

### Computer Engineering

*College of Science, Engineering & Technology*

*Department of Electrical and Computer Engineering and Technology*

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Website: [www.cset.mnsu.edu/ecet](http://www.cset.mnsu.edu/ecet)

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Computer Engineering (CE) encompasses the research, development, design and operation of computers and computerized systems and their components. This program leads to a Bachelor of Science in Computer Engineering. The primary objective of the Computer Engineering program is to educate engineering professionals who possess sound design and analytical background coupled with a strong laboratory experience supporting Computer Engineering concepts. This means that the department prepares its graduates for:

1. Entry into the engineering work environment with well developed design and laboratory skills.
2. Further study toward advanced degrees in engineering and other related disciplines.
3. Advancement into managerial ranks and/or entrepreneurial endeavors.

The educational objectives for our Bachelor of Science in Computer Engineering degree are to prepare our graduates to:

1. Function as responsible members of society with an awareness of the social, ethical, and economic ramifications of their work.
2. Become successful practitioners in engineering and other diverse careers.
3. Succeed in full time graduate and professional studies.
4. Pursue continuing and life-long learning opportunities.
5. Pursue professional registration.
6. Provide foundational education that allows for personal growth and flexibility through their career.

Our metrics for determining success in meeting these objectives will include:

1. Assessment of societal, economic awareness, and ethical performance of our graduates by the graduate and employer.
2. Monitoring of the success of our graduates in the work force.
3. Monitoring of the success of our graduates in graduate and professional programs.
4. Assessment of continuing and life-long learning by the graduate (and their employer as applicable.).
5. Reviewing the number and success of our students completing professional registration to advance their careers.

In support of these objectives, the program provides a curriculum including the following components that will prepare students for excellent careers in Computer Engineering:

1. A strong background in the physical sciences; mathematics, including discrete math; and engineering sciences, including extensive hands-on laboratory instruction.
2. An integrated design component including instruction in basic practices and procedures, creativity, control, economics, and synthesis. The process begins with basic instruction during the first year and concludes with a capstone design project.
3. A choice of sub-disciplines in the senior level electives.
4. Opportunities for students to develop sensitivity to the social and humanistic implications of technology and motivate them to make worthwhile contributions to the profession and society, while upholding the highest standards of professional ethics.
5. A course in engineering economics to promote awareness of the economic aspects of engineering.
6. Preparation for continuing study and professional development.

During the senior year, as allowed by the state, students will be required to take

the Fundamentals of Engineering (FE) examination or its equivalent as described in GPA Policy below.

The curriculum offers students the opportunity to emphasize a number of specialized areas including advanced digital systems, communications, digital signal processing, networking and system design.

The recommended high school preparation is two years of algebra, one year of geometry, one-half year of trigonometry, one-half year of college algebra, and a year each of physics and chemistry plus a programming language. Without this background it may take students longer than four years to earn a degree. During the first two years students take science and mathematics courses common to all branches of engineering (pre-engineering), as well as supporting work in English, humanities, and social sciences. Second-year computer engineering students complete physics, mathematics and 200-level engineering and computer science courses.

All international students wishing to have transfer credits granted from non-U.S. schools will be required to use the ECE evaluation service to be completed no later than first semester at Minnesota State Mankato.

**Admission to Major.** Admission to the college is necessary before enrolling in non-engineering 300- and 400-level courses. Minimum college requirements are:

- a minimum of 32 earned semester credit hours.
- a minimum cumulative GPA of 2.00 ("C").

Please contact the department for application procedures.

During spring semester of the sophomore year, students should submit an application form for admission to the Computer Engineering program. Admission to the program is selective and, following applications to the department, subject to approval from the faculty. The department makes a special effort to accommodate transfer students. Only students admitted to the program are permitted to enroll in upper-division engineering courses. No transfer credits are allowed for upper-division engineering courses except by faculty review followed by written permission.

Before being accepted into the program and admitted to 300-level engineering courses (typically in the fall semester), a student must complete a minimum of 65 semester credits including the following:

- General Physics (calculus-based) (12 credits)
- Calculus, Differential Equations, Probability & Statistics (19 credits)
- Electrical Engineering Circuit Analysis I and II (including lab.) (7 credits)
- Chemistry (3 credits)
- English Composition (4 credits)
- Computer Science (3 credits)
- Introduction to Electrical and Computer Engineering (6 credits)
- Discrete Math (4 credits)
- Speech (3 credits)
- Microprocessor Lab (1 credit)
- Computer Hardware and Org. (3 credits)

A cumulative GPA of 2.5 for all science and math courses must have been achieved for program admittance. Grades must be 1.65 ("C-") or better for courses to be accepted.

