COMPUTER ENGINEERING

Engineering East Building (20), Room 215
Phone: 805.756.1229
https://cpe.calpoly.edu

Director: Lynne Slivovsky

Engineering Student Services
Engineering South (40), Room 115
Phone: 805.756.1461

Academic Program

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The mission of the Computer Engineering Program (CPE) is to provide students with a well-rounded education encompassing the theory and practice of selected, balanced topics in electrical engineering and computer science, to enable students to contribute and continue their education in a wide range of computer-related engineering careers. The program seeks to emphasize "hands-on" experience, problem solving skills, the creative process and responsible action. Through professional development activities, faculty contribute to the advancement of the state-of-the-art, and strive to directly incorporate this experience in the classroom.

Four educational objectives inspire alumni of the Cal Poly Computer Engineering program to excel professionally:

1. Make positive contributions to society and the practice of computer engineering by applying foundational knowledge and the engineering process to solve engineering problems.
2. Work in an individual or team environment in a socially responsible manner.
3. Engage in lifelong learning through continued professional development or graduate studies.
4. Communicate effectively and demonstrate leadership.

The program prepares graduates for professional practice in industry, as well as continued study in graduate school. Cal Poly's "learn by doing" philosophy is emphasized by integrating design throughout the curriculum, especially in the numerous design-centered laboratories. In the required senior capstone experience, which is a group-project based course completed over two quarters, students demonstrate their understanding of engineering knowledge and their ability to apply that knowledge creatively to practical problems.

This integrated approach allows students to work effectively in such diverse areas as digital systems simulation and digital control systems. Knowledge and laboratory experience in computer architecture and structures provide the understanding necessary to design and build computer systems, computer networks and digital communications systems. A thorough knowledge of modern microprocessors and microcontrollers enables the graduate to apply these technologies in applications such as robotics, medical and data acquisition. Twelve units of technical electives allow students the option to specialize in an area of special interest. Current areas of special interest include:

- robotics
- embedded systems
- computer architecture
- computer networks
- computer based controls
- software systems
- graphics and multimedia
- electronics implementation and VLSI

In addition to a sound theoretical background in computer engineering concepts, students experience practical design courses intended to build problem solving skills. Laboratory courses supplement the program to develop "hands on" skills in all areas of study. Students are exposed to a wide variety of computing equipment: microprocessor development systems, workstations and personal computers, and advanced network hardware and software.

Active student groups of interest to computer engineering majors include the Computer Engineering Society, the IEEE Student Branch, the Association for Computing Machinery, the Society of Women Engineers, Women Involved in Software and Hardware, and many other project-oriented student clubs and activities.

For more information about the CPE program, please visit https://eadvise.calpoly.edu.

Undergraduate Program
BS Computer Engineering

The Bachelor of Science in Computer Engineering prepares students interested in the design and application of computers and computer-based systems. The program incorporates a firm foundation in both electrical engineering and computer science, with a focus on the integration of hardware and software systems.

Blended and Graduate Programs

Graduates of the Computer Engineering Program are qualified for admission to Cal Poly master's degree programs in electrical engineering, computer science, general engineering, and biomedical engineering.

The opportunity also exists for advanced students to begin graduate study in these areas prior to completion of the BS degree, via a blended program. This provides a number of advantages to qualified students, and makes it possible for completion of both the BS and MS degrees in as little as five years. Computer engineering students participating in a blended program are permitted to fulfill the computer engineering senior project requirement with the master's degree thesis. Students must be prepared for engineering practice via the curriculum which culminates in a major design experience based on the knowledge and skills acquired in earlier coursework and incorporating engineering standards and realistic constraints, as listed in the ABET Engineering Criteria. Further details are provided in the graduate study sections for each of these programs.

CPE Courses

CPE 100. Computer Engineering Orientation. 1 unit
CR/NC
Introduction to the computer engineering discipline. Success skills and curricular information. Career paths and opportunities. Professional aspects of engineering and computer science. Interaction with upper division students, alumni, faculty and staff. Introduction to computer software and hardware. Credit/No Credit grading only. 1 lecture.
CPE 101. Fundamentals of Computer Science. 4 units  
Prerequisite: Appropriate Math Placement Level; or MATH 117 with a grade of C- or better; or MATH 118 with a grade of C- or better; or consent of instructor.

