programs are also available through distance education. Permission to pursue a doctoral degree through distance education is granted on a case-by-case basis. Most graduate programs in electrical engineering normally include some specialization in one or more of the following six emphasis areas of electrical engineering.

Emphasis Areas

Circuits and Electronics

Topics include network analysis and synthesis, computer-aided circuit design, distributed circuits, communication circuits, and linear and nonlinear electronic circuits.

Communications & Signal Processing

Topics include coding, information theory, modulation, detection, filtering for both analog and digital systems, signal processing, image processing and wireless.

Controls and Systems

Topics include resilience control, wireless sensor/network design and networked control systems, process control, optimal control and estimation, robust control, neural networks, fuzzy logic based control as applied to control of vehicles, chemical processes, manufacturing, robotics, environmental systems and smart structural systems.

Devices and Optics

Topics include the semiconductor devices, microsystems, fiber optics and sensors, optical methods applied to structural monitoring, and optical/quantum computing.

Electromagnetics

Topics include electromagnetic compatibility and signal integrity for high-speed electronic systems, microwaves and applications to nondestructive testing and evaluation.

Power

Topics include power electronic converters, electric machines, electric motor drives, high voltage engineering, transportation electrification, application of computer methods to power system analysis and control, power system relaying and protection, and power quality load management.

Departmental Requirements

Admission Requirements

The graduate certificate programs offered by the ECE department are open to all persons holding a bachelor's degree in any field of engineering from an ABET-accredited undergraduate program, or a degree in a closely related technical field such as physics or mathematics. The minimum undergraduate GPA requirement varies by certificate.

Students who lack the prerequisite courses necessary to take graduate-level courses for the certificate program may be required to take remedial courses at either the undergraduate or graduate level prior to admission.

The nominal GPA requirement for admission to the M.S. degree program in this department is an undergraduate GPA of 3.3 on a 4.0 GPA system. In evaluating the academic performance from universities that may use other grading systems, the department may rely upon statistical data gathered in analyzing academic outcomes for recent graduate students to the extent that such statistical data is available. The department will not offer graduate admissions to students who do not have the equivalent of a four year baccalaureate degree in engineering. As an example, we cannot accept students who have only a diploma or engineering technology degree.

The ECE department requires ETS-reported GRE scores and recommends the following scores:

Q+V≥305, Q≥ 155, A/WR≥ 3.5

This GRE requirement may be waived if the applicant has an undergraduate GPA of 3.5 obtained from the courses offered by the electrical engineering or computer engineering program at Missouri S&T (must be minimum 18 credit hours).

For international students who are required to provide TOEFL scores, the ECE department has no preference as to the computer-based TOEFL (CBT), internet-based TOEFL (iBT), or paper-based TOEFL (PBT). The required score set by campus is 80 (iBT) or equivalent. Where TOEFL is not available, an IELTS score of ≥ 6.5, a PTE score of 58, or a Duolingo score of 105 is strictly required.

Students applying for graduate studies in this department on the basis of degrees in closely related fields may have additional conditions placed on their admission. These conditions are generally imposed to make sure that students lacking a traditional electrical engineering degree will have sufficient background to ensure a reasonable chance for academic success.

Students seeking admission to the Ph.D. program are expected to meet all of the above recommendations and have a graduate GPA of 3.5 or better. All Ph.D. applicants must provide at least three letters of recommendation. Exceptional applicants may apply directly to the Ph.D. program after completing the baccalaureate degree.

M.S. Degree Requirements

Thesis option M.S. program of study requires a minimum of 21 credit hours of coursework exclusive of credit hours earned for thesis research. The thesis option degree is based on a combination of coursework and research. This option requires the student to find a faculty member willing to serve as advisor. This should be done as soon as possible so that the student and advisor will be able to formulate both a plan of coursework and a research project.

Non-thesis option M.S. program is based entirely on coursework. This option requires a minimum of 30 credit hours of coursework. Non-thesis students are assigned an initial advisor by the department, typically the

associate chair for graduate studies. M.S. degree students, both thesis and non-thesis option, may change this degree option and advisors at any time with the consent of their current and new advisors.

M.S. Communication Requirements
An M.S student is required to fulfill a zero credit hour communications requirement to demonstrate a sufficient communications capability to operate effectively at an advanced level in the professional engineering and scientific community. To fulfill this requirement, the advisor will monitor the student's capability through one of the following exemplary activities during the program of study:

1. Authoring at least one accepted publication (major contribution to communication aspects)
2. Taking/transferring one graduate-level communication course
3. Possessing industrial or other professional experiences
4. Having completed example(s) listed above or equivalent before enrolling in the program
5. Other equivalent qualifications as identified by the advisor

Doctoral Degree Requirements

The two types of doctoral degrees offered by this department are the Doctor of Philosophy (Ph.D.) and the Doctor of Engineering (D.E.) with a strong emphasis on research with advisor. The primary difference between these two doctoral degrees is that the research portion of the D.E .degree is conducted as an internship with an industrial concern or government laboratory and is jointly supervised by an internship advisor employed by the cooperating organization and a faculty advisor employed by S&T. In contrast, the research portion of the Ph.D. degree is generally conducted on campus.

The doctoral program of study, for the Ph.D. degree or the D.E. degree, should include 90 credit hours (minimum 48 hours coursework and minimum 42 hours research) beyond the B.S. degree or 60 credit hours (minimum 24 hours coursework and minimum 36 hours research) beyond the M.S. degree.

Doctoral Communication Requirement
A doctoral student is required to fulfill a zero credit hour communications requirement to demonstrate a sufficient communications capability to operate effectively at an advanced level in the professional engineering and scientific community. To fulfill this requirement, the advisor will monitor the student's capability through one of the following exemplary activities during the program of study:

1. Authoring at least one accepted publication (major contribution to communication aspects)
2. Taking/transferring one graduate-level communication course
3. Possessing industrial or other professional experiences
4. Having completed example(s) listed above or equivalent before enrolling in the program
5. Other equivalent qualifications as identified by the advisor

Research

Significant research, suitable for publication, is expected for students pursuing the thesis option M.S. or a doctoral degree. The student should work closely with their major advisor and their advisory committee to determine when these expectations are met. The length of research time and/or the number credit hours earned for thesis research will not automatically satisfy this requirement.

