The creative application of knowledge and skills in Electrical and Computer Engineering

Imagine – Design – Create …

Undergraduate Program Mission Statement

Our mission is to provide our students with the knowledge and skills that will enable them to build productive careers in the field of Electrical and Computer Engineering. Our students will learn the principles and practices of fundamental and applied electrical and computer engineering. We will train them to identify and solve problems systematically, to think creatively, and to recognize the role of engineering in modern society.
INTRODUCTION

The Department of Electrical and Computer Engineering at the University of Rochester was established as a department in 1958 offering undergraduate and graduate degrees. The department currently offers Bachelor of Science in Electrical and Computer Engineering, Masters and PhD’s in Electrical Engineering along with an ECE Minor. Incoming freshman can apply for the Graduate Engineering at Rochester (GEAR) program. If accepted into this program, an undergraduate is given the assurance of admissions into the ECE Master’s program provided that they maintain a grade point average (GPA) of 3.3 or higher.

The ECE B.S. curriculum provides students a rigorous background in all core areas of Electrical and Computer Engineering while still giving them the curricular flexibility to pursue interests in other areas spanning the spectrum of the humanities, social sciences, and the natural sciences. Training in ECE prepares students for a wide range of careers from traditional engineering, research & development to more non-traditional careers in law, finance, and other areas.

Our students also have ample opportunities to participate in departmental research, working closely with faculty members and their research groups. Opportunities available include summer internships with faculty members for course credit or for pay, and independent study courses.

As described later in this guide, our B.S. degree requires one cluster in Humanities or Social Science. Many of our students also use their free electives to obtain a minor in another department.

Electrical and Computer Engineering Advisors:

Each ECE student is assigned an ECE faculty advisor in their freshman year who remains with them throughout their program. In addition to your Faculty advisor, students also should stay in frequent contact with the Department Undergraduate Coordinator (Barbara Dick X5-5719) to ensure that they are making satisfactory progress towards meeting their degree requirements. All paperwork related to academic life is available from Barbara and should be reviewed by the department prior to submission.

In addition to their advisors and the Undergraduate Coordinator, the ECE Undergraduate Committee Chair is also available to discuss student’s plans, for completing major and minor declarations, drop/add forms, transfer credits, independent study, study abroad options, internships, fellowships, cluster exceptions, KEY and Take-5 programs, etc.

Students transferring from other colleges and universities should meet with the Undergraduate Committee Chair to discuss approval of all transfer courses.
Program Objectives

The ECE major gives students …

1. The intellectual breadth and critical reasoning skills to enable them to successfully pursue diverse career paths, both within the engineering profession and in other areas, such as law, medicine, and business.

2. The skills to work productively in collaborative environments.

3. The ability to communicate effectively both within the technical community and with the public at large.

4. Enthusiasm for creativity, research, and lifelong inquiry.

5. Appreciation of the social impacts of engineering and the need to maintain the highest ethical standards in the practice of their chosen profession.

Professional Registration

In the State of New York, engineering degrees must be registered for either professional or general purposes. All degrees conferred by the Department of Electrical and Computer Engineering at the University of Rochester are registered for professional purposes. In contrast, all degrees granted through the Inter-departmental Program are registered for general purposes.

The main difference between professional and general degrees is that students with the professional degree may take part A of the Professional Engineering Examination, also known as the Fundamentals of Engineering (FE) examination. This examination of fundamentals of engineering and science is the first step toward registration as a professional engineer. All ECE students should consider taking the FE examination in the spring of their senior year. Professional registration brings certain recognized benefits. Furthermore, entry-level engineering jobs with the State of New York, as well as many junior level federal positions, require successful completion of the FE.

ABET Accreditation

The BS degree program in electrical and computer engineering is accredited by the Engineering Accreditation Commission of ABET, http://www.abet.org. As such New York State automatically registers it for professional purposes. The current ABET accreditation criteria require that each electrical and computer engineering student complete a curriculum with the following minimum content:

1. Humanities & Social Sciences

2. Mathematics & Basic Science

3. Engineering Science and Design

In item (3) above, students must complete the ECE core and advanced course requirements given in this guide. This will give students a firm foundation in both Engineering Science and Engineering Design. The ECE Senior Design course provides the capstone design experience for our students. The required courses in the ECE curriculum that are listed on page 8 are intended to meet the requirements of the Engineering Accreditation Commission of ABET, http://www.abet.org.
Admission

Students wishing to formally declare a major in Electrical and Computer Engineering must file a completed "ECE Curriculum Planning Form" (See Appendix 1), along with the Concentration Approval Form, ordinarily during the fourth semester of study. This form constitutes application to the upper-division ECE program. The minimum requirements for admission to the ECE program are completion of the following:

1. ECE 111, 112, 113 and 114 with a minimum cumulative GPA of 2.3 in these four courses
2. MTH161, 162, 165, and 164 or the equivalent mathematics sequence, and ECE 270. Students in classes of 2017 and 2018 may take MTH 201 in lieu of ECE 270 although ECE 270 is highly recommended for students that have not yet taken MTH 201.
3. PHY121, 122, and one other physics or natural science course (PHY123 is recommended)
4. University primary writing requirement, usually satisfied by taking WRT105
5. Students on Academic Probation in the College may not be admitted to the major

A submitted plan, though never binding, is very useful in helping students to focus their interests within the field of electrical and computer engineering. Before preparing and submitting a course plan, each student should study this guide and then discuss the alternatives fully with their faculty advisor or another ECE faculty member. The Curriculum Planning Form, approved by the student’s faculty advisor, will then be attached to a Concentration Approval form and submitted to the Dean of the Hajim School of Engineering and Applied Sciences.

Under special circumstances, such as transfer from another institution or a change of intended major in the early years of study, students may not complete all the requirements for admission by the end of the sophomore year. Such circumstances might include lacking one of the three required ECE or seven freshman-sophomore courses in mathematics, physics, and physical sciences. Students finding themselves in this situation may qualify for conditional admission by submitting a form, available from the Undergraduate Coordinator in the ECE Office, to the ECE Undergraduate Committee along with an up-to-date ECE Curriculum Planning Form. The application must present a realistic plan, approved by the student’s advisor, for completion of all ECE program admission requirements within one year. Upon successful completion of these requirements students will be formally accepted into the ECE major.

Only the Administrative Committee of the Hajim School of Engineering and Applied Sciences can make exceptions from the general degree requirements.
ECE Program Requirements

Humanities and Social Sciences

All ECE majors must take a minimum of 5 humanities/social science (H&SS) courses. This includes the three courses taken to satisfy the University Cluster requirement. (Humanities cluster + 2 SS or SS cluster + 2 Hum.) These five courses can be chosen from any recognized Humanities and/or Social Science field listed below. Courses in Business may not be used to satisfy this requirement. Students also are expected to take some of these courses beyond the introductory level. Ordinarily, H&SS Clusters will count for three of the five required courses, but if questions arise, students should consult their advisors. Language courses at the 101 level are only accepted when followed by another, more advanced course in the same language.

Acceptable Humanities Courses: Any English course except for ENG101 or the course taken to satisfy the university primary writing requirement (usually WRT 105); any course in American sign language, art or art history, digital media studies, dance, foreign or comparative literature, a foreign language above 101 level, music theory or music history, philosophy, religious studies, or film studies courses cross-listed in a humanities department.

Acceptable Social Sciences Courses: Any course in anthropology, brain and cognitive sciences, economics, entrepreneurship, history, linguistics, political science, psychology or sociology.

Notes:

1) No computer courses offered in humanities or social science fields may be used as a H/SS distribution course.

2) Ordinarily, courses taken at the University of Rochester to meet the 5-course requirement in H&SS are 4 credit hour courses. Consult your advisor concerning 2 or 3 credit courses (including transfer courses). You may need to petition the Undergraduate Committee to use such courses as credit toward the H&SS distribution requirement.

The following restriction applies to all 2-credit courses used to satisfy the distribution requirement: two 2-credit courses may be combined to fulfill one 4-credit distribution requirement only if both courses are from the same discipline.

Upper Level Writing

It is vitally important for all students to be able to communicate effectively in writing. The University’s Upper-level Writing Requirement applies to all majors. Within Electrical and Computer Engineering the requirement will be met through writing assignments in ECE 111, 112, 113, and ECE 399. Students who transfer credit for any one or more of these courses from another institution to the UR must consult with the ECE Department’s Undergraduate Coordinator to determine if their program satisfies the requirement.

Natural Science Requirement

The following courses may satisfy the Natural Science requirement:

Physics – PHY 123 or higher
Astronomy – AST 111 or higher
Chemistry – CHM 103 or higher
Biology – BIO 110 or higher
Earth & Environmental Sciences – EES 101 or higher
Brain & Cognitive Sciences – BCS 110 or higher
ECE Advanced Electives and Design

In planning a program of study each student must choose one advanced ECE elective course and the capstone design sequence ECE 399, 398, and 349. This requirement assures that all majors devote some of their advanced level course-work to a specialization within ECE leading to a design project. This is the minimum requirement and students are encouraged to take as many advanced electives as they can fit into their schedule. In the design sequence, students will define their design project in consultation an ECE faculty member.

