ORIENTATION NOTES FOR GRADUATE STUDENTS

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Department of Electrical and Computer Engineering
University of Pittsburgh
Pittsburgh, PA

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1. INTRODUCTION

The various aspects of the graduate program in Electrical and Computer Engineering are described in these Notes. Information about the department, the undergraduate and graduate programs, course offerings, laboratory facilities, the research interests of the faculty and their publications can be obtained from the departmental web page at `http://www.engr.pitt.edu/electrical`. There are new degrees in Computer Engineering. More information can be found at `http://www.engr.pitt.edu/computer`. Application and registration forms may be obtained from the ECE Graduate Office in 339 Benedum Hall.

Graduate students are expected to read these Notes and the above mentioned reference materials before consulting with their advisors. Academic questions should be addressed to advisors. The Graduate Program Administrator can answer questions about procedures and regulations. Each graduate student must understand the regulations concerning graduate study and is responsible for completing the degree requirements.

2. GENERAL REGULATIONS

2.1. Academic Integrity

Academic integrity is essential for maintaining the quality of scholarship at the University. Students are expected to maintain academic integrity by refraining from academic dishonesty and by refraining from conduct that aids others in academic dishonesty. Violations of academic integrity will result in disciplinary actions including dismissal from the University.

2.2. Graduate Status

Full Graduate Status. This status is either given at the time of admission, or is obtained by satisfying admission provisions. Full graduate status is required to be considered for teaching assistantships and fellowships, to register for thesis credits, and to apply for graduation.

Provisional Graduate Status. A student with this status has been admitted with certain provisions that must be satisfied before achieving full graduate status. These provisions are intended to either fill a gap in the student's background (e.g., a student is required to take Electrical and Computer Engineering undergraduate courses) or to demonstrate his/her academic potential (e.g., a student is required to obtain B or better grades in his/her first two or three graduate courses).

Active/Inactive Status. A student is on active status, following his/her initial registration, provided that he/she registers for at least three (3) credits in the calendar year. To continue in the graduate program, an inactive student must submit an application for readmission.

Probation Status. A student whose quality point average (QPA) is below 3.00 for two consecutive academic terms will be placed on probation.

Probation and Dismissal Policy. A student whose quality point average is below 3.00 for two consecutive academic terms will be placed on probation. If the QPA is not restored to a minimum of 3.00 within one academic year, he/she will be subject to dismissal.

2.3. Advising

It is the student's responsibility to check on his/her progress by consulting with the Graduate Program Administrator (339 Benedum Hall) and/or consulting with his/her advisor. The following are the sources of advice available to the student.

The Academic Advisor. This is a faculty member selected to advise and supervise the academic program of newly admitted graduate students.

The Major Advisor or Thesis Advisor. This is a faculty member who directs and supervises the student's research and the preparation of his/her thesis.

A faculty member may serve as an academic advisor until the graduate student starts his/her research work, at which time the major advisor assumes the functions of supervising and counseling. The same faculty member is normally the student's academic and major advisor.

A student may change his/her academic advisor by completing a change of advisor form that can be obtained from the Graduate Program Administrator (339 Benedum Hall). The new advisor must approve this request by signing the form.

The Graduate Coordinator. This is the faculty member responsible for the overall operation of the graduate program.

2.4. Grading System

Course Grades. Letter grades A, B, C, D, with "+" or "-", and F are used in grading graduate courses.

Research courses (ECE 2997, 2999, 3997, 3999) as well as the Graduate Seminar (ECE 3893) are graded with S/U (Satisfactory/Unsatisfactory) or S/NC (Satisfactory/No Credit) grades.

Students should be careful to comply with the University and School deadlines and regulations for withdrawing ("W") and auditing ("N") of courses. Refer to the Schedule of Classes bulletin for details.

"G"-Incomplete-grades are typically given because of illness, death in the family, or other unusual circumstances. Awarding of the "G" grade is at the instructor's discretion, and it is the student's responsibility to arrange with the instructor how work will be completed. A "G" grade must be changed within a year by completing the work for the course; an unchanged "G" grade will remain on the transcript and courses with such a grade will not be counted toward graduation. It is the student's responsibility to make sure that "G" grades are changed within one year, and certainly before graduation.

Thesis Grades. A thesis usually requires more than one term to be completed. Until the thesis work is successfully completed, the student receives an "I" (Incomplete) grade. These grades are changed to "S" (Satisfactory) after the thesis work is completed.

Remarks

- An MS student in the research option (see below) must register for a minimum of six credits in ECE 2999. For PhD students, at least 12 research credits must be in ECE 3999. A minimum of six credits must be in ECE 3997.

- Only students who have been formally admitted to doctoral candidacy (see section 3.3) are permitted to register for ECE 3999 (Dissertation Research). Students may register for ECE 3997 for preliminary dissertation work.

Audit Policy. Students may elect to change any course from credit to audit status during the Monitored Withdrawal Period. The instructor of the course must agree to the audit. Students should obtain an audit form from the Office of Engineering Administration (748 Benedum Hall) and return the form to that office.

Academic Standards. All graduate students must maintain a QPA of 3.00 or above to be in good academic standing. Those below this minimum are not permitted to register for MS thesis or to graduate. In addition, a doctoral student must have a cumulative QPA on graduate course work of 3.30 or above to be considered for doctoral candidacy. A student may be placed on probation for poor academic performance and, if no improvement is achieved within a year, he/she may be dismissed.

2.5. Maximum and Minimum Study Program

The normal load in the Fall or Spring term for a full-time graduate student is 9 to 15 credits. Teaching assistants and research assistants are expected to register for at least 10 credits. Non-US students are required by immigration regulations to register for 9 or more credits per term.

Part-time students (those students taking no more than 6 credits per term) should take at least 3 credits per calendar year to continue to be considered active. Part-time students should plan their studies carefully in order not to exceed the statute of limitations associated with the degrees (see section 2.6 below).

2.6. Statute of Limitations

The purpose of the statute of limitations is to ensure that a graduate degree from the University of Pittsburgh represents mastery of current knowledge in the field of study.

MS Students. The requirements for the Master of Science degree must be completed within a period of four (4) consecutive calendar years from the student's initial registration for graduate study in the department.

