
Electrical Engineering

[2009-10 update to the *General Catalog*, changes highlighted]

Baskin School of Engineering
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<http://www.soe.ucsc.edu>

Program Description

Mission Statement

The mission of the Electrical Engineering Department is to build and sustain a teaching and research program to provide undergraduate and graduate students with inspiring and quality education in the theory and practice of hardware- and information-processing-oriented electrical engineering; serving industry, science, and government; and bringing faculty and staff a rewarding career in teaching, research, and service. The electrical engineering program is accredited by the Engineering Accreditation Committee of the Accreditation Board for Engineering and Technology (ABET).

Summary of Objectives

The educational objectives that the Electrical Engineering Department strives to provide for students are focused in five areas: fundamental prerequisites in theory, design, and basic science for a career based on electrical engineering; a scope of application that provides theory and practical knowledge as well as specialized training in hardware- and information-oriented electrical engineering; a professional approach to engineering in terms of high quality work skills in communication, teamwork, responsibility, high ethical standards, and participation in lifelong learning and the professional engineering community; encouragement and motivation based on a milieu of readily available opportunities, mentoring, and advising; and the basis for a successful transition to an engineering career, including an ability to apply research to engineering and opportunities for experience in an industry setting.

Engineering is a profession that emphasizes analysis and design, and electrical engineers apply their knowledge to an expanding array of technical, scientific, and mathematical questions. A good engineering education has three parts: a sound foundation in mathematics and science, substantial design experience to develop skills and engineering aesthetics, and a focus in the humanities and social sciences to learn how and where to apply the skills developed.

Electrical engineering is a very broad discipline; the program at UCSC complements existing campus programs, emphasizing three general areas: electronics/optics (including digital and analog circuits and devices); communications (including signal and image processing and

control); and VLSI design, micro-technology, nanotechnology, and biomedical devices.

The undergraduate curriculum provides a balance of engineering science and design. For the first two years, all electrical engineering students are expected to take a basic set of lower-division mathematics, physical science, and engineering courses. After the first two years, electrical engineering students focus on topics within the discipline and specialize in one of two options: electronics/optics, including digital and analog circuits and devices, VLSI design, optoelectronics, electromagnetics, and biomedical device engineering; or communications, signals, systems, and control, including optical, wireless communication, signal and image processing, networks signal processing, instrumentation, and control. Students interested in admission to the electrical engineering major should contact the Baskin School of Engineering Undergraduate Advising office, (831) 459-5840 or advising@soe.ucsc.edu.

Electrical Engineering Policies

Admissions Policy

Admission to the electrical engineering major is selective. First-year applicants may receive direct admission at the time they apply to UCSC based on their high school record and test scores. Students not directly admitted may still apply during their first year and their acceptance will be based upon their School of Engineering GPA, their high school grade point average, courses completed in mathematics and sciences, and scores on standardized tests. *After the first year, students can apply to declare an electrical engineering major upon successful completion of all the following foundation courses with an SoE GPA of 2.8 or better: Mathematics 19A-B, Applied Mathematics and Statistics 10 and 20, Physics 5A, 5B, and 5C.*

Students who have not met this GPA requirement are required to meet with the EE Undergraduate Director. Please refer to the School of Engineering section of the catalog for the full admissions policy.

~~*After the first year, students can apply to declare an electrical engineering major upon completion (with a grade of C or better) of all of the foundation courses: Mathematics 19A-B, Applied Mathematics and Statistics 10 and 20, Physics 5A, 5B, and 5C. Please refer to the School of Engineering section of the catalog for the full admissions policy.*~~

Course Substitution

Please refer to the School of Engineering section of the catalog for the policy regarding course substitution.

Disqualification Policy

Please refer to the School of Engineering section of the catalog for the Major Disqualification Policy.

Letter Grade Policy

The Electrical Engineering Department requires letter grading for all courses applied toward the B.S. degree, with the exception of two lower-division courses, which students may elect to take Pass/No Pass.

~~This exception does not include course 70/L, which must be taken for a letter grade.~~

Honors in the Major

Electrical engineering majors are considered for “Honors in the Major” and “Highest Honors in the Major” based on the School of Engineering GPA and on results of undergraduate research and other significant contributions to the School of Engineering.

