ELECTRICAL AND COMPUTER ENGINEERING

Undergraduate Program Information
The undergraduate program of the Klipsch School is accredited by the Engineering Accreditation Commission of ABET, Inc., and stresses the development of analytical tools and physical concepts required to prepare students for immediate employment or graduate study. The program is flexible, allowing students to choose elective coursework towards concentrations in microelectronics and computers, communications and signal processing, control and power, or electromagnetics and photonics.

Graduate Program Information
The Klipsch School of Electrical and Computer Engineering offers graduate work leading to the Master of Science and Doctor of Philosophy degrees. Areas of emphasis for masters and doctoral students are:

- communications,
- computer engineering,
- control systems,
- digital signal processing,
- electromagnetics,
- electric energy systems,
- photonics, and
- microelectronics/VLSI.

Research in the above areas currently being conducted by the faculty ensures that doctoral candidates will work on the frontier of knowledge in these areas. The graduate programs are intended to provide broad, graduate-level training in electrical engineering. In addition, appropriate courses in computer science, industrial engineering, mathematics, physics and business management may be integrated into a graduate student's program of study.

Students desiring to work toward an advanced degree in electrical engineering must have completed undergraduate preparation substantially equivalent to that required for the Bachelor of Science in Electrical Engineering degree at this institution. For students with undergraduate degrees in other disciplines, see below. For further information on the Klipsch School of Electrical and Computer Engineering, please consult the web page http://www.ece.nmsu.edu/.

Research Facilities and Highlights
The Center for Telemetry and Telemetering hosts the Manuel Lujan, Jr. Space Tele-Engineering Program and the Frank Carden Chair for Telemetry and Telemetering. Faculty and staff in the Center are involved in education and research programs focusing on:

- telecommunications,
- communication theory,
- coding and information theory,
- wireless networks,
- digital signal processing,
- optical and radio frequency communications, and
- digital image processing.

The Center has several major research sponsors including NASA, the Department of Defense, and the National Science Foundation. The director of the Center and the Frank Carden Chair is Professor Dr. Charles Creusere.

The Advanced Speech and Audio Processing Laboratory is used for both teaching and research in digital signal processing (DSP). Current research areas include:

- speaker recognition,
- signal enhancement,
- low-bit rate coding,
- embedded DSP, and
- GPU-based pattern recognition for speech processing.

Research sponsors for the laboratory include Air Force Research Laboratories, Army Research Laboratory, National Geospatial Intelligence Agency, Freescale Semiconductor, IBM, Motorola, National Science Foundation, and Texas Instruments. The director of the laboratory is Dr. Phillip L. De Leon.

The New Mexico State University R.L. Golden Particle Astrophysics Lab (PAL) is dedicated to measuring and interpreting cosmic ray spectra in an effort to better understand the structure of our universe. Recent measurements of the galactic positron and electron spectra have connections to the dark matter mystery and to the identification of sources of cosmic rays. Additional studies of solar particles (measured along with cosmic rays) will help in the understanding of how solar eruptions affect the earth. The director of PAL is Dr. Steven Stochaj.

The Electromagnetics (EM) and Microwave Laboratory is used for both teaching and research in electromagnetic fields. Current research areas include:

- propagation through dispersive media (soil, seawater, foliage, biological tissues),
- UWB radar and remote sensing system analysis and design,
- antenna analysis, synthesis, and design,
- bio-electromagnetics,
- brain mapping,
- computational physics,
- electromagnetic interference and compatibility,
- high performance computing, and
- nondestructive evaluation.

Research sponsors for the laboratory include American Heart Association, Department of Defense, Los Alamos National Laboratory, NASA, NSF, National Institutes of Health, Sandia National Laboratories, and White Sands Missile Range. The Director of the Electromagnetics and Microwave Laboratory is Dr. Kwong T. Ng.

New Mexico State University's program in Electric Utility Management (EUMP) is sponsored by a group of public and private electric utility companies and industrial organizations and hosts the PNM Chair for Utility Management and The Kersting Professorship. The Master of Science in Electrical Engineering degree program includes course work in public utilities regulation and is designed to prepare the student for a future engineering management position in the electric utility industry. An industry advisory committee provides the vital connecting link between the electric utility industry and the university, so that a coordinated effort may be achieved in realizing the following program objectives:
1. to provide a program of study at the graduate level in the planning, operation, and management of electric power generation, transmission, distribution, and utilization; and the integration of renewable energy and storage;
2. to supply the electric utility industry with the highest caliber of new engineering and management talent; and
3. to provide the university with the required financial and technical support to ensure a quality program.

In addition, faculty in EUMP work with M.S. an Ph.D. students to conduct funded research sponsored by Sandia National Laboratories, EPRI, NSF, DOE, CEC and the electrical utility industry. Much of the current research is focused on renewable energy integration, protection, advanced control and optimization, and customer driven microgrids. Laboratory facilities are available in the El Paso Electric Power Systems laboratory. The program works closely with the Institute for Energy and Environment (IEE) and with Southwest Technology Development Institute (SWTDI) which host the solar energy experiment station. The director of the EUMP and PNM Chair for Utility Management is Dr. Satish Ranade.

Faculty and students in the VLSI Laboratory are involved in the design and analysis of analog and mixed-signal microelectronic circuits and systems. Current research areas include

- wireless bio-circuits and sensors;
- green computing;
- intelligent sensing, sigma-delta sensing;
- low-voltage, low-power circuits;
- high performance operational amplifiers and operational transconductance amplifiers;
- energy harvesting and power management circuits; and
- analog machine vision and image processing.

Research sponsors include the National Science Foundation, Los Alamos National Laboratories and Agilent technologies. The director of the VLSI Laboratory is IEEE Fellow Dr. Jaime Ramirez-Angulo.