**GPA Policy.** Students graduating with a degree in Computer Engineering must have:

1. completed a minimum of 20 semester credit hours of upper division EE and CS courses at Minnesota State Mankato.
2. have a cumulative GPA of 2.25 on all upper division EE and CS courses, and
3. have completed their senior design sequence at Minnesota State Mankato.
4. have taken the Fundamentals of Engineering (FE) exam or its equivalent and achieved the desired competency level.

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**GPA.** A cumulative grade-point average of 2.5 for all science, math and engineering courses must have been maintained. Grades must be 1.65 “C-” or better for course to be accepted. Minnesota State Mankato students should complete the pre-engineering courses listed under the major.

Petition to evaluate transfer credits must occur no later than the first semester the student is enrolled in or declared a major housed in the Department of Electrical and Computer Engineering Technology.

**Accreditation.** The Computer Engineering program is accredited by the Engineering Accreditation Commission of ABET, <http://www.abet.org/>.

**P/N Grading Policy.** A student who majors in CE must elect the grade option for all required courses including courses offered by another department.

### COMPUTER ENGINEERING BSEC

#### **Required General Education**

|      |     |                             |
|------|-----|-----------------------------|
| CHEM | 191 | Chemistry for Engineers (3) |
| ENG  | 101 | Composition I (4)           |
| MATH | 121 | Calculus I (4)              |
| PHYS | 221 | General Physics I (4)       |

(Choose one of the following)

|      |     |                             |
|------|-----|-----------------------------|
| CMST | 102 | Public Speaking (3)         |
| ENG  | 271 | Technical Communication (4) |

(Choose one of the following)

|      |     |                                  |
|------|-----|----------------------------------|
| ECON | 201 | Principles of Macroeconomics (3) |
| ECON | 202 | Principles of Microeconomics (3) |

#### **Prerequisites to the Major**

|      |     |  |
|------|-----|--|
| CS   | 220 | Machine Structures and Programming (3) |
| EE   | 106 | Intro to EE and CE I (3)               |
| EE   | 107 | Intro to EE and CE II (3)              |
| EE   | 230 | Circuit Analysis I (3)                 |
| EE   | 231 | Circuit Analysis II (3)                |
| EE   | 235 | Microprocessor Engineering Lab I (1)   |
| EE   | 240 | Evaluation of Circuits (1)             |
| EE   | 295 | Computer Hardware and Organization (3) |
| MATH | 122 | Calculus II (4)                        |
| MATH | 180 | Mathematics for Computer Science (4)   |
| MATH | 223 | Calculus III (4)                       |
| MATH | 321 | Ordinary Differential Equations (4)    |
| PHYS | 222 | General Physics II (3)                 |
| PHYS | 223 | General Physics III (3)                |
| PHYS | 232 | General Physics II Lab (1)             |
| PHYS | 233 | General Physics III Lab (1)            |

#### **Major Common Core**

|    |     |   |
|----|-----|---|
| CS | 320 | Computer Architecture (3)                       |
| CS | 460 | Operating Systems: Design & Implementation (3)  |
| EE | 332 | Electronics I (3)                               |
| EE | 333 | Electronics II (3)                              |
| EE | 334 | Microprocessor Engineering (3)                  |
| EE | 336 | Principles of Engineering Design I (1)          |
| EE | 337 | Principles of Engineering Design II (1)         |
| EE | 341 | Signals and Systems (3)                         |
| EE | 342 | Electronics Laboratory (1)                      |
| EE | 344 | Design and Evaluation of Microprocessors II (1) |
| EE | 350 | Engineering Electromagnetics (3)                |
| EE | 358 | Control Systems (3)                             |
| EE | 368 | Control Systems Lab (1)                         |
| EE | 381 | Digital System Design with Testability (3)      |
| EE | 382 | Digital System Design with Testability Lab (1)  |
| EE | 450 | Engineering Economics (3)                       |
| EE | 467 | Principles of Engineering Design III (1)        |
| EE | 477 | Principles of Engineering Design IV (1)         |

|    |     |                      |
|----|-----|----------------------|
| ME | 299 | Thermal Analysis (2) |
|----|-----|----------------------|