Students with an SOE GPA of 3.7, in most cases, receive Highest Honors. Students with an SOE GPA of 3.3, in most cases, receive Honors. Students with particularly significant accomplishments in undergraduate research or contributions to the School of Engineering may be considered with a lower SOE GPA. Electrical engineering juniors and seniors may also be eligible for election to the UCSC chapter of Tau Beta Pi, the national engineering honor society founded in 1885.

Transfer Students

Please refer to the School of Engineering section of the catalog for the policy regarding transfer students and admission of transfer students to the electrical engineering major.

School of Engineering Policies

Please refer to the School of Engineering section of the catalog for additional policies that apply to all School of Engineering programs.

Major Requirements

In addition to completing UCSC’s general education requirements, students must complete 15 lower-division science and engineering courses, plus associated laboratories; eight upper-division engineering courses, plus associated laboratories; four engineering electives; and a comprehensive senior design project course. To plan for completion of these requirements within the normative time, students should consult with an adviser at the Baskin School of Engineering Undergraduate Advising office as early as possible.

Lower-Division Requirements

Students gain a solid foundation in calculus, engineering mathematics, physics, computer science, and computer engineering during their first two years. Majors must complete the following ~~15~~ 14 lower-division courses (including corresponding laboratories). These courses form part of the prerequisite sequence and should be completed during the first two years at UCSC. The requirements are rigorous; students must be prepared to begin these courses early in their studies.

Electrical Engineering

~~70/L, Introduction to Electronic Circuits/Laboratory~~

80T, Modern Electronic Technology and How It Works

Computer Engineering/Computer Science

Computer Engineering 12/L, *Computer Systems and Assembly Language/Laboratory*

Computer Engineering 13/L, *Computer Systems and C Programming/Laboratory* or Computer Science 12A/L, *Introduction to Programming (Accelerated)/Laboratory*

Computer Engineering 16, *Applied Discrete Mathematics*; or
Computer Engineering 16H, *Honors Applied Discrete Mathematics*

~~Computer Engineering 12/L, *Computer Systems and Assembly Language/Laboratory*~~

80E, *Engineering Ethics*

Computer Science

~~12A/L, *Introduction to Programming/Laboratory*; or 13H, *Introduction to Programming and Data Structures (Honors)/Laboratory*~~

Mathematics

19A-B, *Calculus for Science, Engineering, and Mathematics*

23A-B, *Multivariable Calculus*

Applied Mathematics and Statistics

10, *Mathematical Methods for Engineers I*

20, *Mathematical Methods for Engineers II*

~~27L, *MATLAB Laboratory*~~

Physics

5A/L, 5B/M, 5C/N, *Introduction to Physics/Laboratories*

5D, *Heat, Thermodynamics, and Kinetics*

Ethics

Students must take one of the following courses (required even for transfer students who have had their general education requirements waived):

Computer Engineering 80E, *Engineering Ethics*

Philosophy 22, *Introduction to Ethical Theory*

Philosophy 24, *Introduction to Ethics: Contemporary Moral Issues*

Philosophy 28, *Environmental Ethics*

Biomolecular Engineering 80G/Philosophy 80G, *Bioethics in the 21st Century: Science, Business, and Society*

Upper-Division Requirements

~~Thirteen~~ ~~Fourteen~~ ~~Fifteen~~ upper-division courses along with associated 1- or 2-credit laboratories are required for the major. The course requirements include both depth and breadth, technical writing, and a comprehensive capstone design project.