The Photonics program at NMSU offers unique opportunities to undergraduate and graduate students interested in pursuing a career in electro-optics, applied optics, photonics, or optical engineering by combining the optics resources of the Klipsch School and the Physics Department. Most of the optics classes are cross-listed in the two departments. The Klipsch School’s Electro-Optics Research Laboratory (EORL) provides a variety of research opportunities in areas such as

- multispectral and polarimetric imaging,
- free-space optical communications,
- adaptive optics,
- nanophotonics and
- integrated electro-optic sensors and systems.

Sponsors include the Air Force Office of Scientific Research, Sandia National Laboratories, Air Force Research Laboratory, Army Research Laboratory, NASA, National Geospatial-Intelligence Agency and the National Science Foundation. SPIE Fellow Dr. David G. Voelz is the director of the EORL and NMSU’s Photonics program.

The Computer Networking Lab (CNL) supports teaching and research in Internet and wireless sensor networks. The mission of CNL is to provide students with the opportunity to do cutting-edge research that has high practical relevance. Currently, research projects in CNL include secure data dissemination in wireless sensor networks, solar-powered sensor networks, and RFID sensor networks. The major research sponsors of CNL include US Army, DHS, Intel, Los Alamos National Lab, and Sandia National Lab. CNL is directed by Dr. Hong Huang.

Students and faculty associated with the Performance Evaluation and Architecture Research Laboratory (PEARL) conduct research in the areas of

- performance modeling and simulation techniques,
- micro-architecture power optimization,
- performance analysis and optimization of large-scale scientific applications, and
- heterogeneous HPC computing for field-deployable systems.

PEARL sponsors include the Army Research Labs (ARL), High Performance Computing Research Center (AHPCRC), Sandia National Laboratories, and Los Alamos National Laboratories. The laboratory’s director is Dr. Hameed Badawy.

The Rio Grande Institute for Soft Computing (RioSoft) is committed to serving private-sector and U.S. government needs in researching and developing intelligent decision-support systems and tools that aid in many aspects of strategic decision-making. Soft computing which includes fuzzy logic, neural networks and evolutionary computation are used for modeling, analysis and control of complex dynamical processes in various software-hardware integrated architectures. In addition RioRoboLab, a NASA Ames funded laboratory, provides facilities for research and development of intelligent autonomous and semi-autonomous systems focusing on advanced concepts of energy harvesting and energy scavenging from ambient energy sources. Research sponsors include the Defense Threat Reduction Agency, Defense Advanced Research Projects Agency, Los Alamos National Laboratory and NASA. The director of RioSoft and RioRob Lab is Dr. Nadipuram (Ram) Prasad.

**Support for Graduate Students**

A number of teaching assistantships, research assistantships and fellowships are available. Teaching assistants are recommended by individual faculty for selection by the ECE Department’s Graduate Studies Committee. International students must pass university screening prior to being eligible for selection as a TA. Nominations for new TAs are made directly by the faculty member who has received a contract or grant for research.

The College of Engineering awards graduate scholarships and fellowships on behalf of Electrical and Computer Engineering. These include:

- the MIT/Lincoln Laboratory Fellowship,
- the Paul and Valerie Klipsch Grad Scholarship,
- the Admiral Paul Arthur Grad Scholarship, and
- the Barry Neil Rappaport Grad Scholarship.

Applications can be completed on-line at https://scholarships.nmsu.edu/ The priority deadline for the Scholar Dollars is March 1st. The Electrical Utility Management Program has a limited number of fellowships for students interested in pursuing master’s degrees in electrical energy systems.
Admission
Prospective graduate students for the Master of Science or Doctor of Philosophy in Electrical Engineering must first meet the entrance requirements of the Graduate School. The prospective US graduate student should make formal application to the Graduate Student Services office (http://gradschool.nmsu.edu). International graduate students must start with the Admissions Office (http://international.nmsu.edu/admissions.html). Official transcripts from all undergraduate and graduate institutions must be sent directly to the Graduate School. In addition, the student must arrange to have an official copy of the GRE (Graduate Record Examination) General Test scores sent to the Graduate School. International students must also submit their TOEFL (Test of English as a Foreign Language) scores. If the applicant meets the Graduate School’s minimum requirements, the application is sent to the Klipsch School’s Graduate Studies Committee for review. U.S. residents are given every chance of being successful in the pursuit of a graduate degree. If they do not meet the requirements of the Klipsch School, they can enter the Graduate School as “undeclared” where they must demonstrate competence in two or more graduate-level E E courses before they re-apply.

Requirements for Students Without BSEE Degree or Equivalent
Students without a BSEE degree or equivalent preparation will be expected to take classes covering the core knowledge required in our BSEE program. This includes mathematics through differential equations and basic engineering physics. The student’s graduate advisor will prepare an individualized deficiency schedule, based on the student’s academic background and work experience.

The following course from our undergraduate program will be considered deficiencies for students without a BSEE

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
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<tbody>
<tr>
<td>E E 100</td>
<td>Introduction to Electrical Engineering</td>
<td>4</td>
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<tr>
<td>E E 112</td>
<td>Embedded Systems</td>
<td>4</td>
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<tr>
<td>E E 200</td>
<td>Linear Algebra, Probability and Statistics Applications</td>
<td>4</td>
</tr>
<tr>
<td>E E 212</td>
<td>Introduction to Computer Architecture and Organization</td>
<td>4</td>
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<tr>
<td>E E 230</td>
<td>AC Circuit Analysis and Introduction to Power Systems</td>
<td>4</td>
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<tr>
<td>E E 240</td>
<td>Multivariate and Vector Calculus Applications</td>
<td>3</td>
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<td>E E 312</td>
<td>Signals and Systems I</td>
<td>3</td>
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<tr>
<td>E E 314</td>
<td>Signals and Systems II</td>
<td>4</td>
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<td>E E 351</td>
<td>Fields and Waves</td>
<td>4</td>
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<tr>
<td>E E 380</td>
<td>Semiconductor Devices and Electronics</td>
<td>4</td>
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Degrees for the Department
Electrical Engineering - Bachelor of Science in Electrical Engineering (http://catalogs.nmsu.edu/nmsu/engineering/electrical-computer-engineering/electrical-engineering-bachelor-science-electrical-engineering)

