ELECTRICAL AND COMPUTER ENGINEERING

Electrical and Computer Engineering Curriculum Guide
The Hajim School of Engineering and Applied Sciences
University of Rochester
Fall/Spring 2020-2021
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.

Imagine – Design – Create …

The creative application of knowledge and skills in Electrical and Computer Engineering
The Department of Electrical and Computer Engineering at the University of Rochester (http://www.hajim.rochester.edu/ece/) 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@rochester.edu) 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, e5 and Take Five Scholars programs, etc.

Students transferring from other colleges and universities should meet with the Undergraduate Coordinator 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/](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 11 are intended to meet the requirements of the Engineering Accreditation Commission of ABET [http://www.abet.org/](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 along with the on-line Major Declaration Form ordinarily during the fourth semester of study. This form constitutes acceptance into the 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. MATH 161, 162, 164, and 165 or the equivalent mathematics sequence
3. PHYS 121 and 122, or the equivalent physics sequence, and one other or natural science or math course (PHYS 123 is recommended)
4. University primary writing requirement, usually satisfied by taking WRTG 105
5. Students on Academic Probation in the College may not be admitted to the major

A submitted plan, which may be amended, 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 The Undergraduate Coordinator. The Curriculum Planning Form, approved by the Undergraduate Coordinator, will accompany the on-line Major Declaration and be on file in the Undergraduate Coordinators office.

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 four required ECE or one of the seven first year-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 College of Arts, Sciences and Engineering can make exceptions from the general degree requirements published in the Official Bulletin of the University. Petition forms for Administrative Committee consideration may also be obtained from the Electrical and Computer Engineering Office.

IMPORTANT DATES
2020 – 2021
TENTATIVE

<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aug. 26</td>
<td>Classes begin</td>
</tr>
<tr>
<td>Sept. 16</td>
<td>Last day to add 4 cr. Indep. Study course</td>
</tr>
<tr>
<td>Sept. 23</td>
<td>Last day to drop/add</td>
</tr>
<tr>
<td>Nov. 2</td>
<td>Spring registration</td>
</tr>
<tr>
<td>Nov. 13</td>
<td>Last day to S/F or withdraw from a class</td>
</tr>
<tr>
<td>Nov. 25</td>
<td>classes end</td>
</tr>
<tr>
<td>Jan. 13</td>
<td>Spring semester begins</td>
</tr>
<tr>
<td>Jan.</td>
<td>Martin Luther King Day</td>
</tr>
<tr>
<td>Feb.</td>
<td>Last day to add 4 cr. Indep. Study course</td>
</tr>
<tr>
<td>Feb.</td>
<td>Last day to drop/add</td>
</tr>
<tr>
<td>Mar.</td>
<td>Spring Break</td>
</tr>
<tr>
<td>April</td>
<td>Fall registration</td>
</tr>
<tr>
<td>April</td>
<td>Last day to S/F or withdraw from a class</td>
</tr>
<tr>
<td>April</td>
<td>Last day of classes</td>
</tr>
<tr>
<td>April</td>
<td>Reading period</td>
</tr>
<tr>
<td>May</td>
<td>Final exams</td>
</tr>
<tr>
<td>May</td>
<td>Commencement</td>
</tr>
</tbody>
</table>
ECE Program Requirements

The BS ECE program is built on a foundation of basic math, science, programming and includes advanced coursework in fundamental engineering science. The credit hour requirements for the BS ECE degree are given in the following table.

<table>
<thead>
<tr>
<th>Core Area</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic Science and Mathematics</td>
<td>32</td>
</tr>
<tr>
<td>Engineering</td>
<td>56</td>
</tr>
<tr>
<td>Writing (WRTG 105, 273)</td>
<td>6</td>
</tr>
<tr>
<td>Hum &amp; Soc Sci</td>
<td>20</td>
</tr>
<tr>
<td>Free electives</td>
<td>16</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>130</strong></td>
</tr>
</tbody>
</table>

Core Requirements

**Mathematics** (Complete one calculus sequence)
MATH 161,162,164,165 or MATH 171,172, 173, 174
MATH 141,142,143 may be substituted for MATH 161,162

**Physics** (2 courses) PHYS 121, PHYS 122; or PHYS 141, PHYS 142

**Other Science and Mathematics** (1 course)
The remaining course may be in astronomy, biology, brain and cognitive sciences, chemistry, earth and environmental sciences, mathematics, physics, or statistics. (PHYS 123 or higher, ASTR 111 or higher, CHEM 103 or higher, BIOL 110 or higher, EESC, 101 or higher, BCSC 110 or higher)

The BS ECE major requires completion of one course as an Advanced elective. The required and elective courses for the BS ECE degree are listed below. All courses are 4 credits unless indicated otherwise.
Core courses