Multiple advanced electives are listed for most areas; please consult with your ECE advisor to make appropriate course selections. Some suggestions are:

- **Signals and Communications**
  - 244, 245, 246

- **VLSI and Electronics**
  - 261, 266, 269

- **Computer Engineering**
  - 201, 204, 205, 206, 207

- **Waves, Fields and Devices**
  - 223, 227, 235

*other upper-level courses as approved*

Transfer Credits

If a student wishes to take a course at another institution to satisfy an ECE degree requirement, **PRIOR APPROVAL** is required and proper supporting documentation about the course must be submitted to the ECE Department Undergraduate Coordinator before taking any courses for transfer. Course Approval Form, available in the ECE Office is used for this purpose. Students are strongly advised to seek the guidance and feedback from their advisor before registering for a course at another institution. Completed forms will be forwarded to the Undergraduate Committee for action.

Internships and Practicum

ECE majors are strongly encouraged to participate in internships with local or nationally based engineering firms. Only in a few cases can internship experiences be used for academic credit. Students who wish to obtain such credit for an internship must obtain prior approval from the ECE Undergraduate Committee.

The Engineering Practicum program, supervised jointly by the Hajim School of Engineering and Applied Sciences and the Gwen M. Greene Career and Internship Center, is a way to gain valuable work experience. A student in this program takes one semester and the preceding or following summer to work for a company. Academic credit is not granted, but the work experience and references obtained are valuable in students’ career development. Usually graduation will be delayed by one semester but students with Advanced Placement credit or summer classes may still graduate in four years. Additional information, including example programs, is available from the Hajim School of Engineering and Applied Sciences office in Lattimore Hall, or from the Gwen M. Greene Career and Internship Center.

Pre-Medical

ECE students interested in preparing for medical school are urged to obtain related materials from the Health Professions Advisor at the Center for Academic Support, Lattimore 312. It is essential that such students begin program planning very early and involve both their ECE advisor and the Health Professions Advisor. Scheduling all of these courses with due regard for prerequisites may be complex and the workload demands strong commitment from the student. Thus, early consultation is strongly urged.
Five-Year BS/MS Program

ECE juniors contemplating earning their Masters degree may wish to consider the special five-year program offered by the Department. This program provides the advantage of a smooth transition between undergraduate and graduate study. Program enrollment is competitive and students are encouraged to apply for admission in their junior year. Successful applicants may begin to take graduate level courses in their Senior year. Through a special program initiated by the Hajim School of Engineering and Applied Sciences, students who have been formally accepted into the program will be granted tuition scholarship for the fifth year of study (only after the BS degree has been awarded).

Students should consult the UR Graduate Studies Official Bulletin for the MS degree requirements and they should meet with a faculty member to develop an integrated BS/MS program of study.

(http://www.rochester.edu/GradBulletin/)

Study Abroad

The ECE Department believes that studying abroad is an integral part of the undergraduate curriculum. With careful planning, students may study abroad. The College offers study abroad programs in more than 40 countries in the fall, spring, full year and summer terms.

Students who are interested in studying abroad should meet with the Undergraduate Coordinator to discuss plans, and attend a study abroad general information meeting to get started. After attending an information meeting, students can set up an appointment to meet with a study abroad adviser.

Study abroad in ECE is usually for one semester sophomore or junior year.

For details and more information, visit the website at http://www.rochester.edu/college/abroad/.

This Guide supplements information found in the 2015-2017 Undergraduate Bulletin of the University of Rochester for the Electrical and Computer Engineering degree program in the Hajim School of Engineering and Applied Sciences.

http://www.rochester.edu/bulletin/

It is the student's obligation to read and study this Curriculum Guide, to attend announced class meetings, and to meet with his or her advisor regularly.
### Recommended Curriculum and Requirements

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<td>ECE 230 – Waves</td>
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<td>ECE 270 – Discrete Math and Probability for Engineers or (MTH 201 Probability as alternative)</td>
<td>ECE 399 – Social Implications of Engineering</td>
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<td>WRT 273 – Communicating Your Professional Identity in Engineering</td>
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<td>ECE 398– ECE Design Seminar</td>
<td>ECE 349 – Capstone Design</td>
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<td>ECE 216 – Microprocessors</td>
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**Plus the following:** - Free electives to complete the remaining balance for the 128 credit hours required for the program. A total of 12 ECE courses, ECE 349, ECE 398 and ECE 399 are minimally required for graduation.

ECE 399 should be taken in the junior year and ECE 398 must be satisfactorily completed, usually in the Fall term of the Senior year, prior to taking ECE 349 - Capstone Design course.

WRT 273 can be taken in the sophomore or junior year.
• Acceptable alternative mathematics sequences: Honors math Sequence: MTH 171, 172, 173, 174, is perfectly appropriate for those with adequate mathematics background. The sequence MTH 141, 142, 143, 165, 164; is acceptable, HOWEVER, it is best to take MTH143 or an equivalent in the SUMMER between the 1st and 2nd years, in order to get back in sequence. Consult with your faculty Advisor and UG administrator to arrange your best sequence.

• Two physics courses, PHY 121 and PHY 122, are required of all ECE majors. In addition, it is strongly recommended that ECE students also complete PHY123. However, other courses in natural science selected from among AST, BCS, BIO, CHM, EES, and PHY may also satisfy the ECE program’s Natural Science requirement. Students must check with the ECE department undergraduate coordinator prior to taking any such course to confirm that the course will satisfy the ECE Natural Science requirement.

• In the ECE program a total of five courses in the humanities and social sciences is required. Three of these courses must constitute an approved Cluster in Humanities or Social Sciences and must be passed with a 2.0 average or better. (Hum. cluster + 2 SS OR SS Cluster + 2 Hum.) See the Cluster Search Engine and descriptions of clusters in the undergraduate bulletin.

(http://www.rochester.edu/College/CCAS/clusters)

• ECE 270 - "Discrete Math and Probability for Engineers” is required for all ECE majors in the class of 2018 and beyond and strongly recommended for classes of 2017 and 2018 that have not already taken MTH 201. Students should normally take ECE 270 concurrently with ECE 241 and ECE 270 must be taken prior to taking ECE 242.

• For those participating in Study Abroad or other off-campus opportunities in the Fall semester of the third year, the requirement for ECE 399 can be satisfied through Independent Study in other semesters with approval of the Undergraduate Committee and the instructor of ECE 399. Consult with your faculty advisor and the Undergraduate Coordinator to make appropriate arrangements BEFORE leaving for off-campus study.

For graduation, Electrical and Computer Engineering majors must achieve a minimum cumulative grade-point average of 2.0 in the twelve required ECE core courses: specifically ECE 111, 112, 113 114, 200, 216, 221, 222, 230, 241, 242, 349. In addition, 128 total credits are required for graduation with an overall cumulative grade point average of 2.0 or higher.
The Department has made it possible for students to participate in a Co-op type program, in which the student takes off 2 semesters to co-op and graduates in 5 years. We propose simply that if a student takes their first Co-op in a Spring semester and their second in a Fall semester, then they can be accommodated. Presumably these would not be in successive semesters, and would not be the final semester. We recommend that students co-op in their sixth and ninth semesters.

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<td>ECE 221 – Elec Devices &amp; Circuits</td>
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<td>ECE 399 – Junior Seminar</td>
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Minors in ECE

The ECE minor gives students the opportunity to design a flexible program of study to achieve either breadth or depth in electrical and computer engineering. In addition to the following recommended programs of study, a student can arrange an individualized program with the guidance of an ECE advisor, normally requiring the equivalent of five 4.0 credit hour courses in ECE.