All students are required to take the following ~~eight~~nine upper-division courses, with associated laboratories:

Electrical Engineering

101/L, *Introduction to Electronic Circuits/Laboratory* (~~pending approval~~)

103, *Signals and Systems*

135/L, *Electromagnetic Fields and Waves/Laboratory*

145/L, *Properties of Materials/Laboratory*

151, *Communications Systems*

171/L, *Analog Electronics/Laboratory*

Computer Engineering

100/L, *Logic Design/Laboratory*

107, *Mathematical Methods of Systems Analysis: Stochastic*

185, *Technical Writing for Computer Engineers*

Required Electives. In addition to completing the above required courses, electrical engineering majors must complete four elective courses chosen from the list below. At least three must be from one of the depth-sequence concentrations listed. Certain graduate-level courses as well as those courses taught in conjunction with graduate courses may also be used to fulfill an elective requirement as listed below. No course may be counted twice. See the electrical engineering web site for course descriptions: www.ee.ucsc.edu/academics.htm.

Electronics/Optics Concentration

Electrical Engineering

115, *Introduction to Micro-Electro-Mechanical-Systems Design*

130/L/ 230, *Introduction to Optoelectronics and Photonics and Laboratory/Optical Fiber Communication*

136, *Engineering Electromagnetics (strongly recommended)*

154/241, *Feedback Control Systems, and Introduction to Feedback Control Systems*

172/221, *Advanced Analog Circuits/Advanced Analog Integrated Circuits*

178, *Device Electronics*

211, *Introduction to Nanotechnology*

231, *Optical Electronics*

Computer Engineering

118/L, *Introduction to Mechatronics/Laboratory*

121/L, *Microprocessor System Design/Laboratory (strongly recommended)*

173/L, *High Speed Digital Design/Laboratory*

Applied Mathematics and Statistics

147, Computational Methods and Applications

Communications, Signals, Systems, and Controls Concentration

Electrical Engineering

*130/L/230, Introduction to Optoelectronics, and Photonics and
Laboratory/Optical Fiber Communication*

136, Engineering Electromagnetics (strongly recommended)

*152/252, Introduction to Wireless Communications and Wireless
Communications*

153/250, Digital Signal Processing

*154/241, Feedback Control Systems and Introduction to Feedback
Control Systems*

251, Principles of Digital Communications

253, Information Theory

261, Error Control Coding

262, Statistical Signal Processing I

264, Image Processing and Reconstruction

~~*261, Error Control Coding*~~

~~*253, Information Theory*~~

Computer Engineering

118/L, Introduction to Mechatronics/Laboratory

150/L, Introduction to Computer Networks/Laboratory

~~*251, Principles of Digital Communications*~~

Applied Mathematics and Statistics

147, Computational Methods and Applications

162, Design and Analysis of Computer Simulation Experiments

The senior-year curriculum enables students to pursue independent study with a faculty member. Electrical engineering students are encouraged to take advantage of the opportunity to work within a faculty member's research group as part of their educational experience. Internship programs with local industry are available.

Disciplinary Communication (DC) Requirement

Students of every major must satisfy that major's upper-division Disciplinary Communication (DC) requirement. The DC requirement will normally be met within one to three courses already required for the major. For detailed information on this major's DC requirement, consult your major adviser or see the 2010-11 general catalog.

Comprehensive Requirement

The senior comprehensive requirement for electrical engineering majors is in two parts: a project course and assessment options.

Project Course

Students must complete one capstone design course that spans two quarters, Electrical Engineering 123A and 123B, or complete a senior thesis. These senior-level courses encompass an in-depth project, including analysis, design, testing, and documentation, requiring students to call upon knowledge acquired throughout their undergraduate studies. Current course choices include the following:

Electrical Engineering

123A and 123B, Engineering Design Project I (5 credits) and Engineering Design Project II (7 credits)
195, Senior Thesis Project (10 credits over two quarters)

Outcomes Assessment Options

The Electrical Engineering Department requires an outcomes assessment. All students are required to complete an exit survey and meet with a faculty member for an exit interview. The specifics of the outcomes assessment may change from year to year; for this catalog year, students must complete one of the following options:

maintenance of a 2.5 grade point average in all required and elective courses for the major; or

senior thesis submission; or

portfolio review.

Portfolios must include the following:

project report(s);

a one- or two-page overview of the student's contribution to the project(s);

a two-page essay concerning the relationship of engineering to society (specific topics will be provided by the Electrical Engineering Department).

The portfolios must be submitted electronically at least seven days before the end of the instruction in the quarter of graduation.

Portfolios will not be returned.

