The required 32 units (8 courses) of departmental electives are taken primarily in the senior year, and they permit students to develop depth in specialty areas of their choice. The 32 units of departmental electives must include at least 2 sequences, one of which must be an approved EE Senior Capstone Design/Project course sequence. A student’s elective course program must be approved by a departmental faculty advisor. The advisor will check the program to ensure satisfaction of the departmental requirements. A wide variety of elective programs will be considered acceptable.

Three matters should be noted: (1) students who fail to attain a grade-point average of at least 2.0 in the major may be denied the privilege of continuing in the major, (2) a large majority of electrical and computer engineering courses have prerequisites which must be completed successfully. Successful completion of prerequisite courses means receiving a grade of C- or better in prerequisite courses except for Mathematics 3A-B, Mathematics 4A-B and Mathematics 6A and 6B which require a grade of C or better to apply these courses as prerequisites, (3) courses required for the pre-major or major, inside or outside of the Department of Electrical Engineering, cannot be taken for the passed/not passed grading option. They must be taken for letter grades.

Bachelor of Science—Computer Engineering

This major is offered jointly by the Department of Computer Science and the Department of Electrical and Computer Engineering. For information about this major, see page 25.

Electrical & Computer Engineering Courses

Many of the ECE courses are restricted to ECE majors only. Instructor and quarter offered are subject to change.

LOWER DIVISION

1A. Computer Engineering Seminar
(1) STAFF
Prerequisite: Open to computer engineering majors only. Seminar: 1 hour
Introductory seminar to expose students to a broad range of topics in Computer Engineering.

1B. Ten Puzzling Problems in Computer Engineering
(1) PARIAMI
Prerequisite: Open to pre-computer engineering and computer engineering majors only.

Not open for credit for those who have taken ECE 1

Gain familiarity with, and motivation to study, the field of computer engineering, through puzzle-like problems that represent a range of challenges facing computer engineers in their daily problem-solving efforts and at the frontiers of research.

3. Introduction to Electrical Engineering
(4) STAFF
Prerequisites: Open to EE majors only. Lecture, 3 hours; laboratory, 2 hours
Introduction to fundamental design problems in Electrical Engineering through programming in Python. Includes basics of software engineering, algorithm design, data structures, with design problems derived from signal systems. Specific areas will include 1-D and 2-D signal processing, basic transforms and applications.

5. Introduction to Electrical & Computer Engineering
(4) STAFF
Prerequisite: Open only to Electrical Engineering and Computer Engineering majors. Lecture: 2 hours; Laboratory: 3 hours
Aims at exposing freshmen students to the different sub-fields within Electric and Computer Engineering. Composed of lectures by different faculty members and a weekly laboratory based on projects that are executed using the Arduino environment.

10A. Foundations of Analog and Digital Circuits & Systems
(3) STAFF
Prerequisite: Mathematics 2A-B or 3A-B or Mathematics 3AH-3BH, and Mathematics 3C or 4A or 4AI with a minimum grade of C; and, Math 4B or 4BI or 5A with a minimum grade of C (may be taken concurrently); Physics 3 or 23 (may be taken concurrently); open only to electrical engineering and computer engineering majors. Lecture: 3 hours
Not open for credit for those who have received a C- or higher in ECE 2A.

The objective of the course is to establish the foundations of analog and digital circuits. The course will introduce the student to the power of abstraction, resistive networks, network analysis, nonlinear analysis and the digital abstraction. (F)

10AL. Foundations of Analog and Digital Circuits and Systems Lab
(2) STAFF
Prerequisite: ECE 10A (may be taken concurrently) with a C- or better grade. Laboratory: 4 hours
Not open for credit for those who have received a C- or higher in ECE 2A.

The goal of 10AL is to provide the student with a hands-on application of the concepts discussed in ECE 10A. The lab will introduce the use of microcontrollers as a data acquisition system, network analysis, resistors, nonlinear analysis and digital abstraction. (F)

10B. Foundations of Analog and Digital Circuits and Systems
(3) STAFF
Prerequisite: ECE 10A with a C- or better grade. Lecture: 3 hours
Not open for credit for those who have received a C- or higher in ECE 2B.