- ECE 111 – Circuits & Signals
- ECE 112 – Logic Design
- ECE 113 – Signals & Systems
- ECE 114 – C/C++ Programming
- ECE 200 – Computer Organization
- ECE 216 – Microprocessors and Data Conversion
- ECE 221 – Electronic Devices and Circuits
- ECE 222 – Integrated Circuits
- ECE 230 – Electromagnetic Waves
- ECE 241 – Signals
- ECE 242 – Communications
- ECE 270 – Discrete Math and Probability for Engineers
- ECE 348 – ECE Design Seminar
- ECE 350 – Social Implications of Engineering
- ECE 349 – Senior Design Capstone
- ONE Advanced Elective (200 level or above)

Humanities and Social Sciences

All ECE majors must take a minimum of 5 humanities and/or social science (H&SS) courses. This includes the three courses taken to satisfy the University Cluster requirement. These five courses can be chosen from any recognized Humanities and/or Social Science field listed below. 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. While it is preferred to have at least one course in each of H&SS, a minor of 5 or more courses in one area will satisfy the H&SS requirement.

Acceptable Humanities Courses: Any English course except for ENGL 101 or the course taken to satisfy the university primary writing requirement (usually WRTG 105); any 4 credit course in American sign language, art or art history, dance, digital media studies, dance, English, modern languages and culture (a foreign language above 101 level), music, philosophy, religion & classics, film studies courses cross-listed in a humanities department, studio art.

Acceptable Social Sciences Courses: Any course in anthropology, health behavior and society, economics, entrepreneurship, health policy, history, international relations, linguistics, political science, psychology, sociology, Gender, sexuality and women’s studies.
Considerations:

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 350 and WRTG 273. 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 Program Coordinator to determine if their program satisfies the requirement.

Natural Science Requirement

Other Science and Mathematics (1 course)
The remaining course may be in astronomy, biology, brain and cognitive sciences, chemistry, earth and environmental sciences, mathematics, physics, or statistics. (PHYS 123 or higher, ASTR 111 or higher, CHEM 103 or higher, BIOL 110 or higher, EESC, 101 or higher, BCSC 110 or higher)

ECE Advanced Electives and Design

In planning a program of study each student must choose one advanced ECE elective course and take the capstone design sequence ECE 348, 350, and 349. This requirement assures that all majors devote some of their advanced level course-work to a specialization within ECE. 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 with an ECE faculty member.

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

Signals, Communications and Image Processing: 244, 245, 246, 247, 272
VLSI and Electronics: 261, 262, 269
Computer Engineering: 201, 204, 271
Waves, Fields and Devices: 223, 261, 266, 269
Robotics: 231, 232

*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 strongly recommended. Proper supporting documentation about the course should be submitted to the ECE Department Undergraduate Coordinator before taking any courses for transfer. A 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. Seeking approval after the fact may result in delays, and refusal to allow a student to take advanced courses for lack of prerequisites.

Internships and Practicum

ECE majors are strongly encouraged to participate in internships with local or nationally based engineering firms for professional development. 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 encouraged.
Applying to the MSEE Program

ECE Seniors contemplating earning their Master’s degree may wish to consider the Master’s 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 Senior year. Applicants may begin to take graduate level courses in their Senior year with the intent to transfer up to 10-credits of graduate level credits. These credits cannot be used toward the BS degree. (Transfer Credit Policy) Successful applicants will be granted a tuition scholarship for the Master’s year of study. Conferral of the BS degree is required in order to matriculate into the Master’s program. Please visit the Master’s Program webpage for up-to-date information: http://www.hajim.rochester.edu/ece/graduate/ms.html

Education Abroad

The ECE Department believes that studying abroad is a valuable contribution to the undergraduate curriculum. The College offers study abroad programs in more than 40 countries in various semesters. Study abroad requires careful planning so students who are interested in studying abroad should meet with the Undergraduate Program 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 in the sophomore or junior year.

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

This Guide supplements information found in the 2019-2021 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.
## Curriculum and Sample Course Schedule