PhD Students. The requirements for the PhD degree must be fulfilled within a period of ten (10) calendar years from the student's initial registration for graduate study in the department. If the student entered the PhD program with an MS degree, he/she has six (6) calendar years, counted from the initial registration as a PhD student in the department, to fulfill the PhD requirements.

Under extenuating circumstances, a student may request an extension of the statute of limitations by writing a letter to the Graduate Coordinator that can be given to the Graduate Program Administrator. The request must include the approval of the student's advisor and clearly state the circumstances necessitating the extension, the period of extension sought, and evidence that the factors causing delay no longer exist.

2.7. Residence Requirements and Leave of Absence

All students admitted into the PhD degree program must spend at least one term of study as a full-time student at the University, which excludes any other employment except as approved by the department. No residence requirements exist for the MS program.

Under special conditions, graduate degree candidates may be granted one leave of absence. A maximum leave of two years may be granted to doctoral candidates, and a maximum leave of one year may be granted

to master's candidates. The length and rationale for the leave must be stated in advance, recommended to the Dean by the department, and approved by the Dean. If approved, the time of the leave shall not count against the total time permitted for the degree being sought by the student. Readmission following an approved leave of absence is a formality.

2.8. Transfer of Credits or Advanced Standing

Graduate courses taken in a degree granting graduate program at other accredited institutions may be credited toward a graduate degree at the University of Pittsburgh provided these courses are comparable to courses offered at the University of Pittsburgh and that the grade obtained in each of these courses is a B or higher.

The responsibility of proposing which courses should be considered for advanced standing lies primarily with the student. The student's advisor (and the members of his/her Program Conference committee in the case of doctoral students) will make a recommendation on which courses to give advanced standing and record them on the Advanced Standing form that can be obtained from the Graduate Program Administrator (339 Benedum Hall). This form is submitted to the Graduate Program Administrator, who then forwards it to the Associate Dean for Academic Affairs for final approval. The grades earned in such courses will not be considered in the calculation of the QPA, but the courses will count towards graduation. The list of courses approved for advanced standing will be included in the student's file. For doctoral students, the request for advanced standing must be made prior to the PhD Proposal Exam.

Students accepted for the MS program may transfer a maximum of 6 credits, and PhD students may transfer a maximum of 30 credits. Students cannot receive credit for courses at the University of Pittsburgh that are equivalent to those for which they have already been given advanced standing. Thesis and dissertation credits are not transferable.

Students may cross-register for graduate courses at Carnegie Mellon University. Students must be registered for at least 9 credits at the University of Pittsburgh when registering for course(s) at CMU. A Cross-Registration form may be obtained from the Office of Engineering Administration (748 Benedum Hall). If approved in advance by the student's advisor, these courses do not need to be transferred. They are listed on the student’s transcript and may be counted for credit toward the graduate degree. Unlike the advanced standing courses, the grades earned in these courses will be used in calculating the student's QPA.

2.9. Graduation Procedure

Students must register for at least three credits during the 12-month period preceding graduation and must be registered for at least one credit in the term in which they graduate. The graduation forms are available in the Office of Engineering Administration (748 Benedum Hall). Within the stated deadline (usually the first three weeks of that term), a student able to graduate must submit an Application for Graduation form to the Office of Engineering Administration. There is a filing deadline after which a late fee is assessed. If the student does not graduate in the term anticipated, a new application form must be filed for the term in which he/she does plan to graduate.

A student completing a thesis is required to submit it on-line at `http://www.pitt.edu/~graduate/etd`. In addition, copies of the thesis should be submitted to each member of his/her final oral examination committee. The Graduate Office must sign off on the submission.

3. GRADUATE DEGREES

3.1. Master of Science (MS) Program in Electrical and Computer Engineering

As a general rule, the admission requirements for the Master of Science degree in Electrical and Computer Engineering are a minimum QPA of 3.0 from an ABET accredited university or from reputable international universities, two letters of recommendation, GRE General Test scores, and the TOEFL for international applicants.

The degree of Master of Science in Electrical and Computer Engineering can be obtained by following either a research or a professional option. The research option includes a thesis while the professional option is 30 credits of course work. Students who intend to continue for a PhD degree are highly encouraged to take the research option.

Course selection for either the research or the professional degree options is to be done in consultation with the student's advisor according to the following requirements:

1) the course selection must include at least 15 graduate credits in ECE, and
2) courses outside ECE must come from the list of recommended courses (see section 6.2).

Courses that are required of students admitted on a provisional status are to be considered additional to these requirements. If the student chooses the research option, only 6 credits of ECE 2999 will count towards the degree requirement. Notice that credits in ECE 2997, research for the MS, and in ECE 3893, the graduate seminar, will not be considered towards the degree requirements.

Professional Option. A minimum of 30 credits of course work conforming to the requirements in section 3.1 is required. Although not required, a three credit graduate project course (ECE 2998) is highly recommended for students who might later choose to enter the PhD program. No comprehensive exam is required for students following the professional option.

Research Option. A minimum of 24 credits of course work is required. In addition, a thesis (with a minimum of six credits of ECE 2999, MS Thesis) must be completed and presented at an oral defense.

It should be emphasized that the above credit requirements for both options are the minimum acceptable and may not necessarily satisfy the degree requirements. In some instances it might be necessary for a student to take undergraduate courses to be accepted into full graduate status. Thus, depending upon the student's background and program, it may be necessary to take more than the minimum number of credits required.

Thesis Requirement. MS students taking the research option must prepare a thesis showing marked attainment in their area of investigation (see section 2.9). A graduate student begins thesis work after the fulfillment of the following conditions:

Completing at least 12 credits,
Being on full graduate status, and
Achieving a cumulative QPA of 3.00 or higher.

Students in the research option must defend their theses orally. A committee consisting of three Electrical and Computer Engineering graduate faculty members and chaired by the student's major advisor is formed to evaluate the thesis and defense. Faculty members with a secondary appointment in Electrical and Computer Engineering may also chair such a committee. The student must provide this committee with copies of the

thesis at least two weeks prior to the day of the oral exam. The names of the faculty on the committee, the time, the title and the abstract of the thesis should be submitted to the Graduate Program Administrator (339 Benedum Hall) at least two weeks before the desired exam date in order to publish an announcement. The oral exam is open to the public. If the student is interested in pursuing a PhD, this exam may be combined with the PhD Preliminary Exam and the Program Conference.