Basic principles of algorithmic problem solving and programming using methods of top-down design, stepwise refinement and procedural abstraction. Basic control structures, data types, and input/output. Introduction to the software development process: design, implementation, testing and documentation. The syntax and semantics of a modern programming language. Credit not available for students who have taken CSC/CPE 108. 3 lectures, 1 laboratory. Crosslisted as CPE/CSC 101.

CPE 105. Fundamentals of Computer Science I Supplemental Instruction. 1 unit  
CR/NC  
Concurrent: CPE/CSC 101.

Facilitated study and discussion of fundamental concepts of computer science and familiarization with programming environments. Credit/No Credit grading only. 1 laboratory. Crosslisted as CPE/CSC 105.

CPE 108. Accelerated Introduction to Computer Science. 4 units  
Prerequisite: MATH 118 (or equivalent) with a grade of C- or better, significant experience in computer programming, and consent of instructor.

Accelerated introduction to basic principles of algorithmic and object-oriented problem solving and programming. Introduction to programming language concepts including control structures, data types, classes, and inheritance. Program design principles. Use and implementation of algorithms (searching, sorting, recursion) and data structures (lists, stacks, and queues). Intended for students with experience in algorithmic problem solving and using basic control structures and data types in a modern programming language (CPE/CSC 101), but who are not ready for CPE/CSC 202. Not open to students with credit in CPE/CSC 102 or CPE/CSC 202. 3 lectures, 1 laboratory. Crosslisted as CPE/CSC 108.

CPE 123. Introduction to Computing. 4 units  
Prerequisite: Basic computer literacy.

Use of a supportive software development environment to design, develop, and test applications in a selected topic domain that demonstrates the potential of careers in computing. An introduction to computing and to the selected topic domain. The Class Schedule will list topic selected. No programming experience required. Not for students with credit in CPE/CSC 103 or CPE/CSC 203. 3 lectures, 1 laboratory. Crosslisted as CPE/CSC 123.

CPE 133. Digital Design. 4 units  
Prerequisite: An orientation course in student’s major (EE 111 and EE 151; or CPE 100) and CPE/CSC 101.

Number systems, Boolean algebra, Boolean functions, and function minimization. Analysis and design of combinational and sequential digital logic circuits. Hardware Description Language (HDL) concepts and applications digital design and synthesis in FPGAs. Course may be offered in classroom-based or online format. 3 lectures, 1 laboratory. Crosslisted as CPE/EE 133.

CPE 200. Special Problems for Undergraduates. 1-2 units  
Prerequisite: Consent of instructor.

Individual investigation, research, studies, or surveys of selected problems. Total credit limited to 4 units, with a maximum of 2 units per quarter.

CPE 202. Data Structures. 4 units  
Prerequisite: CPE/CSC 101 with a grade of C- or better; MATH 141 or MATH 221 with a grade of C- or better, or consent of instructor.

Introduction to data structures and analysis of algorithms. Abstract datatypes. Specification and implementation of advanced data structures. Theoretical and empirical analysis of recursive and iterative algorithms. Software performance evaluation and testing techniques. Not open to students with credit in CSC/CPE 108. 3 lectures, 1 laboratory. Crosslisted as CPE/CSC 202.

CPE 203. Project-Based Object-Oriented Programming and Design. 4 units  
Prerequisite: CPE/CSC 202 with a grade of C- or better or consent of instructor.

Object-oriented programming and design with applications to project construction. Introduction to class design, interfaces, inheritance, generics, exceptions, streams, and testing. 3 lectures, 1 laboratory. Crosslisted as CPE/CSC 203.

CPE 233. Computer Design and Assembly Language Programming. 4 units  
Prerequisite: CPE/EE 133.

Design and implementation of digital computer circuits via CAD tools for programmable logic devices (PLDs). Basic computer design with its datapath components and control unit. Introduction to assembly language programming of an off-the-shelf RISC-based microcontroller. Not open to students with credit in CPE/EE 229. 3 lectures, 1 laboratory. Crosslisted as CPE/EE 233.