Electrical Engineering - Master of Science in Electrical Engineering (http://catalogs.nmsu.edu/nmsu/engineering/electrical-computer-engineering/electrical-engineering-master-science-electrical-engineering)

Electrical Engineering - Doctor of Philosophy (http://catalogs.nmsu.edu/nmsu/engineering/electrical-computer-engineering/engineering-doctor-philosophy)

Minors for the Department
Computer Engineering - Undergraduate Minor (http://catalogs.nmsu.edu/nmsu/engineering/electrical-computer-engineering/computer-engineering-undergraduate-minor)

Electrical Engineering - Undergraduate Minor (http://catalogs.nmsu.edu/nmsu/engineering/electrical-computer-engineering/electrical-engineering-undergraduate-minor)

The Klipsch School of Electrical and Computer Engineering
Professor, Satish Ranade, Department Head
Associate Professor, Paul Furth, Associate Department Head
Professor, Steve Stochaj, Associate Department Head

Professors: Borah, Creusere, DeLeon, Ng, Ramirez-Angulo, Ranade, Stochaj, Voelz. Associate Professors: Boucheron, Brahma, Cho, Dawood, Furth, Huang, Petersen, Prasad; Assistant Professors: Badawy, Mitchell, Tang; College Assistant Professors: Boehmer; Emeritus Professors: Carden, Giles, Sheila Horan, Stephen Horan, Johnson, Jordan, Kersting, Ludeman, Merrill, Reinfelds, Smolleck, Steelman, Taylor

Registered Professional Engineer (NM)

E E 100. Introduction to Electrical Engineering
4 Credits (3+3P)
Introduction to analog (DC) and digital electronics. Including electric component descriptions and equations, Ohm’s law, Kirchhoff’s voltage and current laws, ideal op-amp circuits, Boolean algebra, design of combinational and sequential logic circuits and VHDL or VERILOG.
Prerequisite(s): C or better in MATH 190.

E E 109. The Engineering of How Things Work
4 Credits (3+3P)
This class provides Integrated Learning Community students with an introduction to various aspects of engineering.

E E 112. Embedded Systems
4 Credits (3+3P)
Introduction to programming through microcontroller-based projects. Extensive practice in writing computer programs to solve engineering problems with microcontrollers, sensors, and other peripheral devices.
Prerequisite(s): C or better in E E 100.

E E 161. Computer Aided Problem Solving
4 Credits (3+3P)
Introduction to scientific programming. Extensive practice in writing programs to solve engineering problems. Items covered will include: loops, input and output, functions, decision statements, and pointers.
Pre/Corequisite(s): MATH 190G.

E E 162. Digital Circuit Design
4 Credits (3+3P)
Design of combinational logic circuits based on Boolean algebra. Introduction to state machine design. Implementation of digital projects with hardware description language.
Prerequisite(s): C or better in E E 161 and MATH 190G.
E E 200. Linear Algebra, Probability and Statistics Applications
4 Credits (3+3P)
The theory of linear algebra (vectors and matrices) and probability (random variables and random processes) with application to electrical engineering. Computer programming to solve problems in linear algebra and probability.
Prerequisite(s): C- or better in E E 112 and MATH 192G.

E E 201. Electric Circuit Analysis
3 Credits
Electric component descriptions and equations. Kirchhoff's voltage and current laws, formulation and solution of RLC network equations using time domain concepts. For nonmajors only. Minimum 2.0 GPA.
Prerequisite(s): C or better in MATH 192G.

E E 212. Introduction to Computer Architecture and Organization
4 Credits (3+3P)
Introduction to computer architecture and performance analysis techniques. Design and optimization of systems such as personal mobile devices and cloud computing systems.
Prerequisite(s): C- or better in E E 112 and MATH 190G.

E E 230. AC Circuit Analysis and Introduction to Power Systems
4 Credits (3+3P)
Electric component descriptions and equations; complete solutions of RLC circuits; steady-state analysis of AC circuits; introduction to frequency response techniques; introduction to power systems in the steady-state. May be repeated up to 4 credits. Restricted to: E E majors.
Prerequisite(s): C- or better in E E 100, PHYS 215G and MATH 192G.

E E 240. Multivariate and Vector Calculus Applications
3 Credits
Vector algebra, cylindrical and spherical coordinates, partial derivatives, multiple integrals. Calculus of vector functions through electrostatic applications. Divergence, gradient, curl, divergence theorem, Stokes' theorem, Coulomb's Law, Gauss's Law, electric field, electric potential. Applications in Matlab.
Prerequisite(s): C- or better in MATH 192G and E E 112.

E E 260. Embedded Systems
4 Credits (3+3P)
Applications of microcontrollers, FPGAs, interfaces and sensors. Introduction to Assembly language programming.
Prerequisite(s): C or better in E E 162.

E E 280. DC and AC Circuits
4 Credits (3+3P)
Electric component descriptions and equations; Kirchhoff's voltage and current laws; formulation and solution of network equations for dc circuits; ideal op-amp circuits. Complete solutions of RLC circuits; steady-state analysis of ac circuits, ac power; introduction to frequency response techniques.
Prerequisite(s): C or better in MATH 192G and PHYS 216G.

E E 300. Cornerstone Design
2 Credits
Application and realization of engineering principles to a guided team-based design project. Formulation and implementation of test procedures, evaluation of alternate solutions and oral and written communication of the design and test results. May be repeated up to 6 credits. Restricted to: E E majors. Restricted to Las Cruces campus only.
Prerequisite(s): C- or better in E E 212 and E E 230.

E E 310. Engineering Analysis II
3 Credits
Prerequisite(s): C- or better in E E 210 and MATH 291G.