3.2. Joint MBA/Master's Program

The program consists of 64.5 credits for full-time students or 69 credits part-time students and leads to a Master of Business Administration (MBA) and a Master of Science in Electrical Engineering (MSEE). The joint full-time program requires students to take 39 credits minimum of business and 25.5 credits minimum in electrical and computer engineering. The full-time option can be completed in two academic years whereas the part-time option may require a period of four to five years. The program is only for those students seeking a professional MS Engineering degree. Please complete an application through the Katz School of Business. Detailed information may be located at
`http://www.engr.pitt.edu/electrical/graduate/mbamsee.html`.

3.3. Dual ECE-Math Master's Program

A student in the dual ECE-Math Master's Degree Program earns a Master of Science degree in Electrical and Computer Engineering and a Master of Arts degree in Mathematics. The credit requirements are as follows:

Students with an ECE Undergraduate Degree:
18 in 2000/3000 level math courses
15 in 2000/3000 graduate ECE courses
6 in 1000 level undergraduate math courses
6 in MS thesis

Students with a Math Undergraduate Degree:
18 in 2000/3000 graduate ECE courses
15 in 2000/3000 level math courses
6 in senior elective ECE courses (to be determined)
6 in MS thesis

Advisors from the Department of Electrical and Computer Engineering and from the Mathematics Department are required. See section 2.9 for the thesis format.

3.4. MS Nuclear Engineering Certificate

Students must first be admitted to the Department of Electrical and Computer Engineering. Once admitted, students may apply internally for admission to the certificate program. The certificate requires the completion of 36 credits of coursework, 21 of which are from the Electrical and Computer Engineering Department and 15 credits are to be completed from a published list of engineering courses. More information may be found at
`http://www.engr.pitt.edu/electrical/graduate/nuclear.html`.

3.5. Doctor of Philosophy (PhD) Program in Electrical and Computer Engineering

The objective of the PhD program is to achieve a high degree of competence in one major field in Electrical and Computer Engineering. A minimum of 72 credits after the BS degree and a dissertation are required for the PhD degree. The dissertation should embody an extended original and independent investigation of a problem of significance in Electrical and Computer Engineering. Of the credits, at least 18 must be in dissertation research (6 or more in ECE 3997 and 12 or more in ECE 3999), and at least 24 course credits must be attained beyond the minimum of 30 credits for the MS degree. The 24 credits must include:

(1) At least 3 "book courses" (9 credits) that are in the catalog and have been approved by the entire faculty.
(2) A maximum of 2 courses (6 credits) of ECE 3998.
(3) A maximum of 3 research courses (9 credits), ECE 3995 (or similar courses) that would be directed toward research. Research courses require the approval of the student's Program Conference Committee. In addition, the student is required to write a 1-2 page proposal for each such course citing the topic, the teacher, the rationale for the course, and a deliverable from the course experience. The deliverable can be a submitted full journal paper, a research proposal for funding, or a complete patent application. Research courses will be specifically designated.

Entrance Requirements. To be accepted into the PhD program a student who graduated from the University of Pittsburgh with an MS degree in Electrical and Computer Engineering must have a QPA of 3.30 or better and the recommendation from the MS thesis committee. The student must submit an application to continue into the PhD program. Applications can be obtained from the Graduate Program Administrator (339 Benedum Hall). For students who obtained the MS degree from other institutions, the QPA and letters of recommendation, GRE general exam and TOEFL (if required) results will be used for admission. A written request to the Graduate Committee is needed for direct entrance to the PhD program from the BS degree.

Exams. There are four separate exams that must be passed in order to obtain the PhD degree. The student must also have a Program Conference with a faculty committee to approve his/her plan of study. Descriptions of each follow.

Preliminary Exam. The purpose of the preliminary exam is to ascertain the capabilities of a student to do independent research. The exam generally consists of an oral presentation of a written document, prepared by the student, to a committee of ECE faculty members. The student and his/her advisor will determine the subject of the document.

Students completing the MS research option who are interested in pursuing doctoral studies have already demonstrated their ability to do independent research. Therefore, their MS thesis oral and the preliminary exam may be administered simultaneously.

Continuing MS students who elected the professional option or who obtained their degrees from other institutions must schedule a preliminary exam. The student must prepare a written document of the same caliber as an MS thesis. This may be done by either taking a graduate project course (ECE 3998) or by using a thesis presented at another institution. The student's advisor will then assist the student in forming a committee with a composition similar to that of an MS thesis exam committee. Two weeks before the exam, the written report should be given to the committee members and the Graduate Program Administrator (339 Benedum Hall) should be informed of the composition of the committee, time, title and abstract of the thesis in order to publish an announcement.

Program Conference. During the first year, a PhD student should schedule a meeting with a faculty committee to present a tentative program of study for approval. The committee consists of the student's advisor, who chairs the committee, and a minimum of two other faculty members from the department.

On the Program Conference form, the student must list all of the courses he/she has taken as a graduate student in the department as well as those for which he/she has obtained advanced standing. Courses that he/she is planning to take in the future in Electrical and Computer Engineering as well as in related areas (see Section 6.2) should also be included. Finally, the form should list the courses to be taken for the written PhD Comprehensive Exam and a tentative schedule for the different exams and the residency requirements. The committee can approve, reject or make modifications to the proposed program. The advisor is

responsible for supervising the student's progress in the approved program. The program conference can be scheduled at the same time as the preliminary exam.

PhD Comprehensive Exam. The objective of the comprehensive exam is to determine the student's competence in his/her major field. It consists of a written examination on four courses (lasting 6 hours) that is administered on the first Friday of October in the Fall term, and on the first Friday of February in the Spring term. A passing average grade is considered to be 3.25.

Of the four courses, three must be chosen from the student's major area. The fourth course may be from the major area, or from a minor/cognate area, at the discretion of the Program Conference committee. The student's Program Conference committee must approve the courses. To take this exam, a student must have passed the PhD preliminary exam, have had the program conference before the registration deadline (the last week of July or last week of November), and have returned an application for this exam to the Graduate Program Administrator (339 Benedum Hall) with the advisor's signature.