CPE 290. Selected Topics. 1-4 units  
Prerequisite: Open to undergraduate students and consent of instructor.

Directed group study of selected topics. The Class Schedule will list topic selected. Total credit limited to 8 units. 1 to 4 lectures.

CPE 315. Computer Architecture. 4 units  
Prerequisite: CSC/CPE 102 and CSC/CPE 103, or CSC/CPE 202 and CSC/CPE 203; and one of the following: CSC 225, CPE/EE 229, or CPE/EE 233.

In-depth study of the instruction set architecture and hardware design of a specific CPU. Introduction to pipelines, input/output and multiprocessors. Computer abstractions and performance measurement. Not open to students with credit in CPE 333. 3 lectures, 1 laboratory.

CPE 316. Microcontrollers and Embedded Applications. 4 units  
Prerequisite: CPE 357. Corequisite: EE 211.

Introduction to microcontrollers and their applications as embedded devices. Hardware/software tradeoffs, microcontroller selection, use of on-chip and off-chip peripherals, interrupt driven real-time operation, A/D conversion, serial and parallel communications, watch-dog timers, and low power operation. Not open to students with credit in CPE329 or CPE336. 3 lectures, 1 laboratory.
CPE 321. Introduction to Computer Security. 4 units
Prerequisite: CPE/CSC 357.

Survey of topics in computer system and network security, including protection, access control, distributed access control, operating system security, applied cryptography, network security, firewalls, secure coding practices, and case studies from real-world systems. 3 lectures, 1 laboratory. Crosslisted as CPE/CSC 321.

CPE 327. Digital Signals and Systems. 3 units
Prerequisite: EE 212, MATH 244. Concurrent: CPE 367.

Signal and system description and analysis, with emphasis on discrete-time signals and linear time-invariant (LTI) systems. Sampling theorem. Frequency spectrum, Convolution and its application to LTI systems. The z transform, discrete-time Fourier transform, and discrete Fourier transform. Introduction to digital filters. 3 lectures.

CPE 328. Discrete Time Signals and Systems. 3 units
Prerequisite: BMED 355 or EE 228. Concurrent: CPE/EE 368.

Discrete-time systems and analysis, with emphasis on linear time-invariant (LTI) systems. Sampling theorem. Classification of discrete-time systems. Convolution and its application to LTI systems. The z transform, discrete-time Fourier transform, and discrete Fourier transform. Introduction to digital filters. Not open to students with credit in CPE 327. 3 lectures. Crosslisted as CPE/EE 328.

CPE 329. Microcontroller-Based Systems Design. 4 units
Prerequisite: EE 307 & EE 347, EE 229 & EE 269 or CPE/EE 233.

Theory and application of concepts relevant to autonomous mobile robots. Sensor and actuator interfacing, programming mobile robots, communication, basic sensor fusion techniques, Pulse Width Modulation (PWM) motor actuation, and web-based interfacing for remote system monitoring. 3 lectures, 1 laboratory. Crosslisted as CPE/CSC 357.

CPE 330. Capstone I. 4 units
Prerequisite: CPE 316 or CPE 329 or CPE 336.

Definition and specification of a system to be constructed in CPE 450; requirements elicitation techniques, research and data gathering methods, project planning, time and budget estimating, project team organization. Ethics and professionalism. 3 lectures, 1 laboratory.

CPE 357. Systems Programming. 4 units
Prerequisite: CSC/CPE 102 and CSC/CPE 103 with a grade of C- or better or consent of instructor, or CSC/CPE 202 and CSC/CPE 203 with a grade of C- or better or consent of instructor, and CSC 225 or CPE/EE 229 or CPE/EE 233.

C programming language from a system programming perspective. Standard C language including operators, I/O functions, and data types in the context of system functions. Unix commands, shell scripting, file system, editors. 3 lectures, 1 laboratory. Crosslisted as CPE/CSC 357.

CPE 366. Capstone II. 4 units
Prerequisite: EE 224. Concurrent: CPE 327.

Laboratory work pertaining to discrete-time signals and linear systems; including frequency response and Fourier spectral analysis, signal sampling and aliasing, digital signal processing techniques, and digital filter design and implementation. 1 laboratory.