#### **Major Restricted Electives**

At least two lecture courses must be in the same area

|    |     |   |
|----|-----|---|
| EE | 453 | Advanced Communications Systems Engineering (3)   |
| EE | 471 | Advanced Control Systems (3)                      |
| EE | 472 | Digital Signal Processing (3)                     |
| EE | 475 | Integrated Circuit Engineering (3)                |
| EE | 476 | Antennas, Propagation & Microwave Engineering (3) |
| EE | 479 | Superconductive Devices (3)                       |
| EE | 480 | Integrated Circuit Fabrication Lab (1)            |
| EE | 481 | VLSI Design Laboratory (1)                        |
| EE | 484 | VLSI Design (3)                                   |
| EE | 487 | RF Systems Engineering (3)                        |

#### **Other Graduation Requirements**

(Choose one of the following)

|      |     |  |
|------|-----|--|
| MATH | 354 | Concepts of Probability and Statistics (3) |
| ME   | 291 | Engineering Analysis (3)                   |

Choose a minimum of 13 credits of Humanities and Social Sciences courses.

Humanities (6-7 credits)

Social Sciences (6-7 credits)

***For a complete listing of approved Humanities and Social Science courses please consult the department website or the department chair.***

In general, graduation credits toward the humanities requirement is not allowed for any course in subject areas such as communication studies, writing, art, music or theater that involve performance or practice of basic skills.

At least 3 credits of the courses selected to complete the above requirements must be 300-level or above. At least one 300-level course must follow a lower level course in the same subject area.

**Required Minor: None.**

### COURSE DESCRIPTIONS

#### Computer Science

##### **CS 220 (3) Machine Structures and Programming**

This course introduces students to assembly language programming and basic machine structures. Topics include number systems; basic central processing unit (CPU) organization, instruction formats, addressing modes and their use with a variety of data structures; and parameter passing techniques.

Pre: CS 110 and EE 106

Fall, Spring

##### **CS 320 (3) Computer Architecture**

This course presents historical and current concepts and implementations of computer organization. Topics include instruction set design, digital storage, performance metrics, processor datapath and control, pipelining, memory hierarchy, busses and I/O interfacing, and parallel processors.

Pre: CS 111 and CS 220, or EE 334

Spring

##### **CS 460 (3) Operating Systems: Design & Implementation**

This course studies historical and current concepts and implementations of computer operating systems. Basic operating systems topics include processes, interprocess communication, interprocess synchronization, deadlock, memory allocation, segmentation, paging, resource allocation, scheduling, file systems, storage, devices, protection, security, and privacy.

Pre: CS 210 and CS 320

Spring

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### Electrical Engineering Courses

#### EE 106 (3) Introduction to Electrical/Computer Engineering I

This introductory course covers digital systems topics including binary numbers, logic gates, Boolean algebra, circuit simplification using Karnaugh maps, flip-flops, counters, shift registers and arithmetic circuits. Problem solving methods, study skills and professional development will be addressed throughout the course.

Pre: MATH 112

Fall Spring

#### EE 107 (3) Introduction to Electrical/Computer Engineering II

The course presents algorithmic approaches to problem solving and computer program design using the C language. Student will explore Boolean expressions, implement programs using control structures, modular code and file input/output, and interface with external hardware using robots and sensors.

Pre: EE 106

Spring

#### EE 230 (3) Circuit Analysis I

This course is meant to develop Electrical Engineering Circuit Analysis skills in DC and AC circuits. It includes circuit laws and theorems, mesh and node analysis. Natural and step response of RL, RC, and RLC circuits.

Pre: PHYS 222 or concurrent, MATH 321 or concurrent

Fall

#### EE 231 (3) Circuit Analysis II

Continuation of Circuit Analysis I to include special topics in circuit analysis.

Pre: EE 230 and EE 240, MATH 321, PHYS 222

Spring

#### EE 235 (1) Microprocessor Engineering Laboratory I

Use of development boards and assembly language programming to handle interrupts, interface with parallel I/O ports, memory, and timers. Experiments will involve signal and frequency measurements, data conversions, and interface design.

Pre: EE 106, EE 107, CS 200 and EE 235 taken concurrently

#### EE 240 (1) Evaluation of Circuits

Laboratory support for EE 230. Use of laboratory instrumentation to measure currents and voltages associated with DC and AC circuits. Statistical analysis of measurement data. Measurements of series, parallel and series-parallel DC and AC circuits. Measurement of properties for circuits using operational amplifiers. Measurement of transient responses for R-L and R-C circuits. Simulation of DC and AC circuits using PSpice. Concepts covered in EE 230 will be verified in the laboratory.