Electrical Engineering Major Planners

The following are two sample academic plans for students to complete during their first two years as preparation for the electrical engineering major.

Plan One			
Year	Fall	Winter	Spring
1st (frsh)	Math -MATH 19A PHYS hys 5A/L College core	Math -MATH 19B PHYS hys 5B/M EE 80T	AMS 10 Phys -PHYS 5C/N gen ed (C2)
2nd	Phys -PHYS 5D	EE 70 101/L	EE 171/L

Plan One			
(soph)	MATH ath 23A CMPE mpe 12A/L	AMS 20 Math-MATH 23B	CMPE mpe 13/L gen ed

Plan Two			
Year	Fall	Winter	Spring
1st (frsh)	AMS 3 C mpe -CMPE 8 College core	Math 19A Cmpe 12/L EE 80T	Math 19B CMPE mpe 13/L gen ed (C2)
2nd (soph)	Phys-PHYS 5A/L AMS 10 gen ed	Phys-PHYS 5B/M AMS 20 CMPE mpe 100/L	Phys-PHYS 5C/N MATH ath 23A CMPE mpe 80E

Additional information about this program can be found on the department's web site at <http://www.ee.ucsc.edu/undergraduates>
~~www.soe.ucsc.edu/programs/undergraduate/~~

Electrical Engineering Minor

The electrical engineering minor provides a solid foundation in the core areas of electronic circuits and signals and systems, as well as the prerequisite material in mathematics and physics. Concentration of upper division electives in either of the major tracks constitutes substantial and focused work in the discipline of electrical engineering. This minor is particularly suitable for students with majors in Applied Physics or any School of Engineering major.

Electrical Engineering Minor Requirements

Requirements for the minor in electrical engineering are the following:

Mathematics

Mathematics 19A-B, Calculus for Science, Engineering, and Mathematics

Mathematics 23A, Multivariable Calculus

Applied Mathematics and Statistics 27/L, Mathematical Methods for Engineers/Laboratory; or Applied Mathematics and Statistics 10, Mathematical Methods for Engineers I, and 20, Mathematical Methods for Engineers II, ~~and 27L, MATLAB for Engineers Laboratory~~; or Mathematics 21, Linear Algebra and Mathematics 24, Ordinary Differential Equations, and Applied Mathematics and Statistics 27L, MATLAB for Engineers Laboratory.

Science

Physics 5A/L or 6A/L, Mechanics and 5C/N or 6C/N, Electricity and Magnetism

Core Requirements

Electrical Engineering

Electrical Engineering 70101/L, *Introduction to Electronic Circuits/Laboratory*; and

Electrical Engineering 103, *Signals and Systems*; and

Electrical Engineering 171/L, *Analog Electronics/Laboratory*

Upper Division Electives

At least 15 units of upper-division or graduate electrical engineering courses, all chosen from one of the existing electrical engineering major tracks. All of the upper-division electives must come from the same track.

Graduate Programs

The Department of Electrical Engineering (EE) at the University of California, Santa Cruz (UCSC) offers M.S. and Ph.D. degree programs and conducts research in:

Photonics and Electronics focusing on VLSI, electronic and optoelectronic materials, devices, circuits and systems for information transmission, storage, processing, and display, especially for optical fiber communications and lower power, high performance systems, biomedical device instrumentation and MEMS;

Signal Processing and Communications, including wireless and optical communications, coding, digital signal processing, image and video processing;

Remote Sensing including wave propagation and scattering radar oceanography, and microwave remote sensing.

Nanotechnology including applications to bio-medicine, integrated optics for biomedical imaging, opto-thermo-electric energy conversion, near-field scanning optical microscopy, nano-magneto-optics, micro-mechanics and micro-fluidics.

