Electrical and Computer Engineering

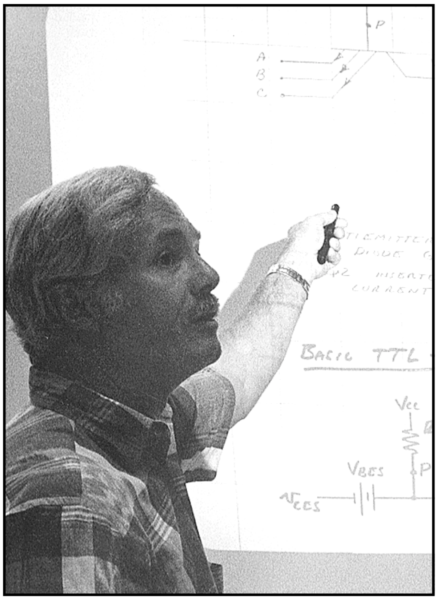
The Department

The Department of Electrical and Computer Engineering offers Bachelor of Science degrees in Electrical Engineering and Computer Engineering. Although many courses are common to both programs, there are significant differences between the graduation requirements for electrical engineering and for computer engineering. Students are advised to decide early in their program of study which major they intend to pursue. The department also offers a master's degree in engineering with emphasis in electrical engineering in cooperation with Edwards Air Force Base. For more information, see the Master of Engineering Program, page 311-312.

Mission and Educational Objectives

The mission of the Department of Electrical and Computer Engineering is to fulfill the needs of the region and state by providing an undergraduate technical education in electrical engineering and computer engineering to a diverse group of students. Additionally, the department strives to continually update its strong program of study in order to qualify its graduates for positions in industry located in the region and beyond while providing sufficient breadth and depth in its program to assure its graduates a successful practice in the profession. At the same time, students are grounded in the rigorous scientific and theoretical foundations of the discipline, in order not only to enable graduates to enter and be successful in any advanced level educational program of their choosing, but also to be able to build upon this strong foundation and extend it to new depths.

The faculty members possess depth and breadth in their specialty areas and are active in bringing these experiences and skills to the classroom. The identifiable strengths of the academic program are the laboratory and hands-on experience for students, the proper attention given to the scientific and mathematical foundation of electrical engineering and computer engineering, and the rigor of upper-division courses coupled with design and culminating senior projects. The technical and liberal arts components of the curriculum provide the students with the opportunity for gaining self-development, technical competence, and awareness of economic and ethical responsibilities. The technical curriculum includes (1) basic engineering science, (2) core electrical and computer engineering subjects, and (3) a junior-/senior-level choice for more depth in communications and analog systems, power systems and controls, or digital systems and computers.



The department has a mandatory advising program to help students make sound academic decisions.

Electrical Engineering

The Electrical Engineering Program is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (ABET).

Electrical engineers design and develop electronic circuits, equipment and systems in the areas of electromagnetics (antennas; radar, radio, and television systems), communications and control (telephone systems, satellite communications; laser and optical fiber communications; aircraft and missile guidance systems), computers and digital systems (computers, microprocessors, and microcomputers; artificial intelligence), physical electronics and optics (transistors; integrated circuits; optical display devices; lasers; optical fibers), power systems and energy conversion (hydro, thermal, nuclear, solar electric power generation; analysis and synthesis of power transmission and distribution systems; on-line power control and dispatch centers), and control systems (computer control, robotics, automated manufacturing, intelligent sensors).

College of Engineering
and Computer Science

Department of Electrical and Computer Engineering
Nagy N. Bengiamin, *Chair*
Engineering East Building, Room 254
(559) 278-2726

B.S. in Electrical Engineering

B.S. in Computer Engineering

M.S. in Engineering, Electrical Engineering Option
(see page 311-312)

Computer Engineering

The Computer Engineering Program is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (ABET). Computer engineering is a discipline which allows the student to obtain expertise in the design, programming, and applications of computers. It prepares the graduate for professional practice or graduate studies. The program combines:

a. A strong emphasis on electrical engineering (primarily electronic circuits and systems)
b. A broad basis in mathematics, physical science, and general engineering
c. Fundamentals of computer science including programming methodology, software engineering, and operating systems
d. Introductory and advanced concepts in the design of computers and computer systems

A rich set of technical area courses is available to allow students to broaden their knowledge within any of several computer engineering areas.