In selecting the courses for this exam, a major area is to be understood as the area of research interest of the PhD student. If the Program Conference committee chooses a graduate course from outside the department, the chair of the committee is responsible for securing the exam and its evaluation. The courses that appear on the PhD Comprehensive Exam application form must coincide with the courses approved by the Program Conference committee.

Dissertation Proposal Exam. For the dissertation proposal examination, the student prepares a written proposal of his/her dissertation and presents it orally to a exam committee. Students must have a cumulative graduate QPA of 3.30 to be considered for doctoral candidacy. The committee consists of at least five members, four of whom must be from the Electrical and Computer Engineering Department, and at least one who must be from outside the department (external member). Three of the departmental members must be graduate faculty members and at least one of the external members must be a graduate faculty member from another department in the university. Other appropriate member(s) may also serve on the committee. A faculty member from another accredited university may serve as an external graduate faculty member of the committee if that individual's academic background is comparable to the qualifications for graduate faculty status at the University of Pittsburgh.

The dissertation proposal should be given to the committee members at least two weeks before the exam, and the student must inform the Graduate Program Administrator (339 Benedum Hall) of the composition of the committee and provide a proposal with a completion time line as well as a title and an abstract at least two weeks prior to the exam date.

If the doctoral committee approves the dissertation proposal, the student is then formally admitted to Candidacy for the Doctor of Philosophy Degree. The proposal exam must be completed at least one term before the student plans to graduate. Students can register for ECE 3997 for preliminary work for the PhD proposal exam.

Final Oral Exam. The final oral exam is administered by the doctoral committee and determines the acceptability of the student's dissertation and his/her ability to comprehend, organize and make original contributions to his/her area of research.

Only students who have passed the dissertation proposal exam may register for dissertation research (ECE 3999). A minimum of 18 research credits is required for graduation, of which at least 12 must be in ECE 3999. Once a student registers for research, he/she must continue to register for Fall and Spring terms until the final oral examination has been passed.

At least two weeks before the date set for the exam, the student must submit a copy of the dissertation to each member of the exam committee and register with the Graduate Program Administrator (339 Benedum Hall). The final oral exam is open to the public.

Students scheduling their final oral exam must submit at least one paper from their thesis work to a refereed journal. The publication form must be signed by the major advisor and submitted to the Graduate Program Administrator (339 Benedum Hall) at least two weeks before the final oral exam. Submitting a paper to a refereed journal is a requirement for the PhD degree. A student completing a dissertation must follow the rules in Section 2.9.

4. FINANCIAL AID

4.1. Teaching Assistantships (TA) and Teaching Fellowships (TF)

Teaching Assistantships and Teaching Fellowships are awarded to those students who show exceptional promise in graduate work and who are able to assist in the teaching of undergraduate courses. Teaching assistants hold a Bachelor of Science degree in electrical/computer engineering and teaching fellows have an MS degree in electrical/computer engineering. The award of these assistantships is done on a competitive basis. Students who apply for admission to the graduate program on a full time basis are considered for these assistantships by the Graduate Committee. Continuing students can file an application form available from the Graduate Program Administrator (339 Benedum Hall). The application deadline is February 1.

The evaluation is based on letters of recommendation, the grade transcripts, Graduate Record Examination (GRE) general test, the ranking of the institution from which the applicant has graduated, a statement from the student outlining his/her research interests, and the TOEFL exam, in the case of international applicants.. Continuing students must request two letters of recommendation from faculty in the department, which together with the students' records are considered in the evaluation. Fluency in English is required for appointment as a teaching assistant. International students who are appointed as TA/TFs will be tested in their fluency of English, and remedial tutoring will be given to those with deficiencies.

TA/TFs are required to work 20 hours per week on teaching-related assignments. In addition to a monthly stipend, a tuition scholarship and health insurance are part of the benefits given to TA/TFs. The tuition scholarship includes tuition, student health, security, safety and transportation, and computer and network services fees. Faculty members serve as supervisors of TA/TFs assigned to courses or laboratories.

A TA/TF will receive a warning after obtaining a "C" grade and will lose financial support from the department after the second "C" grade.

4.2. Research Assistantships

Research assistantships (RAs) are typically awarded to graduate students who have been in the department for at least one term and have distinguished themselves for their academic and research abilities. Faculty with research funds select RAs and arrange the conditions and salary on an individual basis.

4.3. Scholarships and Other Sources of Financial Aid

A limited number of scholarships are available to very qualified students. University funds permit the department to offer a few scholarships on a yearly basis. Also, federal agencies as well as companies offer students the opportunity to apply for graduate fellowships. Information on these fellowships can be found at `http://www.engr.pitt.edu/electrical/graduate/fellowships.html`.

4.4. Graduate Seminar

The Graduate Seminar, ECE 3893, is a series of presentations given by industry and university researchers. The Graduate Seminar is a one credit course, and it does not count toward graduation. Although registration in this course is not mandatory, it is highly encouraged. All TA/TF/RAs are required to attend the Graduate Seminar.

5. REGISTRATION

Registration usually begins at least two months before the beginning of each term. Course descriptions and times can be found at `http://www.engr.pitt.edu/electrical/courses/index.html`.

Newly admitted and readmitted students are permitted to register until the day before classes begin. Continuing students are encouraged to register early in the registration period to insure that courses have sufficient enrollment and are not cancelled.

All students should consult their faculty advisors about their course of study. Because it is desirable that the advisor be informed about the student's progress in his/her studies, the registration form should be signed by the student's advisor. For information about the faculty member's office hours, please ask in the ECE Departmental Office (348 Benedum Hall).

6. COURSE LISTINGS

It is important that students have a good understanding of the course offerings in general, the way courses relate to departmental areas, and the types of courses offered. Prerequisites must be carefully considered in selecting courses. Whenever in doubt about prerequisites or the content of a course, students should contact the faculty member responsible for that course.

ECE 2997 and ECE 2999 are research courses for MS students, and ECE 3997 and ECE 3999 are PhD research courses.

ECE 2997 and ECE 3997 are intended for students who are engaged in preliminary investigations that are expected to lead to their thesis research. ECE 2997 credits are not counted toward graduation requirements. A PhD candidate must complete at least 6 credits of 3997.