Computers
- ECE 112 Logic Design
- ECE 114 Intro to Computers and Programming
- ECE 200 Computer Organization
- ECE 201 Advanced Computer Architecture
- ECE 216 Microprocessors and Data Conversion

Electronics
- ECE 111 Introduction to Signals and Circuits
- ECE 112 Logic Design
- ECE 113 Circuits and Signals
- ECE 216 Microprocessors and Data Conversion
- ECE 221 Electronic Devices and Circuits

Integrated Electronics
- ECE 111 Introduction to Signals and Circuits
- ECE 112 Circuits and Signals
- ECE 221 Electronic Devices and Circuits
- ECE 222 Integrated Circuits Design & Analysis
- ECE 261 Digital Integrated Circuit Design

Signals and Communications
- ECE 111 Introduction to Signals and Circuits
- ECE 113 Circuits and Signals
- EE 114 Intro to Computers and Programming
- ECE 241 Signals
- ECE 242 Communications

Solid State Devices
- ECE 111 Introduction to Signals and Circuits
- ECE 113 Circuits and Signals
- ECE 223 Semiconductor Devices
- ECE 234 Microelectromechanical Systems
- ECE 235 Introduction to Optoelectronics

Digital Audio and Music
- ECE 114 Programming for Engineers
- ECE 111 Introduction to Signals and Circuits
- ECE 113 Circuits and Signals
- ECE 140 Intro to Digital Audio
- ECE 241 Signals

Waves, Fields and Devices
- ECE 111 Introduction to Signals and Circuits
- ECE 113 Circuits and Signals
- ECE 230 Electromagnetic Waves
- Plus one ECE elective chosen in consultation with ECE advisor

And choose one of the following:
- ECE 223 Semiconductor Devices
- ECE 227 Electric Power
- ECE 235 Introduction to Optoelectronics
Course Descriptions

This is a list of the courses that are being offered for AY 2016–2017, as well as courses that have been offered in recent years or may be offered in subsequent years. Semesters in which courses are to be taught are indicated at the end of each description. Please note that these are subject to change.

AME 140 Introduction to Audio and Music Engineering: The course provides an introduction to the science and technology of audio. Students will learn about the vibration of strings, musical tuning systems, overtones and timbre, modes of oscillation through the concept of a guitar. Fourier analysis, transducers and passive electrical components and circuits will be introduced when discussing amps and audio components. The class will utilize hands on projects to introduce the fundamental concepts of electronics, including voltage, current, resistance and impedance, basic circuit analysis, ac circuits, impedance matching, and analog signals. The course then moves on to introduce basic digital signal processing concepts, where they will use Arduinos and Pure Data to learn about conversion of sound to digital format, frequency analysis, digital filtering and signal processing and musical sound synthesis. Lectures and weekly lab sessions. Prerequisite: High School Algebra and Trigonometry Restrictions: AME140 is recommended as an introduction to the Audio and Music Engineering major but it is accessible to students of music or other non-technical disciplines who wish to learn the fundamentals of music technology and enjoy building projects. F16

AME 191 The Art and Technology of Recording: This course covers the acoustical and psychoacoustic fundamentals of audio recording including the nature of sound, sound pressure level, frequency and pitch, hearing and sound perception, reflection, absorption and diffusion of sound, sound diffraction, room acoustics, reverberation, and studio design principles. The course also provides practical experience in audio recording including an introduction to recording studio equipment, microphones and microphone placement techniques, signal flow, amplification, analog and digital recording, analog to digital conversion, digital processing of sound, multi-track recording and an introduction to mixing and mastering. Each student is required to complete a substantive recording project at the end of the course. F16/S17

AME 192 Critical Listening for Audio Production: This course is a continuation of AME191. Emphasis is on the development of critical listening skills and proficiency in audio mixing and mastering. Fundamental topics covered include the human auditory system, theories of hearing and audio perception, perception of loudness and pitch, critical bands and auditory masking, beats and roughness, temporal and pitch acuity, binaural hearing. Listening skills development include hearing “width” and “depth” in audio, mixing techniques in various musical genres, recognition of various effects including reverb, delay, compression, phasing and distortion. Production skills development includes equalization and achieving spectral balance, the use of compression and dynamic range control, achieving depth and dimension in recordings, panning and auditory scene control. Students will complete an extensive mixing and mastering project at the end of the course. Prerequisite: AME 191 F16/S17

AME 193 Sound Design: The course is intended to provide students a basic understanding of sound design, and working with sound for picture. The emphasis is on demonstrations and hands-on experience to enable students to gain a practical knowledge of sound and music production using computers. Topics include synthesizers & samplers; recording and editing with Pro Tools; sound effect creation; foley & automatic dialog replacement; basic soundtrack composition; and working to picture. Many techniques are explored employing software and hardware based sound creation tools throughout the course. Students will complete a major project at the conclusion of the course. Prerequisite: Only AME and MUR Majors. Instructor’s permission required F16/S17

AME 194 Audio for Visual Media: This course is intended to provide students with a basic understanding of the process and the skills for creating music for picture. The course emphasizes hands-on experience where students gain practical skills in scoring to picture using computers and it features guest lectures by industry leading professionals, who will share their insights on creating music for TV Shows, Advertising, Movies, Gaming, Animation, and Industrial Work. Topics also include soft synthesizers, samplers and virtual instruments; recording and editing with Pro Tools and Logic; and sound design on audio workstations. Students will complete a number of projects throughout the course. Prerequisite: Strong musical ability, basic piano keyboard proficiency, AME 193 or familiarity with either Pro Tools, Logic Pro, or Ableton are highly recommended for this course. Instructor’s permission required F16/S17
AME 196 Interactive Music Programming: In this course, students will explore digital audio synthesis and real-time interactive technologies by studying two audio programming languages, ChucK and Pure Data. They will be able to manipulate sound with MIDI controllers, laptops, mobile devices, joysticks, mice, and Wiimotes. Students will have a midterm presentation to demonstrate their programs in ChucK and at the end of the semester, we will have an interactive performance showcase. This interdisciplinary course does not require any programming experience. Prerequisite: All students, including music and technology majors, are welcomed to take this course. F16

AME 223/ECE 429 Audio Electronics: The devices, circuits, and techniques of audio electronics are covered in this course. Included is a survey of small signal amplifier designs and small-signal analysis and characterization, operational amplifiers and audio applications of opamps, large-signal design and analysis methods including an overview of linear and switching power amplifiers. The course also covers the design of vacuum tube circuits, nonlinearity and distortion. Other important audio devices are also covered including microphones, loudspeakers, analog to digital and digital to analog converters, and low-noise audio equipment design principles. Prerequisite: ECE 221 or Permission of Instructor S17

AME 233/ECE 233/433 Musical Acoustic: Aspects of acoustics. Review of oscillators, vibratory motion, the acoustic wave equation, reflection, transmission and absorption of sound, radiation and diffraction of acoustic waves. Resonators, hearing and speech, architectural and environmental acoustics. Prerequisite: Linear algebra and Differential Equations (MTH 165), Multivariable Calculus (MTH 164), and Physics (PHY 121) or equivalents. S17

AME 240 Revolutions in Sound: Artistic and Technical Evolution of Sound Recording: Sound recording and reproduction have changed the way we listen to music and the way music is performed for over a century. The course title, “Revolutions in Sound,” refers not only to the invention of new audio technologies, but also to the ways that engineers, producers, musicians, and even listeners used the technologies to create new musical experiences. This course will provide a multifaceted account of the evolution of sound technologies, starting with Edison’s invention of the phonograph in 1877 through the development of microphones, radio, magnetic tape recording, vinyl records, multitrack recording, digital audio, compact discs, the MP3 format, and online music streaming. We will discuss how technology has shaped the musical experience, and, conversely, how the performance of various genres of music, including classical, rock, jazz, hip-hop, and country, has influenced the development of audio technologies. We will also investigate, drawing from a variety of primary and secondary sources, how certain legendary recordings were produced, including those of Enrico Caruso, Bessie Smith, Les Paul, Louis Armstrong, Elvis Presley, The Beatles, Michael Jackson, and Madonna. A special topic will focus on the digital preservation and restoration of historic audio recordings. We will visit the Rush Rhees Library and the Sibley Music Library to hear about their current digitalization projects. All students are welcome! Prerequisite: All students, including technology and music majors, are welcome. S17

AME 262/ECE 475 Audio Software Design I: This course aims to give students the ability to develop their own audio/music programs in C and a few major open-source audio programming languages. It begins with an introduction to computer music and audio programming, and a comparative survey of audio programming languages. After an overview of the C language, we then explore the topics of programming for sound synthesis. The second half of this course introduces the primary techniques of sound design using the audio programming environments of Pure Data and Csound. Students will practice their programming techniques through a series of programming assignments and a final project. Prerequisite: ECE114 or instructor permission F16

AME 264/ECE 476 Audio Software Design 2: This course is a sequel to AME262/ECE475/TEE475 Audio Software Design I. The first part of the course will explore designing audio plug-ins with Faust (Function AUdio STream), which is a high-level functional programming language designed for real-time audio digital signal processing (DSP) and sound synthesis. Students will learn how to design plug-ins for Pro Tools, Logic and other digital audio workstations (DAWs). The second part of the course will focus on audio programming for iOS apps in Swift, which is the new programming language for iOS and OS X. Students will learn how to make musical apps with the sound engine libpd, which turns Pure Data (Pd) into an embeddable library. A special topic will introduce audio programming for video games with Wwise and FMOD. S17 Prerequisite: AME 262 or ECE 475 or Instructor Permission S17
AME 272/ECE 272/472  Audio Signal Processing: This course is a survey of audio digital signal processing fundamentals and applications. Topics include sampling and quantization, analog to digital converters, time and frequency domains, spectral analysis, vocoding, digital filters, audio effects, music audio analysis and synthesis, and other advanced topics in audio signal processing. Implementation of algorithms using Matlab and on dedicated DSP platforms is emphasized. Prerequisite: ECE 114 and basic Matlab programming, ECE 241 or other equivalent signals and systems courses  S17