CPE 368. Signals and Systems Laboratory. 1 unit
Prerequisite: EE 242. Concurrent: CPE 327.

Laboratory work pertaining to discrete-time signals and linear systems; including frequency response and Fourier spectral analysis, signal sampling and aliasing, digital signal processing techniques, and digital filter design and implementation. 1 laboratory.

CPE 400. Special Problems for Undergraduates. 1-4 units
Prerequisite: Consent of instructor.

Individual investigation, research, studies, or surveys of selected problems. Total credit limited to 4 units.

CPE 414. Robotic Systems Integration. 4 units
Prerequisite: EE/CPE 329 or EE/CPE 336 or CSC/CPE 357 or ME 305.

Integration of sensors, actuators, chassis, and Linux-based computational platforms into functioning autonomous robotic systems. Embedded Linux system programming, inter-process software communication, basic sensor fusion techniques, Pulse Width Modulation (PWM) motor actuation, and web-based interfacing for remote system way-pointing and monitoring. 3 lectures, 1 laboratory. Crosslisted as CPE/EE 414.

CPE 416. Autonomous Mobile Robotics. 4 units
Prerequisite: CPE/EE 329 or CPE/EE 336 or both CPE 315 and CPE/CSC 357.

Theory and application of concepts relevant to autonomous mobile robots. Sensor and actuator interfacing, programming mobile robots, mobile robot configurations, software architectures and algorithms. 3 lectures, 1 laboratory.
CPE 419. Applied Parallel Computing. 4 units
Prerequisite: CPE/CSC 357. Corequisite: CSC 141 or CSC 348. Recommended: CPE 315.

Introduction to applied parallel computing paradigms: software models, resource allocation, performance measurement, and data sharing. Emphasis on massively parallel computation and performance improvement for a real-world application of significant scope. 3 lectures, 1 laboratory.

CPE 422. Network and Web Security. 4 units
Prerequisite: CPE 464.

Introduction to network and web security, including denial of service, botnets, access control, routing attacks, transport layer attacks, tunneling mechanisms, VPNs, IDS, firewalls, penetration testing, key distribution, browser security, social network security, email security, jamming, and wireless security. 3 lectures, 1 laboratory. Crosslisted as CPE/CSC 422.

CPE 426. Introduction to Hardware Security. 4 units
Prerequisite: CPE 315 or CPE 333; and CPE 233.

An introduction to hardware security from embedded systems to secure VHDl design. Topics may include digital rights management, hardware based trojans, hardware implementation of cryptography, sidechannel attacks, secure communication protocols, hardware based overflow detection, physical device verification, and physically unclonable functions. 3 lecture, 1 laboratory.

CPE 428. Computer Vision. 4 units
Prerequisite: CPE 327 or CPE/CSC 357 or EE 328 or ME 305.

Introduction to the concepts of 2D and 3D computer vision: low-level image processing methods such as filtering and edge detection; feature extraction; segmentation and clustering; stereo vision; appearance-based and model-based algorithms. 3 lectures, 1 laboratory. Crosslisted as CPE/EE 428.

CPE 431. Compiler Construction. 4 units
Prerequisite: CSC 430.

Intermediate code representations, memory management, functions and parameter passing, code transformations and optimizations, code generation, register allocation. 3 lectures, 1 laboratory. Crosslisted as CPE/CSC 431.

CPE 432. Digital Control Systems. 3 units
Prerequisite: EE 302 and EE 342; or CPE 327 and CPE 367. Concurrent: CPE/EE 472. Recommended: EE 328 and EE 368.

Theory and applications of digital computers in linear control systems. Analysis and design of microprocessor-based controls. Introduction of continuous and discrete transform methods for design of closed-loop dynamic systems. Applications in robotics, automotive, aircraft and industrial process control. 3 lectures. Crosslisted as CPE/EE 432.

CPE 439. Introduction to Real-Time Operating Systems. 4 units
Prerequisite: CPE/EE 329 or CPE/EE 336.