ECE 2999 and 3999 are to be used when students have identified and are actively engaged in their thesis research. Six credits of 2999 are used to satisfy thesis credit requirements for the MS with research options, and 12 credits of 3999 are used to satisfy thesis credit requirements for the PhD.

ECE 2998 and ECE 3998 are MS and PhD project courses, respectively, that are used for independent study. Three credits of 2998 and 6 credits of 3998 may be used toward graduation.

ECE 3000, Practicum, is a one credit course for full-time students interested in industrial internships as a means of gaining practical experience in their areas of research. Students are responsible for arranging a practicum with industry. The practicum requires permission.

ECE 3995, Research Topics in Electrical and Computer Engineering, is a research course for PhD students that focuses on specific skills required by students to conduct original research in a particular area of Electrical and Computer Engineering. Students will complete a project, such as a full journal paper, a proposal for research funding, or a complete patent application, as specified by the faculty teaching the

course. The project should be beyond material to be included in the student's dissertation. This course requires approval by the Program Conference Committee, based on a 1-2 page proposal citing the topic, rationale for the course, the professor, and the specific project to be completed.

6.1. Graduate Electrical and Computer Engineering Courses

Computer Engineering

ECE 2120, Hardware Design Methodologies 1, 3 cr.
This course teaches hardware design processes through use of industry tools. Students use graphical tools to design, simulate and synthesize designs using hardware description languages (e.g. VHDL/Verilog). High-level design and problem decomposition are also taught. Optimization, simulation and synthesis of combinatorial functions, data paths, and finite state machines are covered in depth. Architecture encapsulation and reuse through "Intellectual Property" (IP) modules is described and covered in detail. Students will work individually and as a part of a team to create, simulate, model, document, and test IP models. Prerequisites: ECE/CoE 0142, CoE 1502 or permission of instructor.

ECE 2121, Hardware Design Methodologies 2, 3 cr.
This course teaches students how to integrate multiple "Intellectual Property" (IP) modules to create a larger, more complex architecture. Organized as a full semester project, emphasis is on architectural exploration of digital systems that can be manufactured as a single chip. Students form groups to design and implement different IP-based projects. These projects are synthesized, prototyped and tested using field-programmable gate array (FPGA) technology. Application-specific integrated circuit (ASIC) technologies are explored to determine the design characteristics of the final product. This course requires independent thinking and self-motivation. The majority of the grade will depend on a demonstration of a working prototype and a conference-quality paper that explains the benefits of the architecture. Prerequisite: ECE 2120

ECE 2130, Topics in VLSI CAD, 3 cr.
The course introduces state-of-the-art computer-aided design algorithms with application to VLSI. The course starts with a review of fundamental algorithms, from graph theory, sorting, searching and hashing, and then proceeds to focus on major CAD application areas in architectural, logical, and physical design. Major topics discussed are multiple level combinational logic synthesis and optimization, sequential logic optimization (retiming, clock scheduling), convex optimization and its applications, testing—test pattern generation and design for testability, placement and routing, simulated annealing. Hot current research topics will be surveyed briefly. Prerequisites: ECE 2192, CS 1501 or permission of instructor.

ECE 2140, Systems-on-a-Chip Design, 3 cr.
This course is a full semester project involving the entire class in one System on a Chip design experience. This includes requirements definition, high-level design, system specification, algorithm modeling, decomposition, IP selection and/or IP creation for re-use, synthesis simulation and testing. The system will be a true SoC with at least one processor core with associated system and application software. Lectures will be the philosophy of SoC as well as the practical issues involved in the SoC design methodology. State of the art CAD software will be used for design and co-simulation of the hardware/software platform. Prerequisite: ECE 2120 or permission of instructor.

ECE 2141, Validation and Verification Techniques of Digital Systems, 3 cr.
This course presents state of the art methodologies and tools for simulation based validation and formal verification of complex digital systems implemented as a systems on a chip. Topics include testing strategies, test bench design, coverage, and model checking. Prerequisites: ECE 2140 or ECE 2121 or permission of instructor.

ECE 2159, Automata Theory, 3 cr.
Finite automata and sequential machines, representation, decomposition, measurement, control and identification, regular expressions and machine specifications, linear sequential machines, Turing machines, and formal languages.

ECE 2160, Embedded Computer System Design, 3 cr.
Design and implementation of embedded microprocessor systems. Topics include "C" language, top down iteration for assembly language programming, data structures, co-routines, I/O software structures and real time operating systems. Prerequisite: ECE/CoE 0142

ECE 2161, Embedded Computer System Design 2, 3 cr.
Organized as a full term project carried out by student design groups. A complex embedded system will be designed, implemented and tested using Altera and other CAD tools. Grade will be based on project reviews and the final project report. Proper design process will be emphasized. Prerequisite: ECE 2160

ECE 2162, Computer Architecture 1, 3 cr.
Review of basic architecture concepts, data representation, microprocessor and minicomputer architectures, memory, I/O subsystems, stack computers, parallel and pipelined computers. Prerequisite: ECE/CoE 0142

ECE 2192, Introduction to VLSI Design, 4 cr.
Introduction to the concepts and techniques of modern integrated circuit design. Use of Computer Aided Design (CAD) tools for circuit design and simulation. Prerequisite: ECE/CoE 142.

ECE 2193, Advanced VLSI Design, 3 cr.
This course is organized as a full semester project in conjunction with lecture material on advanced CMOS and BiCMOS digital design techniques, as well as the group design process itself. Students form groups that design and implement different VLSI projects which are then fabricated by the NSF MOSIS (MOS Implementation Service) facility and returned for testing. The majority of the course is focused on group projects with written and oral reviews and reports. Prerequisite: ECE 2192

ECE 2195, Special Topics: Computers, 3 cr.
An MS level course in special topics of current interest in computer engineering.