Pre: Must be taken concurrently with EE 230.

Fall

#### EE 244 (2) Introduction to Digital Systems

Simple coding schemes, Boolean algebra fundamentals, elements of digital building blocks such as gates, flip-flops, shift registers, memories, etc.; basic engineering aspects of computer architecture.

#### EE 253 (1) Logic Circuits Lab

Laboratory support to complement EE 244. Use of laboratory instrumentation to measure characteristics of various logic circuits and digital subsystems. Experimental evaluation of digital logic devices and circuits including logic gates, flip-flops, and sequential machines.

Pre: EE 230 and concurrent with EE 244.

Spring

#### EE 254 (1) Digital and Circuits Lab

Laboratory support for EE 231 and EE 244. Experimental evaluation of AC and transient circuits, digital logic devices including logic gates, flip flops, and sequential machines.

Pre: EE 230, EE 240 and concurrently with EE 231 and EE 244

Spring

#### EE 295 (3) Computer Hardware and Organization

This course introduces the computer engineering fundamentals on which current computer systems are based and includes Boolean algebra and simple logic circuits that describe the hardware of modern computer systems. Students gain a deeper understanding of computers by building and microprogramming their own machine.

Pre: CS 220 and EE 235

Spring

#### EE 298 (1-4) Topics

Varied topics in Electrical and Computer Engineering. May be repeated as topics change.

Pre: to be determined by course topic

#### EE 303 (3) Introduction to Solid State Devices

Introduction to crystal structure, energy band theory, conduction and optical phenomenon in semiconductors, metals and insulators. Study of equilibrium and non-equilibrium charge distribution, generation, injection, and recombination. Analysis and design of PN-junctions, (bipolar transistor, junction) and MOS field-effect transistors. Introduction to transferred electron devices and semiconductor diode laser.

Pre: PHYS 222, and MATH 321

Fall

#### EE 304 (1) Lab: Introduction to Solid State Devices

Laboratory support for EE 303. Experiments include resistivity and sheet resistance measurements of semiconductor material, probing material, probing of IC chips, PN-junction IV and CV measurements, BJT testing to extract its parameters, MOSFET testing and evaluating its parameters, cv-measurements of MOS structure, and familiarization with surface analysis tools.

Fall

#### EE 332 (3) Electronics I

Introduction to discrete and microelectronics circuits including analog and digital electronics. Device characteristics including diodes, BJT's, JFET's, and MOS-FET's will be studied. DC bias circuits, small and large signal SPICE modeling and analysis and amplifier design and analysis will be discussed.

Pre: EE 231

#### EE 333 (3) Electronics II

The second course of the electronics sequence presenting concepts of feedback, oscillators, filters, amplifiers, operational amplifiers, hysteresis, bi-stability, and non-linear functional circuits. MOS and bipolar digital electronic circuits, memory, electronic noise, and power switching devices will be studied.

Pre: EE 332

Spring

#### EE 334 (3) Microprocessor Engineering II

A more advanced study of microprocessors and microcontrollers in embedded system design. Use of C language in programming, interrupt interfaces such as SPI, I2C, and CAN. External memory design and on-chip program memory protection are also studied.

Pre: EE 295

Fall

#### EE 336 (1) Principles of Engineering Design I

Electrical and computer engineering project and program management and evaluation techniques will be studied. Emphasis will be placed on the use of appropriate tools for planning, evaluation, and reporting on electrical and computer engineering projects.

Pre: Junior Standing

Fall

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### EE 337 (1) Principles of Engineering Design II

Application of the design techniques in the engineering profession. Electrical engineering project and program management and evaluation including computer assisted tools for planning and reporting, design-to-specification techniques and economic constraints.

Pre: EE 336

Spring

### EE 341 (3) Signals & Systems

Analysis of linear systems and signals in the time and frequency domain. Laplace and Fourier transforms. Z-transform and discrete Fourier transforms.

Pre: EE 230, MATH 321 and PHYS 222

Fall

### EE 342 (1) Electronics Laboratory

This lab is designed to accompany EE 332. The lab covers the experimental measurement and evaluation of diode, BJT, and MOS characteristics; various feedback topologies; oscillator and op-amp circuits; and rectifiers and filter circuitry.

Pre: EE 231 and EE 332 taken concurrently.