Organizations

Student chapters of the Institute of Electrical and Electronic Engineers and Eta Kappa Nu (the national honor society for electrical engineers) are active in the department. The College of Engineering and Computer Science, in addition, has chapters of Tau Beta Pi, the Society of Women Engineers, the Society of Hispanic Engineers, and the National Society of Black Engineers.

Co-op Program

The department participates in the Cooperative Educational Program which allows students to integrate planned industrial experiences into their academic programs. Students interested in this program should contact the chair of the Department of Electrical and Computer Engineering and the campus co-op coordinator.

Administrative Academic Probation

A minimum GPA of 2.0 must be maintained in all courses taken in the College of Engineering and Computer Science. Students who fail to maintain a 2.0 GPA in courses within their major may be placed on administrative academic probation. Failure to eliminate the grade point deficiency can result in disqualification from the College of Engineering and Computer Science.

Mandatory Advising

Students must complete mandatory advising with a faculty member at least once during each academic year. Students who fail to do so by the established deadline (usually around the end of April) will be prevented from participating in the STAR registration process prior to the start of classes.

Career Opportunities

According to a report by the American Electronics Association, a shortage of electrical and computer engineers is projected for the next several years; it is anticipated that computer engineering positions will increase more than any other major profession. New developments are evolving in optical communications, microelectronics, intelligent controls, computers, radar, microwave communications, and innovative alternative energy sources at an explosive pace which should assure a solid growth pattern for electrical and computer engineers into the foreseeable future.

Faculty

Nagy N. Bengiamin, *Chair*
Daniel C. Bukofzer
Albert A. Heaney
Robert W. Hecht
Ramakrishna Nunna
Larry D. Owens
Robert D. Regier

Faculty and Facilities

The faculty, comprised of academically well-qualified engineers, have a wide range of teaching and industrial experience. Their backgrounds include significant research accomplishments, engineering teaching experience, consulting work, and related engineering experience.

Excellent facilities are housed in the Engineering East Building. A 52,000 square-foot engineering building addition provides additional classroom space, faculty offices, and expanded modern laboratories that include: a microcomputer laboratory, a CAD/CAM laboratory, and laboratories for microprocessors and digital systems, electronics, computer development, optical communications, digital control/robotics, special projects, and power systems.

Bachelor of Science Degree Requirements[1]

Electrical Engineering Major — Units

Major requirements **69**
- ECE 1, 71, 85, 85L, 90, 90L, 102, 118, 121, 124, 125, 126, 128, 128L, 138, 138L, 155, 186A or 186B .... (44)
- Select two from ECE 119L, 120L, 121L, 136L .... (2)
- CE 29 or ME 29 .... (3)
- IE 160, IE 182W .... (5)
- ME 136 .... (3)
- Technical Area Courses .... (12)
  - Select mandatory technical area courses from the following (at least two courses from the same group):
  - *Electronics and Communications (including Telecommunications):* ECE 134, 135, 136, 136L, 140, 162, 166, 168, 171, 176
  - *Computers and Digital Systems:* ECE 106, 107, 115, 132, 146, 148, 172, 173, 174
  - *Power and Control Systems and Energy Conversion:* ECE 151, 152, 173; ME 116

Other requirements **67**
- General Education
  - Select one course from each of the G.E. areas: Area A1, A2, B2, C1, D1, D2, D3. (See pages 93-96 for G. E. listings.)
  - The following courses are required to satisfy both G.E. and additional requirements: MATH 75 [B4], CHEM 1A [B1], PHIL 20 [C2], ECE 114 [IB], PHIL 120 [IC], PLSI 120 [M/I]
- Additional requirements
  - MATH 76, 77, 81
  - PHYS 4A; PHYS 4B, 4BL; PHYS 4C; choose one from MATH 121, 123, 128, 152, 171, 181, 182

Total **136**

Note: Engineering majors are exempt from G.E. Area A3, third course Area C, Area E, and Area ID.