E E 312. Signals and Systems I
3 Credits
Continuous and discrete time signals and systems. Linear, time-invariant systems. Fourier series, continuous and discrete time Fourier transforms. Time and frequency characterization of signals and systems. May be repeated up to 3 credits.
Prerequisite(s)/Corequisite(s): MATH 392. Prerequisite(s): C- or better in E E 210 and E E 280.

E E 314. Signals and Systems II
4 Credits (3+3P)
Introduction to communication systems including amplitude, frequency, and pulse-amplitude modulation. Introduction to control systems including linear feedback systems, root-locus analysis, Nyquist criterion. Introduction to digital signal processing including sampling, digital filtering, and spectral analysis. May be repeated up to 4 credits.
Prerequisite(s): C- or better in E E 312 and MATH 392.

E E 330. Environmental Management Seminar I
1 Credit

E E 351. Fields and Waves
4 Credits (3+3P)
Static electromagnetic field. Maxwell's equation and time-varying electromagnetic fields. Generalized plane wave propagation, reflection, transmission, superposition and polarization. Transmission line theory. Extensions to optical wave propagation. Applications including Time Domain Reflectometry (TDR) and fiber optic transmission. Laboratory experience with RF/microwave test equipment and optical apparatus. Restricted to Majors: Electrical Engineering.
Prerequisite(s): C- or better in E E 310.

E E 363. Computer Systems Architecture
4 Credits (3+3P)
Concepts of modern computer architecture. Processor microarchitectures, hardwired vs. micro-programmed control, pipelining and pipeline hazards, memory hierarchies, bus-based system architecture and memory mapping, hardware-software interface, and operating system concepts. Comparison of architectures to illustrate concepts of computer organization; relationships between architectural and software features.
Prerequisite(s): C or better in C S 273 or E E 260.

E E 380. Semiconductor Devices and Electronics
4 Credits (3+3P)
Prerequisite(s): C- or better in E E 230.
E E 391. Introduction to Electric Power Engineering
4 Credits (3+3P)
Introduction to the principles, concepts, and analysis of the major components of an electric power system. Basic electromechanics, energy conversion and source conversion, transformers, transmission lines, rectifiers, regulators, and system analysis.
Prerequisite(s): C or better in E E 280.

E E 395. Introduction to Digital Signal Processing
3 Credits
Undergraduate treatment of sampling/reconstruction, quantization, discrete-time systems, digital filtering, Z-transforms, transfer functions, digital filter realizations, discrete Fourier transform (DFT) and fast Fourier transform (FFT), finite impulse response (FIR) and infinite impulse response (IIR) filter design, and digital signal processing (DSP) applications.
Prerequisite(s): C or better in E E 314.

E E 400. Undergraduate Research
1-3 Credits
Directed undergraduate research. May be repeated for a maximum of 9 credits.
Prerequisite: consent of the department head.

E E 402. Capstone Design
3 Credits (2+3P)
Application and realization of engineering principles to a significant team-based design project with significant student management and autonomy. Determination of performance requirements, including safety, economics, ethics and manufacturability; extensive communication of design choices and test results to broad audiences; and interfacing of design with other hardware and software. May be repeated up to 3 credits. Restricted to: E E majors.
Prerequisite(s): C- or better in E E 300, E E 314, E E 351, and E E 380.

E E 418. Capstone Design I
3 Credits (1+6P)
Application of engineering principles to a significant design project. Includes teamwork, written and oral communications, and realistic technical, economic, and public safety requirements.
Prerequisite(s)/Corequisite(s): E E 461. Prerequisite(s): C or better in E E 260, E E 314, E E 351, E E 380, and E E 391.

E E 419. Capstone Design II
3 Credits (1+6P)
Realization of design project from E E 418 within time and budget constraints.
Prerequisite(s)/Corequisite(s): E E 461. Prerequisite(s): (C or better in E E 260, E E 314, E E 351, E E 380, and E E 391) OR (C or better in E E 418).

E E 425. Introduction to Semiconductor Devices
3 Credits
Energy bands, carriers in semiconductors, junctions, transistors, and optoelectronic devices, including light-emitting diodes, laser diodes, photodetectors, and solar cells. Taught with E E 525.
Prerequisite(s): C or better in E E 380 and E E 351.

E E 426. Introduction to Smart Grid
3 Credits
The course will serve as an introduction to the technologies and design strategies associated with the Smart Grid. The emphasis will be on the development of communications, energy delivery, coordination mechanisms, and management tools to monitor transmission and distribution networks. Taught with E E 546. Crosslisted with: C S 494.
Prerequisite(s): C- or better in E E 280.

E E 431. Power Systems II
3 Credits
Analysis of a power system in the steady-state. Includes the development of models and analysis procedures for major power system components and for power networks.
Prerequisites: C or better in E E 391.

E E 432. Power Electronics
3 Credits (2+3P)
Basic principles of power electronics and its applications to power supplies, electric machine control, and power systems.
Prerequisites: C or better in E E 380 and E E 391.
Corequisites: E E 312 and E E 314.

E E 438. Mobile Application Development
3 Credits
Introduction to mobile application development. Students will develop applications for iOS devices including iPhone and iPad. Topics include object-oriented programming using the Objective-C language, model-view-controller (MVC) pattern, memory management, view controllers, graphical user interface design, callbacks, and web services.
Corequisite(s): E E 161 or C S 172 or C S 271 or C S 450 or C S 451 or C S 452.

E E 443. Mobile Application Development
3 Credits
Introduction to mobile application development. Students will develop applications for iOS devices including iPhone and iPad. Topics include object-oriented programming using Swift, model-view-controller (MVC) pattern, view controllers including tables and navigation, graphical user interface (GUI) design, data persistence, GPS and mapping, camera, and cloud and web services. May be repeated up to 3 credits.
Prerequisite(s): C- or better in C S 172 or C S 177 or C S 187 or C S 271 or C S 450 or C S 451 or C S 452.