<table>
<thead>
<tr>
<th>Yr</th>
<th>Fall – 16 cr.</th>
<th>Spring – 16 cr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>MATH 161 – Differential Calculus</td>
<td>MATH 162 – Integral Calculus</td>
</tr>
<tr>
<td></td>
<td>ECE 101 or EAS XXX</td>
<td>PHYS 121 – Mechanics</td>
</tr>
<tr>
<td></td>
<td>WRTG 105</td>
<td>ECE 112 – Logic Design</td>
</tr>
<tr>
<td></td>
<td>Cluster Elective/Natural Science</td>
<td>Cluster Elective</td>
</tr>
<tr>
<td>2</td>
<td>Fall – 16 cr.</td>
<td>Spring – 18 cr.</td>
</tr>
<tr>
<td></td>
<td>MATH 165 – Linear Alg &amp; Differential Equations</td>
<td>MATH 164 – Multivariate Calc</td>
</tr>
<tr>
<td></td>
<td>PHYS 122 – E&amp;M</td>
<td>PHYS 123/Natural Science/Elective</td>
</tr>
<tr>
<td></td>
<td>ECE 111 – Circuits &amp; Signals</td>
<td>ECE 113 – Signals &amp; Systems</td>
</tr>
<tr>
<td></td>
<td>Cluster Elective</td>
<td>ECE 114 – C/C++ Programming</td>
</tr>
<tr>
<td></td>
<td>Fall – 16 cr.</td>
<td>WRTG 273 – Communicating Your Professional Identity in Engineering</td>
</tr>
<tr>
<td>3</td>
<td>Spring – 14 cr.</td>
<td>Spring – 16 cr.</td>
</tr>
<tr>
<td></td>
<td>ECE 216 – Microprocessors</td>
<td>ECE 222 – Integrated Circuits</td>
</tr>
<tr>
<td></td>
<td>ECE 241 – Signals</td>
<td>ECE 242 – Communications</td>
</tr>
<tr>
<td></td>
<td>ECE 270 – Discrete Math and Probability for Engineers or (MTH 201 Probability as alternative)</td>
<td>ECE 350 – Social Implications of Engineering</td>
</tr>
<tr>
<td></td>
<td>Fall – 16 cr.</td>
<td>Spring – 16 cr.</td>
</tr>
<tr>
<td>4</td>
<td>ECE 348– ECE Design Seminar</td>
<td>ECE 349 – Capstone Design</td>
</tr>
<tr>
<td></td>
<td>ECE 230 – Waves</td>
<td>Elective</td>
</tr>
<tr>
<td></td>
<td>Advanced Elective</td>
<td>Elective</td>
</tr>
<tr>
<td></td>
<td>Elective</td>
<td>Elective</td>
</tr>
</tbody>
</table>

**Plus the following:** - Free electives to complete the remaining balance for the 130 credit hours required for the program. A total of 15 ECE courses, WRTG 273 can be taken in the sophomore or junior year
• Free electives to complete the remaining balance for the 130 credit hours required for the program.

• ECE 350 should be taken in the junior year and ECE 348 must be satisfactorily completed, in the Fall term of the Senior year, prior to taking ECE 349 - Capstone Design course.

• WRTG 273 is required of all majors and can be taken in the sophomore or junior year.

• Acceptable alternative mathematics sequences: Honors math Sequence: MATH 171, 172, 173, 174, is perfectly appropriate for those with adequate mathematics background. The sequence MATH 141, 142, 143 is acceptable, **HOWEVER**, it is best to take MATH 143 or an equivalent in the **SUMMER** between the 1st and 2nd years, in order to remain in sequence. Consult with your faculty advisor and Undergraduate Program Coordinator to arrange your best sequence.

• Two physics courses, PHYS 121 and PHYS 122, are required of all ECE majors. In addition, it is strongly recommended that ECE students also complete PHYS123. However, other courses in natural science selected from among ASTR, BCSC, BIOL, CHEM, EESC, and PHYS may also satisfy the ECE programs Natural Science requirement. Students must check with the ECE department Undergraduate Program 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/or social sciences is required. Three of these courses must constitute an approved Cluster in Humanities or Social Sciences or all courses must be part of a minor and must be passed with a 2.0 average or better. See the Cluster Search Engine and descriptions of clusters in the undergraduate bulletin.
  
  [https://www.rochester.edu/college/ccas/undergraduate/curriculum/clusters.html](https://www.rochester.edu/college/ccas/undergraduate/curriculum/clusters.html)

• ECE 270 - "Discrete Math and Probability for Engineers” is required for all ECE majors.

• For those participating in Education Abroad or other off-campus opportunities in the Spring semester of the third year, the requirement for ECE 350 can be waived or satisfied through Independent Study in other semesters with approval of the Undergraduate Committee and the instructor of ECE 350. Consult with your Undergraduate Coordinator to make appropriate arrangements **BEFORE** leaving for off-campus study.

• Degree requirements: 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, 130 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.