Advising Notes

1. Courses in mathematics, the physical sciences, or engineering taken *CR/NC* are not counted toward fulfillment of degree requirements in electrical engineering.
2. Electrical engineering majors might consider a math minor (see faculty adviser for details).
3. Since the electrical engineering major curriculum is very demanding, some students not fully prepared in mathematics and the physical sciences may take 4½ or more years to graduate rather than the traditional 4 years. Students not fully prepared in chemistry should consider taking CHEM 3A in lieu of CHEM 1A. If needed, students may go to the Learning Resource Center in Lab School, Room 137 and request tutorial assistance.

See the catalog Web Site for recommended program at *http://www.csufresno.edu/catoffice/current/engelrec.html*.

Bachelor of Science Degree Requirements[1]

Computer Engineering Major — Units

Major requirements **64**
- ECE 1, 85, 85L, 90, 90L, 115, 118, 120L, 124, 125, 128, 128L, 148, 186A or 186B ... (32)
- CE 29 or ME 29 .... (3)
- IE 160, IE 182W .... (5)
- Computer Design Option
  - ECE 174 .... (3)
  - CSCI 144 or 156, 150 .... (6)
- Technical Area .... (15)
  - *Design Courses (at least 6 units)*
    ECE 106, 107, 132, 138, 138L, 140, 176
  - *Technical Area Courses*
    ECE 134, 135, 146, 155, 172

Other requirements **72**

General Education
Select one course from each of the G.E. areas: Area A1, A2, B2, C1, D1, D2, D3. (See pages 93-96 for G. E. listings.)
The following courses are required to satisfy both G.E. and major requirements: MATH 75 [B4], CHEM 1A [B1], PHIL 20 [C2], ECE 114 [IB], PHIL 120 [IC], Pl SI 120 [M/I]
Additional requirements
MATH 76, 77, 81; PHYS 4A-C, 4BL; CSCI 40, 41

Total 136

. Note: Engineering majors are exempt from G.E. Area A3, third course Area C, Area E, and Area ID.

Advising Notes

1. Courses in mathematics, the physical sciences, or engineering taken *CR/NC* are not counted toward fulfillment of degree requirements in computer engineering.
2. Computer engineering majors might consider a math minor. (See faculty adviser for details.)
3. Since the computer engineering major curriculum is very demanding, some students not fully prepared in mathematics and the physical sciences may take more than the traditional 4 years to graduate. Students not fully prepared in chemistry should consider taking CHEM 3A in lieu of CHEM 1A. If needed, students also may go to the Learning Resource Center in Lab School, Room 137 and request tutorial assistance.

See the catalog Web Site for recommended program at *http://www.csufresno.edu/catoffice/current/engelrec.html*.

COURSES

Electrical and Computer Engineering (ECE)

Note: Students may be expected to purchase supplementary materials for senior projects and special topic laboratory and activity classes.

1. Introduction to Electrical and Computer Engineering (1)
The electrical and computer engineering professions, career opportunities and preparation, orientation to the department and college, exposure to computer productivity tools, laboratory safety, and hands-on projects.

70. Engineering Computations Using C and FORTRAN (3)
Prerequisites: Students must take the ELM exam; students who do not pass the exam must record a grade of *C* or better in a college-taught intermediate algebra course; trigonometry. Use of FORTRAN and C computer languages in engineering analysis and design. A systematic development in program structure, specification, testing, and debugging.

71. Engineering Computations (3)
Prerequisites: Students must take the ELM exam; students who do not pass the exam must record a grade of *C* or better in a college-taught intermediate algebra course; trigonometry. Use of the C programming language in engineering analysis and design. A systematic development in program structure, specification, documentation, testing, and debugging.

85. Digital Logic Design (3)
Discrete mathematics, logic, and Boolean algebra. Number systems and binary arithmetic, logic gates, combinatorial logic, minimization techniques. Analysis and design of combinatorial circuits. Flipflops, multivibrators, registers, and counters. Introduction to sequential circuits and state machines. Synchronous state machine design.