AME 277 Computer Audition Computer audition is the study of how to design a computational system that can analyze and process auditory scenes. Problems in this field include source separation (splitting audio mixtures into individual source tracks), pitch estimation (estimating the pitches played by each instrument), streaming (finding which sounds belong to a single event/source), source localization (finding where the sound comes from) and source identification (labeling a sound source). F * Prerequisite: ECE 246/446 or ECE 272/472 or other equivalent signal processing courses, and Matlab programming. Knowledge of machine learning techniques such as Markov models, support vector machines is also helpful, but not required  F16

AME 292 Acoustics Portfolio: This is a follow on course to AME233, Musical Acoustics. In this course students will complete a major project in acoustics, such as the acoustical characterization of an architectural space, design or re-design of an architectural or studio space, development of acoustical computer simulation tools, design or characterization of acoustic musical instruments, design and fabrication of loudspeakers, design and implementation of a live sound or sound reinforcement system, or any other project in acoustics with the agreement of the instructor. Weekly meetings and progress reports are required. Prerequisite: AME 233  F16

AME 294 Audio DSP (Digital Signal Processing) Portfolio Lab: This is a follow on course to AME272, Audio Digital Signal Processing. Students will complete a major design/build project in the area of audio digital signal processing in this course. Examples include a real-time audio effects processor, music synthesizer or sound analyzer or other projects of student interest. Weekly meetings and progress reports are required. Prerequisite: ECE 241; strong MATLAB expertise, and C/C++ programming familiarity (ECE 111 and ECE 113 recommended)  F16/S17

AME 295 Audio Electronics Portfolio: This is a follow on course to AME223, Audio Electronics. In this course students will complete a major design/build project in the area of audio electronics. Examples include a solid state or tube-based instrument amplifier, audio power amplifier, audio effects processor, audio analog/digital interface or any other audio electronic project with the agreement of the instructor. Weekly meetings and progress reports are required. Prerequisites: AME 223  S17

AME 386 Senior Design Project I: Senior Design Project in Audio and Music Engineering. In this first semester of the year-long AME Senior Project course students will define their product, possibly in collaboration with an outside customer, and then develop product concept documentation, detailed requirements specifications, system level designs, detailed sub-system designs and hopefully build demonstration prototypes.  F16

AME 387 Senior Design Project II: Senior Design Project in Audio and Music Engineering. In the second semester of the year-long AME Senior Project course students will complete their projects including final system level designs, detailed sub-system designs, prototype building, testing, evaluation and final presentation to the customer.  S17

AME 472 Audio Signal Processing: This course is a survey of audio digital signal processing fundamentals and applications. Topics include sampling and quantization, analog to digital converters, time and frequency domains, spectral analysis, vocoding, analysis and synthesis of digital filters, audio effects processing, musical sound synthesis, and other advanced topics in audio signal processing. Implementation of algorithms on dedicated DSP platforms is emphasized.  S17

AME 477 – Computer Audition: Computer audition is the study of how to design a computational system that can analyze and process auditory scenes. Problems in this field include source separation (splitting audio mixtures into individual source tracks), pitch estimation (estimating the pitches played by each instrument), streaming (finding which sounds belong to a single event/source), source localization (finding where the sound comes from) and source identification (labeling a sound source). Prerequisite: ECE 246/446 or ECE 272/472 or other equivalent signal processing courses, and Matlab programming. Knowledge of machine learning techniques such as Markov models, support vector machines is also helpful, but not required.  F16
ECE 101 Introduction to Computing Systems: A general, high-level understanding of workings of modern computing systems from circuit, computing system architecture, to programming. ECE101 is not a required course. Lecture materials will eventually be covered in subsequent courses. It is intended to introduce you to (a subset of) principle topics in computer system designs. There is an emphasis on hands-on experience to give you a “feel” of the materials that will be discussed in more depth later on.  

Prerequisite: Concurrent registration in MTH 165 and PHY 122 F16

ECE 111 Introduction to Signals and Circuits: This course serves to reinforce the Basic Science and Mathematics learned in MTH 165 and PHY 122, as well as give concrete, engineering, examples of how the techniques learned in those courses are applied to real problems. In addition, it serves to illustrate where and how many of the equations studied in the Mathematics courses are originally developed. Many examples, homework problems, and exam problems include the use of linear algebra and differential equations.  

Prerequisite: Concurrent registration in MTH 165 and PHY 122 F16

ECE 112 Logic Design: Students are exposed to Combinational logic elements including all of the following: logic gates, Boolean algebra, Karnaugh Maps, conversion between number systems, binary, tertiary, octal, decimal, and hexadecimal number systems, and arithmetic on signed and unsigned binary numbers using 1's and 2's complement arithmetic. Also covered are programmable logic devices, synchronous finite state machines, State Diagrams, FPGA’s and coding logic in VHDL.  

Prerequisite: One semester of college mathematics. Ability to operate a computer. S17

ECE 113 Circuits and Signals: The principal focus of ECE113 is frequency domain representation of time signals, starting with phasors and ending with elements of Fourier series and Fourier transforms. Mathematics is introduced as needed for the specific material being covered, including: complex numbers, initial value problems, Laplace transform pairs, matrices, Fourier series, and Fourier transforms, including convolution. In addition, some effort is devoted to non-linear circuit analysis using loadlines.  

Prerequisite: ECE111, MTH165; concurrent with MTH164 S17

ECE 114 Introduction to C/C++ Programming: This course provides an introduction to the C and C++ programming languages and the key techniques of software programming in general. Students will learn C/C++ syntax and semantics, program design, debugging, and software engineering fundamentals, including object-oriented programming. In addition, students will develop skills in problem solving with algorithms and data structures. Programming assignments will be used as the primary means of strengthening and evaluating these skills. F16/S17

ECE 140/AME 140 Intro to Audio and Music Engineering: The course provides an introduction to the science and technology of audio. Students will learn about the vibration of strings, musical tuning systems, overtones and timbre, modes of oscillation through the concept of a guitar. Fourier analysis, transducers and passive electrical components and circuits will be introduced when discussing amps and audio components. The class will utilize hands on projects to introduce the fundamental concepts of electronics, including voltage, current, resistance and impedance, basic circuit analysis, ac circuits, impedance matching, and analog signals. The course then moves on to introduce basic digital signal processing concepts, where they will use Arduinos and Pure Data to learn about conversion of sound to digital format, frequency analysis, digital filtering and signal processing and musical sound synthesis. Lectures and weekly lab sessions.  

Prerequisite: High School Algebra and Trigonometry  

Restrictions: AME140 is recommended as an introduction to the Audio and Music Engineering major but it is accessible to students of music or other non-technical disciplines who wish to learn the fundamentals of music technology and enjoy building projects. F16

ECE 200 Computer Organization: Instruction set principles; processor design, pipelining, data and control hazards; datapath and computer arithmetic; memory systems; I/O and peripheral devices; internetworking. Students learn the challenges, opportunities, and tradeoffs involved in modern microprocessor design. Assignments and labs involve processor and memory subsystem design using hardware description languages (HDL).  

Prerequisite: ECE114, ECE 112 or CSC 171, or permission of Instructor S17


Prerequisite: ECE200 or equivalent F16

ECE 204/404 Microprocessor Architecture: This course provides in-depth discussions of the design and implementation issues of multiprocessor system architecture. Topics include cache coherence, memory consistency, interconnect, their interplay and impact on the design of high-performance micro-architectures.  