Additional Information

Additional information about departmental emphasis areas, requirements, graduate handbook, faculty, research opportunities, financial aid, and facilities can be found by visiting the department's web page at http://ece.mst.edu. We can be contacted by telephone at 573-341-4519 or e-mail ece@mst.edu. For information about S&T Global-St. Louis, visit their webpage at https://distance.mst.edu/about/locations/.

Graduate Certificate Programs Admissions

The ECE department offers three graduate certificate programs that utilize graduate-level courses in electrical engineering to develop the skills of practicing engineers: automation engineering and plc, electric machines and drives, and electric power systems engineering. These programs are offered through distance education and are designed to appeal to working professionals. The four courses taken to fulfill the requirements of any of the graduate certificate programs can be counted towards an M.S. degree in EE or CpE. However, any prerequisite or foundational courses taken to provide background for one or more of the four graduate certificate program courses cannot be counted towards an M.S. degree.

The graduate certificate programs are open to all persons holding a B.S. degree in any field of engineering from an ABET accredited undergraduate program or a degree in a closely related field such as physics or mathematics. The minimum undergraduate GPA requirement varies by certificate. Students who lack the prerequisite courses necessary to take graduate-level courses for the certificate program may be required to take foundational courses at either the undergraduate or graduate level prior to admission.

Once admitted to the program, the student must take four designated courses from the certificate curriculum given below. The student will be given three years to complete the program. A student may take a leave of absence, up to one year only, which will not count toward the three-year time limit. To apply for a leave of absence, the student must consult with their academic advisor to complete the Leave of Absence Request form and submit for approval, first to the department chair and then to the vice provost of graduate education. In order to receive the graduate certificate, the student must earn a grade of B or better in each of the four courses taken for the certificate.

Students admitted to the certificate program will have non-degree graduate status. Completion of a certificate program does not guarantee subsequent admission to the MS programs in EE or CpE at Missouri S&T. Upon application to the MS program in EE or CpE, the GRE requirement will be waived for applicants who meet all other admission requirements and have completed a certificate offered by the ECE department.

Automation Engineering and PLC

This graduate certificate program is designed to provide specialized graduate level education in the area of automation engineering and PLC.

Curriculum

Students enrolled in this graduate certificate program will take two required courses and two elective courses. Alternative courses may be substituted with departmental approval.

Required courses:	
CHEM ENG 5190/ ELEC ENG 5350	Plantwide Process Control
ELEC ENG 5340	Advanced PLC
Choose two of the following:	
CHEM ENG 5355	Process Control System Safety, Security and Alarms
or ELEC ENG 5355	Process Control System Safety, Security and Alarms
ELEC ENG 5345	PLC Motion Control
ELEC ENG 5870/ MECH ENG 5478	Mechatronics
MECH ENG 5449	Robotic Manipulators and Mechanisms
MECH ENG 5655	Manufacturing Equipment Automation

Electric Machine and Drives

This graduate certificate program is designed to provide specialized graduate level education in the area of electric machine and drives.

Curriculum

Students enrolled in this graduate program will take two required courses and two elective courses. Alternative courses may be substituted with departmental approval.

The following two courses must be taken:	
ELEC ENG 5500	Electric Drive Systems
ELEC ENG 6500	AC Drives: Dynamic and Control
A minimum of two of the following electric power systems courses must be taken:	
ELEC ENG 5550	Electric Power Quality
ELEC ENG 5300	Digital Control
ELEC ENG 5520	Power Electronics
ELEC ENG 5600	Interference Control in Electronic Systems
ELEC ENG 6001	Special Topics
ELEC ENG 6550	Power System Stability
ELEC ENG 6300	Linear Control Systems

Electrical Power Systems Engineering

This graduate certificate program is designed to provide specialized graduate level education in the area of electric power systems engineering.

Curriculum

Students enrolled in this graduate certificate program will take two required courses and two elective courses. Alternative courses may be substituted with departmental approval.

The following two electric power systems courses must be taken:	
ELEC ENG 5540	Power Systems Engineering
ELEC ENG 5550	Electric Power Quality
A minimum of two of the following electric power systems courses must be taken:	
ELEC ENG 6300	Linear Control Systems
ELEC ENG 5570	Extra High Voltage Engineering
ELEC ENG 6540	Computer Methods In Power System Analysis
ELEC ENG 6550	Power System Stability
ELEC ENG 6560	Power System Protection
ELEC ENG 6570	Surge Phenomena In Power Systems
ELEC ENG 6580	Power System Operations

Levent Acar, Associate Professor
PHD Ohio State University
Control and systems, intelligent control with applications to robotics, neural network and fuzzy logic systems, large-scale systems and optimization.

Ahmad Alsharoa, Assistant Professor
PHD Iowa State University

Daryl G Beetner, Professor[1]
DSC Washington University
Computer Engineering, parallel processing, hardware-software co-design, skin cancer detection, and electro-cardiology. Interests in electro-cardiology include body-surface mapping, the inverse problem, and risk-assessment.

Rui Bo, Associate Professor
PHD Univeristy of Tennessee-Knoxville
Computation, optimization and economics in power system operation and planning, high performance computing and its application in power systems, electricity market simulation, evaluation and design.

Minsu Choi, Associate Professor
PHD Oklahoma State University
Computer architecture & VLSI, embedded systems, fault tolerance testing, quality assurance, reliability modeling & analysis, configurable computing, distributed systems, dependable instrumentation & measurement.

Kristen Marie Donnell, Associate Professor
PHD Missouri Univeristy of Science & Technology
Microwave nondestructive testing, modulated antennas/scatterers, terahertz methodologies and electronics design.