Electrical Engineering enjoys a close relationship with the Departments of Applied Mathematics and Statistics, Computer Science, Computer Engineering, Biomolecular Engineering, Chemistry, Physics, Astronomy, and Molecular, Cell and Developmental Biology faculty. The Electrical Engineering faculty are affiliated with: 1) several federally funded and nationally recognized centers such as the Center for Biomimetic MicroElectronic Systems, the Center for Adaptive Optics, and the Center for Biomolecular Science and Engineering; 2) state-funded centers such as the Institute for Quantitative Biology (QB3), the Center for Information Technology Research in the Interest of Society (CITRIS), and the Institute for Regenerative Medicine (CIRM); and 3) many EE faculty participate in the University Affiliated Research Center (UARC) at NASA-Ames, which is managed by UCSC. The department also has ties to nearby industry, employing electrical engineering professionals as visiting and adjunct faculty and arranging for students to gain practical research experience through work in industrial labs. Indeed,

the department strongly encourages students of all nationalities to seek practical training as part of their graduate education.

Students begin the program with the completion of courses in a core area of interest and then proceed to do research in their area of specialization. The M.S. degree can be completed in two years. M.S. students must complete a master's thesis. A Ph.D. degree is usually completed in four to six years. Ph.D. students are required to take a preliminary exam within their first two years of study. After completing the course requirements, students must pass an oral qualifying exam and write a dissertation. Part-time study is possible for students working in industry while attending school.

Requirements for the Master's Degree

Course Requirements

Each student is required to take 45 units which must consist of:

At least 15 units in one of the four core areas of emphasis defined above.

At least 25 of the total 45 units must be satisfied through EE graduate courses.

At most 10 units of independent study (EE 297, EE 299) are counted toward the EE course requirements.

Total units required for the M.S. degree = 45.

Note that each graduate course satisfying the above requirements typically covers 5 units.

Thesis

Completion of a master's thesis is required for the Master's degree. To fulfill this requirement, the student submits a written proposal to a faculty member, usually by the third academic quarter. By accepting the proposal, the faculty member becomes the thesis adviser. In consultation with the adviser, the student forms a Master's Thesis Reading Committee with at least two additional faculty members, each of whom is provided a copy of the proposal. Upon completion of the thesis work, the student presents an expository talk on the thesis research, and the final thesis must be accepted by the review committee before the award of the Master of Science degree.

MS students admitted to continue to the Ph.D. program must pass an oral preliminary exam covering fundamental undergraduate course work and a research topic (see below).

Requirements for the Ph.D. Degree

Course Requirements*

Each student is required to take 50 units which must consist of:

At least 20 units in one of the four core areas of emphasis defined above.

At least 30 of the total 50 units must be satisfied through EE graduate courses.

At most 10 units of independent study (EE297, EE299) are counted toward EE course requirements.

Total units required for the PhD. degree = 50

* For students already holding an MSEE or equivalent degree, at most 20 units of transfer credit may be granted for equivalent course work performed at the

students' M.S. granting institution. Credit transfer is subject to approval by the adviser and the electrical engineering graduate committee.

Preliminary Examination

At the end of the first year, i.e., no later than the fall quarter in the following year after their entry, students admitted to the Ph.D. program must take a written exam covering basic knowledge in electrical engineering. This examination will cover material from the following technical areas:

Circuits at the level of Electrical Engineering ~~70~~101

Electromagnetics at the level of Electrical Engineering 135

Systems and signals at the level of Electrical Engineering 103

Materials at the level of EE 130 and Electrical Engineering 145

Applied Mathematics and Statistics at the level of Computer

Engineering 107, and Applied Mathematics and Statistics 10 and 20.

The student will choose three areas from the above list in which to be examined. If the student does not pass the preliminary examination, the Electrical Engineering graduate committee may allow the student to repeat the preliminary examination once. If the student is to leave the Ph.D. program, and the student wishes to obtain a master's degree prior to departure, all requirements for the master's degree must still be satisfied.

After the student passes the preliminary examination, the student begins work on a thesis prospectus in preparation for the qualifying examination. During this period the student finds an adviser willing to supervise the student's thesis research, works with the adviser to prepare for the qualifying examination, and assembles a dissertation reading committee, consisting of the student's research supervisor (chair of the committee) and three or four appropriate faculty members in electrical engineering and other relevant departments. The committee must consist of at least two electrical engineering faculty members in addition to the student's supervisor.