ECE 3163, Computer Architecture 2, 3 cr.
Architectural considerations of computers from microprocessors through super computers, von Neuman-Harvard advantages and limitations, pipelining, chaining and multiple processors, memory and processor configurations, performance evaluation, stochastic models, operating systems, software and technology considerations. Prerequisite: ECE 2162

ECE 3167, Computer Networks, 3 cr.
This course covers the design and implementation of network components (systems), software and the networks themselves. The course will follow a lecture, project and homework format with an individual and a group project designed to demonstrate research and development within standards and potential standard improvements. Prerequisite: ECE 2162

ECE 3195, Advanced Topics: Computers, 3 cr.
A PhD level course in advanced topics of current interest in the area of computer engineering.

Control

ECE 2636, Fuzzy Logic and Intelligent Control, 3 cr.
Fuzzy logic is a design method that can be effectively applied to problems that, because of complex, nonlinear, or ambiguous system models, cannot be easily solved using traditional analytical control techniques. This course discusses the types of applications for which fuzzy control is useful and introduces basic concepts of fuzzy set theory, fuzzy logic operations, fuzzification and de-fuzzification. Several types of fuzzy controllers are discussed, including rule-based, PI-type, supervisory, and adaptive controllers, with emphasis on issues that are important to applications. Development of hardware implementations and the role of fuzzy logic in intelligent control are considered. Prerequisites: ECE 1552 or ECE 1673 and knowledge of MATLAB or similar computer application language.

ECE 2646, Linear System Theory, 3 cr.
Linear spaces and operators, mathematical descriptions of linear systems, controllability and observability, irreducible realization of rational transfer-function matrices, canonical forms, state feedback and state estimators, stability.

ECE 2654, Digital Control Systems, 3 cr.
Transform domain approach to analysis and design of digital computer control systems, linear discrete dynamic systems analysis and the z-transform, discrete equivalents to continuous transfer functions, sampled data systems, design of digital control systems using transform techniques, quantization effects, sample rate selection. Prerequisite: ECE 1673

ECE 2671, Optimization Methods, 3 cr.
Analytical and computational aspects of finite dimensional optimization, unconstrained and equality constrained problems, basic descent methods, conjugate direction methods, nonlinear programming and the Kuhn-Tucker theorem, linear programming, dynamic programming, multicriteria optimization.

ECE 2695, Special Topics: Control, 3 cr.
An MS level course in special topics of current interest in control.

ECE 3647, Optimal Stochastic Systems, 3 cr.
Deterministic system models, probability theory and static models, stochastic processes and linear dynamic system models, optimal filtering with linear system models, design and performance analysis of Kalman filters, square root filtering, applications to tracking. Prerequisites: ECE 2521, ECE 2646

ECE 3648, Nonlinear Systems Theory, 3 cr.
An introduction to the (differential) geometric approach to nonlinear control (including feedback linearization, nonlinear observers with linear error dynamics and disturbance decoupling), Lyapunov theory and variable structure control. Prerequisite: ECE 2646

ECE 3650, Optimal Control, 3 cr.
Variation calculus and optimality conditions, linear quadratic problems, the Riccati equation, Pontryagin maximum principle, time-optimal control, dynamic programming and the Hamilton-Jacobi equation, numerical methods, decentralized control, multicontroller-multiobjective systems, differential games. Prerequisite: ECE 2646

ECE 3695, Advanced Topics: Control, 3 cr.
A PhD level course in advanced topics of current interest in the area of control.

Electronics

ECE 2231, Fundamentals of Semiconductor and Quantum Electronic Devices, 3 cr.
Fundamental quantum theory, electron in potential well, harmonic oscillator, band theory of solids, Kronig-Penney model. Prerequisite: ECE 1247

ECE 2235, Monolithic Integrated Circuits, 3 cr.
Fabrication of integrated silicon monolithic circuits, thermal oxidation, solid state diffusion, epitaxial growth, ion implantation, photo and electron lithography, design considerations, active and passive elements in monolithic blocks, surface effects. Prerequisite: ECE 1247

ECE 2240, Nano-Optics, 3 cr.
A graduate level course designed for students who want to understand the mechanisms of interaction of light and matter at the nanometer scale, and become acquainted with nano-optics-based technologies. Topics include: electromagnetic theory of optical interaction with matter, optical waves in periodic media, photonic bandgap structures, surface plasmons, optical interaction with metal nanostructures (metal nanoapertures and arrays, and metal nanoparticles), surface plasmon resonance spectroscopy, plasmon coupling and concentration/funneling of electromagnetic energy, surface-enhanced Raman scattering, near-field imaging and microscopy, and negative refraction. Prerequisite: Junior or senior level EM theory course.

ECE 2250, Power Electronics, 3 cr.
The objective of this course is to cover the fundamental concepts in the field in sufficient depth to allow students to analyze and design power electronics circuits. The course covers DC-DC converters and DC-AC converters. Prerequisite: ECE 0257

ECE 2295, Special Topics: Electronics, 3 cr.
An MS level course in special topics of current interest in electronics.

ECE 3232, Quantum Electronics, 3 cr.
Quantum theory of the interaction of electromagnetic radiation with matter, optical absorption and emission, lasers. Selected topics from the areas of dielectric and magnetic properties of materials. Prerequisite: ECE 2231

ECE 3233, Semiconductor Device Modeling, 3 cr.
Topics of current interest in the field of solid state electron devices. Prerequisite: ECE 2231

ECE 3235, Semiconductor Lasers, 3 cr.
Properties of heterojunctions, stimulated emission in semiconductors, carrier and optical confinement, fabrication and operating characteristics of semiconductor lasers including double-heterostructure lasers, quantum-well lasers, distributed feedback lasers, surface emitting lasers, various modulation techniques of semiconductor lasers. Prerequisite: ECE 2231

ECE 3236, Semiconductor Optics and Devices, 3 cr.
Fundamentals of semiconductor optics and devices, band structures, optical absorption, excitons, nonlinear optical properties of semiconductors. Optoelectronic devices including nonlinear Fabry-Perot etalons, nonlinear directional couplers, and self-electro-optic effect devices (SEED). Prerequisite: ECE 2231

ECE 3239, High-Speed Electronic Devices, 3 cr.
Compound semiconductors, heterojunctions and supperlattices and their application to electronic and opto-electronic devices such as HBTs, MODFETs, resonant tunnel transistors, injection lasers, detectors and modulators. Prerequisite: ECE 2231

ECE 3295, Advanced Topics: Electronics, 3 cr.
A PhD level course in advanced topics of current interest in the area of electronics.