Kelvin Todd Erickson, Curators' Distinguished Teaching Professor[1]
PHD Iowa State University
Chemical process control, advanced control algorithms, digital control, programmable logic controllers, system identification.

Mina Esmaeelpour, Assistant Professor
PHD Lehigh University

Mehdi Ferdowsi, Professor
PHD Illinois Institute of Technology
Power electronics, power converters and electric drives.

Jie Huang, Associate Professor
PHD Clemson University
Fiber optic sensors, laser machining, sensors and instrumentation for applications in harsh environments, microwave-photonic sensing imaging and spectroscopy.

Ali Hurson, Professor
PHD University of Central Florida
Parallel and distributed systems, databases, mobile databases, pervasive and mobile computing.

Chulsoon Hwang, Associate Professor
PHD KAIST, Korea
Signal and power integrity of IC/package/PCB system, electromagnetic modeling, time/frequency domain simulation/measurement techniques.

Lijun Jiang, Professor
PHD University of Illinois at Urbana-Champaign

DongHyun (Bill) Kim, Assistant Professor
PHD KAIST, Korea

Chang-Soo Kim, Professor
PHD Kyungpook National University, Korea
Micro-and nano-sensors, bio-MEMS (Micro Electro Mechanical System), microsystems, sensor engineering, biomedical/agricultural engineering.

Jonathan William Kimball, Professor[1]
PHD University of Illinois-Urbana
Power electronics, energy harvesting, alternative energy, multi-phase converters.

Mohamed Nafea, Assistant Professor
PHD Penn State University

Jagannathan Sarangapani, Curators' Distinguished Professor
PHD University of Texas-Arlington
Control of networks, embedded systems and resilience, sensors and neural network control, diagnostics/prognostics, cyber physical systems, event-triggered control.

Sahra Sedigh Sarvestani, Associate Professor
PHD Purdue University, W. Lafayette
Dependable networks and systems, cyber-physical systems, quantitative modeling and prediction for complex networked systems, critical infrastructure.

Pourya Shamsi, Associate Professor
PHD University of Texas-Dallas
Smart-grids, stability assessments in micro-grids, energy management, switching power converters, VHF/UHF dc-dc converters, and motor drives.

Ronald Joe Stanley, Professor
PHD University of Missouri-Columbia
Image processing, pattern recognition software methods, automation and medical informatics.

Steve E Watkins, Professor
PHD University of Texas at Austin
Fiber optic sensing, optical and electronic materials, electro-optic devices and Fourier optics.

Donald C Wunsch II, Professor[1]
PHD University of Washington
Adaptive critic designs, neural networks, fuzzy systems, surety, nonlinear adaptive control, intelligent agents, applications, financial engineering.

Maciej J Zawodniok, Associate Professor
PHD University of Missouri-Rolla
Embedded systems for cyber infrastructure, wireless sensor and ad hoc networks, and general wireless communications systems.

ELEC ENG 5000 Special Problems (IND 0.0-6.0)
Problems or readings on specific subjects or projects in the department. Consent of instructor required.

ELEC ENG 5001 Special Topics (LAB 0.0 and LEC 0.0)
This course is designed to give the department an opportunity to test a new course. Variable title.

ELEC ENG 5040 Oral Examination (IND 0.0)
After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/ comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

ELEC ENG 5070 Teaching Engineering (LEC 3.0)
Introduction to teaching objectives and techniques. Topics include: using course objectives to design a course; communication using traditional and cutting-edge media; textbook selection; assessment of student learning; grading; student learning styles; cooperative/active learning; and student discipline. Prerequisite: Graduate standing. (Co-listed with Eng Mgt 5070, Env Eng 5070, Comp Eng 5070, Civ Eng 5070).

ELEC ENG 5085 Internship (IND 1.0-15)
Students working toward a master degree may select, with the advice of their committees, an appropriate internship opportunity as an integral part of the degree program. The internship plan must conform to the purpose of providing a high level engineering experience consistent with the intent of the master degree. This course will explore how well the current graduate curriculum prepares students for tackling the practical problems that they will encounter in the workplace. Assessment may be based upon the Satisfactory/Unsatisfactory grading option depending on the quality of reports and/or presentations summarizing the outcomes of internship activity to the student's academic advisor.

ELEC ENG 5099 Special Research And Thesis (IND 0.0-15)
Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

ELEC ENG 5100 Advanced Electronic Circuits (LEC 3.0)
Application of feedback theory, oscillators and frequency standards, precision analog techniques, low-power circuit design, interfacing sensors, designing for high reliability, electronics for harsh environments. Prerequisite: Elec Eng 3120.

ELEC ENG 5140 High-Frequency Amplifiers (LEC 3.0)
Analysis and design of high frequency amplifiers. Topics include parameter conversions, activity and passivity, stability criteria, device operating conditions, Smith chart usage, matching networks, microstrip, scattering parameters, and practical applications. Prerequisites: Elec Eng 3120, 3600.

ELEC ENG 5150 Photovoltaic Systems Engineering (LEC 3.0)
Physics and characteristics of photovoltaic (solar) cell technologies, electronic control of alternative energy sources, site selection, array design, energy storage methods, electrical code compliance, stand-alone systems, grid-intertie systems, legal and economic considerations. Prerequisite: Senior or graduate standing in Science or Engineering.

ELEC ENG 5160 Computer-Aided Network Design (LEC 3.0)
Analysis and design of active and passive electric networks. Theory and computer application, including methods for automatic formulation of network state equations, network tolerance, network optimization, and device modeling. Prerequisites: Elec Eng 3100.

ELEC ENG 5200 Classical Optics (LEC 3.0)
Physical optics and advanced topics in geometrical optics. Topics include ray propagation, electromagnetic propagation, mirrors, lenses, interference, diffraction, polarization, imaging systems, and guided waves. Prerequisites: Math 2222 and Physics 2135 or 2111. (Co-listed with Physics 4503).