The objective of the course is to introduce the MOSFET both as a simple digital switch and as controlled current source for analog design. The course will cover basic digital design, small-signal analysis, charge storage elements and operational amplifiers. (W)

10BL. Foundations of Analog and Digital Circuits and Systems Lab
(2) STAFF
Prerequisite: ECE 10B (may be taken concurrently) with a C- or better grade. Laboratory: 4 hours
Not open for credit for those who have received a C- or higher in ECE 2B.

The goal of 10BL is to provide the student with a hands-on application of the concepts discussed in ECE 10B. The lab will utilize the microcontroller to introduce students to the understanding of datasheets for both digital and analog circuits, single-stage

3. Introduction to Electrical Engineering
(4) STAFF
Prerequisites: Open to EE majors only. Lecture, 3 hours; laboratory, 2 hours
Introduction to fundamental design problems in Electrical Engineering through programming in Python. Includes basics of software engineering, algorithm design, data structures, with design problems derived from signal systems. Specific areas will include 1-D and 2-D signal processing, basic transforms and applications.

5. Introduction to Electrical & Computer Engineering
(4) STAFF
Prerequisite: Open only to Electrical Engineering and Computer Engineering majors. Lecture: 2 hours; Laboratory: 3 hours
Aims at exposing freshmen students to the different sub-fields within Electric and Computer Engineering. Composed of lectures by different faculty members and a weekly laboratory based on projects that are executed using the Arduino environment.

10A. Foundations of Analog and Digital Circuits & Systems
(3) STAFF
Prerequisite: Mathematics 2A-B or 3A-B or Mathematics 3AH-3BH, and Mathematics 3C or 4A or 4AI with a minimum grade of C; and, Math 4B or 4BI or 5A with a minimum grade of C (may be taken concurrently); Physics 3 or 23 (may be taken concurrently); open only to electrical engineering and computer engineering majors. Lecture: 3 hours
Not open for credit for those who have received a C- or higher in ECE 2A.

The objective of the course is to establish the foundations of analog and digital circuits. The course will introduce the student to the power of abstraction, resistive networks, network analysis, nonlinear analysis and the digital abstraction. (F)

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Prerequisite: ECE 10A (may be taken concurrently) with a C- or better grade. Laboratory: 4 hours
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10B. Foundations of Analog and Digital Circuits and Systems
(3) STAFF
Prerequisite: ECE 10A with a C- or better grade. Lecture: 3 hours
Not open for credit for those who have received a C- or higher in ECE 2B.

The objective of the course is to introduce the MOSFET both as a simple digital switch and as controlled current source for analog design. The course will cover basic digital design, small-signal analysis, charge storage elements and operational amplifiers. (W)

10BL. Foundations of Analog and Digital Circuits and Systems Lab
(2) STAFF
Prerequisite: ECE 10B (may be taken concurrently) with a C- or better grade. Laboratory: 4 hours
Not open for credit for those who have received a C- or higher in ECE 2B.

The goal of 10BL is to provide the student with a hands-on application of the concepts discussed in ECE 10B. The lab will utilize the microcontroller to introduce students to the understanding of datasheets for both digital and analog circuits, single-stage
amplifier design and basic instrumentation.

10C. Foundations of Analog and Digital Circuits and Systems

121. Introduction to Nanoelectro-mechanical Systems (NEMS/NANO)

122A. VLSI Principles

122B. VLSI Architecture and Design

123. High-Performance Digital Circuit Design

124A or 124B. Quantitative Analysis of Linear Models

125. High Speed Digital Integrated Circuit Design

126. High Speed Digital Integrated Circuit Design

127A. Circuits and Electronics I

127B. Circuits and Electronics II

130A. Signal Analysis and Processing

130B. Signal Analysis and Processing

131. Signal Analysis and Processing

132. Introduction to Solid-State Electronic Devices

133. Introduction to Fields and Waves

135. Optical Fiber Communication

137A. Circuits and Electronics I

137B. Circuits and Electronics II

139. Probability and Statistics

146A. Digital Communication Fundamentals (5) MADHOW
Prerequisite: ECE 130A-B with a minimum grade of C-; open to EE majors only. Lecture: 3 hours; Laboratory: 6 hours
- Signal and channel models, with emphasis on wireless systems; digital modulation; demodulation basics; statistical modeling of noise, including review of probability theory and random variables.