E E 446. Digital Image Processing
3 Credits
Two-dimensional transform theory, color images, image enhancement, restoration, segmentation, compression and understanding. Taught with E E 596. Prerequisite(s): E E 395

E E 447. Neural Signal Processing
3 Credits
Cross-disciplinary course focused on the acquisition and processing of neural signals. Students in this class will learn about basic brain structure, different brain signal acquisition techniques (fMRI, EEG, MEG, etc.), neural modeling, and EEG signal processing. To perform EEG signal processing, students will learn and use Matlab along with an EEG analysis package that sits on top of Matlab. Taught with E E 597.
Prerequisite(s): C- or better in E E 314.

E E 449. Smart Antennas
3 Credits
Smart antenna and adaptive array concepts and fundamentals, uniform and planar arrays, optimum array processing. Adaptive beamforming algorithms and architectures: gradient-based algorithms, sample matrix inversion, least mean square, recursive mean square, sidlobes cancellers, direction of arrival estimations, effects of mutual coupling and its mitigation. Taught with E E 549.
Prerequisite(s): C or better in E E 314 and E E 351.
E E 452. Introduction to Radar
3 Credits
Basic concepts of radar. Radar equation; detection theory. AM, FM, and CW radars. Analysis of tracking, search, MTI, and imaging radar. Taught with E E 548. Restricted to undergraduate students. Pre/Prerequisite(s): C or better in E E 210 and E E 351.
Corequisite(s): E E 496.

E E 453. Microwave Engineering
3 Credits
Topics for microwave measurements and communication system design, including transmitters, waveguide, and components. Microwave network analysis and active device design. Taught with E E 521. Restricted to undergraduate students. Restricted to: Main campus only.
Prerequisite(s): C or better in E E 351.

E E 454. Antennas and Radiation
3 Credits
Basic antenna analysis and design. Fundamental antenna concepts and radiation integrals. Study of wire antennas, aperture antennas, arrays, reflectors, and broadband antennas. Taught with E E 541. Restricted to undergraduate students. Restricted to: Main campus only.
Prerequisite(s): C or better in E E 351.

E E 460. Space System Mission Design and Analysis
3 Credits
Satellite system design, including development, fabrication, launch, and operations. A systems engineering approach to concepts, methodologies, models, and tools for space systems.
Prerequisite: junior standing.

E E 461. Systems Engineering and Program Management
3 Credits
Modern technical management of complex systems using satellites as models. Team project demonstrates systems engineering disciplines required to configure satellite components.
Prerequisite(s): Junior standing.

E E 469. Communications Networks
3 Credits (2+3P)
Introduction to the design and performance analysis of communications networks with major emphasis on the Internet and different types of wireless networks. Covers network architectures, protocols, standards and technologies; design and implementation of networks; networks for data, audio and video; performance analysis. Taught with E E 569.
Prerequisite(s): C or better in E E 162 and (E E 210 or STAT 371).

E E 473. Introduction to Optics
3 Credits
The nature of light, geometrical optics, basic optical instruments, wave optics, aberrations, polarization, and diffraction. Elements of optical radiometry, lasers, and fiber optics. Taught with: PHYS 473
Prerequisite(s): PHYS 216G or PHYS 217.

E E 475. Automatic Control Systems
3 Credits
Design and synthesis of control systems using state variable and frequency domain techniques. Compensation, optimization, multi-variable system design techniques.
Prerequisite(s): C or better in E E 314.

E E 476. Computer Control Systems
3 Credits
Representation, analysis and design of discrete-time systems using time-domain and z-domain techniques. Microprocessor control systems.
Prerequisite: C or better in E E 314.

E E 478. Fundamentals of Photonics
4 Credits (3+3P)
Crosslisted with: PHYS 478.
Prerequisite(s): PHYS 216G or PHYS 217.

E E 479. Lasers and Applications
4 Credits (3+3P)
Laser operation principles, characteristics, construction and applications. Beam propagation in free space and fibers. Laser diode construction and characteristics. Hands-on laboratory. Taught with E E 529. Crosslisted with: PHYS 479
Prerequisite(s): C or better in E E 351 or PHYS 461.

E E 480. Introduction to Analog and Digital VLSI
4 Credits (2+3P)
Introduction to analog and digital VLSI circuits implemented in CMOS technology. Design of differential amplifiers, opamps, CMOS logic, flip-flops, and adders. Introduction to VLSI fabrication and CAD tools. Taught with: E E 510.
Prerequisite(s): C or better in E E 260 and E E 380.

E E 482. Electronics II
3 Credits
Feedback analysis, application of operational amplifiers, introduction to data converters, analog filters, oscillator circuits.
Prerequisite: C or better in E E 380.

E E 485. Analog VLSI Design
3 Credits (2+3P)
Analysis, design, simulation, layout and verification of CMOS analog building blocks, including references, opamps, switches and comparators. Teams implement a complex analog IC. Taught with E E 523. Restricted to undergraduate students. Restricted to: Main campus only.
Prerequisite(s): C or better in E E 312 and E E 480.

E E 486. Digital VLSI Design
3 Credits
An introduction to VLSI layers. Static and dynamic logic design, memory circuits, arithmetic operators, and digital phase-locked loops. Taught with E E 524. Restricted to undergraduate students.
Prerequisite(s): C or better in E E 260 and E E 380.

E E 486 L. Digital VLSI Design Laboratory
1 Credit
Simulation, schematic capture, layout, and verification using software tools of material presented in E E 486. An introduction to measurement of digital VLSI circuits. Taught with E E 524L.
Prerequisite(s): C or better in E E 260 and E E 380.
Corequisite(s): E E 486.