85L. Digital Logic Design Laboratory (1)
Prerequisite: ECE 85 or concurrently. Usage, design, and implementation techniques for combinatorial and sequential circuits. Experiments utilizing logic gates, Karnaugh maps, multiplexers, decoders, programmable logic devices, latches, flipflops, counters and shift registers. Combinatorial and state machine design projects. Computer Assisted Engineering (CAE). (3 lab hours)

90. Principles of Electrical Circuits (3)
Prerequisites: PHYS 4B; MATH 77 or concurrently. Direct-current circuit analysis; circuit theorems; transient phenomena in RL and RC circuits, phasor concept; sinusoidal steady-state response; power and RMS calculations in single-phase and polyphase alternating-current circuits; principles of electrical instruments; computer solutions. (CAN ENGR 12)

90L. Principles of Electrical Circuits Laboratory (1)
Prerequisite: ECE 90 or concurrently. Experiments on direct- and alternating-current circuits, including single-phase and polyphase systems. Use of electrical instruments, development of laboratory techniques, and verification of basic principles. (3 lab hours)

91. Introduction to Electrical Engineering (3)
Prerequisites: PHYS 4B; MATH 76. (No credit given for ECE 91 if taken after ECE 90). Direct current circuit analysis, transient and AC steady state circuit analysis, basic electronics, diodes, transistors, digital systems, digital logic circuit, simple microprocessors, DC and AC machines.

91L. Introduction to Electrical Engineering Laboratory (1)
Prerequisites: ECE 91 or concurrently. Experiments on direct and alternating current, basic electronics, digital logic circuits, and electric machines.

102. Advanced Circuit Analysis (3)
Prerequisites: MATH 81, ECE 90. Transfer functions, RLC transient circuit analysis, mutual inductance, transformers, two-port circuits, pole-zero analysis, Bode plots, stability concepts, circuit response to periodic inputs, Lapace solution techniques, frequency response, analysis of active circuits.

106. Switching Theory and Logical Design (3)
Prerequisite: ECE 85 or equivalent. Quine-McCluskey minimization; switching functions; finite and nonfinite state machines; state assignments; synchronous and asynchronous machines; incompletely specified sequential circuits; pulse-mode circuits.

107. Digital Signal Processing (3)
Prerequisites: ECE 70 or CSCI 40; ECE 85, 124. Data acquisition by computers, numerical evaluation of Fourier transforms, A/D and D/A conversion, digital filter design, programming, and emulation of a popular digital signal processor.

114. Physical Electronics (3)
Prerequisites: PHYS 4C, ECE 128 or concurrently. Semiconductor fundamentals: the valence bond and energy band models of solids, carrier densities and current components. Discrete devices: the pn junction

diode, BJT, MOS FET, and JFET; the Schottky barrier diode and GaAs MESFET. Integrated circuits and VLSI Systems. Modern fabrication techniques for discrete and integrated devices.

115. Computer Organization (3)
Prerequisites: ECE 85 and either CSCI 40 or ECE 70. Structural organization, hardware architecture and design of digital computer systems; binary representation of data; CPU, memory and I/O organization; register transfer and micro-operations; hardware/software design trade-offs. Introduction to RISC architecture and memory organization.

118. Microprocessor Architecture and Programming (3)
Prerequisite: ECE 85 and either CSCI 40 or ECE 70. Binary representation of data. Hardware architecture and programming models of a microprocessor. Assembly Language program specifications, development, testing, and documentation. Modular programming, parameter passing, macros.

119L. Senior Laboratory (1)
Prerequisite: senior standing and permission of instructor. Hands-on experience in topics in electrical and computer engineering. (3 lab hours)

120L. Computer Systems Laboratory (1)
Prerequisite: ECE 118. Experiments on computer architecture and systems; logic analyzers; serial communications; hardware and software development. Design projects. (3 lab hours)

121. Electromechanical Systems and Energy Conversion (3)
Prerequisites: ECE 90 or ECE 91. Principles of direct- and alternating-current machinery and other energy-conversion devices and associated apparatus.

121L. Electromechanical Systems and Energy Conversion Laboratory (1)
Prerequisite: ECE 121 or concurrently. Experiments and computations on direct- and alternating-current machinery and on other energy-conversion devices and associated apparatus. (3 lab hours)

124. Signal and Systems (3)
Prerequisites: ECE 90, MATH 81. Analysis of discrete and continuous linear circuits, systems, and signals. Fourier transforms, Fourier series. Difference equations, frequency response, Z-transform. Idealized sampling and aliasing. Stability analysis.