146B. Communication Systems Design (5) MADHOW
Prerequisite: ECE 130A-B and 146A with minimum grades of C-; open to EE majors only. Lecture: 3 hours; Laboratory: 6 hours
- Optimal demodulation, including signal space geometry; communication performance characterization; advanced wireless communication techniques, including multi-antenna and multicarrier systems; other emerging frontiers in communications.

147A. Feedback Control Systems - Theory and Design (5) TEEL
Prerequisite: ECE 130A-B with a minimum grade of C- in each; open to EE and computer engineering majors only. Lecture: 3 hours; Laboratory: 6 hours
- Feedback systems design, specifications in time and frequency domains. Analysis and synthesis of closed loop systems. Computer aided analysis and design.

147B. Digital Control Systems - Theory and Design (5) BYE
Prerequisite: ECE 147A with a minimum grade of C-; open to EE and computer engineering majors only. Lecture: 3 hours; Laboratory: 3 hours
- Analysis of sampled data feedback systems; state space description of linear systems; observability, controllability, pole assignment, state feedback, observers. Design of digital control systems. (W)

147C. Control System Design Project (5) MISHRA
Prerequisite: ECE 147A or ME 155B or ME 173 with a minimum grade of C- in each course; open to electrical engineering, computer engineering, and computer science majors only. Lecture: 3 hours; Laboratory: 3 hours
- Students are required to design, implement, and document a significant control systems project. The project is implemented in hardware or in high-fidelity numerical simulators. Lectures and laboratories cover special topics related to the practical implementation of control systems.

148. Applications of Signal Analysis and Processing (4) LEE
Prerequisite: ECE 130A and 130B with a minimum grade of C- in both. Lecture: 3 hours; Discussion: 2 hours
- Recommended Preparation: concurrent enrollment in ECE 130C.
- A sequence of engineering applications of signal analysis and processing techniques; in communications, image processing, analog and digital filter design, signal detection and parameter estimation, holography and tomography, Fourier optics, and microwave and acoustic sensing.

149. Game Theory for Networked Systems (4) MADKEN
Prerequisite: upper division standing or consent of instructor.
- An overview of game theory with an emphasis on application to multiagent systems. Game theory focuses on the study of systems that are comprised of interacting and possibly competing decision-making entities. Examples drawn from engineered, economic, and social systems.

150. Mobile Embedded Systems (4) STAFF
Prerequisite: Proficiency in JAVA programming, and a C- in ECE 152A.
- Architectures of modern smartphones and their key hardware components including mobile application processors, communications chips, display subsystems, graphics, power management, battery, GPS, and various sensors; the OS and software development platform of smartphones; smartphone applications; low power design techniques.

152A. Digital Design Principles (5) STAFF
Prerequisite: ECE 15A and 2A or ECE 10A & ECE 10AL with a minimum grade of C- in each course; or Computer Science 30 or 64 with a minimum grade of C- in each course; open to electrical engineering, computer engineering, and computer science majors only. Lecture: 3 hours; Laboratory: 6 hours
- Design of synchronous digital systems: timing diagrams, propagation delay, latches and flip-flops, shift registers and counters, Mealy/Moore finite state machines, Verilog, 2-phase clocking, timing analysis, CMOS implementation, S-RAM, RAM-based designs, ASMs, state minimization.
157A. Machine Learning in Design and Test Automation
(4) LI C. WANG
Prerequisite: ECE 152A with a minimum grade of C-.
Introduces the various machine learning techniques and how they are utilized to improve hardware design and test automation processes. The potential benefits and theoretical barriers for implementing a machine learning solution in practice are explained.

157B. Artificial Intelligence in Design and Test Automation
(4) LI C. WANG
Prerequisite: ECE 157A with a minimum grade of C-.
Introduces an artificial intelligence system view to apply machine learning in design and test automation processes. The various components for building an Intelligent Engineering Assistant (IEA) to perform an engineering task in an industrial setting are explained.