ELEC ENG 5210 Fourier Optics (LEC 3.0)
Applications of Fourier analysis and linear systems theory to optics. Topics include scalar diffraction theory, Fourier transforming properties of lenses, optical information processing, and imaging systems. Prerequisites: Both Elec Eng 3430 and Elec Eng 3600 or Physics 4211. (Co-listed with PHYSICS 5503).

ELEC ENG 5220 Fiber And Integrated Optics (LEC 3.0)
Introduction to optical waveguides and their applications to communication and sensing. Topics include dielectric waveguide theory, optical fiber characteristics, integrated optic circuits, coupled-mode theory, optical communication systems, and photonic sensors. Prerequisite: Elec Eng 3600 or Physics 4211. (Co-listed with Physics 5513).

ELEC ENG 5250 Quantum Computing (LEC 3.0)
Introduction to the principles, subsystems, and architectures of quantum computing. Topics include architectural and general considerations of quantum systems which are suitable for parallel computing applications using a rule-based approach. Prerequisite: Comp Eng 2210. (Co-listed with Comp Eng 5230).

ELEC ENG 5270 Smart Materials and Sensors (LAB 1.0 and LEC 2.0)
Smart structures with fiber reinforced polymer (FRP) composites and advanced sensors. Multi-disciplinary topics include characterization, performance, and fabrication of composite structures; fiber optic, resistance, and piezoelectric systems for strain sensing; and applications of smart composite structures. Laboratory and team activities involve manufacturing, measurement systems, instrumented structures, and performance tests on a large-scale smart composite bridge. Prerequisites: Senior standing and Math 3304. (Co-listed with Aero Eng 5229, Mech Eng 5229 and Civ Eng 5118).

ELEC ENG 5300 Digital Control (LEC 3.0)
Analysis and design of digital control systems. Review of ztransforms; root locus and frequency response methods; state space analysis and design techniques; controllability, observability and estimation. Examination of digital control algorithms. Prerequisite: Elec Eng 3320.

ELEC ENG 5320 Neural Networks Control and Applications (LEC 3.0)
Introduction to artificial neural networks and various supervised and unsupervised learning techniques. Detailed analysis of some of the neural networks that are used in control and identification of dynamical systems. Applications of neural networks in the area of Control. Case studies and a term project. Prerequisites: Elec Eng 3320.

ELEC ENG 5325 Applied Nonlinear Control (LEC 3.0)
Review of State Variable Models, Nonlinear Model and Phenomena, Lyapunov Stability, Phase Plane Analysis, Feedback Linearization, Sliding Mode and Backstepping Control, and Control Applications Prerequisite: Elec Eng 3320 or graduate standing.

ELEC ENG 5340 Advanced PLC (LAB 1.0 and LEC 2.0)
Advanced programmable logic controller (PLC) programming, function block, structured text, function chart, sequencer. Factory communications, system simulation, human-machine interface (HMI) programming. Advanced PID control. Network security and reliability. Class-wide project. Prerequisite: Elec Eng 3340.

ELEC ENG 5345 PLC Motion Control (LAB 1.0 and LEC 2.0)
Factory automation motion control integrated with programmable logic controllers, servo control, variable-speed drive control, PackML state model, sizing motors and drives, machine safety, and experience with commercial hardware/software. Laboratory exercises on small-scale standard applications such as coordinated motion of multiple axes and camming. Prerequisite: Elec Eng 3340.

ELEC ENG 5350 Plantwide Process Control (LEC 3.0)
Synthesis of control schemes for continuous and batch chemical plants from concept to implementation. Mulitloop control, RGA, SVD, constraint control, multivariable model predictive control, control sequence descriptions. Design project involving a moderately complicated multivariable control problem. Prerequisites: Chem Eng 4110 or Elec Eng 3320 or Elec Eng 3340 or graduate standing. (Co-listed with Chem Eng 5190).

ELEC ENG 5355 Process Control System Safety, Security and Alarms (LEC 3.0)
Lifecycle approach for industrial automation in the context of IEC 61511 (safety) and IEC 62443 (IACS cybersecurity) standards. Functional safety and cybersecurity fundamentals for risk analysis, safety/cybersecurity requirements, inherently safer/secure design techniques, SIL/SL verification, operations, real-world cybersecurity attacks, alarm management. Prerequisites: Elec Eng 3320, Elec Eng 3340, or Chem Eng 4110. (Co-listed with Chem Eng 5355).

ELEC ENG 5360 System Simulation And Identification (LEC 3.0)
Computationally efficient methods of digital simulation of linear systems. Non-parametric identification. Parametric identification with least squares and recursive least squares algorithms. Algorithms programmed using MATLAB. Prerequisite: Elec Eng 3320.

ELEC ENG 5380 Autonomous Mobile Robots (LEC 3.0)
This course will provide an introduction to mobile robots and current approaches to robot autonomy. Topics include mobile robot systems, modeling and control, sensors and estimation, localization and mapping, and motion planning. Prerequisites: Elec Eng 3320 or equivalent and Stat 3117 or equivalent.

ELEC ENG 5400 Digital Signal Processing II (LEC 3.0)
Spectral representations, sampling, quantization, z-transforms, digital filters and discrete transforms including the Fast Fourier transform. Prerequisites: Elec Eng 3410.

ELEC ENG 5420 Communications Systems II (LEC 3.0)
Random signals and their characterization; noise performance of amplitude, angle and pulse modulation systems; digital data transmission; use of coding for error control. Prerequisite: Elec Eng 3430.

ELEC ENG 5430 Wireless Networks (LAB 1.0 and LEC 2.0)
Introduction to wireless communications and networking. Topics include transmission fundamentals, wireless channel, coding techniques and error control, satellite and cellular networks, cordless systems, mobile IP and management, multiple access techniques and wireless protocols, wireless LAN, IEEE 802.11, and adhoc and sensor networks. Prerequisites: Comp Eng 3150. (Co-listed with Comp Eng 5430 and Sys Eng 5323).