Prerequisite: ECE 200 or CSC 252 or permission of instructor S17
ECE 205/405 Advanced Digital Design Using FPGA Review of complex embedded project development with Xilinx Virtex FPGA eval board and Xilinx CAD tools using Verilog HDL and C programming language. Embedded development and introduction to ethernet, USB, SATA, VGA, DVI, PS2, RS232, GPIO, and soft processor cores. **Prerequisite:** ECE200, or ECE216, or ECE201/401. Familiarity with assembly language and C programming language. Instructor approval F#

ECE 206/406 GPU Parallel Programming Using C/C++ GPU micro-architecture, including global memory, constant memory, texture memory, SP, SM, scratchpad memory, L1 and L2 cache memory, multi-ported memory, register file, and task scheduler. Parallel programming applications to parallel sorting, reduction, numeric iterations, fundamental graphics operations such as ray tracing. Desktop GPU programming using Nvidia's CUDA (Compute-Uniform Device Architecture). CPU/GPU cooperative scheduling of partially serial/partially parallel tasks. No midterms or written exams. Course consists of seven hands-on projects using CUDA. **Prerequisite:** ECE 200, or ECE 216, or ECE 201/401, or equivalent. Familiarity with assembly language and C programming language. Instructor approval F#

ECE 207/407 Advanced GPU Program Development Students develop an advanced project for the GPU platform. A GPU compute-cluster can be employed, as well as a single GPU computer. Students meet with the instructor twice a week to report the progress and the new direction is determined based on the results and the ongoing progress. Project options include: Protein folding (BLAST algorithm), Face recognition (using Open CV), 3D Image reconstruction of biomedical images, and other sophisticated image processing algorithms. **Prerequisite:** ECE 206/406 or equivalent strongly recommended. Instructor approval S#

ECE 210 Circuits and Microcontrollers for Scientists and Engineers: 4 credit hour course, with laboratory, intended for physical scientists and (non-electrical) engineers. Electrical concepts will be developed based on modern needs and techniques: Current, Voltage, Components, Sources, Operational Amplifiers, Analysis Techniques, First and Second Order Circuits, Sinusoids and AC. Technical elective for non-ECE majors. **Prerequisites:** Concurrent registration in MTH 163/165 and PHY 122 S17

ECE 216 Microprocessor and Data Conversion: All elements of a data acquisition system are discussed including transducers, buffers, sample/hold devices, multiplexers, filters, and microprocessor system. Also, architecture of microprocessor and embedded microcontroller systems discussed including central processing unit, memory, bus structures (PCI, USB, CAN, IEEE488 Bus), I/O devices, and programmable peripheral interface controllers. As part of the course, students will learn to write assembly language programs and program controllers to demonstrate operation using Microchip development systems. Also described are controller components including timer/counters, analog-to-digital converters, digital-to-analog converters, multiplexers, and interrupt structures. **Prerequisite:** ECE112, ECE113, ECE114 F16

ECE 221 Electronic Devices and Circuits This course discusses the fundamentals of semiconductor devices – how they are formed; how they function in circuits; how they “integrate” to make the “IC’s” that drive all modern electronic technology. We will examine the basic properties of semiconductors, the design and analysis of basic electronic circuits, including PN junction diodes and diode circuits, bipolar junction transistors (BJT’s), field effect transistors (FET’s), single and multi-stage amplifiers, and differential amplifiers. We will study the small-signal characteristics of these circuits and their time and frequency responses. **Prerequisite:** ECE 113, or ECE 210 F16


ECE 223/423 Semiconductor Devices: Review of modern solid-state electronic devices, their principles of operation, and fabrication. Solid state physics fundamentals, free electrons, band structure, and transport properties of semiconductors. Nonequilibrium phenomena in semiconductors. P-N junctions, Schottky diodes, field-effect, and bipolar transistors. Modern, high-performance devices. Ultrafast devices. **Prerequisite:** ECE221, ECE230, PHY123 or permission of instructor F16
ECE 227/427 Electric Power: Conversion, Transmission, and Consumption: We will describe how the principal sources of energy - coal, natural gas, impounded water (hydroelectric), and fissile materials - are exploited to create electric power, how it is transmitted and distributed through the grid and finally the patterns of its consumption. To assure that students gain a proper appreciation for the factors that determine the real cost of electricity per kilowatt-hour, the subject will be treated in a highly quantitative way. The goal will be to provide students with the information and tools they need for informed analysis of the true prospects and technological challenges involved in integration of new energy sources, such as solar, wind, geothermal, and tidal power, with the existing grid. There will be weekly homework and a midterm. Two projects with oral presentations, including a major one at the end of the semester. Prerequisite: Enrollment will be restricted to seniors and graduate students who possess some background in either thermodynamics or AC circuits. S17


ECE 231 Robot Control: This course covers control and planning algorithms with applications in robotics. Topics include transfer function models, state-space models, root-locus analysis, frequency-response analysis, Bode diagrams, controllability, observability, PID control, linear quadratic optimal control, model-predictive control, stochastic control, forward and inverse kinematics, dynamics, joint space control, operational space control, and robot trajectory planning. Prerequisite: MTH 165 and ECE 114 or CSC 171 F16

ECE 232/437/ SEE CSC 232 Autonomous Mobile Robots: This course covers models and algorithms for autonomous mobile robots. Topics include sensors, perception, state estimation, mapping, planning, control, and human-robot interaction. Proficiency with Matlab/C++ is recommended. Lab required. S 17 Prerequisite: MTH 165 and ECE 114, or CSC 171

ECE 233/433 AME 233 Musical Acoustics: Aspects of acoustics. Review of oscillators, vibratory motion, the acoustic wave equation, reflection, transmission and absorption of sound, radiation and diffraction of acoustic waves. Resonators, hearing and speech, architectural and environmental acoustics. Prerequisite: Linear algebra and Differential Equations (MTH 165), Multivariable Calculus (MTH 164), and Physics (PHY 121) or equivalents S17

ECE 235/435 Introduction to Opto-Electronics: Introduction to fundamentals of wave propagation in materials, waveguides and fibers, generation, modulation, and detection of light using semiconductor devices, and elements of optocommunication systems. S 17 Prerequisite: ECE230 and ECE221 equivalent or permission of instructor. S*

ECE 241 Signals: Introduction to continuous and discrete time signal theory and analysis of linear time-invariant systems. Signal representations, systems and their properties, LTI systems, convolution, linear constant coefficient differential and difference equations. Fourier analysis, continuous and discrete-time Fourier series and transforms, properties, inter-relations, and duality. Filtering of continuous and discrete time signals. Sampling of continuous time signals, signal reconstruction, discrete time processing of continuous time signals. Laplace transforms. Laboratory. Prerequisite: MTH 165 and ECE 113 or ECE 210 F16

ECE 242 Communication Systems In this course we will study the following topics: Amplitude and frequency modulations – bandwidth, power, complexity trade-offs, spectral analysis. Random processes and random variables – statistical averages, autocorrelation, covariance, probability distribution functions, covariance, basic probability. Noise in communication systems – compare the signal-to-noise ratio of different communication systems, pre-emphasis and de-emphasis filtering in FM systems. Analog to digital conversion – reconstruction filters, sampling theorems, pulse code modulations, differential pulse code modulations, delta modulations, and adaptive delta modulations. Binary communication systems – pulse position modulation, pulse amplitude modulation, optimum receiver of binary modulation systems, M-ary modulations. Prerequisite: ECE 241 and MTH 201 S17
ECE 244/444 Digital Communications: Digital communication system elements, characterization and representation of communication signals and systems. Digital transmission, binary and M-ary modulation schemes, demodulation and detection, coherent and incoherent demodulators, error performance. Channel capacity, mutual information, simple discrete channels and the AWGN channel. Basics of channel coding and error correction codes. Prerequisite: ECE 242 or permission of Instructor F16

ECE 245/445 Wireless Communications: This course teaches the underlying concepts behind traditional cellular radio and wireless data networks as well as design trade-offs among RF bandwidth, transmitter and receiver power and cost, and system performance. Topics include channel modeling, digital modulation, channel coding, network architectures, medium access control, routing, cellular networks, WiFi/IEEE 802.11 networks, mobile ad hoc networks, sensor networks and smart grids. Issues such as quality of service (QoS), energy conservation, reliability and mobility management are discussed. Students are required to complete a semester-long research project in order to obtain in-depth experience with a specific area of wireless communication and networking. Prerequisite: ECE 242 or equivalent or consent of instructor F16

ECE 246/446 Digital Signal Processing: Analysis and design of discrete-time signals and systems, including: difference equations, discrete-time filtering, z-transforms, A/D and D/A conversions, multi-rate signal processing, FIR and IIR filter design, the Discrete Fourier Transform (DFT), circular convolution, Fast Fourier Transform (FFT) algorithms, windowing, and classical spectral analysis. Prerequisites: ECE 241 and math programming skills F16

ECE 247/447 An Introduction to Digital Image Processing using Python: This course will introduce the students to the basic concepts of digital image processing, and establish a good foundation for further study and research in this field. The theoretical components of this course will be presented at a level that seniors and first year graduate students who have taken introductory courses in vectors, matrices, probability, statistics, linear systems, and computer programming should be comfortable with. Topics cover in this course will include intensity transformation and spatial filtering, filtering in the frequency domain, image restoration, morphological image processing, image segmentation, image registration, and image compression. The course will also provide a brief introduction to python (ipython), the primary programming language that will be used for solving problems in class as well as take-home assignments. Prerequisite: ECE 242 and ECE 440 & 446 are recommended or permission of instructor F16

ECE 261/461 Introduction To VLSI: Introduction to high performance integrated circuit design. Semiconductor technologies. CMOS inverter. General background on CMOS circuits, ranging from the inverter to more complex logical and sequential circuits. The focus is to provide background and insight into some of the most active high performance related issues in the field of high performance integrated circuit design methodologies, such as CMOS delay and modeling, timing and signal delay analysis, low power CMOS design and analysis, optimal transistor sizing and buffer tapering, pipelining and register allocation, synchronization and clock distribution, retiming, interconnect delay, dynamic CMOS design techniques, power delivery, on-chip regulators, 3-D technology and circuit design, asynchronous vs. synchronous tradeoffs, clock distribution networks, low power design, and CMOS power dissipation. Prerequisite: ECE 112 and ECE 221 F16