E E 490. Selected Topics
1-3 Credits
May be repeated for a maximum of 9 credits. Graduate students may not use credits of E E 490 toward an M.S. or Ph.D. in electrical engineering.
Prerequisite: consent of instructor.
E E 493. Power Systems III
3 Credits
Analysis of a power system under abnormal operating conditions. Topics include symmetrical three-phase faults, theory of symmetrical components, unsymmetrical faults, system protection, and power system stability. Taught with E E 543. Restricted to undergraduate students. Pre/Prerequisite(s): C or better in E E 391. Corequisite(s): E E 431.

E E 496. Introduction to Communication Systems
4 Credits (3+3P)
Introduction to the analysis of signals in the frequency and time domains. A study of baseband digital transmission systems and digital/analog RF transmission systems. Introduction to telecom systems as well as satellite systems. Prerequisite(s): C or better in E E 314.

E E 497. Digital Communication Systems I
3 Credits
Techniques for transmitting digital data over commercial networks. Topics include baseband and bandpass data transmission and synchronization techniques. Taught with E E 581. Recommended foundation: E E 496. Prerequisite(s): E E 210 and E E 314.

E E 501. Research Topics in Electrical and Computer Engineering
1 Credit
Ethics and methods of engineering research; contemporary research topics in electrical and computer engineering.

E E 510. Introduction to Analog and Digital VLSI
4 Credits (3+3P)
Introduction to analog and digital VLSI circuits implemented in CMOS technology. Design of differential amplifiers, opamps, CMOS logic, flip-flops, and adders. Introduction to VLSI fabrication and CAD tools. Recommended preparation is E E 260 and E E 380 or equivalent. Taught with E E 480 with differentiated assignments for graduate students. Crosslisted with: E E 480.

E E 512. ASIC Design
3 Credits (2+3P)
This course provides students with experiential knowledge of modern application specific integrated circuits. Topics include ASIC packaging and testing, I/O pads and ESD, Verilog programming and simulation, FPGA verification, Register-transfer level synthesis, timing and area optimization, floorplanning and routing, digital interfaces, full custom and standard cell design, post-layout simulation, and PCB schematics and layout. Prerequisite(s): E E 486 or E E 524.

E E 514. Biosensor Electronics
3 Credits
Course provides students with knowledge of basic integrated analog and RF blocks and how to combine these circuits into sensory systems for biomedical applications. Target areas are in physiology, brain-machine interfaces, neural recording and stimulation. Lecture includes details on amplifiers, current-mode circuits, A/D converters, low-power radio transmitters and receivers, and simulation and layout of VLSI circuits. Lectures are in the form of recent paper reviews and discussion. Includes teamwork, written and oral communication, and realistic technical requirements. Pre/Prerequisite(s): E E 486 OR E E 524. Corequisite(s): E E 485 OR E E 523.

E E 515. Electromagnetic Theory I
3 Credits
Electromagnetic theory of time-harmonic fields in rectangular, cylindrical and spherical coordinates with applications to guided waves and radiated waves. Induction and equivalence theorems, perturbational and variational principles applied to engineering problems in electromagnetics. Recommended preparation is E E 351 or equivalent. Restricted to: Main campus only.

E E 516. Electromagnetic Theory II
3 Credits
Continuation of E E 515.

E E 518. Integrated Power Management Circuits
3 Credits
Design and analysis of power management integrated circuits, including linear voltage regulators, voltage references, buck, boost, and buck-boost DC-DC converters, and charge pumps. Extensive use of CAD tools are used to simulate these circuits. Pre/Prerequisite(s): E E 486 or E E 524. Corequisite(s): E E 485 or E E 523.

E E 519. RF Microelectronics
3 Credits

E E 520. A/D and D/A Converter Design
3 Credits
Practical design of integrated data converters in CMOS/BJT technologies, OP-AMPS, comparators, sample and holds, MOS switches, element mismatches. Nyquist rate converter architectures: flash, successive approximation, charge redistribution, algorithmic, two step, folding, interpolating, pipelined, delta-sigma converters. Restricted to: Main campus only. Prerequisite(s): E E 523.

E E 521. Microwave Engineering
3 Credits
Techniques for microwave measurements and communication system design, including transmission lines, waveguides, and components. Microwave network analysis and active device design. Recommended preparation is E E 351 or equivalent. Taught with E E 453 with differentiated assignments for graduate students. Restricted to: Main campus only.

E E 522. Advanced Analog VLSI Design
3 Credits
Design of high-performance operational amplifiers; class-AB, rail-to-rail, low-voltage, high-bandwidth, fully-differential. Design of linear operational transconductance amplifiers, high-frequency integrated filters, four-quadrant multipliers, and switched-capacitor circuits. Prerequisite(s): E E 523.

E E 523. Analog VLSI Design
3 Credits (2+3P)
Analysis, design, simulation, layout and verification of CMOS analog building blocks, including references, opamps, switches and comparators. Teams implement a complex analog IC. Recommended preparation is E E 312 and E E 480 or equivalent. Taught with E E 485 with differentiated assignments for graduate students. Restricted to: Main campus only.
E E 524. Digital VLSI Design
3 Credits
An introduction to VLSI layers. Static and dynamic logic design, memory circuits, arithmetic operators, and digital phase-locked loops. Taught with E E 486 with differentiated assignments for graduate students. Recommended foundation: E E 260 and E E 380.

E E 524 L. Digital VLSI Design Laboratory
1 Credit
Simulation, schematic capture, layout, and verification using software tools of material presented in E E 524. An introduction to measurement of digital VLSI circuits. Taught with E E 486L with differentiated assignments for graduate students.

E E 525. Introduction to Semiconductor Devices
3 Credits
Energy bands, carriers in semiconductors, junctions, transistors, and optoelectronic devices, including light-emitting diodes, laser diodes, photodetectors, and solar cells. Recommended preparation is E E 380 and E E 351. Taught with: E E 425 with differentiated assignments for graduate students.