ELEC ENG 5440 Stochastic Signal Analysis I (LEC 3.0)
Introduction to the application of probabilistic models to typical electrical engineering problems. Topics include: methods for describing random voltages, random digital signals, correlation, linear mean-square estimation, linear transformation of random digital signals, and bit-error rate calculation for communication systems. Prerequisites: Math 3304 and Elec Eng 2120.

ELEC ENG 5450 Digital Image Processing (LEC 3.0)
Fundamentals of human perception, sampling and quantization, image transforms, enhancement, restoration, channel and source coding. Prerequisites: Elec Eng 3430.(Co-listed with Comp Eng 5450).

ELEC ENG 5460 Machine Vision (LEC 3.0)
Image information, image filtering, template matching, histogram transformations, edge detection, boundary detection, region growing and pattern recognition. Complementary laboratory exercises are required. Prerequisites: Elec Eng 3430. (Co-listed with Comp Eng 5460).

ELEC ENG 5500 Electric Drive Systems (LEC 3.0)
Course content is roughly 1/3 power electronics, 1/3 applied control and 1/3 electric machinery and focuses on analysis, simulation, and control design of electric drive based speed, torque, and position control systems. Prerequisites: Elec Eng 3320.

ELEC ENG 5510 Electric-Drive Vehicles (LEC 3.0)
Course covers introductory topics related to understanding/analysis of electric, hybrid/plug-in hybrid power trains. Classification of hybrid drivetrains, driving cycles, energy storage systems, mechanical coupling devices, automotive applications of fuel cells and introduction to power converters. Prerequisite: Senior standing and Physics 2135.

ELEC ENG 5520 Power Electronics (LEC 3.0)
Analysis, design, modeling, and control of switching mode power converter circuits for ac-dc, dc-dc, dc-ac, and ac-ac conversion. Power semiconductor devices, passive components, and non-ideal sources and loads. Applications to industry, consumer goods, electric vehicles, and alternative energy. Prerequisite: Elec Eng 3100.

ELEC ENG 5521 Power Electronics Laboratory (LAB 2.0)
An introduction to power electronic circuits is presented. Students will construct several dc/dc, dc/ac and ac/dc converters. Various switching algorithms, including pulse width modulation, delta modulation, and hysteresis control will be developed to regulate and control the respective circuits. Prerequisite: Co-requisite Elec Eng 5520.

ELEC ENG 5540 Power Systems Engineering (LEC 3.0)
Network analysis applied to power systems; the load flow concept; economic operation of power systems; synchronous machine reactances and transient stability; symmetrical components and asymmetrical faults; protective relaying. Prerequisite: Elec Eng 3540.

ELEC ENG 5550 Electric Power Quality (LEC 3.0)
Definitions of power quality, types of power quality problems; sources of sags, transient overvoltages and harmonics; distribution overcurrent protection methods and their effect on power quality and reliability; harmonic analysis, principles of controlling harmonics, devices for filtering harmonics; power quality improvement methods. Prerequisite: Elec Eng 3500 or Elec Eng 3540.

ELEC ENG 5570 Extra High Voltage Engineering (LEC 3.0)
The physical phenomena associated with high voltage dielectric breakdown are presented. Methods of generating and measuring high voltages and currents are explained. Type-tests performed on a variety of high voltage equipment are introduced. Prerequisite: Senior standing.

ELEC ENG 5600 Interference Control in Electronic Systems (LEC 3.0)
Principles of high frequency effects in PCBs and components, generation of unwanted radio-frequency (RF) signals by ICs, RF radiation mechanisms, shielding, and immunity against electrostatic discharge and RF signals. Prerequisites: Elec Eng 3430 and 3600.

ELEC ENG 5620 Signal Integrity in High-Speed Digital & Mixed Signal Design (LEC 3.0)
Signal integrity ensures signals transmitted over a propagation path maintain sufficient fidelity for proper receiver operation. Compromised signal integrity is often associated with parasitics (e.g. unintentional inductance, capacitance). Theory and CAD tools used for signal integrity analysis of functioning designs. Prerequisites: Elec Eng 3600 or Comp Eng 3150, and Senior standing. (Co-listed with Comp Eng 5620).

ELEC ENG 5630 Wave Propagation and Transmission Lines (LEC 3.0)
The materials in this course are intended to provide a) follow up electromagnetics related courses, b) electromagnetics related career including RF design and c) a graduate degree in electromagnetic related fields an in-depth understanding of the basics of wave propagation and transmission lines. Prerequisite: Elec Eng 3600.

ELEC ENG 5640 Antennas and Propagation (LEC 3.0)
Propagated fields of elemental dipole, directivity and gain, radiation resistance, the half-wave dipole, wire antennas, arrays, broadband antennas, aperture antennas, horn antennas, and antenna temperature. Prerequisite: Elec Eng 3600.

ELEC ENG 5650 Microwave and Millimeter Wave Engineering and Design (LEC 3.0)
Introduce senior and graduate students to the concept of microwave and millimeter wave engineering and passive component design such as waveguide, cavities, couplers, detectors, mixers, etc., including network theory and scattering matrix. Finally, their specific application in the design of various microwave circuits will be discussed. Prerequisites: Elec Eng 3600.

ELEC ENG 5660 Microwave Principles For Mixed-Signal Design (LEC 3.0)
Transmission lines; coupled transmission lines; microwave network analysis; impedance matching and tuning; design of microwave amplifiers and oscillators. Prerequisite: Elec Eng 3600.

ELEC ENG 5670 Nondestructive Testing (LEC 3.0)
Principles and applications of various means of non-destructive testing of metallic materials. Radiological inspection methods, ultrasonic testing, magnetic methods, electrical and eddy current methods and others. Prerequisite: Physics 2135 or 2111. (Co-listed with Met Eng 5510).

ELEC ENG 5680 Introduction to Radar Systems (LEC 3.0)
The objective of this course is to introduce senior and graduate students to various radar system principles, designs and applications (e.g., pulse, frequency-modulated, chirp, Doppler radars). Topics related to signals, systems, noise, resolution, multiple sampling, different imaging modalities, and remote sensing will also be discussed. Prerequisites: Elec Eng 3430, Elec Eng 3600, Math 3304, Math 3108, and Stat 3115 or Stat 3117 or Stat 5643.