<table>
<thead>
<tr>
<th></th>
<th>Fall</th>
<th>Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>MATH 161 – Calculus I</td>
<td>MATH 162 – Calculus II</td>
</tr>
<tr>
<td></td>
<td>ECE 101 or EAS 1XX</td>
<td>PHYS 121 – Mechanics</td>
</tr>
<tr>
<td></td>
<td>WRTG 105</td>
<td>ECE 112 – Logic Design</td>
</tr>
<tr>
<td></td>
<td>Elective/Nat. Science</td>
<td>Elective</td>
</tr>
<tr>
<td>2</td>
<td>MATH 165 – Linear Alg &amp; De</td>
<td>MATH 164 – Multivariate Calc.</td>
</tr>
<tr>
<td></td>
<td>PHYS 122 – E&amp;M</td>
<td>PHYS 123/Nat. Sci/Elective</td>
</tr>
<tr>
<td></td>
<td>ECE 111 – Circuits &amp; Signals</td>
<td>ECE 113 – Signals &amp; Systems</td>
</tr>
<tr>
<td></td>
<td>WRTG 273</td>
<td>ECE 114 – C/C++ Programming</td>
</tr>
<tr>
<td>3</td>
<td>ECE 221 – Elec Devices &amp; Circuits</td>
<td>Co-op Semester</td>
</tr>
<tr>
<td></td>
<td>ECE 216 – Microprocessors</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ECE 241 – Signals</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ECE 270 – Discrete Math and Probability for Engineers</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ECE 230 - Waves</td>
<td>ECE 222 – Integrated Circuits</td>
</tr>
<tr>
<td></td>
<td>Advanced Elective</td>
<td>ECE 242 – Communications</td>
</tr>
<tr>
<td></td>
<td>Elective</td>
<td>ECE 350 – Junior Seminar</td>
</tr>
<tr>
<td>5</td>
<td>Co-op Semester</td>
<td>ECE 349 – Capstone Design</td>
</tr>
<tr>
<td></td>
<td>Elective</td>
<td>Elective</td>
</tr>
<tr>
<td></td>
<td>Elective</td>
<td>Elective</td>
</tr>
</tbody>
</table>
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 C/C++ 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 113 Circuits and Signals
- ECE 221 Electronic Devices and Circuits
- ECE 222 Integrated Circuits Design & Analysis
- ECE 261 Digital Integrated Circuit Design

**Signals, Communications**
- ECE 111 Introduction to Signals and Circuits
- ECE 113 Circuits and Signals
- ECE 114 Intro to C/C++ 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 261 Introduction to VLSI
- ECE 266 RF and Microwave Integrated Circuits

**Digital Audio and Music**
- ECE 114 Intro. To C/C++ Programming
- ECE 111 Introduction to Signals and Circuits
- ECE 113 Circuits and Signals
- ECE 140 Intro to Audio Music
- 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 an ECE advisor

*And choose one of the following:*

- ECE 223 Semiconductor Devices
- ECE 261 Introduction to VLSI
- ECE 266 RF and Microwave Integrated Circuits
- ECE 269 High Speed Integrated Electronics
Course Descriptions

This is a list of the courses that are being offered for AY 2020–2021, 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, High School Algebra and Trigonometry 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.  F

AME 141 Fundamentals of Digital Audio  This course covers the fundamentals of manipulating and encoding sound in a digital format. Mathematical representations of digital signals are introduced and the effects of simple filters are analyzed in the context of audio. This course further provides students with an introduction to programming in Matlab through a series of assignments exploring sound synthesis algorithms and audio effects processing.  S

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. Prerequisite: AME 140 and INSTRUCTOR PERMISSION ONLY.  F & S

AME 192 Critical Listening for Audio Production  This course is a continuation of AME 191. 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 INSTRUCTOR PERMISSION ONLY.  F

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. Only AME and MUR Majors. Instructor permission required.  F & S

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. 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 PERMISSION ONLY.  S
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. All students, including music and technology majors, are welcome to take this course. S

AME 197 Audio for Gaming The course is intended to provide students a basic understanding of audio for gaming. The emphasis is on demonstrations and hands-on experience to enable students to gain a practical knowledge of the integration of sound and music into video games using middleware. Students will primarily work with Wwise, Unity, Reaper, Pro Tools and Logic Pro X; Topics will include basic soundtrack composition for interactive; Advanced sound effect creation; foley; Dialog recording and editing; Working directly within a game environment; and audio for virtual reality. Supplementary software discussed will include FMOD, Unreal, Fabric, Nuendo, and Elais. The course will also feature guest lectures by industry leading professionals, who will share their experience and insights. Instructor permission required. F

AME 223 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. Prerequisites: ECE 221 or Permission of Instructor. S

AME 227 Podcasting History: Hear UR This team-taught class will explore the life and works of the father of modern taxidermy, Carl Akeley, who trained in Rochester. Akeley rose to fame in the early 20th century as the designer of the taxidermy animals in New York's American Museum of Natural History. In lieu of writing a final research paper, students will team up to create a podcast series. Based in part on documents at the University's department of Rare Books, Special Collections, and Preservation. F/S

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. Prerequisites: Linear algebra and Differential Equations (MATH 165), Multivariable Calculus (MATH 164), and Physics (PHYS 121) or equivalents. S

AME 240 Revolutions in Sound: Artistic and Technical Evolution of Sound Recording This course provides a multifaceted account of the evolution of sound technologies, starting with Edison, Ános invention of the phonograph in 1877 through the development of microphones, radio, magnetic tape recording, vinyl records, multi-track recording, digital audio, compact discs, the MP3 format, surround sound, online music streaming, and 3D audio. 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 focuses on spatial audio for virtual reality (VR) and augmented reality (AR), binaural recording, and ambisonics All students, including technology and music majors, are welcome. F