158. Digital Signal Processing
(4) GIBSON
Prerequisites: ECE 130A-B with a minimum grade of C- in both; open to EE majors only.
Lecture: 3 hours; laboratory: 3 hours.
Recommended Preparation: Mathematics 124A.
Mathematics 124A is required but not required.
Digital Signal Processing, with Applications: The Fast Fourier transform, discrete cosine transform, and multirate digital signal processing techniques, with applications to digital cellular communications and wireless access points, and audio, voice, still image, video, and biological signal analysis, recognition and compression.

160. Multimedia Systems
(4) MANJUNATH
Prerequisites: Upper-division standing; open to electrical engineering, computer engineering, computer science, and creative studies majors only.
Lecture: 3 hours; laboratory: 3 hours.
Not open for credit to students who have completed CMPSC 182.
Introduction to multimedia and applications, including WWW, image/video databases and video streaming. Covers media content analysis, media data organization and indexing (image/video databases), and media data distribution and interaction (video-on-demand and interactive TV).

162A. The Quantum Description of Electronic Materials
(4) Staff
Prerequisites: ECE 130A-B and 134 with a minimum grade of C- in all; open to EE, seniors in the BS/MS program and Materials graduate students only.
Same course as Materials 162A. Lecture: 4 hours.

162B. Fundamentals of the Solid State
(4) Staff
Prerequisite: ECE 162A with a minimum grade of C-; open to EE, senior students in the BS/MS programs and Materials graduate students only.
Same course as Materials 162B. Lecture: 3 hours; discussion: 1 hour.

162C. Optoelectronic Materials and Devices
(4) Staff
Prerequisites: ECE 162A-B with a minimum grade of C-; open to electrical engineering and materials majors only. Lecture: 3 hours; discussion: 1 hour.

178. Introduction to Digital Image and Video Processing
(4) Staff
Prerequisites: open to EE, computer engineering, and computer science majors with upper-division standing. Lecture: 3 hours; discussion: 1 hour.
Basic concepts in image and video processing. Topics include image formation and sampling, image transforms, image enhancement, including JPEG and MPEG coding standards.

179D. Introduction to Robotics: Dynamics and Control
(4) ByL
Prerequisites: ECE 130A or ME 155A (may be taken concurrently).
Same course as ME 179D.
Dynamic modeling and control methods for robotic systems. LaGrangian method for deriving equations of motion, introduction to the Jacobian, and modeling and control of forces and contact dynamics at a robotic end effector.
Laboratories encourage a problem-solving approach to control.

179F. Introduction to Robotics: Planning and Kinematics
(4) Bullo
Prerequisites: ENGR 3; and either ME 17 or ECE 130C (may be taken concurrently).
Same course as ME 179F.
Motion planning and kinematics topics with an emphasis on geometric reasoning, programming, and matrix computations. Motion planning: configuration spaces, sensor-based planning, decomposing and sampling methods, and advanced planning algorithms. Kinematics: reference frames, rotations and displacements, kinematic motion models.

180. Introduction to Deep Learning
(4) Manjunath
Prerequisite: Open to EE, Computer Engineering and Computer Science with upper-division standing.
Introduction to multilayered neural networks, early models of perceptions, and associative memories. Back-propagation learning; convolutional neural networks; recurrent neural networks; attention models; applications to natural language processing and computer vision.

181. Introduction to Computer Vision
(4) Manjunath
Prerequisite: Upper-division standing in Electrical Engineering, Computer Engineering, Computer Science, Chemical Engineering or Mechanical Engineering.
Lecture: 3 hours; discussion: 1 hour.
Same course as Computer Science 181B.
Repeat Comments: Not open for credit to students who have completed ECE/CMPSC 181B with a grade of C or better. ECE/CMPSC 181B is a legal repeat of ECE/CMPSC 181B.
Overview of computer vision problems and techniques for analyzing the content of images and video. Topics include image formation, edge detection, image segmentation, pattern recognition, texture analysis, optical flow, stereo vision, shape representation and recovery techniques, issues in object recognition, and case studies of practical vision systems.