E E 528. Fundamentals of Photonics
4 Credits (3+3P)
Ray, wave and guided optics, lasers and thermal sources, radiometry, photon detection and signal-to-noise ratio. Elements of photonic crystals, polarization, acousto-optics, electro-optics, and optical nanostructures. Taught with E E 478 with differentiated assignments for graduate students. Recommended foundation: (PHYS 216 or PHYS 217) and E E/PHYS 473. Crosslisted with: PHYS 528.

E E 529. Lasers and Applications
4 Credits (3+3P)
Laser operating principles, characteristics, construction and applications. Beam propagation in free space and fibers. Laser diode construction and characteristics. Hands-on laboratory. Recommended foundation: E E 351 or PHYS 461. Taught with: E E 479 with differentiated assignments for graduate students. Crosslisted with: PHYS 529

E E 530. Environmental Management Seminar I
1 Credit
Same as CH E 530, C E 530, I E 530.

E E 531. Power System Modeling and Computational Methods
3 Credits
Development and analysis of fast computational methods for efficient solution of large scale power-system problems. Algorithms for constructing the bus impedance matrix; sparse matrix techniques; partial-inverse methods; compensation of mutual coupling. Pre/Restricted to: Main campus only.
Corequisite(s): E E 543.

E E 532. Dynamics of Power Systems
3 Credits
Transient and dynamic stability of power systems; synchronous machine modeling and dynamics; prediction and stabilization of system oscillations. Recommended preparation is E E 493 or equivalent. Restricted to: Main campus only.

E E 533. Power System Operation
3 Credits
AGC, economic dispatch, unit commitment, operations planning, power flow analysis and network control, system control centers. Recommended preparation is E E 493 or equivalent. Restricted to: Main campus only.

E E 534. Power System Relaying
3 Credits
Fundamental relay operating principles and characteristics. Current, voltage, directional, differential relays; distance relays; pilot relaying schemes. Standard protective schemes for system protection. Operating principles and overview of digital relays. Recommended preparation is E E 493 or equivalent.

E E 537. Power Electronics
3 Credits (2+3P)
Basic principles of power electronics and its applications to power supplies, electric machine control, and power systems. Recommended preparation is E E 314, E E 380, and E E 391. Taught with E E 432 with differentiated assignments for graduate students.

E E 541. Antennas and Radiation
3 Credits
Basic antenna analysis and design. Fundamental antenna concepts and radiation integrals. Study of wire antennas, aperture antennas, arrays, reflectors, and broadband antennas. Recommended preparation is E E 351 or equivalent. Taught with E E 454 with differentiated assignments for graduate students. Restricted to: Main campus only.

E E 542. Power Systems II
3 Credits
Analysis of a power system in the steady-state. Includes the development of models and analysis procedures for major power system components and for power networks. Recommended preparation is E E 391 or equivalent. Taught with E E 431 with differentiated assignments for graduate students. Restricted to: Main campus only.

E E 543. Power Systems III
3 Credits
Analysis of a power system under abnormal operating conditions. Topics include symmetrical three-phase faults, theory of symmetrical components, unsymmetrical faults, system protection, and power system stability. Recommended preparation is E E 431 or equivalent. Taught with E E 493 with differentiated assignments for graduate students. Restricted to: Main campus only.

E E 544. Distribution Systems
3 Credits
Concepts and techniques associated with the design and operation of electrical distribution systems. Recommended preparation is E E 542 and E E 543. Taught with E E 494 with differentiated assignments for graduate students.

E E 545. Digital Signal Processing II
3 Credits
Non-ideal sampling and reconstruction, oversampling and noise shaping in A/D and D/A, finite word length effects, random signals, spectral analysis, multirate filter banks and wavelets, and applications. Recommended preparation is E E 395 or equivalent. Restricted to: Main campus only.

E E 546. Introduction to Smart Grid
3 Credits
The course will serve as an introduction to the technologies and design strategies associated with the Smart Grid. The emphasis will be on the development of communications, energy delivery, coordination mechanisms, and management tools to monitor transmission and distribution networks. Taught with E E 426. Crosslisted with: C S 514.
E E 548. Introduction to Radar
3 Credits
Basic concepts of radar. Radar equation; detection theory, AM, FM, and CW radars. Analysis of tracking, search, MTI, and image radar. Recommended preparation is E E 310, E E 351, and E E 496 or equivalent. Taught with E E 452 with differentiated assignments for graduate students. Restricted to: Main campus only.

E E 549. Smart Antennas
3 Credits
Smart antenna and adaptive array concepts and fundamentals, uniform and planar arrays, optimum array processing. Adaptive beamforming algorithms and architectures: gradient-based algorithms, sample matrix inversion, least mean square, recursive least mean square, sidelobes cancellers, direction of arrival estimations, effects of mutual coupling and its mitigation. Taught with E E 449. Recommended foundation is E E 314 and E E 351.

E E 551. Control System Synthesis I
3 Credits
An advanced perspective of linear modern control system analysis and design, including the essential algebraic, structural, and numerical properties of linear dynamical systems.

E E 552. Control System Synthesis II
3 Credits
An overview of optimal controls for linear dynamical systems, analysis and design of control systems using Lyapunov techniques, control system design using semidefinite programming. An introduction to stochastic filtering and control.

E E 555. Advanced Linear Systems
3 Credits
Advanced level study of linear systems and associated mathematical tools including linear equations, spectral theory, normal matrices, projections, quadratic forms, discrete and continuous time dynamical systems. Recommended preparation is MATH 480 or equivalent. Restricted to: Main campus only.

E E 563. Computer Performance Analysis I
3 Credits
Issues involved and techniques used to analyze performance of a computer system. Topics covered include computer system workloads; statistical analysis techniques such as principal component analysis, confidence interval, and linear regression; design and analysis of experiments; queuing system analysis; computer system simulation; and random number generation. Recommended foundation: E E 210 and E E 363.

E E 564. Advanced Computer Architecture I
3 Credits
Multiprocessor and distributed computer architectures; models of parallel computation; processing element and interconnection network structures, and nontraditional architectures. Recommended preparation is E E 363 or equivalent. Crosslisted with: C S573.