ELEC ENG 5810 Computational Intelligence (LEC 3.0)
Introduction to Computational Intelligence (CI), Biological and Artificial Neuron, Neural Networks, Evolutionary Computing, Swarm Intelligence, Artificial Immune Systems, Fuzzy Systems, and Hybrid Systems. CI application case studies covered include digital systems, control, power systems, forecasting, and time-series predictions. Prerequisite: Graduate Standing. (Co-listed with Comp Eng 5310 and Sys Eng 5211).

ELEC ENG 5820 Introduction to Neural Networks and Applications (LEC 3.0)
The course provides an introduction to basic neural network architectures and their applications. Students learn to construct neural networks and train them to solve engineering problems, specifically pattern recognition and function approximation. Mathematical analysis of network architectures, training algorithms and practical applications of neural nets. Prerequisites: Graduate Standing. (Co-listed with Sys Eng 5212).

ELEC ENG 5870 Mechatronics (LAB 1.0 and LEC 2.0)
This course will introduce students to the basics of mechatronics (i.e., the integration of mechanical, electrical, computer, and control systems). Students will learn the fundamentals of sensors and actuators for mechanical systems, computer interfacing, microcontrollers, real-time software, and control. Prerequisite: Mech Eng 4479 or equivalent. (Co-listed with Mech Eng 5478, Aero Eng 5478 and Comp Eng 5820).

ELEC ENG 5880 Introduction to Robotics (LEC 3.0)
This course provides an introduction to robotics, covering robot hardware, fundamental kinematics, trajectories, differential motion, robotic decision making, and an overview of current topics in robotics. Prerequisite: A grade of "C" or better in both Math 3108 and Comp Sci 1575. (Co-listed with Comp Sci 5403 and Comp Eng 5880).

ELEC ENG 6000 Special Problems (IND 0.0-6.0)
Problems or readings on specific subjects or projects in the department. Consent of instructor required.

ELEC ENG 6001 Special Topics (LAB 0.0 and LEC 0.0)
This course is designed to give the department an opportunity to test a new course. Variable title.

ELEC ENG 6040 Oral Examination (IND 0.0)
After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/ comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

ELEC ENG 6050 Continuous Registration (IND 1.0)
Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

ELEC ENG 6085 Internship (IND 1.0-15)
Students working toward a doctoral degree may select, with the advice of their committees, an appropriate internship opportunity as an integral part of the degree program. The internship plan must conform to the purpose of providing a high level engineering experience consistent with the intent of the doctoral degree. This course will explore how well the current graduate curriculum prepares students for tackling the practical problems that they will encounter in the workplace. Assessment may be based upon the Satisfactory/Unsatisfactory grading option depending on the quality of reports and/or presentations summarizing the outcomes of internship activity to the student's academic advisor.

ELEC ENG 6099 Special Research And Thesis (IND 0.0-15)
Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

ELEC ENG 6140 Advanced RF & Time Domain Measurements (LAB 1.0 and LEC 2.0)
Advanced measurement techniques and instrumentation: Oscilloscopes (Real time and sampling, A/D conversion errors, Probing, Jitter, Noise), Spectrum analyzer (concepts, applications), Network Analyzer (concepts, calibration), Impedance measurements. Lab experiments are a main part of this class. Prerequisite: Graduate standing.

ELEC ENG 6150 Signal Integrity, High Speed Digital and RF Design Laboratory (LAB 3.0)
This is an RF and digital electronics design class. Student groups will design, manufacture and test RF and/or digital circuits during the class. Besides this project work the lecture part will emphasize circuit design, layout, parasitic effects and design for testability. Prerequisite: Elec Eng 3600.

ELEC ENG 6200 Electromagnetic Optics (LEC 3.0)
Propagation, control, and modulation of laser radiation. Topics include optical polarization, interference, layered and anisotropic media, electro-optic devices, acousto-optic devices, and nonlinear optics. Prerequisite: Elec Eng 3600 or Physics 4211.

ELEC ENG 6260 Integrated Microsystems Engineering (LAB 1.5 and LEC 1.5)
Theory and practice of multidisciplinary integrated microsystem technologies. The topics include (1) micromachining technology, (2) review of mechanical, optical, microfluidic and (bio) chemical microsensors and microactuators, (3) hands-on lab session for design, fabrication, and characterization of microsystems. Prerequisite: Graduate standing.

ELEC ENG 6290 Advanced Topics in Optics and Devices (LEC 3.0)
Advanced topics of current interest in optics and devices. Selected topics include semiconductor materials, electronic devices, wave-based sensing, fiber optic systems, optoelectronics, and photonic engineering. Prerequisite: Graduate Standing.

ELEC ENG 6300 Linear Control Systems (LEC 3.0)
Review of linear algebra, state variable formulations, solutions of state equations; controllability and observability; multivariable systems, matrix-fraction decompositions; design of state and output feedback controllers and observers; introduction to calculus of variations; linear quadratic regulators. Prerequisite: Elec Eng 3320.

ELEC ENG 6310 Optimal Control and Estimation (LEC 3.0)
Review of linear quadratic regulators, LQR extensions; constrained optimization (Pontragin's minimum principle); review of probability theory and random processes; optimal prediction and filters; frequency domain properties of LQR and Kalman filters; linear quadratic Gaussian (LQG) control; model uncertainties, frequency shaping, LQG/LTR design methodology. Prerequisites: Elec Eng 6300 or Mech Eng 5481 or Aero Eng 5481. (Co-listed with Aero Eng 6410 and Mech Eng 6410).

ELEC ENG 6320 Nonlinear Control Systems (LEC 3.0)
Numerical solution methods, describing function analysis, direct and indirect methods of Liapunov stability, applications to the Lure problem - Popov circle criterion. Applications to system design and feedback linearizations. Prerequisite: Elec Eng 6300. (Co-listed with MECH ENG 6420).