AME 262 Audio Software Design 1 In this course, students will develop the ability to design programs in C, Python, Max, and Pure Data for audio/music research, computer music, and interactive performance. We will begin with an introduction to computer music and audio programming, and a survey of audio programming languages. After a quick review of the C language, which is the most popular language for high-performance DSP applications today, we will use the PortSF soundfile library to generate and process basic envelopes and waveforms, and to explore the development of the table-lookup oscillator and other DSP tools. Max and Pure Data are similar visual programming languages for music and multimedia with a large collection of internal and external libraries. We will use Max/MSP/Jitter to explore topics in sound synthesis, signal processing, and sound analysis, as well as computer music. Python is a general-purpose programming language used in many application domains. We will use PytonMusic, a special version of Python, for music making, building graphical user interfaces, and for connecting external human interface devices. Students will practice their programming techniques through a series of programming assignments and a final research/design project. Prerequisites: ECE 114 or instructor permission. F
AME 264 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. Prerequisites: AME 262 or ECE 475 or Instructor Permission. S

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. Prerequisites: ECE 114 and basic Matlab programming, ECE 241 or other equivalent signals and systems courses. S

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). 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

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. F

AME 294 Audio DSP (Digital Signal Processing) Portfolio Lab This is a follow on course to AME 272, 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. ECE 241; strong MATLAB expertise, and C/C++ programming familiarity (ECE 210 recommended) The course is intended for junior/senior undergraduate level students in Audio and Music Engineering. Prerequisite: AME 272. F

AME 295 Audio Electronics Portfolio This is a follow on course to AME 223, 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. Prerequisite AME 223. F

AME 386 Senior Design Project 1 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. F

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. S

AME 433 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. Prerequisites: MATH 165, MATH 164 and PHYS 121 or equivalent. S

AME 460 Digital Programs and Programing I 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 MIDI; synthesizers & samplers; recording and editing with Pro Tools and Logic Pro X; 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. ESM students only. F & S
AME 461 Digital Programs and Programming II The course emphasizes hands-on experience where students gain practical skills in scoring to picture using digital audio workstations. 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. AME 460 - ESM students only.  F & S

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. Prerequisites: ECE 114 and basic Matlab programming, ECE 241 or other equivalent signals and systems courses.  S

AME 473 Music and Sound for Gaming The course is intended to provide students a basic understanding of music and audio for gaming. With demonstrations and hands-on experience, students will gain a practical knowledge in the integration of sound and musical elements into a video game environment using middleware. Students will primarily work with Wwise, Unity, Reaper, Pro Tools and Logic Pro X; Topics will include basic soundtrack composition for interactive; Advanced sound effect creation; foley; Dialog recording and editing; Working directly within a game environment; and audio for virtual reality. ESM students only Instructor permission required.  F

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). Prerequisites: 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

AME 393 Applied Sound Design In this course students will complete a major Sound Design independent project culminating in a live machine assisted music performance or an entirely machine generated music performance. Other possible projects include live gallery-based sound installations, web-based music projects, film/video scoring, voice over and sound effects or any other creative endeavors in the area of sound design. Frequent planning meetings with a faculty advisor and progress reports are required. Final course evaluation will be based on the quality of the finished product. Prerequisite: AME 193.  F/S*

ECE 101 Introduction to Computing Systems A general, high-level understanding of workings of modern computing systems from circuit, computing system architecture, to programming. 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. ECE101 is not a required course.  F

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. Workshop experience is an integral part of this course, students will be expected to attend a Workshop section (up to 2 hours each) almost every week of the semester. Days and times for these sections are arranged during the first week of classes, working with the Workshop Leaders and students. Prerequisite: Concurrent registration in MATH 165 and PHYS 122.  F

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,Åos and coding logic in VHDL. Prerequisite: one semester of Math (MATH 161, OR MATH 141, OR MATH 171).  S
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. Workshop experience is an integral part of this course, students will be expected to attend a Workshop section (up to 2 hours each) almost every week of the semester. Days and times for these sections are arranged during the first week of classes, working with the Workshop Leaders and students. Prerequisites: ECE 111, MATH 165; concurrent with MATH 164. S

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. F&S

ECE 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. High school algebra and trigonometry. 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. F

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). Prerequisites: ECE 114, ECE 112 or CSC 171, or permission of Instructor. S


ECE 204 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. Prerequisites: ECE 200 or CSC 252 or permission of instructor. S

ECE 210 Circuits and Microcontrollers for Scientists and Engineers  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 MATH 165 and PHYS 122. S

ECE 216 Microprocessors 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 micro-controller 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. Prerequisites: ECE 112, ECE 113, ECE 114. F