Image Processing/Computer Vision

ECE 2372, Pattern Recognition, 3 cr.
Emphasis on machine pattern recognition and learning: Bayes decision theory, parameter estimation, Bayesian belief networks, discriminant functions, supervised learning, nonparametric techniques, feature extraction, principal component analysis, hidden Markov models, expectation-maximization, support vector machines, artificial neural networks, unsupervised learning, clustering, and syntactic pattern recognition.

ECE 2373, Artificial Neural Networks, 3 cr.
This course discusses models and theories of artificial neural networks as applied to neural computing and adaptive systems. Topics cover modeling of artificial neurons and their interconnections, various learning and self-organizing processes. These include multi-layered feedforward networks, back propagation training, radial basis function networks, recurrent neural networks, associative memory and Hopfield networks, self-organizing, feature mapping, reinforcement learning and competitive learning, global search methods in artificial neural networks.

ECE 2390, Image Processing and Computer Vision, 3 cr.
This first level graduate course covers essential elements of image processing for computer vision and introductory subjects in computer vision; Image segmentation: region-based, edge detection, scale space, active contours ; shape description, deformable templates; textures ; perspective camera model and its parameters; geometry of multiple (2) views, fundamental matrix; scene planes and homographies; consistent labeling; locating objects in 3-D space; motion analysis.

ECE 2391, Projects in Computer Vision, 3 cr.
A set of full-term projects attacking problems in image processing and computer vision. Projects will typically involve the development of problem solutions on computer vision workstations in the c programming language. Prerequisite: ECE 1390

ECE 2395, Special Topics: Image Processing/Computer Vision, 3 cr.
An MS level course in special topics of current interest in image processing/computer vision.

ECE 3374, Applications of Wavelet Transforms, 3 cr.
This course presents applications of wavelet transforms to multiresolution signal/image processing and pattern recognition. Topics include basic notions of scaling functions with compact support, localization property, multiresolution analysis, continuous wavelet transform, discrete dyadic wavelet transform, wavelet packets, image compression, signal/image denoising, edge localization, texture feature extraction, and multiresolution data fusion. Prerequisite: ECE 1390 or ECE 2523 or permission of instructor.

ECE 3395, Advanced Topics: Image Processing/Computer Vision, 3 cr.
A PhD level course in advanced topics of current interest in the area of image processing/computer vision.

Power

ECE 2774, Power System Analysis 2, 3 cr.
Steady state phenomena, matrix transformations, system parameters, system unbalances, digital methods, and numerical analysis techniques applied to load flow, state estimators, and fault studies in large power systems. Prerequisite: ECE 1769

ECE 2777, Power System Transients 1, 3 cr.
Lumped parameter analysis, switching transients in AC/DC systems, arc modeling, damping, current suppression, traveling wave phenomena, line discontinuities, ferroresonance, transient recovery voltage. Prerequisite: ECE 1769

ECE 2795, Special Topics: Power, 3 cr.
An MS level course in special topics of current interest in power.

ECE 3775, Power System Steady State Control, 3 cr.
Power system component modeling, automatic generation control, area and multiarea control, economic dispatch, optimal real and reactive power flow, hydrothermal coordination, unit commitment. Prerequisite: ECE 2774

ECE 3776, Power System Control and Stability, 3 cr.
The power system model for stability studies, response to disturbances, the behavior of machines, the effect of excitation, and mathematical techniques for stability studies. Prerequisite: ECE 3775

ECE 3778, Power Systems Transients 2, 3 cr.
Lightning phenomena, dynamic overvoltages, transient switching surges, transformer winding transients, insulation characteristics, insulation breakdown, field theory applications, line design concepts, insulation coordination. Prerequisite: ECE 2777

ECE 3795, Advanced Topics: Power, 3 cr.
A PhD level course in advanced topics of current interest in power.

Signal Processing/Communications

ECE 2410, Foundations of Wireless Communications, 3 cr.
Concept related to wireless communication at the lower layers of the DSI stack and some architectural issues. Broad overview of network topologies, the cellular concept and architecture, rudimentary concepts of radio propagation and multipath fading, antennas, introduction to digital modulation, error control coding in wireless systems, multiple-access schemes, and spectrum issues. Topics treated with existing systems as examples rather than as abstractions. Both mathematical and qualitative. Prerequisite: Telcom 2210

ECE 2422, Introduction to Information Theory, 3 cr.
Topics of entropy, mutual information, data compression, channel capacity, rate distortion theorem and channel coding theorem are covered. Co-requisite: ECE 2521

ECE 2429, Digital Communications 1 – Modeling and Coding, 3 cr.
Concepts in digital modulation and coding theory with emphasis on techniques employed in a variety of communication systems, including equalization, detection of signals in noise, spread spectrum communications, modulation and coding, and frequency hopping.

ECE 2430, Queuing Theory, 3 cr.
Development and application of the mathematical techniques used for analyzing the performance of communications networks. Topics include Markovian queues, Non-Markovian queues, products form networks, approximation techniques, nonstationary queues. Prerequisites: Telcom 2120, Telcom 2310

ECE 2521, Analysis of Stochastic Processes, 3 cr.
Probability theory, random variables, sums and limits of random variable sequences, time and frequency domain, modeling of continuous and discrete random signals, least-squares estimation.

ECE 2523, Digital Signal Processing, 3 cr.
Discrete-time signal processing, discrete Fourier transform and FFT implementation, design and stability considerations of FIR and IIR filters, filter implementation and finite register effects.

ECE 2525, Detection and Estimation Theory, 3 cr.
A study of optimal techniques for extracting information from the observation of random variables or random signals. This includes hypothesis testing, estimation theory, optimal receiver design, Wiener and Kalman-Bucy filtering, and application such as digital communications and medical imaging. Prerequisite: ECE 2521

ECE 2595, Special Topics: Signal Processing/Communications, 3 cr.
An MS level course in special topics of current interest in signal processing/communications.