Qualifying Examination

This oral examination is a defense of the student's thesis prospectus and a test of the student's knowledge in advanced technical areas of relevance to the dissertation topic. This oral examination consists of a seminar-style talk before the examining committee, where the student describes the thesis prospectus, followed by questions from the committee on the substance of the talk or the areas of presumed expertise of the student. The exam, taken typically in the third year of Ph.D. study, is administered by a Ph.D. qualifying exam committee, consisting of at least four examiners. The composition of the committee is proposed by the department (in consultation with the student and his/her adviser) to the dean of graduate studies at least one month before the date of the exam. The composition of the committee must be approved by the dean of graduate studies, whereupon the student and the committee are notified.

If the student does not pass the qualifying exam, the student may be asked to complete additional course work, or other research-related work, before retaking the exam. The student may be allowed to retake the qualifying exam once, and the composition of the examining

committee will remain the same for the second try. Students who fail the qualifying exam twice may be dismissed from the Ph.D. program. Ph.D. students who have not advanced to candidacy by the end of the fourth year may be recommended for academic probation.

Dissertation and Advancement to Ph.D. Degree Candidacy

Advancement to candidacy requires that the student:

- pass the preliminary exam;
- complete all course requirements prior to taking the qualifying exam;
- clear all Incompletes from the student's record;
- pass the qualifying exam; and
- have an appointed Ph.D. dissertation reading committee.

After advancement to candidacy, work on the thesis research progresses until the dissertation is completed. The Ph.D. dissertation must show the results of in-depth research, be an original contribution of significant knowledge to the student's field of study, and include material worthy of publication. The student is strongly advised to submit research work for publication in advance of completing the thesis so that the latter requirement is clearly satisfied. The Ph.D. thesis results are presented in both oral and written forms, the oral form being a dissertation defense (see below) and the written form being the Ph.D. dissertation. The student must submit his or her written Ph.D. dissertation to the dissertation reading committee at least one month before the defense.

Dissertation Defense

Each Ph.D. candidate submits the completed dissertation to a Ph.D. thesis reading committee at least one month prior to the dissertation defense. The appointment of the dissertation reading committee is made immediately after the qualifying exam and is necessary for advancing to candidacy. The candidate presents his or her research results in a public seminar sponsored by the dissertation supervisor. The seminar is followed by a defense of the dissertation to the reading committee (only), who will then decide whether the dissertation is acceptable or requires revision. Successful completion of the dissertation fulfills the final academic requirement for the Ph.D. degree.

Transfer Credit

For students already holding an MSEE or equivalent degree, at most 20 credits of transfer credit may be granted for equivalent course work performed at the student's M.S. granting institution. Credit transfer is subject to approval by the adviser and the electrical engineering graduate committee.

Students not already holding an MSEE degree, who are studying for the Ph.D. degree, may apply to be granted a M.S. degree when they have fulfilled all the M.S. degree requirements (including an M.S. thesis).

Review of Progress

Each year, the faculty reviews the progress of every student. Students not making adequate progress toward completion of degree requirements (see the Graduate Student Handbook for the policy on

satisfactory academic progress) are subject to dismissal from the program. Students with academic deficiencies may be required to take additional courses. Full-time students with no academic deficiencies are normally expected to complete the degree course requirements at the rate of at least two courses each quarter. Full-time students must complete all course requirements within two years for the M.S. and three years for the Ph.D.

Students receiving two or more grades of U (unsatisfactory) or below B in the School of Engineering courses are not making adequate progress and will be placed on academic probation for the following three quarters of registered enrollment. Withdrawing or taking a leave of absence does not count as enrollment. Part-time enrollment is counted as a half-quarter of enrollment.

If an electrical engineering graduate student fails a School of Engineering course while on probation, the Electrical Engineering Department may request the graduate dean to dismiss that student from the graduate program. If after being removed from probation, the student again fails a School of Engineering course, he or she will return immediately to academic probation.

Graduate students experiencing circumstances or difficulties that impact their academic performance should contact their adviser and the graduate director immediately. Students may appeal their dismissal to the graduate committee.

Materials Fee

Please see the section on fees under School of Engineering.