125. Random Signals and Stochastic System Analysis (3)
Prerequisites: MATH 81, ECE 124. Probability theory and statistical principles, random variables and their characterization, transformations of random variables, random processes, correlations and power spectral densities, noise characterization and noise figure, systems' response to stochastic inputs, matched filters, applications to communication and control systems.

126. Electromagnetic Theory and Applications I (3)
Prerequisite: ECE 90. Electrostatics; boundary value problems; magnetostatics; time-varying fields; Maxwell's equations. Transmission of electromagnetic energy.

128. Electronics I (3)
Prerequisite: ECE 90. Characteristics and properties of solid state devices; theory and analysis of electronic circuits; power supply design; device and circuit models; single- and multi-stage amplifier analysis and design; analysis of digital circuits; computer solutions as appropriate.

128L. Electronics I Laboratory (1)
Prerequisite: ECE 128 or concurrently. Experiments on static and dynamic characteristics of solid state devices in analog and digital electronic circuits; computer solutions as appropriate. (3 lab hours)

132. Design of Digital Systems (3)
Prerequisites: ECE 115, 118. Design of Digital Systems utilizing microprocessors; application of assembly programming language to input/output programming, interrupts and traps, DMA and memory management.

134. Communication Engineering (3)
Prerequisite: ECE 124. Mathematical modeling of signals; spectral density; linear and nonlinear modulation theory; demodulators; phase lock loops; link analysis; sampling theory; PCM and DM; digital communications; effect of noise on systems; link design; computer simulations.

135. Digital Communications (3)
Prerequisite: ECE 125. Principles, analysis methodology, statistical performance characteristics and design considerations of digital communication systems. Source and channel coding, Viterbi decoding, binary and M-ary digital AM, FM, PM, and hybrid modulation schemes. Noise performance of receivers, modem design. Computer simulations.

136. Electromagnetic Theory and Applications II (3)
Prerequisite: ECE 126. Plane wave propagation and reflection; waveguides; striplines and microstrip impedance matching, microwave circuits and S-parameters; amplifier power gain and stability, amplifier design, antenna analysis and design; methods for computer solution.

136L. Electromagnetic Theory and Applications Laboratory (1)
Prerequisite: ECE 136. Experiments on the transmission of electromagnetic energy through wires, waveguides, and space; filters and antennas; impedance matching; cross-over networks; location of faults on lines. (3 lab hours)

138. Electronics II (3)
Prerequisites: ECE 102, 124, 128, 128L. Analysis and design of high frequency amplifiers; high frequency models of transistors; operational amplifiers and applications; feedback amplifiers; oscillators, modulators, bandpass amplifiers, and demodulators for communications. Emphasis on modern design methods.

138L. Electronics II Laboratory (1)
Prerequisite: ECE 138 or concurrently. Design oriented experiments to study the characteristics, limitations, and design trade-offs of circuits from ECE 138. Emphasis on circuit and system design to meet preestablished specifications. Design project included; computer solutions as appropriate. (3 lab hours)

140. VLSI System Design (3)
Prerequisites: ECE 114, 115, 128. Emphasis on the design of a substantial, full custom VLSI system. Digital circuit design, fabrication principles, physical and electrical design rules, control and data path design techniques, system timing, design verification, simulation and testing. Project design requires utilization of engineering workstations running an industry standard CAD framework and incorporating a complete suite of IC design tools. Fabrication is available for potentially successful student design projects.

146. Computer Networking and Distributed Processing (3)
Prerequisites: ECE 115, 125. Analysis and design of modern computer networks: layered protocols, routing; flow and congestion control; packet, message, and circuit switching; error control and recovery; performance analysis. Local area networks, asynchronous transfer mode and ISDN.

148. Analysis and Design of Digital Circuits (3)
Prerequisites: ECE 85, 114, 128. Analysis and design of solid state digital circuits utilizing various logic families suitable for integration: TTL, ECL, NMOS, CMOS; logic gates; multivibrators; ROM, PROM, EPROM, and EEPROM; SRAM and DRAM.