Theory, design and implementation of real-time operating system-based embedded systems. Scheduling algorithms, operating system resources, peripheral device interfacing and embedded system architecture. Resource management issues in a resource-limited (microcontroller-based) environment. 3 lectures, 1 laboratory. Crosslisted as CPE/EE 439.

CPE 441. Computer-Aided Design of VLSI Devices. 4 units
Prerequisite: EE 307 and EE 347. Recommended: EE 308 and EE 348, for students interested in analog design.

Design of VLSI circuits using state-of-the-art CAD software. Design issues and algorithms related to design using CAD. Full custom design through automated design and a major multi-week chip design project in lab. 3 lectures, 1 laboratory. Crosslisted as CPE 441/EE 431.

CPE 442. Real Time Embedded Systems. 4 units
Prerequisite: CPE/EE 329 or CPE/EE 336 or CPE 316.

Theory, design and implementation of modern embedded systems. Scheduling algorithms and operating system resources. System on Chip (SoC) design issues such as interfacing with custom hardware description language (HDL) peripherals, high-performance chip interconnect standards, energy use, area, and hardware versus software performance trade-offs. 3 lectures, 1 laboratory. Crosslisted as CPE/EE 442.

CPE 446. Design of Fault-Tolerant Digital Systems. 4 units
Prerequisite: CPE/EE 329 or CPE/EE 336 or CPE 316. Recommended: STAT 350.

Hardware and software fault tolerance concepts: fault models, coding in computer systems, module and system level fault detection mechanisms, reconfiguration techniques for general purpose processors and ASICs, and software fault tolerance techniques such as recovery blocks, N-version programming, checkpointing, and recovery. 3 lectures, 1 laboratory. Crosslisted as CPE/EE 446.

CPE 447. Stringed Musical Instrument Acoustics, Mechanics, and Transducer Design. 4 units
Prerequisite: EE/CPE 329 or EE/CPE 336 or CPE 316 or ME 305.

Acoustics, sound production, and transducer design in the context of stringed musical instruments. Introduces music theory, scales and temperament, sound radiation, structural dynamics of stringed instruments. Integrates engineering topics including frequency spectrum analysis, electromagnetics, properties of materials, digital and analog circuit design. 3 lectures, 1 laboratory. Crosslisted as CPE/EE 447.

CPE 450. Capstone II. 3 units
Prerequisite: CPE 350.

Team-based design, construction and deployment of an embedded system that includes a custom-built computer. Technical management of product development teams. Technical documentation, configuration management, quality assurance, integration and systems testing. Professionalism. 1 lecture, 2 laboratories.

CPE 453. Introduction to Operating Systems. 4 units
Prerequisite: CSC/CPE 357, and CSC/CPE 225 or CPE/EE 229 or CPE/EE 233.

Introduction to sequential and multiprogramming operating systems; kernel calls, interrupt service mechanisms, scheduling, files and protection mechanisms, conventional machine attributes that apply to operating system implementation, virtual memory management, and I/O control systems. 3 lectures, 1 laboratory. Crosslisted as CPE/CSC 453.
CPE 454. Implementation of Operating Systems. 4 units
Prerequisite: CSC/CPE 453.

Design and implementation of multiprogramming kernels, systems programming methodology, interprocess communications, synchronization, device drivers and network access methods. 3 lectures, 1 laboratory. Crosslisted as CPE/CSC 454.

CPE 458. Current Topics in Computer Systems. 4 units
Prerequisite: CSC/CPE 357.

Selected aspects of design, implementation and analysis of networks, advanced operating and distributed systems. Topics may include process management, virtual memory, process communication, context switching, file system designs, persistent objects, process and data migration, load balancing, security and networks. The Class Schedule will list topic selected. Total credit limited to 8 units. 3 lectures, 1 laboratory. Crosslisted as CPE/CSC 458.

CPE 461. Senior Project I. 3 units
Prerequisite: CPE 350.

Selection and completion of an individual or team project in laboratory environment. Project results are presented in a formal report. 3 laboratories.

CPE 462. Senior Project II. 2 units
Prerequisite: CPE 450.

Selection and completion of an individual or team project in laboratory environment. Project results are presented in a formal report. 2 laboratories.