Fall

### EE 344 (1) Design & Evaluation of Microprocessors

Laboratory support for EE 334. Use of development boards and C Programming language to handle I/O devices, interrupts, and all peripheral functions. Multiple functions such as timers, A/D converters, I/O devices, interrupts, and serial modules will be used together to perform desired operations.

Pre: Concurrent with EE 334

Fall

### EE 350 (3) Engineering Electromagnetics

Vector fields. Electrostatic charges, potential and fields; displacement. Steady current/current density; magnetostatic fields, flux density. Materials properties. Faraday's Law and Maxwell's equations. Skin effect. Wave propagation, plane waves, guided waves. Radiation and antennas. Transmission line theory.

Pre: EE 231, MATH 223, MATH 321 and PHYS 222

Spring

### EE 353 (3) Communications Systems Engineering

Signals and Systems, Fourier transforms, Parseval's theorem. Autocorrelation functions and spectral density functions. Information theory. Noise and noise figure, probability and statistics. Transformation of random variables, probability of error and bit error rate. Modulation and demodulation. Overview of analog, sampled analog and digital communication systems. Spread spectrum systems.

Pre: EE 341, MATH 223

Spring

### EE 358 (3) Control Systems

Theory and principles of linear feedback control systems. Analysis of linear control systems using conventional techniques like block diagrams, Bode plots, Nyquist plots and root-locus plots. Introduction to cascade compensation: proportional, derivative and integral compensation. State space models.

Pre: EE 341

Spring

### EE 363 (1) Communication Systems Laboratory

Measurement techniques using the oscilloscope, spectrum analyzer and network analyzer. Signals and spectra. Frequency response. Noise and noise figure measurements. Intermodulation products. Amplitude and frequency modulation/demodulation. Sampling, aliasing, and intersymbol interference. Bit error measurement.

Pre: Concurrent with EE 353

Spring

### EE 368 (1) Control Systems Laboratory

Laboratory support for EE 358. Experimental evaluation of basic control system concepts including transient response and steady state performance. Analog and digital computers.

Pre: EE 341 and concurrent with EE 358

Spring

### EE 381 (3) Digital System Design with Testability

Practical aspects of digital systems design and hardware testability will be presented in this course. Software tools and theoretical presentations will emphasize necessary concepts of digital design.

Pre: EE 106, CS 220, and EE 295

Fall

### EE 382 (1) Digital System Design with Testability Lab

Laboratory support for EE 381. Practical aspects of digital systems design and hardware testability will be presented through laboratory experiences.

Pre: Concurrent with EE 381

Fall

### EE 439 (3) Electronics for Non-Electrical Engineering Majors

Topics covered include power supplies, operational amplifiers and feedback circuits, linear and nonlinear circuits and applications, analog switches, digital logic gates and devices, A/D and D/A converters, microprocessors, and basic control systems.

Pre: PHYS 221 and PHIL 222

Variable

### EE 450 (3) Engineering Economics

Overview of accounting and finance and their interactions with engineering. Lectures include the development and analysis of financial statements, time value of money, decision making tools, cost of capital, depreciation, project analysis and payback, replacement analysis, and other engineering decision making tools.

Pre: Advanced standing in the program

Fall

### EE 453 (3) Advanced Communications Systems Engineering

Behavior of analog systems and digital systems in the presence of noise, principles of digital data transmission, baseband digital modulation, baseband demodulation/detection, bandpass modulation and demodulation of digital signals. Channel coding, modulation and coding trade-offs, spread spectrum techniques, probability and information theory.

Pre: EE 353 and EE 363

Fall

### EE 463 (3) Advanced Digital System Design

Design of combinational and sequential systems and peripheral interfaces. Design techniques using MSI and LSI components in an algorithmic state machine; implementation will be stressed. Rigorous timing analysis transmission-line effects and metastability of digital systems will be studied.

Pre: EE 244

### EE 467 (1) Principles of Engineering Design III

The design and organization of engineering projects. Project proposals, reporting, feasibility studies, and interpretation. Specification preparation, interpretation, and control. Issues involving creativity, project planning and control, and intellectual property rights. Students enrolled in this course must initiate and complete a design project in a small team format.

Pre: EE 337 and senior standing

Fall

### EE 471 (3) Advanced Control Systems

This course is a continuation of EE 358. Techniques for the analysis of continuous and discrete systems are developed. These techniques include pole placement, state estimation, and optimal control.