151. Electrical Power Systems (3)
Prerequisites: ECE 90 (or concurrently). Power system networks and equipment, steady-state operation, short-circuit analysis, power system stability analysis by digital computation, synchronous generator excitation and governor systems, system load representation, numerical analysis techniques.

152. Symmetrical Components and Short Circuit Analysis (3)
Prerequisites: ECE 90 (or concurrently). Theory of symmetrical components and their use in power systems analysis; sequence impedances of system components; applications in fault calculations.

155. Control Systems (3)
Prerequisites: MATH 81, ECE 102. Analysis, design, and synthesis of linear control systems; modeling, performance evaluation, frequency response, and stability.

162. Analog Integrated Circuits and Applications (3)
Prerequisite: ECE 138. Analysis of monolithic operational amplifiers; case studies; Widlar and Wilson current sources; linear and nonlinear applications; multipliers, phase-lock loops, phase detectors; higher order active filters; all-pass equalizers; D/A and A/D converters; oscillators, function generators; mixers, modulators, regulators; system design.

166. Microwave Devices and Circuits Design (3)
Prerequisite: ECE 136. Microwave theory and techniques: slow-wave structures, S parameters, and microwave devices, including solid-state devices such as Gunn, IMPATT, TRAPATT, and BARITT diodes, and vacuum tubes such as klystrons, reflex klystrons, traveling-wave tubes, magnetrons and gyrotrons.

168. Microwave Amplifier and Oscillator Design (3)
Prerequisite: ECE 136. Small-signal and large-signal amplifier designs such as high-gain, high-power, low-noise, narrow-band and broadband amplifiers; microwave oscillator designs such as high-power, broadband, Gunndiode and IMPATT oscillator designs; power combining and dividing techniques; reflection amplifier design and microwave measurements.

171. Quantum Electronics (3)
Prerequisite: ECE 126. Review of wave properties; cavity mode theory; radiation laws; theory and morphology of lasers; laser and fiber-optic communications; designs of optical communication systems and components.

172. Sequential Machine and Automata Theory (3)
Prerequisite: ECE 106. Structure of sequential machines; covers; partitions; decompositions and synthesis of multiple machines. State identification and fault detection experiments; memory characteristics of finite automata.

173. Digital Controls and Robotics (3)
Prerequisites: ECE 155. Introduction to digital controls; development and classification of robots; components and operation of robots, types of sensors; vision sensors; artificial intelligence; classroom demonstrations and practice with a robot.

174. Advanced Computer Architecture (3)
Prerequisites: ECE 115, MATH 107 or ECE 125. Advanced computing architecture concepts: discrete math; pipelining; multiprocessing and multiprogramming; cache and virtual memory; direct memory access, local and system bus architectures; instruction set design and coding; CPU and system performance analysis.

176. Computer-Aided Engineering in Digital Design (3)
Prerequisites: ECE 120L or concurrently. Use of Computer-Aided Engineering tools in the design and implementation of digital systems utilizing Applications Specific Integrated Circuits. Design projects from specification through implementation using Field Programmable Gate Arrays (FPGAs) and Complex Programmable Logic Devices (CPLDs); simulation, timing analysis, Hardware Definition Languages. Hands-on exposure to current tools.

186A. Senior Design I (1)
Prerequisites: senior standing in computer or electrical engineering or permission of instructor; IE 182W or concurrently. Design projects in electrical and computer engineering.

186B. Senior Design II (2)
Prerequisite: ECE 186A. Design projects in electrical and computer engineering.

190. Independent Study (1-3; max total 6)
See *Academic Placement — Independent Study*. Approved for *SP* grading.

191T. Topics in Electrical and Computer Engineering (1-3; max total 6)
Prerequisite: permission of instructor. Investigation of selected electrical engineering subjects not in current courses.

193. Electrical and Computer Engineering Cooperative Internship (1-6; max 12)
Prerequisite: permission of adviser. Engineering practice in an industrial or governmental installation over a period of about seven months duration. Each period must span a summer-fall or spring-summer interval. This course cannot be used to meet graduation requirements. *CR/NC* grading only.