CPE 464. Introduction to Computer Networks. 4 units
Prerequisite: CSC/CPE 357. Recommended: STAT 312 or STAT 321 or STAT 350.

Computer network architectures; communications protocol standards; services provided by the network; historical and current examples presented. 3 lectures, 1 laboratory.

CPE 465. Advanced Computer Networks. 4 units
Prerequisite: CSC/CPE 453 and CPE 464.

Advanced topics in computer networks; greater detail of protocol standards and services provided by the network; focus on current industry and research topics. 3 lectures, 1 laboratory.

CPE 469. Distributed Systems. 4 units
Prerequisite: CSC/CPE 357.

Foundations of distributed systems, distributed hash tables (peer-to-peer systems), failure detectors, synchronization, election, interprocess communication, consensus, replication, key-value stores, and measurements. 3 lectures, 1 laboratory. Crosslisted as CSC/CPE 469.

CPE 470. Selected Advanced Topics. 1-4 units
Prerequisite: Consent of instructor.

Directed group study of selected topics for advanced students. Open to undergraduate and graduate students. The Class Schedule will list topic selected. Total credit limited to 8 units. 1 to 4 lectures.

CPE 471. Introduction to Computer Graphics. 4 units
Prerequisite: CPE/CSC 357.

Graphics software development and use of application programming interfaces for 3D graphics. The graphics pipeline, modeling, geometric and viewing transforms, lighting and shading, rendering, interaction techniques and graphics hardware. 3 lectures, 1 laboratory. Crosslisted as CPE/CSC 471.

CPE 472. Digital Control Systems Laboratory. 1 unit
Concurrent: CPE/EE 432.

Design and programming of microprocessor-based digital controls for electro-mechanical plants. Topics include digital control laws, translation of transfer functions into algorithms, assembly language programming, real-time software design, sample rate selection, finite word-length considerations. 1 laboratory. Crosslisted as CPE/EE 472.

CPE 476. Real-Time 3D Computer Graphics Software. 4 units
Prerequisite: CPE/CSC 471.

Basic and advanced algorithms for real-time, interactive, 3D graphics software. Modeling (polygon mesh, height field, scene graph), real-time rendering and shading (visibility processing, LOD, texture and light maps), collision detection (bounding volumes, complexity management), interactive controls, multi-player game technology, game engine architecture. 3 lectures, 1 laboratory. Crosslisted as CPE/CSC 476.

CPE 479. Selected Advanced Laboratory. 1-4 units
Prerequisite: Consent of instructor.

Directed group laboratory study of selected topics for advanced students. Open to undergraduate and graduate students. The Class Schedule will list topic selected. Total credit limited to 8 units. 1 to 4 laboratories.

CPE 482. Advanced Topics in Systems for Computer Engineering. 4 units
Corequisite: CPE 350.

Selected aspects of design, implementation, verification and analysis of advanced computer systems. Topics may include computer systems, embedded systems, robotics, mechatronics, haptics, human computer interfaces, digital control, digital signal processing, wireless computing, real time operating systems, and networks. The Class Schedule will list topic selected. Total credit limited to 8 units, repeatable in same term. 3 lectures, 1 laboratory.

CPE 485. Autonomous Robot Navigation. 4 units
Prerequisite: CPE/CSC 357.

Overview of existing autonomous mobile robot systems, basic kinematic modeling, control structures, sensing and sensor modeling, localization, and motion planning algorithms. Implementation of autonomous navigation capabilities. 3 lectures, 1 laboratory.

CPE 488. Microelectronics and Electronics Packaging. 4 units
Prerequisite: EE 112 or EE 113 or EE 201. Recommended: MATE 210.

CPE 493. Cooperative Education Experience. 2 units
CR/NC
Prerequisite: Sophomore standing and consent of instructor.
Part-time work experience in business, industry, government, and other areas of student career interest. Positions are paid and usually require relocation and registration in course for two consecutive quarters. Formal report and evaluation by work supervisor required. Credit/No Credit grading only. No major credit allowed; total credit limited to 6 units.