ELEC ENG 6330 Robust Control Systems (LEC 3.0)
Performance and robustness of multivariable systems, linear fractional transformations, LQG/LTR advanced loop shaping, Youla parameterization, H (subscript infinity) optimal control, mixed H (subscript 2) and H (subscript infinity) control, controller synthesis for multiple objective optimal control, linear matrix inequalities theory and case studies. Prerequisites: Elec Eng 6300 or Mech Eng 5481 or Aero Eng 5481. (Co-listed with Aero Eng 6430 and Mech Eng 6430).

ELEC ENG 6335 Discrete-Time Neural Network Control (LEC 3.0)
Neural network topologies, universal function approximation property, background on Lyapunov stability & dynamic systems, control of a class of nonlinear systems using single and multilayer neural networks, feedback linearization, strict & nonstrict feedback systems, MIMO system, system identification, output feedback control, and hardware implementation. Prerequisites: Elec Eng 6300.

ELEC ENG 6350 Neural Network Control of Nonlinear Continuous-time Systems (LEC 3.0)
Neural network topologies, universal function approximation property, background on Lyapunov stability and dynamic systems, control of a class of nonlinear systems and robot manipulators, feedback linearization, backstepping control, force control, neural observers, decentralized neural network control, neural network-based optimal control and applications. Prerequisite: Elec Eng 6300.

ELEC ENG 6360 Adaptive Dynamic Programming (LEC 3.0)
Review of Neurocontrol and Optimization, Introduction to Approximate Dynamic Programming (ADP), Reinforcement Learning (RL), Combined Concepts of ADP and RL - Heuristic Dynamic Programming (HDP), Dual Heuristic Programming (DHP), Global Dual Heuristic Programming (GDHP), and Case Studies. Prerequisites: Elec Eng 5370 or Comp Eng 5310. (Co-listed with Comp Eng 6320, Mech Eng 6458, Aero Eng 6458 and Sys Eng 6215).

ELEC ENG 6370 Adaptive Control (LEC 3.0)
Intro to adaptive control, Lypunov stability, positive real and strictly positive real, Kalman-Yukabovich lemma, system identification, direct/indirect adaptive control, adaptive observers, adaptive control design, nonlinear adaptive design tools-adaptive control with multiple models, adaptive neural network control, decentralized adaptive control design. Prerequisites: Elec Eng 6300. (Co-listed with MECH ENG 6470).

ELEC ENG 6400 Advanced Digital Signal Processing (LEC 3.0)
Continuation of Elec Eng 5400. Effects of discrete noise sources in digital signal processing; discrete spectral analysis of random signals; discrete time signal detection, estimation, and filtering algorithms. Prerequisites: Elec Eng 5400 or Elec Eng 5420; Elec Eng 5440 or Stat 5643.

ELEC ENG 6401 Introduction to Positioning, Navigation, and Timing (LAB 1.0 and LEC 2.0)
This course provides a technical introduction to Global Navigation Satellite Systems (GNSS), covering theory, procedures, and accuracy issues. Fundamental principles of GNSS measurements are covered, including the various sources of error that can affect their accuracy. Practical skills will be emphasized, including the ability to compute positions using both code and phase techniques, and utilize GNSS post-processing software. Quality control and assurance. Surveying techniques. Prerequisites: Geo Eng 3148 or graduate standing. (Co-listed with Geophys 6401).

ELEC ENG 6403 Advanced Positioning, Navigation, and Timing (LAB 1.0 and LEC 2.0)
Advanced topics in Global Navigation Satellite Systems (GNSS). Processing phase and code observations. Data Q/C, accuracy and precision estimates. Kalman filtering and other non-GNSS PNT systems will be explored. Practical applications and technology advancements will be emphasized. Prerequisites: Geophys 6401. (Co-listed with Geophys 6403).

ELEC ENG 6410 Information Theory And Coding (LEC 3.0)
Principles of information generation, transmission and processing; quantitative measure of information, entropy source encoding; channels; mutual information; channel capacity; Shannon's second theorem for discrete channels; introduction to coding for error controls; continuous information sources. Prerequisites: Elec Eng 5420 or Elec Eng 5440 or Stat 5643. (Co-listed with Comp Eng 6350).

ELEC ENG 6420 Wireless Communications (LEC 3.0)
Introduction to the principle of wireless communication systems. Topics include: wireless channel characteristics, cellular concepts, channel capacity analysis, transceiver architectures, diversity techniques, multiple access schemes, and practical wireless systems. Prerequisite: Elec Eng 5420 or Elec Eng 5440 or equivalent.

ELEC ENG 6430 Wireless Ad hoc and Sensor Networks (LEC 3.0)
Introduction to ad hoc and sensor networks, IEEE standards, heterogeneity, quality of service, wireless channel issues, energy awareness, power and topology control, routing, scheduling, rate adaptation, self-organization, admission and flow control, energy harvesting, security and trust levels, hardware and applications. Prerequisite: Comp Eng 5430 or Comp Eng 5420 or equivalent. (Co-listed with Comp Eng 6420 and Sys Eng 6324).

ELEC ENG 6440 Stochastic Signal Analysis II (LEC 3.0)
Continuous-time stochastic signals, multi-dimensional signals, Wiener and matched filters, LMS equalization, non-linear systems with random inputs, spectral estimation and Markov chains. Prerequisites: Stat 5643 or Elec Eng 5440.

ELEC ENG 6450 Statistical Decision Theory (LEC 3.0)
Classical detection and estimation theory with applications; hypothesis testing, detection of known signals, matched filter receiver implementation, detection of signals with unknown parameters, sequential and nonparametric detection, detection of stochastic signals: Parameter estimation theory with application to modulation. Prerequisite: Elec Eng 5440.

ELEC ENG 6490 Advanced Topics In Communications (LEC 3.0)
Advanced topics of current interest in communications and signal processing such as spread spectrum, digital processing of communications, speech, and radar signals, applications of pattern recognition, communications networks, specialized coding topics. Repeatable for additional credit toward degree each time a different subtitle offered. Prerequisite: Elec Eng 5420 or 5440.