GRADUATE COURSES

(See *Course Numbering System*.)

Electrical Engineering (EE)

241. Applied Electromagnetics (3)
Prerequisite: ECE 136 or permission of coordinator. Electrostatic field boundary conditions, energy relations, and forces; multidimensional potential problems; magnetic field boundary conditions, scalar and vector potentials, and magnetization; Maxwell's equations for stationary and moving media; energy, force, and momentum in an electromagnetic field; plane waves; waves near metallic boundaries; inhomogeneous wave equation.

243. Modern Methods in Synchronous Sequential Design (3)
Prerequisite: ECE 172 or permission of coordinator. Synchronous machine design with PLDs and FPGAs; algorithmic state machines; incompletely specified machines; maximum compatibility classes; partitioning of sequential machines; state merging and state splitting.

245. Communications Engineering (3)
Prerequisite: ECE 134 or permission of coordinator. Basic modulation concepts; statistical properties of signals; transmission systems optimization against noise; digital transmission and modulation methods; attenuation and phase distortion in analog and digital systems; intermodulation distortion; random multipath channels; intersystem interference.

247. Modern Semiconductor Devices (3)
Prerequisite: ECE 114 or permission of coordinator. Crystal structures and elastic constants; lattice energy and vibrations; thermal and dielectric properties of solids; ferroelectric and magnetic properties of crystals; free electron model of metals; quantum statistics distributions; band theory; semiconductor crystals; superconductivity; photoconductivity and luminescence; dislocations.

249. Advanced Communication Engineering (3)
Prerequisite: ECE 245 or permission of coordinator. The measure of information; noiseless coding; models of communication channels; channel capacity; discrete memoryless channels; error correcting codes; information sources; discrete channels with memory; continuous channels.

251. Antennas and Propagation (3)
Wave equation, plane waves, metallic boundary conditions; wave equation for the potentials Lorentz transformation; covariant formulation of electrodynamics; radiation from a moving charge; scattering and dispersion; Hamiltonian formulation of Maxwell's equations.

253. Advanced Asynchronous Machine Design (3)
Asynchronous machine design; primitive flow tables; static/dynamic hazards; state assignment; covers; partitions; decompositions; state identification and fault detection experiments; pulse mode circuits; iterative networks; introduction to hardware description languages.

255. Digital Signal Processing (3)
Prerequisite: ECE 107 or permission of coordinator. Discrete-time signals; Fourier transforms; random discrete-time signals; filtered random signals; correlation functions; power-spectral-density estimation; cross-spectral estimates; detection of signals in noise; estimation of signals in noise; recursive estimation of time-varying signals.

257. Optical Communications and Lasers (3)
Quantum measure of light, linear, elliptical, and circular polarization; optical waveguide equations, ray and mode theory; source and detector characteristics; attenuation, dispersion, and noise effects; correlation, spectral density, noise equivalent bandwidth, coding, modulation, multiplexing techniques; systems and link design.

259. Radar System Design (3)
The nature and history of radar, the radar equation, PRF and range considerations, CW and FM radars. MTI and pulse-Doppler radars, tracking radars. Radar power generation, antenna types and design considerations, receivers, detection of signals in noise, extraction of information from radar signals, propagation of radar wave, the effects of clutter, weather and interference. Examples of radar system engineering and design.

290. Independent Study (1-3; max total 6)
Prerequisite: graduate status in engineering. See *Academic Placement — Independent Study*. Approved for *SP* grading.

291T. Topics in Electrical Engineering (1-3; max total 6)
Prerequisite: graduate status in engineering or permission of instructor. Selected electrical engineering subjects not in current courses.

298. Project (3; max total 3)
Prerequisite: graduate status in engineering. See *Criteria for Thesis and Project*. Independent investigation of advanced character such as analysis and/or design of special engineering systems or projects; critical review of state-of-the-art special topics, as the culminating requirement of the master's degree. Abstract required. Approved for *SP* grading.

299. Thesis (3-6; max total 6)
Prerequisite: see *Criteria for Thesis and Project*. Preparation, completion, and submission of an acceptable thesis for master's degree. Approved for *SP* grading.