CPE 494. Cooperative Education Experience. 6 units
CR/NC
Prerequisite: Sophomore standing and consent of instructor.
Full-time work experience in business, industry, government, and other areas of student career interest. Positions are paid and usually require relocation and registration in course for two consecutive quarters. Formal report and evaluation by work supervisor required. Credit/No Credit grading only. No major credit allowed; total credit limited to 18 units.

CPE 495. Cooperative Education Experience. 12 units
CR/NC
Prerequisite: Sophomore standing and consent of instructor.
Full-time work experience in business, industry, government, and other areas of student career interest. Positions are paid and usually require relocation and registration in course for two consecutive quarters. A more fully developed formal report and evaluation by work supervisor required. Credit/No Credit grading only. No major credit allowed; total credit limited to 24 units.

CPE 515. Computer Architecture. 4 units
Prerequisite: CPE 315 or CPE 333, and graduate standing; or consent of instructor.
Comparative study and design of multiprocessor, dataflow, RISC, high level language and other new computer architectures. VLSI processor design techniques. 3 seminars, 1 laboratory. Crosslisted as CPE/CSC 515.

CPE 521. Computer Systems. 4 units
Prerequisite: CPE/EE 329 or CPE/EE 336, or equivalent, and graduate standing or consent of instructor.
Organization of modern general purpose, high speed digital computer systems. Design of arithmetic units, control units, memories and memory subsystems. Cost, power and speed trade-offs in the design of such systems. 3 seminars, 1 laboratory. Crosslisted as CPE/EE 521.

CPE 522. Advanced Real-Time Operating Systems Design. 4 units
Prerequisite: CPE/EE 439.
Define and implement a microcontroller-based Real-Time Operating System (RTOS). Advanced real-time concepts, kernel structure, task and time management, various intertask communication constructs including semaphores, queues and mailboxes. Scheduler design, memory management and shared resource management in a resource-constrained microcontroller environment. 3 seminars, 1 laboratory. Crosslisted as CPE/EE 522.

CPE 523. Digital Systems Design. 4 units
Prerequisite: CPE/EE 329 or CPE/EE 336, and graduate standing.
Full-custom design and analysis of digital circuits using full CMOS, pass-transistor and dynamic circuit topologies. Transistor sizing for minimizing power consumption, delay and other design criteria. 3 seminars, 1 laboratory. Crosslisted as CPE/EE 523.

CPE 532. VLSI Circuit Testing. 1 unit
Prerequisite: EE 531/CPE 541.
Characterization, testing and documentation of custom-fabricated Very Large Scale Integrated (VLSI) circuits. Use of specialized test equipment. 1 laboratory. Crosslisted as CPE/EE 532.

CPE 541. Advanced VLSI Design. 4 units
Prerequisite: CPE 441/EE 431.
Advanced Very Large Scale Integrated (VLSI) design using state-of-the-art software. Advanced topics in digital, analog and mixed signal circuit design to enable a quarter-long design project culminating in a tapeout-ready integrated circuit design. 3 lectures, 1 laboratory. Crosslisted as CPE 541/EE 531.

CPE 542. Advanced Real Time Embedded Systems. 4 units
Prerequisite: CPE/EE 442.
Advanced study and application of modern embedded systems. Memory bandwidth matching, clock-domain crossing, IP creation and verification, and student-led lectures on modern System on Chip (SoC) design topics. Building a prototype embedded system. 3 lectures, 1 laboratory. Crosslisted as CPE/EE 542.

CPE 564. Computer Networks: Research Topics. 4 units
Prerequisite: CSC/CPE 464 and graduate standing, or consent of instructor.
Exploration of advanced topics in emerging computer networking technologies; focus on leading edge computer network research topics. 3 lectures, 1 laboratory. Crosslisted as CPE/CSC 564.

CPE 569. Distributed Computing. 4 units
Prerequisite: CSC 141 or CSC 348; and CPE/CSC 357; or graduate standing and consent of instructor.
Principles and practices in distributed computing: interprocess communications, group communications, client-server model, distributed objects, message queue system, distributed services, mobile agents, object space, Internet protocols. Distributed algorithms: consensus protocols, global state protocols. Fault tolerance: classification of faults, replication. 3 lectures, 1 laboratory. Crosslisted as CPE/CSC 569.