ELEC ENG 6500 AC Drives: Dynamic and Control (LEC 3.0)
Introduction to a standardized formulation of energy conversion processes in electrical machines including the review and modeling of ac machines. Introduction to reference frame theory, modeling machines in rotational frames, and vector drive of ac machines. Introduction to a variety of topological, sensors, and tools used in practical motor drives. Taking steps to an experimental implementation of a vector-controlled ac drive. Prerequisites: Elec Eng 3500 and Elec Eng 5500.

ELEC ENG 6510 Advanced Electric Drive Vehicles (LEC 3.0)
This course covers an entire range of advanced topics related to the analysis, design, control, simulation, and optimization of electric, hybrid, and plug-in hybrid power-trains including the automotive applications of adjustable speed motor drives, energy storage systems, and advanced power converters. Prerequisite: Elec Eng 5500 or Elec Eng 5520.

ELEC ENG 6520 Advanced Power Electronics (LEC 3.0)
The purpose of this course is to cover selected areas of power electronics in greater depth. The topics covered include small signal analysis of power converters, voltage- and current- mode control, soft switching techniques, power factor correctors, multi-level converters, and PWM techniques. Prerequisite: Elec Eng 5520.

ELEC ENG 6525 Power Converter Modeling and Design (LEC 3.0)
Students will integrate electrical, magnetic, and thermal modeling techniques into a design process for switching power converters. A variety of applications will be considered, including dc-dc, ac-dc, and dc-ac converters over a wide power range. Prerequisite: Elec Eng 5520.

ELEC ENG 6530 Power System Reliability (LEC 3.0)
Reliability definition and measures. Probability concepts and Markov chains. Failure models and availability models. Generator system reliability. Loss of load probability method. Evaluation of transmission network reliability. Analysis of the electric power system reliability. Prerequisite: Stat 5643 or Elec Eng 5420.

ELEC ENG 6540 Computer Methods In Power System Analysis (LEC 3.0)
Algorithms for large scale system solution, non-linear systems, ordinary differential equations, eigenvalue problems, modal information, and optimization. Applications to power systems analysis. Prerequisite: Elec Eng 3540 or similar course.

ELEC ENG 6550 Power System Stability (LEC 3.0)
Synchronous machine theory and modelling; AC transmission; power system loads; excitation systems; control of active and reactive power; small signal stability; transient stability; voltage stability; mid-term and long-term stability; subsynchronous oscillations; stability improvement. Prerequisite: Elec Eng 3540 or similar course.

ELEC ENG 6560 Power System Protection (LEC 3.0)
Protective relaying incorporating electromechanical, solid state and computer relaying methods for high voltage transmission systems; instrument transformers; generator, transformer, line and bus protection; effect of system grounding; pilot protection and out of step relaying principles. Prerequisite: Elec Eng 5540.

ELEC ENG 6565 Power System Protection II (LEC 3.0)
Protective relaying advanced topics focusing on methods for generation and high voltage transmission systems; generator, motor, transformer, transmission line and bus protection; pilot protection and out of step relaying principles; and NERCPRC (Protective Relay and Control) reliability standard requirements. Prerequisite: Elec Eng 6560.

ELEC ENG 6570 Surge Phenomena In Power Systems (LEC 3.0)
Study of transmission system insulation, distributed constant lines, terminations, multiple reflections, lighting performance, characteristics of sustained and switching overvoltages, surge voltages due to system faults, energizing and reclosing of circuit breakers. Methods of reducing overvoltages to acceptable levels. Prerequisite: Elec Eng 5540.

ELEC ENG 6580 Power System Operations (LEC 3.0)
Optimal dispatch operations, economic loading of power plants, mathematical optimization, locational marginal pricing, optimal power flow; effect of hydro and wind power plants on system economics; contingency analysis and system security, state estimation. Prerequisite: Elec Eng 5540.

ELEC ENG 6600 Advanced Electromagnetics I (LEC 3.0)
Review of Maxwell's equations, constitutive relations, and boundary conditions. Wave propagation and polarization. Vector magnetic and electric potentials. Equivalent representations of fields, Babinet's principle. Circular waveguides. Green's functions. Prerequisite: Elec Eng 3600 or equivalent undergraduate electromagnetics course.

ELEC ENG 6610 Electromagnetic Waves II (LEC 3.0)
Circular waveguides, circular cavities, scattering by cylinders, apertures in cylinders, spherical cavities, orthogonality relationships, source of spherical waves, scattering by spheres, perturbational and variational techniques, microwave networks, probes in cavities, and aperture coupling to cavities. Prerequisite: Elec Eng 6600.

ELEC ENG 6630 Computational Electromagnetics (LEC 3.0)
Differential-equation based numerical methods-finite element, finite-difference, and finite-difference time-domain-for solving static and dynamic equations of electromagnetics. Applications considered are multi-conductor transmission lines, Maxwell's equations for radiation and scattering, and electric machinery. Prerequisite: Elec Eng 3600.

ELEC ENG 6640 Advanced Topics in Antenna Analysis and Design (LEC 3.0)
Introduction and discussion of advanced antenna design issues including: polarization, antenna synthesis and source modeling, broadband antennas, aperture and microstrip antenna simulation and design, and antenna pattern measurement techniques including near-field to far-field transformation. Prerequisite: Elec Eng 5640 or equivalent.

ELEC ENG 6830 Clustering Algorithms (LEC 3.0)
An introduction to cluster analysis and clustering algorithms rooted in computational intelligence, computer science and statistics. Clustering in sequential data, massive data and high dimensional data. Students will be evaluated by individual or group research projects and research presentations. Prerequisite: At least one graduate course in statistics, data mining, algorithms, computational intelligence, or neural networks, consistent with student's degree program. (Co-listed with Comp Eng 6330, Sys Eng 6214, Comp Sci 6405 and Stat 6239).