183. Nonlinear Phenomena
(4) Staff
Prerequisites: Physics 105A or Physics 103; or ME 163 or upper-division standing in ECE.
Same course as Physics 106 and ME 169. Not open for credit to students who have completed ECE 163C. Lecture: 3 hours; discussion: 1 hour.
An introduction to nonlinear phenomena. Flows and bifurcations in one and two dimensions, chaos, fractals, strange attractors. Applications to physics, engineering, chemistry, and biology.

188A. Senior Electrical Engineering Project
(3) Ben Yaacov
Prerequisite: ECE 130A and ECE 130B with a C- or better in both; or ECE 137A and ECE 137B with a C- or better in both.
Student groups design a significant project based on the knowledge and skills acquired in earlier coursework and integrate their technical knowledge through a practical design experience. The project is evaluated through written reports, oral presentations, and demonstrations of performance.

188B. Senior Electrical Engineering Project
(3) Ben Yaacov
Prerequisite: ECE 188A with a minimum grade of C-.
Lecture: 3 hours; laboratory: 3 hours.
Student groups design a significant project based on the knowledge and skills acquired in earlier coursework and integrate their technical knowledge through a practical design experience. The project is evaluated through written reports, oral presentations, and demonstrations of performance.

189A. Senior Computer Systems Project
(4) Isukapalli
Prerequisite: ECE 153B; senior standing in Computer Engineering, Computer Science or EE. Lecture: 3 hours; laboratory: 3 hours.
Not open for credit to students who have completed Computer Science 189A-B.
Student groups design a significant computer-based project. The focus will be on designing a significant project based on the knowledge and skills acquired in earlier coursework and fulfill the requirements. The project is evaluated through written reports, oral presentations, and demonstrations of performance.

189B. Senior Computer Systems Project
(4) Isukapalli
Prerequisite: ECE 189A; senior standing in Computer Engineering, Computer Science or EE. Lecture: 3 hours; laboratory: 3 hours.
Not open for credit to students who have completed Computer Science 189A-B.
Student groups design a significant computer-based project. The focus will be on building and maintaining an embedded hardware system. Each group works independently with interaction among groups via interface specifications and informal meetings. The project is evaluated through successful completion of milestones and individual/group project reports and presentations.

189C. Senior Computer Systems Project
(4) Isukapalli
Prerequisite: ECE 189B; senior standing in Computer Engineering, Computer Science or EE. Lecture: 3 hours; laboratory: 3 hours.
Not open for credit to students who have completed Computer Science 189A-B.
Student groups design a significant computer-based project. The focus is on building and implementing an embedded hardware system. Each group works independently. The project is evaluated through project reports, achieving milestones and through successful demonstration of hardware functionality.
192. Projects in Electrical and Computer Engineering
(4) STAFF
Prerequisite: consent of instructor. Discussion, 2 hours; laboratory, 6 hours.
Projects in electrical and computer engineering for advanced undergraduate students.

193. Internship in Industry
(1-8) STAFF
Prerequisite: consent of department. Must have a 3.0 grade-point-average. May not be used as departmental electives. May be repeated to a maximum of 12 units. Field, 1-8 hours.
Special projects for selected students. Offered in conjunction with engineering practice in selected industrial and research firms, under direct faculty supervision.

194AA-ZZ. Special Topics in Electrical and Computer Engineering
(1-5) STAFF

196. Undergraduate Research
(2-4) STAFF
Prerequisites: upper-division standing; consent of instructor. Must have a minimum 3.0 grade-point average for the preceding three quarters. May be repeated for up to 12 units. Not more than 4 units may be applied to departmental electives.
Research opportunities for undergraduate students. Students will be expected to give regular oral presentations, actively participate in a weekly seminar, and prepare at least one written report on their research.

199. Independent Studies in Electrical and Computer Engineering
(1-5) STAFF
Prerequisites: upper division standing; completion of two upper-division courses in electrical and computer engineering; consent of instructor. Must have a minimum 3.0 grade-point average for the preceding three quarters. Students are limited to five units per quarter and 30 units total in all 98/99/198/199/199DC/199RA courses combined.
Directed individual study, normally experimental.

GRADUATE COURSES
Graduate courses for this major can be found in the UCSB General Catalog.