Pre: EE 358 and EE 368

Fall

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### EE 472 (3) Digital Signal Processing

Develop design and analysis techniques for discrete signals and systems via Z-transforms, Discrete Fourier Transforms, implementation of FIR and IIR filters. The various concepts will be introduced by the use of general and special purpose hardware and software for digital signal processing.

Pre: EE 341

Spring

### EE 475 (3) Integrated Circuit Engineering

Introduction to theory and techniques of integrated circuit fabrication processes, oxidation, photolithography, etching, diffusion of impurities, ion implantation, epitaxy, metallization, material characterization techniques, and VLSI process integration, their design and simulation by SUPREM.

Pre: EE 303 and EE 332

Fall

### EE 476 (3) Antennas, Propagation, & Microwave Engineering

Principles of electromagnetic radiation, antenna parameters, dipoles, antenna arrays, long wire antennas, Microwave antennas, Mechanisms of radiowave propagation, scattering by rain, sea water propagation, guided wave propagation, periodic structures, transmission lines, microwave/millimeter wave amplifiers and oscillators, MIC & MMIC technology.

Pre: EE 350

Variable

### EE 477 (1) Principles of Engineering Design IV

Completion of design projects and reports. Lectures on ethics, issues in contracting and liability, concurrent engineering, ergonomics and environmental issues, economics and manufacturability, reliability and product lifetimes. Lectures by faculty and practicing engineers.

Pre: EE 467 and Senior Standing

Spring

### EE 479 (3) Superconductive Devices

Magnetic and superconducting properties of materials, microscopic theory of superconductivity and tunneling phenomenon. Josephson and SQUID devices, survey of computer memories, memory cell and shift register, A/D converters and microwave amplifiers. Integrated circuit technology and high temperature superconductors.

Pre: EE 303

Variable

### EE 480 (1) Integrated Circuit Fabrication Lab

Introduction to integrated circuit fabrication processes, device layout, mask design, and experiments related to wafer cleaning, etching, thermal oxidation, thermal diffusion, photolithography, and metallization. Fabrication of basic integrated circuit elements pn junction, resistors, MOS capacitors, BJT and MOSFET in integrated form. Use of analytic tools for in process characterization and simulation of the fabrication process by SUPREM.

Pre: Concurrent with EE 475

Fall

### EE 481 (1) VLSI Design Laboratory

This laboratory accompanies EE 484. The laboratory covers the basics of layout rules, chip floor planning, the structure of standard cells and hierarchical design, parasitic elements, routing, and loading. Students will learn to design and layout standard cells as well as how to use these cells to produce complex circuits. The laboratory culminates with the individual design and layout of a circuit.

Pre: Concurrent with EE 484

Spring

### EE 482 (3) Electromechanics

Electrical power and magnetic circuit concepts, switch-mode converters, mechanical electromechanical energy conversion, DC motor drives, feedback controllers, AC machines and space vectors, permanent magnet AC machines and drives, induction motors and speed control of induction motors, stepper motors.

Pre: EE 230

Fall

### EE 484 (3) VLSI Design

The basics of digital VLSI technology. Bipolar and MOS modeling for digital circuits. Physical transistor layout structure and IC process flow and design rules. Custom CMOS/BICMOS static and dynamic logic styles, design and analysis. Clock generation, acquisition, and synchronization procedures. Special purpose digital structures including memory, Schmitt triggers, and oscillators. Individual design projects assigned.

Pre: EE 333

Spring

### EE 487 (3) RF Systems Engineering

Overview of wireless communication and control systems. Characterization and measurements of two-port RF/IF networks. Transmission lines. Smith chart. Scattering parameters. Antenna-preselector-preamplifier interface. Radio wave propagation. Fading. RF transistor amplifiers, oscillators, and mixer/modulator circuits. Multiple access techniques. Transmitter/receiver design considerations. SAW matched filters.

Pre: EE 353 and EE 363

Variable

### EE 488 (2) Thermal Systems Engineering

Thermodynamic concepts, properties and laws. Thermodynamic cycles and energy conversion; control volume analysis. Heat transfer by conduction, convective flow and radiation. Heat sink design. Design problems in electronics packaging, reliability, thermoelectric effects and cooling devices. Environmental proper sensors.

Pre: PHYS 222 and EE 333

Variable

### EE 491 (1-4) In-Service

### EE 497 (1-6) Internship

### EE 498 (1-4) Topics

Varied topics in Electrical and Computer Engineering. May be repeated as topics change.

Pre: to be determined by course topic

### EE 499 (1-6) Individual Study