E E 565. Pattern Recognition and Machine Learning
3 Credits
Statistical pattern classification, supervised and unsupervised learning, feature selection and extraction, clustering, image classification and syntactical pattern recognition. Recommended preparation is E E 210 or equivalent probability and statistics and linear algebra courses.

E E 567. ARM SOC Design
3 Credits
The course aims to produce students who are capable of developing ARM-based SoCs from high level functional specifications to design, implementation and testing on real FPGA hardware using standard hardware description and software programming languages. 

Prerequisite(s): C+ or higher in E E 512.

E E 569. Communications Network
3 Credits (2+3P)
Introduction to the design and performance analysis of communications networks with major emphasis on the Internet and different types of wireless networks. Covers network architectures, protocols, standards and technologies; design and implementation of networks; networks applications for data, audio and video; performance analysis. Taught with E E 469. Recommended foundation is E E 162 and (E E 210 or STAT 371).

E E 571. Random Signal Analysis
3 Credits
Application of probability and random variables to problems in communication systems, analysis of random signal and noise in linear and nonlinear systems.

E E 572. Modern Coding Theory
3 Credits
Error control techniques for digital transmission and storage systems. Introduction to basic coding bounds, linear and cyclic block codes, Reed-Solomon codes, convolutional codes, maximum likelihood decoding, maximum a posteriori probability decoding, factor graphs, low density parity check codes, turbo codes, iterative decoding. Applications to data networks, space and satellite transmission, and data modems. Recommended foundation is E E 210 and E E 496.

E E 573. Signal Compression
3 Credits
Fundamentals of information source encoding and decoding. Includes information theory bounds on source coding, lossless coding algorithms, scalar quantizing and vector quantizing. 

Prerequisite: E E 571.

E E 577. Fourier Methods in Electro-Optics
3 Credits
Linear systems theory, convolution and Fourier transformation are applied to one-dimensional and two dimensional signals encountered in electro-optical systems. Applications in diffraction, coherent and incoherent imaging, and optical signal processing. Recommended foundation: E E 312 and E E 528. Crosslisted with: PHYS 577.

E E 578. Optical System Design
3 Credits
Optical design software is used to study optical systems involving lenses, mirrors, windows and relay optics. Systems considered include camera lenses, microscopes and telescopes. Recommended foundation: E E/PHYS 473, E E/PHYS 528 and E E/PHYS 577. Crosslisted with: PHYS 578.

E E 581. Digital Communication Systems I
3 Credits
Techniques for transmitting digital data over commercial networks. Topics include baseband and bandpass data transmission and synchronization techniques. Recommended foundation is E E 210, E E 314, and E E 496. Taught with E E 497.
E E 583. Wireless Communication
3 Credits
Cellular networks, wireless channels and channel models, modulation and demodulation, MIMO, diversity and multiplexing, OFDM, wireless standards including LTE and WiMAX. Recommended foundation: E E 571 or equivalent.
Prerequisite(s): E E 314 or E E 571.

E E 584. Mathematical Methods for Communications and Signal Processing
3 Credits
Applications of mathematical techniques from estimation theory, optimization principles and numerical analysis to the problems in communications and signal processing.
Prerequisites: E E 571 and E E 555 or knowledge of linear algebra.

E E 585. Telemetering Systems
3 Credits
Covers the integration of components into a command and telemetry system. Topics include analog and digital modulation formats, synchronization, link effects, and applicable standards. Recommended preparation is E E 395, E E 496, and E E 497, or equivalent. Restricted to: Main campus only.

E E 586. Information Theory
3 Credits
This class is a study of Shannon’s measure of information and discusses mutual information, entropy, and channel capacity, the noiseless source coding theorem, the noisy channel coding theorem, channel coding and random coding bounds, rate-distortion theory, and data compression. Restricted to: Main campus only. Crosslisted with: MATH 509
Prerequisite(s): E E 571 or STAT 515.

E E 590. Selected Topics
1-9 Credits
May be repeated for a maximum of 18 credits.

E E 593. Mobile Application Development
3 Credits
Introduction to mobile application development. Students will develop applications for iOS devices including iPhone and iPad. Topics include object-oriented programming using Swift, model-view-controller (MVC) pattern, view controllers including tables and navigation, graphical user interface (GUI) design, data persistence, GPS and mapping, camera, and cloud and web services. Taught with E E 443 with differentiated assignments for graduate students. Recommended foundation is C++ or Java programming course. May be repeated up to 3 credits.

E E 596. Digital Image Processing
3 Credits
Two-dimensional transform theory, color images, image enhancement, restoration, registration, segmentation, compression and understanding. Recommended foundation is E E 571. Taught with E E 446.

E E 597. Neural Signal Processing
3 Credits
Cross-disciplinary course focused on the acquisition and processing of neural signals. Students in this class will learn about basic brain structure, different brain signal acquisition techniques (fmri, EEG, MEG, etc.), neural modeling, and EEG signal processing. To perform EEG signal processing, students will learn and use Matlab along with an EEG analysis package that sits on top of Matlab. Taught with E E 447.

E E 598. Master’s Technical Report
9 Credits
Individual investigation, either analytical or experimental, culminating in a technical report. May be repeated for a maximum of 18 credits. Graded PR/S/U.

E E 599. Master’s Thesis
15 Credits
Thesis.

E E 600. Doctoral Research
1-15 Credits
Research.

E E 615. Computational Electromagnetics
3 Credits
The numerical solution of electromagnetics problems. Topics include differential equation techniques, integral equation methods, hybrid techniques, algorithm development and implementation, and error analysis. Particular algorithms, including FEM, finite differences, direct solvers, and iterative solvers, are studied.

E E 690. Selected Topics
1-9 Credits
May be repeated for a maximum of 9 credits.

E E 700. Doctoral Dissertation
15 Credits
Dissertation.

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