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. Prerequisites: ECE 113, or ECE 210. F

ECE 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. Prerequisites: ECE 221, ECE 230, PHYS 123 or permission of instructor.    F

ECE 224 Intro to Cond Matter Physics  An emphasis on the wide variety of phenomena that form the basis for modern solid state devices. Topics include crystals; lattice vibrations; quantum mechanics of electrons in solids; energy band structure; semiconductors; superconductors; dielectrics; and magnets. (same as MSC 420, ECE224, ECE424, PHYS420) Prerequisites: PHY 217, 227, 237.    *F


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. Prerequisites: MTH 165, ECE 114 (or equivalent), and ECE 241 (or equivalent) or permission of instructor.    F

ECE 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. Prerequisites: MATH 165 and ECE 114, or CSC 171.    S

ECE 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. Prerequisites: Linear algebra and Differential Equations (MATH 165), Multivariable Calculus (MATH 164), and Physics (PHYS 121) or equivalents.    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. Prerequisites: MATH 165 and ECE 113 or ECE 210.    F

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. Prerequisites: ECE 241 and ECE 270.    S

ECE 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. Prerequisites: ECE 242 and ECE 271 or permission of Instructor.    F

ECE 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,
Prerequisites: ECE 242 or equivalent or consent of instructor.  S

ECE 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. Prerequisites: ECE 241 and math programming skills  .  F

ECE 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. Prerequisites: ECE 242 and ECE 440 & 446 are recommended or permission of instructor.  S

ECE 251 Ultrasound Imaging This course investigates the imaging techniques applied in state-of-the-art ultrasound imaging and their theoretical bases. Topics include linear acoustic systems, spatial impulse responses, the k-space formulation, methods of acoustic field calculation, dynamic focusing and apodization, scattering, the statistics of acoustic speckle, speckle correlation, compounding techniques, phase aberration correction, velocity estimation, and flow imaging. A strong emphasis is placed on readings of original sources and student assignments and projects based on realistic acoustic simulations. Prerequisites: BME 230, ECE 241 or equivalent.  F

ECE 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. Prerequisites: ECE 112 and ECE 221.  F

ECE 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.). Prerequisites: ECE 222, ECE 230 or equivalent. Permission of instructor.  F

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. Prerequisites: ECE 222 and ECE 230.  *S
ECE 270 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. F

ECE 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. Prerequisites: ECE 242 or equivalent. F

ECE 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. Prerequisites: ECE 114 and basic Matlab programming, ECE 241 or other equivalent signals and systems courses. S

ECE 274 Biomed Sensors, Circuit & Intr Course will cover circuits and sensors used to measure physiological systems at an advanced level. Both signal conditioning and sensor characteristics will be addressed. Topics will include measurement of strain, pressure, flow, temperature, biopotentials, and physical circuit construction. The co-requisite laboratory will focus on the practical implementation of electronic devices for biomedical measurements. For graduate students will add an independent study. Prerequisites: BME 210, EC 113 or equivalent or permission of Instructor. S

ECE 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). This seminar course aims to examine several major questions posed in physics, mathematics, logic, and cognitive sciences. The goal is to understand the boundaries where important research questions or limiting factors remain. Topics include: dark matter and energy; “The unreasonable effectiveness of mathematics” (Wigner), Godel’s Incompleteness Theorem, and the mechanisms of reasoning. Weekly readings and short position papers are required through the semester. S

ECE 280 Uncertainties and Major Scientific Puzzles Some writers claim we are approaching an unprecedented acceleration of knowledge and technology (Kurzweil: The Singularity). Conversely, some argue that a wall of diminishing returns threatens progress (Horgan: The End of Science). One way of assessing these conflicting claims is to examine some of the major unresolved scientific questions that have been posed over the last century. This seminar course aims to examine several major questions posed in physics, mathematics, logic, and cognitive sciences. The goal is to understand the boundaries where important research questions or limiting factors remain. Topics include: dark matter and energy; “The unreasonable effectiveness of mathematics” (Wigner), Godel’s Incompleteness Theorem, and the mechanisms of reasoning. Weekly readings and short position papers are required through the semester. F

ECE 348 Design Seminar Students majoring in Electrical and Computer Engineering will 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. Prerequisites: ECE 111, 112, 113, 114. F

ECE 349 Senior Design Project Prior faculty approval required or design project proposal. MAJORS ONLY. Prerequisites: All required courses including an advanced elective in the ECE program. ECE 398 and 399. Requirement for all ECE students. Taken in the spring semester senior year. S

ECE 350 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. Prerequisites: Accepted as an ECE Major. (formerly ECE 399) S