ECE 3422, Information Theory, 3 cr.
Markov source statistics, the theory of information, channel capacity for noise-free and noisy channels, Huffman codes and other source coding techniques, introduction to error correcting channel codes. Prerequisite: ECE 2521

ECE 3431, Channel Coding Theory and Practice, 3 cr.
Introduction to algebraic codes and advanced error correction techniques; linear block codes, cyclic codes, BHC codes, Reed-Solomon codes, low density parity check codes, convolutional codes, and turbo codes. Prerequisite: ECE 2429

ECE 3524, Digital Speech Processing, 3 cr.
The application of digital signal processing techniques in the representation, analysis, and synthesis of speech signals. Topics include digital modeling of speech signals, waveform coders, time and frequency methods in speech processing, linear predictive coding of speech, and discussion of speech processing systems in the area of human-machine communication by voice. Prerequisites: ECE 2521, ECE 2523

ECE 3526, Modern Spectral Estimation, 3 cr.
An overview of concepts of modern spectral analysis covering traditional approaches and modern estimation methods. The properties, advantages and disadvantages of each estimator will be covered in detail and demonstrated using computer experiments. Also covered are applications of spectral estimation to signal detection and beam forming. Prerequisite: ECE 2521

ECE 3528, Time-Frequency Signal Analysis, 3 cr.
This course covers the theory and application of time-varying spectral analysis. Topics include why spectra change, the AM/FM model of signals, instantaneous frequency and bandwidth, signal density functions, the short-time Fourier transform, the Wigner distribution, Cohen's class of time-frequency distributions, signal-dependent distributions and the evolutionary spectrum. Prerequisite: ECE 2523

ECE 3530, Digital Communications 2, 3 cr.
Binary and M-Ary computer based communications, representation theory and the geometric interpretation of the communication channel, maximum likelihood decisions, multicarrier modulation, spread spectrum techniques. Prerequisite: ECE 2521

ECE 3557, Statistical Signal Processing, 3 cr.
Random vectors, discrete-time stochastic processes; rational and state-space Gaussian-Markov discrete-time models; estimation; parameter estimation, Wiener and Levinson filtering, Kalman filtering (modeling, filtering and prediction, stability and computational aspects); adaptive filtering. Prerequisites: ECE 2521, ECE 2523, ECE 2646

ECE 3595, Advanced Topics: Signal Processing, 3 cr.
A PhD level course in advanced topics of current interest in the area of signal processing/communications.

6.2. Non-ECE Courses

BIOENGINEERING
BioE 2035, Biomechanics Modeling of Movement
BioE 2351, Computer Applications in Bioengineering
BioE 2380, Medical Imaging Systems 1
BioE 2382, Medical Imaging Systems 2
BioE 2525, Applied Biostatistics
BioE 2580, Biomedical Applications of Signal Processing
BioE 2630, Methods in Image Analysis
BioE 2696, Control Theory in Neuroscience
BioE 2721, Human Movement Biomechanics
BioE 2810, Biomaterials and Biocompatibility
BioE 3528, Time-Frequency Signal Analysis
CHEMISTRY
Chem 2620, Atoms, Molecules and Materials
COMPUTER SCIENCE
CS 1510, Design & Analysis of Algorithms
CS 1515, Scientific Computation
CS 1538, Introduction to Simulation
CS 1550, Introduction to Operating Systems
CS 1555, Database Management Systems
CS 1566, Introduction to Computer Graphics
CS 1622, Introduction to Compiler Design
CS 1631, Software Design Methodology
CS 1651, Advanced System Software
CS 1652, Data Communication & Computer Networks
CS 2045, Introduction to High Performance Computing Systems
CS 2110, Theory of Computation
CS 2150, Design & Analysis of Algorithms
CS 2210, Compiler Design
CS 2310, Software Engineering
CS 2450, Parallel Computing
CS 2510, Computer Operating Systems
CS 2520, Wide Area Networks
CS 7480, Computer & Network Security
CS 2550, Principles of Database Systems
CS 2610, Interface Design & Evaluation
CS 2620, Interdisciplinary Modeling and Visualization
CS 2650, Distributed Multimedia Intelligence
CS 2710, Foundations of Artificial Intelligence
CS 2731, Introduction to Natural Language Processing
CS 2750, Machine Learning & Communications
INDUSTRIAL ENGINEERING
IE 2003, Engineering Management
IE 2082, Nonlinear Optimization

MECHANICAL ENGINEERING & MATERIALS SCIENCE
ME 2005, Structure of Materials
ME 2046, Digital Control Systems
ME 2047, Finite Element Analysis
ME 2055, Computer Aided Analysis in Transport Phenomena
ME 2060, Numerical Methods
MSE 2044, Scanning Electron Microscopy and EPMA
MSE 2069, Materials Science of Nanostructures
MSE 2077, Thin Film Processes and Characterization
MSE 2078, Nanoparticles: Science and Technology
MATH
Math 1530, Advanced Calculus 1
Math 1540, Advanced Calculus 2
Math 1550, Vector Analysis & Its Applications
Math 1560, Complex Variables & Applications
Math 2030, Numerical Linear Algebra
Math 2300, Measure Theory
Math 2301, Fourier Analysis
Math 2370, Matrices & Linear Operators
PHYSICS
Phys 1370, Introduction to Quantum Mechanics 1
Phys 1371, Introduction to Quantum Mechanics 2
Phys 1372, Electromagnetic Theory
Phys 2274, Computational Methods
Phys 2513, Dynamical Systems
Phys 2541, Statistical Mechanics & Thermodynamics
Phys 2555, Classical Electricity & Magnetism 1
Phys 2556, Classical Electricity & Magnetism 2
Phys 2565, Non-Relativistic Quantum Mechanics 1
Phys 2566, Non-Relativistic Quantum Mechanics 2
Phys 3705, Physics of Atomic Collisions
Phys 3707, Intermediate Quantum Mechanics Physics
Phys 3715, Solid-State Physics
Phys 3716, Advanced Solid State Physics
TELECOMMUNICATIONS
Telcom 2130, Queueing Theory
Telcom 2229, Digital Communications 1 – Modeling and Coding
Telcom 2310, Computer Networks
Telcom 2321, Wide Area Networks
Telcom 2710, Foundations of Wireless Communications
Telcom 2720, Cellular Radio & Personal Communications
Telcom 2721, Mobile Data Networks
Telcom 2821, Network Security

**Italics* for outside courses=cross-listed courses with EE.