ECE 262/462 Advanced CMOS VLSI Design: Senior design course for "Computer Design" or "Integrated Electronics" concentrations. Review of CMOS Subsystem design. Design focus on digital or mixed-signal systems, such as a simple microprocessor, a self-timed multiplier, a digital filter, data converter, or memory. Project design requirements include architectural design, logic and timing verification, layout design, and test pattern generation. Extensive use of CAD tools. The resulting VLSI chips may be fabricated. Prerequisite: ECE 261 or ECE 222 S*

ECE 266/466 RF and Microwave Integrated Circuits: This course involves the analysis and design of radio-frequency (RF) and microwave integrated circuits at the transistor level. We begin with a review of electromagnetics and transmission line theory. Several design concepts and techniques are then introduced, including Smith chart, s- parameters, and EM simulation. After the discussion of RLC circuits, high-frequency narrow-band amplifiers are studied, followed by broadband amplifiers. Then we examine the important issue of noise with the design example of low-noise amplifiers (LNA). Nonlinear circuits are studied next with the examples of mixers. A study of oscillators and phase noise follows. Afterwards we introduce phase-locked loops (PLL) and frequency synthesizers. The course concludes with an overview of transceivers architectures. The course emphasizes the development of both circuit design intuition and analytical skills. There are bi-weekly design labs and a term project using industry-standard EDA tools (ADS, Asitic, etc.). Prerequisite: ECE 222, ECE 230 or equivalent. Permission of instructor S*
ECE 269 High Speed Integrated Electronics: An introduction course for state-of-the-art integrated electronics in high speed and wideband applications, which spans the fields of wireless communications, computing, fiber optics, and instrumentation. We begin with an overview of high speed semiconductor technologies (CMOS, SiGe, SOI, GaAs, InP, etc) and devices (MOSFET, MESFET, HEMT, HBT, and tunneling diodes), followed by discussion of device characterization and technology optimization for circuit performance. In the second part of the course, we focus on the design of wideband and high power amplifiers, which includes discussions on feedback, impedance matching, distributed amplifiers, power combining, and switching power amplifiers. The third part of the course involves the design of high speed phase locked and delay-locked loops (PLL and DLL). After a review of PLL basics, we discuss its building blocks: VCO, frequency divider, phase detector, and loop filter. We also analyze its performance, in particular phase noise, jitter, and dynamic performance, and how to improve them. Two important applications, frequency synthesis and clock recovery, serve as the examples in our discussion. Each part of the course also includes related simulation methods and measurement techniques. The course emphasizes the understanding of basic circuit operation, and the development of circuit design intuition. **Prerequisite:** ECE222 and ECE230  

ECE 270 Discrete Math and Probability for Engineers: Logic, introduction to proofs, set operations, algorithms, introduction to number theory, recurrence relations, techniques of counting, graphs. Probability spaces, independence, discrete and continuous probability distributions, commonly used distributions (binomial, Poisson, and normal), random variables, expectation and moment generating functions, functions of random variables, laws of large numbers.  

ECE 271/440 Introduction to Random Processes: The goal of this course is to learn how to model, analyze and simulate stochastic systems, found at the core of a number of disciplines in engineering, for example communication systems, stock options pricing and machine learning. This course is divided into five thematic blocks: Introduction, Probability review, Markov chains, Continuous-time Markov chains, and Gaussian, Markov and stationary random processes. **Prerequisite:** ECE242 or equivalent  

ECE 272/472/AME 272 Audio Signal Processing: This course is a survey of audio digital signal processing fundamentals and applications. Topics include sampling and quantization, analog to digital converters, time and frequency domains, spectral analysis, vocoding, digital filters, audio effects, music audio analysis and synthesis, and other advanced topics in audio signal processing. Implementation of algorithms using Matlab and on dedicated DSP platforms is emphasized. **Prerequisite:** ECE 114 and basic Matlab programming, ECE 241 or other equivalent signals and systems courses.  

ECE 277/477 Computer Audition: Computer audition is the study of how to design a computational system that can analyze and process auditory scenes. Problems in this field include source separation (splitting audio mixtures into individual source tracks), pitch estimation (estimating the pitches played by each instrument), streaming (finding which sounds belong to a single event/source), source localization (finding where the sound comes from) and source identification (labeling a sound source). **Prerequisite:** ECE 246/446 or ECE 272/472 or other equivalent signal processing courses, and Matlab programming. Knowledge of machine learning techniques such as Markov models, support vector machines is also helpful, but not required.  

ECE 294 Audio DSP (Digital Signal Processing) Portfolio Lab: This is a follow on course to AME272, Audio Digital Signal Processing. Students will complete a major design/build project in the area of audio digital signal processing in this course. Examples include a real-time audio effects processor, music synthesizer or sound analyzer or other projects of student interest. Weekly meetings and progress reports are required. **Prerequisite:** ECE 241; strong MATLAB expertise, and C/C++ programing familiarity (ECE 111 and ECE 113 recommended)  

ECE 349 Senior Design Project: Senior design course. Prior faculty approval required or design project proposal. **Prerequisite:** Majors only, all required courses including an advanced elective in the ECE program
### ECE 398 Design Seminar

Students majoring in Electrical and Computer Engineering will take this course at the same time as their concentration elective and prepare a proposal for the Design Project to be started in the Fall semester and completed in the Spring semester. Students and Instructor will consult with design project supervisors in various areas to devise a project plan. Proposal might include presentations and documentation discussing the following: definition of project requirements and product specifications; clarification and verification of end user requirements; subsystem definition and interfaces; generation of project and testing plans including Gantt charts; reliability analysis, product safety, compliance issues, manufacturability, reverse engineering a comparable device, cost, and documentation. **Prerequisite:** ECE 111, 112, 113, 114  \( \text{F16} \)

### ECE 399 Junior Seminar

Case studies on ethical, social, economic and safety considerations that can arise in engineering practice, along with preliminary planning for Capstone Design Projects. Occasional presentations by outside speakers. **Prerequisite:** Accepted as ECE Major. \( \text{S17} \)

### ECE 400/200 Computer Organization

Instruction set principles; processor design, pipelining, data and control hazards; datapath and computer arithmetic; memory systems; I/O and peripheral devices; internetworking. Students learn the challenges, opportunities, and tradeoffs involved in modern microprocessor design. Assignments and labs involve processor and memory subsystem design using hardware description languages (HDL). **Prerequisite:** ECE114, ECE 112 or CSC 171, or permission of Instructor \( \text{S17} \)

### ECE 401/201 Advanced Computer Architecture

Instruction set architectures. Advanced pipelining techniques. Instruction level parallelism. Memory hierarchy design. Multiprocessing. Storage systems. Interconnection network. **Prerequisite:** ECE 200 or equivalent. \( \text{F16} \)

### ECE 404 Multiprocessor Architecture

This course provides in-depth discussions of the design and implementation issues of multiprocessor system architecture. Topics include cache coherence, memory consistency, interconnect, their interplay and impact on the design of high-performance micro-architectures. **Prerequisite:** ECE 200 or CSC 252 or permission of instructor \( \text{S17} \)

### ECE 405/205 Advanced Digital Design Using FPGA

Review of complex embedded project development with Xilinx Virtex FPGA eval board and Xilinx CAD tools using Verilog HDL and C programming language. Embedded development and introduction to ethernet, USB, SATA, VGA, DVI, PS2, RS232, GPIO, and soft processor cores. **Prerequisite:** ECE200, or ECE216, or ECE201/401. Familiarity with assembly language and C programming language. Instructor approval \( \text{F*} \)

### ECE 406/206 GPU Parallel Programming Using C/C++

GPU micro-architecture, including global memory, constant memory, texture memory, SP, SM, scratchpad memory, L1 and L2 cache memory, multi-ported memory, register file, and task scheduler. Parallel programming applications to parallel sorting, reduction, numeric iterations, fundamental graphics operations such as ray tracing. Desktop GPU programming using Nvidia's CUDA (Compute-Uniform Device Architecture), CPU/GPU cooperative scheduling of partially serial/partially parallel tasks. No midterms or written exams. Course consists of seven hands-on projects using CUDA. **Prerequisite:** ECE 200, or ECE 216, or ECE 201/401, or equivalent. Familiarity with assembly language and C programming language. Instructor approval \( \text{F*} \)