ECE 400 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). Prerequisites: ECE 114, ECE 112 or CSC 171, or permission of Instructor. S
ECE 401 Advanced Computer Architecture  Instruction set architectures. Advanced pipelining techniques. Instruction level parallelism. Memory hierarchy design. Multiprocessing. Storage systems. Interconnection network. **Prerequisites:** ECE 200 or equivalent.  F

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. **Prerequisites:** ECE 200 or CSC 252 or permission of instructor.  S

ECE 409 Machine Learning  This course presents the mathematical foundations of AI, including probability, decision theory and machine learning. **Prerequisites:** CSC 242 and MATH 165.  S

ECE 421 Opto Priorities Of Materials  Optical properties of electrons, phonons, plasmons, and polaritons in semiconductors, metals and insulators are detailed.  S

ECE 422 Nanoelectronic Devices  Topics in semiconductor device physics, electronic band structure, materials science, and magnetism with a focus on applications to new and emerging electronic device technologies. This background will serve as a jumping off point to discuss potential future electronic devices with novel properties beyond the current status quo. Looking beyond just next-generation technology, the course will explore what electronics could look like on the 25+ year timescale. Basic trends from condensed matter physics, materials science and electrical engineering will be discussed. Topics include: 2D electronic materials/transistors, magnetic memory, spintronics, multiferroic memory, topological matter/devices **Prerequisites:** ECE 223/423 or instructors approval.  S

ECE 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. **Prerequisites:** ECE 221, ECE 230, PHYS 123 or Instructor’s approval.  F

ECE 429 Audio Electronics  The devices, circuits, and techniques of audio electronics are covered in this course. Also 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 to analog converters, and low-noise audio equipment design principles. **Prerequisites:** ECE 221 or Permission of Instructor.  S

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. **Prerequisites:** MATH 164 and PHYS 121.  S

ECE 433 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. **Prerequisites:** MATH 165, MATH 164 and PHYS 121 or equivalents.  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. **Prerequisites:** ECE 230 or 235; OPT 262 or 462, or 468, or 223, or 412; PHYS 237, or 407.  F

ECE 437 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. **Prerequisites:** MATH 165 and ECE 114, CSC 190, or CSC 171.  S

ECE 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. **Prerequisites:** ECE 242 or equivalent.  F
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. Prerequisites: MATH 164 and ECE 113 or ECE 210.  S

ECE 442 Network Science Analytics  The science of networks is an emerging discipline of great importance that combines graph theory, probability and statistics, and facets of engineering and the social sciences. This course will provide students with the mathematical tools and computational training to understand large-scale networks in the current era of Big Data. It will introduce basic network models and structural descriptors, network dynamics and prediction of processes evolving on graphs, modern algorithms for topology inference, community and anomaly detection, as well as fundamentals of social network analysis. All concepts and theories will be illustrated with numerous applications and case studies from technological, social, biological, and information networks. Prerequisites: Some mathematical maturity, comfortable with linear algebra, probability, and analysis (e.g., MTH164-165). Exposure to programming and Matlab useful, but not required.  S

ECE 443 Probabilistic Models for Inference and Estimation  Probability and stochastic processes, IID and Markov processes, basics of inference and estimation, MAP and ML estimates, modeling with latent variables, expectation maximization, hidden Markov Models, stochastic context free grammars, Markov and conditional random fields, energy models. Select applications in computer vision, machine learning, image processing, communications, and bioinformatics.  F*

ECE 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. Prerequisites: ECE 242 and ECE 440 or permission of instructor.  F

ECE 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. Prerequisites: ECE 242 or permission of instructor.  S

ECE 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, mutli-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 Matlab programming skills.  F

ECE 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. Prerequisites: ECE 242 and ECE 440 & 446 are recommended or permission of instructor.  F

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.  S

ECE 449 Machine Vision  Fundamentals of computer vision, including image formation, elements of human vision, low-level image processing, and pattern recognition techniques. Advanced topics include modern visual features, graphical models, model-based and data-driven approaches, and contextual inference, as well as examples of successes and challenges in applications. CSC 449, a graduate-level course, requires additional readings and assignments (including a course project). Prerequisites: MATH 161 and CSC 242.  S
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. Prerequisites: ECE 270. F

ECE 451 Biomedical Ultrasound  The course presents the physical basis for the use of high-frequency sound in medicine. Topics include acoustic properties of tissue, sound propagation (both linear and nonlinear) in tissues, interaction of ultrasound with gas bodies (acoustic cavitation and contrast agents), thermal and non-thermal biological effects of ultrasound, ultrasongraphy, dosimetry, hyperthermia and lithotripsy. Prerequisites: MATH 164, PHYS 122 or Permission of instructor. S

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. Prerequisites: ECE 242 or equivalent experience with Fourier transformer operations. F