### ECE 407/207 Advanced GPU Project Development

Students develop an advanced project for the GPU platform. A GPU compute-cluster can be employed, as well as a single GPU computer. Students meet with the instructor twice a week to report the progress and the new direction is determined based on the results and the ongoing progress. Project options include: Protein folding (BLAST algorithm), Face recognition (using Open CV), 3D Image reconstruction of biomedical images, and other sophisticated image processing algorithms. **Prerequisite:** ECE 206/406 or equivalent strongly recommended. Instructor approval \( \text{S*} \)
ECE 423/223  **Semiconductor Devices:** Review of modern solid-state electronic devices, their principles of operation, and fabrication. Solid state physics fundamentals, free electrons, band structure, and transport properties of semiconductors. Nonequilibrium phenomena in semiconductors. P-N junctions, Schottky diodes, field-effect, and bipolar transistors. Modern, high-performance devices. Ultrafast devices. **Prerequisite:** ECE 221, ECE 230, PHY 123 or Instructor's approval F16

ECE 427/227  **Electric Power: Conversion, Transmission, and Consumption:** We will describe how the principal sources of energy - coal, natural gas, impounded water (hydroelectric), and fissionable materials - are exploited to create electric power, how it is transmitted and distributed through the grid and finally the patterns of its consumption. To assure that students gain a proper appreciation for the factors that determine the real cost of electricity per kilowatt-hour, the subject will be treated in a highly quantitative way. The goal will be to provide students with the information and tools they need for informed analysis of the true prospects and technological challenges involved in integration of new energy sources, such as solar, wind, geothermal, and tidal power, with the existing grid. There will be weekly homework and a midterm. Two projects with oral presentations, including a major one at the end of the semester, are required. There is no final exam. Several required field trips to local power facilities occur during the semester. Enrollment is restricted to seniors and graduate students who possess some background in either thermodynamics or AC circuits. **Prerequisite:** Enrollment will be restricted to seniors and graduate students who possess some background in either thermodynamics or AC circuits  S17

ECE 429  **Audio Electronics:** The devices, circuits, and techniques of audio electronics are covered in this course. Included is a survey of small signal amplifier designs and small-signal analysis and characterization, operational amplifiers and audio applications of opamps, large-signal design and analysis methods including an overview of linear and switching power amplifiers. The course also covers the design of vacuum tube circuits, nonlinearity and distortion. Other important audio devices are also covered including microphones, loudspeakers, analog to digital and digital to analog converters, and low-noise audio equipment design principles. **Prerequisite:** ECE 221 or Permission of Instructor  S17

ECE 432  **Acoustical Waves:** Introduction to acoustical waves. Topics include acoustic wave equation; plane, spherical, and cylindrical wave propagation; reflection and transmission at boundaries; normal modes; absorption and dispersion; radiation from points, spheres, cylinders, pistons, and arrays; diffraction; nonlinear acoustics. **Prerequisite:** MTH 164 and PHY 121 SR17

ECE 433/233/AME 233  **Musical Acoustics:** Aspects of acoustics. Review of oscillators, vibratory motion, the acoustic wave equation, reflection, transmission and absorption of sound, radiation and diffraction of acoustic waves. Resonators, hearing and speech, architectural and environmental acoustics. **Prerequisite:** MTH 165, MTH 164 and PHY 121 or equivalents S17

ECE 435/235  **Introduction to Opto-electronics:** Introduction to fundamentals of wave propagation in materials, waveguides and fibers, generation, modulation, and detection of light using semiconductor devices, and elements of optocommunication systems. **Prerequisite:** ECE 230 and ECE 221 equivalent or permission of instructor S*

ECE 436  **Nanophotonic and Nanomechanical Devices:** Various types of typical nanophotonic structures and nanomechanical structures, fundamental optical and mechanical properties: micro/nano-resonators, photonic crystals, plasmonic structures, metamaterials, nano-optomechanical structures. Cavity nonlinearoptics, cavity quantum optics, and cavity optomechanics. Fundamental physics and applications, state-of-art devices and current research trends. This class is designed primarily for graduate students. It may be suitable for senior undergraduates if they have required basic knowledge. **Prerequisite:** This class is designed primarily for graduate students. It may be suitable for senior undergraduates if they have required basic knowledge **Restrictions:** ECE 230 or 235/435; OPT 262 or 462, or 468, or 223, or 412; PHY 237, or 407 F16

ECE 437/232  **Autonomous Mobile Robots**  This course covers models and algorithms for autonomous mobile robots. Topics include sensors, perception, state estimation, mapping, planning, control, and human-robot interaction. Proficiency with Matlab/C++ is recommended. Lab required. **Prerequisite:** MTH 165 and ECE 114, CS 170, or CSC 171 S17
ECE 440/271 Introduction to Random Processes: The goal of this course is to learn how to model, analyze and simulate stochastic systems, found at the core of a number of disciplines in engineering, for example communication systems, stock options pricing and machine learning. This course is divided into five thematic blocks: Introduction, Probability review, Markov chains, Continuous-time Markov chains, and Gaussian, Markov and stationary random processes. Prerequisite: ECE242 or equivalent  F16

ECE 441 Detection and Estimation Theory: Loss and utility; Bayesian inference; risk functions, randomized decisions, admissible decisions; empirical Bayes for unknown prior; Neyman-Pearson hypothesis testing, receiver operating characteristic; sufficient and minimal sufficient statistics and Rao-Blackwellization; unbiased estimation; minimum variance unbiased estimation and Cramer-Rao inequality, maximum likelihood estimation; nonparametric estimation of cdfs. Prerequisite: MTH 164 and ECE 113 or ECE 210  S17*

ECE 444/244 Digital Communications: Digital communication system elements, characterization and representation of communication signals and systems. Digital transmission, binary and M-ary modulation schemes, demodulation and detection, coherent and incoherent demodulators, error performance. Channel capacity, mutual information, simple discrete channels and the AWGN channel. Basics of channel coding and error correction codes. Prerequisite: ECE 242 or permission of instructor  F*

ECE 445/245 Wireless Communications: This course teaches the underlying concepts behind traditional cellular radio and wireless data networks as well as design trade-offs among RF bandwidth, transmitter and receiver power and cost, and system performance. Topics include channel modeling, digital modulation, channel coding, network architectures, medium access control, routing, cellular networks, WiFi/IEEE 802.11 networks, mobile ad hoc networks, sensor networks and smart grids. Issues such as quality of service (QoS), energy conservation, reliability and mobility management are discussed. Students are required to complete a semester-long research project in order to obtain in-depth experience with a specific area of wireless communication and networking. Prerequisite: ECE 242 or permission of instructor  F16

ECE 446/246 Digital Signal Processing: Analysis and design of discrete-time signals and systems, including: difference equations, discrete-time filtering, z-transforms, A/D and D/A conversions, multi-rate signal processing, FIR and IIR filter design, the Discrete Fourier Transform (DFT), circular convolution, Fast Fourier Transform (FFT) algorithms, windowing, and classical spectral analysis. Prerequisite: ECE 241 and math programming skills  F16

ECE 447/247 An Introduction to Digital Image Processing using Python This course will introduce the students to the basic concepts of digital image processing, and establish a good foundation for further study and research in this field. The theoretical components of this course will be presented at a level that seniors and first year graduate students who have taken introductory courses in vectors, matrices, probability, statistics, linear systems, and computer programming should be comfortable with. Topics cover in this course will include intensity transformation and spatial filtering, filtering in the frequency domain, image restoration, morphological image processing, image segmentation, image registration, and image compression. The course will also provide a brief introduction to python (ipython), the primary programming language that will be used for solving problems in class as well as take-home assignments. Prerequisite: ECE 242 and ECE 440 & 446 are recommended or permission of instructor  S17

ECE 448 Wireless Sensor Networks: This course will cover the latest research in the area of wireless sensor networks. We will cover all aspects of these unique and important systems, from the hardware and radio architecture through protocols and software to applications. Topics will include sensor network architectures, hardware platforms, physical layer techniques, medium access control, routing, topology control, quality of service (QoS) management, localization, time synchronization, security, storage, and other advanced topics. Each student must complete a semester-long course project related to wireless sensor networks.  S17

ECE 450 Information Theory: Entropy, Relative Entropy, mutual information, asymptotic equipartition property, data compression, channel capacity, joint source channel coding theorem, Gaussian channels, rate distortion theory, selected applications. Prerequisite: MTH 201, or permission of Instructor  F16
ECE 452 Medical Imaging - Theory and Implementation: Physics and implementation of X-ray, ultrasonic, and MR imaging systems. Special attention given to the Fourier transform relations and reconstruction algorithms of X-ray and ultrasonic-computed tomography, and MRI. Prerequisite: ECE 242 or equivalent experience with Fourier transformer operations F16

ECE 457 Digital Video Processing: Basics of digital video, digital video filtering, and video-based object recognition and tracking. Core topics to include: algorithms for 2-D motion estimation, compression, video segmentation, image enhancement, transform and sub-band/wavelet coding, compression, feature extraction from video, and 3-D video processing. Projects will apply video-based techniques for solving a wide variety of problems in areas such as person and object tracking, human motion analysis, biometrics, and scene understanding. Prerequisite: ECE 446 (Digital Signal Processing) S17

ECE 461/261 Introduction To VLSI: Introduction to high performance integrated circuit design. Semiconductor technologies. CMOS inverter. General background on CMOS circuits, ranging from the inverter to more complex logical and sequential circuits. The focus is to provide background and insight into some of the most active high performance related issues in the field of high performance integrated circuit design methodologies, such as CMOS delay and modeling, timing and signal delay analysis, low power CMOS design and analysis, optimal transistor sizing and buffer tapering, pipelining and register allocation, synchronization and clock distribution, retiming, interconnect delay, dynamic CMOS design techniques, power delivery, on-chip regulators, 3-D technology and circuit design, asynchronous vs. synchronous tradeoffs, clock distribution networks, low power design, and CMOS power dissipation. Prerequisite: ECE 112 and ECE 221 F16

ECE 462/262 Advanced CMOS VLSI Design: Senior design course for "Computer Design" or "Integrated Electronics" concentrations. Review of CMOS Subsystem design. Design focus on digital or mixed-signal systems, such as a simple microprocessor, a self-timed multiplier, a digital filter, data converter, or memory. Project design requirements include architectural design, logic and timing verification, layout design, and test pattern generation. Extensive use of CAD tools. The resulting VLSI chips may be fabricated. Prerequisite: ECE261 or ECE 222 S*

ECE 466/266 RF and Microwave Integrated Circuits: This course involves the analysis and design of radio-frequency (RF) and microwave integrated circuits at the transistor level. We begin with a review of electromagnetics and transmission line theory. Several design concepts and techniques are then introduced, including Smith chart, s- parameters, and EM simulation. After the discussion of RLC circuits, high-frequency narrow-band amplifiers are studied, followed by broadband amplifiers. Then we examine the important issue of noise with the design example of low-noise amplifiers (LNA). Nonlinear circuits are studied next with the examples of mixers. A study of oscillators and phase noise follows. Afterwards we introduce phase-locked loops (PLL) and frequency synthesizers. The course concludes with an overview of transceivers architectures. The course emphasizes the development of both circuit design intuition and analytical skills. There are bi-weekly design labs and a term project using industry-standard EDA tools (ADS, Asitic, etc.). Prerequisite: ECE 222, ECE 230 or equivalent. Permission of instructor S*

ECE 467 Advanced Analog Integrated Circuit Design: MOSFET and bipolar device structures and models. Analysis and design of analog CMOS integrated circuits. Modern opamp design with noise, offset and distortion analysis, feedback, frequency compensation, and stability. Current mirrors and bandgap references. Sampling devices and structures. More advanced design projects and use of design aids and CAD tools (including simulation and synthesis) are included. Prerequisite: ECE 113, ECE 221 S17

ECE 468 Advanced Analog CMOS Integrated Circuit Design Circuitry, algorithms, and architectures used in analog and mixed-mode CMOS integrated circuits. Switched-capacitor (SC) elements, amplifier stages, and filters. Other SC circuits: S/H stages, comparators, PGAs, oscillators, modulators, voltage boosters, and dividers, Non-ideal effects in SC circuits, and correction techniques. Low-voltage SC design. Nyquist-rate data converter fundamentals; SC implementations of DACs and ADCs. Oversampling (delta-sigma) data converters: fundamentals and implementations. Prerequisite: ECE 113, ECE 221, ECE 222, ECE 246/446,ECE 467 S*
ECE 469 High Speed Integrated Electronics: An introduction course for state-of-the-art integrated electronics in high speed and wideband applications, which spans the fields of wireless communications, computing, fiber optics, and instrumentation. We begin with an overview of high speed semiconductor technologies (CMOS, SiGe, SOI, GaAs, InP, etc) and devices (MOSFET, MESFET, HEMT, HBT, and tunneling diodes), followed by discussion of device characterization and technology optimization for circuit performance. In the second part of the course, we focus on the design of wideband and high power amplifiers, which includes discussions on feedback, impedance matching, distributed amplifiers, power combining, and switching power amplifiers. The third part of the course involves the design of high speed phase locked and delay-locked loops (PLL and DLL). After a review of PLL basics, we discuss its building blocks: VCO, frequency divider, phase detector, and loop filter. We also analyze its performance, in particular phase noise, jitter, and dynamic performance, and how to improve them. Two important applications, frequency synthesis and clock recovery, serve as the examples in our discussion. Each part of the course also includes related simulation methods and measurement techniques. The course emphasizes the understanding of basic circuit operation, and the development of circuit design intuition. Prerequisite: ECE 222 and ECE 230  S17

ECE 472/AME 472 Audio Signal Processing: This course is a survey of audio digital signal processing fundamentals and applications. Topics include sampling and quantization, analog to digital converters, time and frequency domains, spectral analysis, vocoding, digital filters, audio effects, music audio analysis and synthesis, and other advanced topics in audio signal processing. Implementation of algorithms using Matlab and on dedicated DSP platforms is emphasized. Prerequisite: ECE 114 and basic Matlab programming, ECE 241 or equivalent  S17

ECE 475/AME 262 Audio Software Design: I: This course aims to give students the ability to develop their own audio/music programs in C and a few major open-source audio programming languages. It begins with an introduction to computer music and audio programming, and a comparative survey of audio programming languages. After an overview of the C language, we then explore the topics of programming for sound synthesis. The second half of this course introduces the primary techniques of sound design using the audio programming environments of Pure Data and Csound. Students will practice their programming techniques through a series of programming assignments and a final project. Prerequisite: ECE 114 or instructor permission  F16

ECE 476 Audio Software Design II: This course is a sequel to AME262/ECE475/TEE475 Audio Software Design I. The first part of the course will explore designing audio plug-ins with Faust (Function AUdio STream), which is a high-level functional programming language designed for real-time audio digital signal processing (DSP) and sound synthesis. Students will learn how to design plug-ins for Pro Tools, Logic and other digital audio workstations (DAWs). The second part of the course will focus on audio programming for iOS apps in Swift, which is the new programming language for iOS and OS X. Students will learn how to make musical apps with the sound engine libpd, which turns Pure Data (Pd) into an embeddable library. A special topic will introduce audio programming for video games with Wwise and FMOD. Prerequisite: AME 262, ECE 475 or Instructor Permission  S17

ECE 477/277 Computer Audition: Computer audition is the study of how to design a computational system that can analyze and process auditory scenes. Problems in this field include source separation (splitting audio mixtures into individual source tracks), pitch estimation (estimating the pitches played by each instrument), streaming (finding which sounds belong to a single event/source), source localization (finding where the sound comes from) and source identification (labeling a sound source). Prerequisite: ECE 246/446 or ECE 272/472 or other equivalent signal processing courses, and Matlab programming. Knowledge of machine learning techniques such as Markov models, support vector machines is also helpful, but not required.  F*

ECE 479 Audio Recording: Technology and Fundamentals: This course covers the acoustical and psychoacoustic fundamentals of audio recording including the nature of sound, sound pressure level, frequency and pitch, hearing and sound perception, reflection, absorption and diffusion of sound, sound diffraction, room acoustics, reverberation, and studio design principles. The course also provides practical experience in audio recording including an introduction to recording studio equipment, microphones and microphone placement techniques, signal flow, amplification, analog and digital recording, analog to digital conversion, digital processing of sound, multi-track recording and an introduction to mixing and mastering. Each student is required to complete a substantive recording project at the end of the course. Prerequisite: Instructor’s permission required  F16/S17
ECE 520 Spin-based electronics: theory, devices & applications: Up until now CMOS scaling has given us a remarkable ride with little concern for fundamental limits. It has scaled multiple generations in feature size and in speed while keeping the same power densities. However, after years of exponential growth CMOS is finally encounters fundamental limits. Given this impasse, there is an immense on going effort in several cutting edge research frontiers to propose alternative technologies. One such example is the research in spin-based electronics (spintronics) which is motivated by the natural ordering a ferromagnetic phase can add to large scale electronics circuits. Generally speaking, we are left to manipulate the information whereas nature takes care of preserving it. The course is intended for students who are interested in research frontiers of future electronics technologies. The course begins with introduction to the basic physics of magnetism and of quantum mechanical spin. Then it covers aspects of spin transport with emphasis on spin-diffusion in semiconductors. The second part of the course is comprised of student and lecturer presentations of selected spintronics topics which may include: spin transistors, magnetic random access memories, spin-based logic paradigms, spin-based lasers and light emitting diodes, magnetic semiconductors, spin-torque devices for memory applications and the spin Hall effect. Prerequisites: Permission of Instructor & familiarity with elementary quantum mechanics

S17
### Contact Information

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### CLASS ADVISORS

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### CLASS 2019