ECE 453 Ultrasound Imaging  This course investigates the imaging techniques applied in state-of-the-art ultrasound imaging and their theoretical bases. Topics include linear acoustic systems, spatial impulse responses, the k-space formulation, methods of acoustic field calculation, dynamic focusing and apodization, scattering, the statistics of acoustic speckle, speckle correlation, compounding techniques, phase aberration correction, velocity estimation, and flow imaging. A strong emphasis is placed on readings of original sources and student assignments and projects based on realistic acoustic simulations. Prerequisites: BME 230 or ECE 241 or equivalent. F

ECE 455 Software Analysis and Improvement Programming  is the automation of information processing. Program analysis and transformation is the automation of programming itself—how much a program can understand and improve other programs. Because of the diversity and complexity of computer hardware, programmers increasingly depend on automation in compilers and other tools to deliver efficient and reliable software. This course combines fundamental principles and (hands-on) practical applications. Specific topics include data flow and dependence theories; static and dynamic program transformation including parallelization; memory and cache management; type checking and program verification; and performance analysis and modeling. The knowledge and practice will help students to become experts in software performance and correctness. Students taking the graduate level will have additional course requirements and a more difficult project. Prerequisites: CSC 254 or CSC 252 recommended. S

ECE 461 Intro 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. Prerequisites: ECE 112 and ECE 221. F

ECE 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.) Prerequisites: 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. Prerequisites: ECE 113, ECE 221. *S
ECE 468 Advanced Analog CMOS Circuits and Systems: 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. **Prerequisites:** ECE 113, ECE 221, ECE 222, ECE 246/446, ECE 467. F

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. **Prerequisites:** ECE 222 and ECE 230. *S

ECE 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. **Prerequisites:** ECE 114 and basic Matlab programming, ECE 241 or equivalent. S

ECE 474 Biomed Sensors, Circuits & Intr.: Course will cover circuits and sensors used to measure physiological systems at an advanced level. Both signal conditioning and sensor characteristics will be addressed. Topics will include measurement of strain, pressure, flow, temperature, biopotentials, and physical circuit construction. The co-requirement laboratory will focus on the practical implementation of electronic devices for biomedical measurement. For graduate students will add an independent study. **Prerequisites:** BME 210 or ECE 113 or equivalent, or permission of Instructor. S

ECE 475 Audio Software Design I: In this course, students will develop the ability to design programs in C, Python, Max, and Pure Data for audio/music research, computer music, and interactive performance. We will begin with an introduction to computer music and audio programming, and a survey of audio programming languages. After a quick review of the C language, which is the most popular language for high-performance DSP applications today, we will use the PortSF soundfile library to generate and process basic envelopes and waveforms, and explore the development of the table-lookup oscillator and other DSP tools. Max and Pure Data are similar visual programming languages for music and multimedia with a large collection of internal and external libraries. We will use Max/MSP/Jitter to explore topics in sound synthesis, signal processing, and sound analysis, as well as computer music. Python is a general-purpose programming language used in many application domains. We will use JythonMusic, a special version of Python, for music making, building graphical user interfaces, and for connecting external human interface devices. Students will practice these programming techniques through a series of programming assignments and a final research/design project. **Prerequisites:** ECE 114 or instructor permission. F

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. **Prerequisites:** AME 262, ECE 475 or Instructor Permission. S

ECE 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). **Prerequisites:** 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 478  Revolutions in Sound: Artistic and Technical Evolution of Sound Recording
This course provides 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, multi-track recording, digital audio, compact discs, the MP3 format, surround sound, online music streaming, and 3D audio. 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 focuses on spatial audio for virtual reality (VR) and augmented reality (AR), binaural recording, and ambisonics.

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.

ECE 597  ECE SEMINAR SERIES  SEMINAR SERIES  F & S
Contact Information and class advisors

Department Chair:  Marvin Doyley  
CSB 518  5-4879  marvin.doyley@rochester.edu

Undergraduate Committee Chair: Prof. Jack Mottley  
CSB 622  5-4308  jack.mottley@rochester.edu

Undergraduate Coordinator: Barbara A. Dick  
CSB 510  5-5719  barbara.dick@rochester.edu

CLASS ADVISORS

CLASS 2021
H. Wu  CSB 416  5-2112  hui.wu@rochester.edu
S. Wu  CSB 610  5-3497  stephen.wu@rochester.edu

CLASS 2022
M. Cetin  CSB 719  6-5061  mudjat.cetin@rochester.edu
K. Parker  CSB 724  5-3294  kevin.parker@rochester.edu

CLASS 2023
T. Howard  CSB 732  5-3755  thomas.howard@rochester.edu
S. Kose  CSB 621  5-1735  skose@ur.rochester.edu

CLASS 2024
M. Huang  CSB 414  5-52111  michael.huang@rochester.edu
Q. Lin  CSB 721  5-3799  qiang.lin@rochester.edu

HAJIM
SCHOOL OF ENGINEERING
& APPLIED SCIENCES
UNIVERSITY OF ROCHESTER

28