

ELECTRICAL ENGINEERING AND COMPUTER SCIENCE
DEPARTMENT

MASTER OF SCIENCE AND Ph.D. REQUIREMENTS OF THE
ELECTRICAL ENGINEERING
GRADUATE PROGRAM



The University of Michigan
Department of Electrical Engineering and Computer Science
Electrical Engineering Graduate Program
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1. THE MASTER'S PROGRAM OF THE EECS DEPARTMENT

The Department of Electrical Engineering and Computer Science has three Graduate Programs; they are Computer Science and Engineering (CSE), Electrical Engineering: Systems (EES) and Electrical Engineering (EE). Each has a Master's Program comprising of several technical areas and each offers two degrees: Master of Science in Engineering (MSE) and Master of Science (MS). The three Master's Programs are governed by similar rules and guidelines. This document describes the rules and guidelines that apply to the EE Master's Programs.

Each Program is administered by a Graduate Committee, and a Graduate Chair.

1.1 Admissions

Admission to the MSE Program in EE requires the satisfactory completion of an undergraduate engineering degree or the equivalent of the undergraduate Electrical Engineering program at The University of Michigan.

Admission to the MS Program in EE requires the satisfactory completion of an undergraduate degree in a relevant or related area, such as engineering, mathematics, or the physical sciences. (A student with an engineering background in the relevant discipline is also eligible for the MS degree if he/she wishes.)

1.2 Requirements

1. Thirty (30) credit hours must be completed in graduate level courses. These courses should be 400-level or above, and they must be approved by the program advisor.
2. At least twenty-four (24) credit hours must be earned in technical courses.
3. At least twelve (12) credit hours must be earned in EECS course work at the 500 level or higher. Credit hours earned in other departments or universities and credit hours earned in individual study, research or seminar courses cannot be counted towards this requirement.
4. At least nine (9) credit hours must be earned from the kernel of a major area including at least six (6) at the 500 level or higher. (See the next section.)
5. At least three (3) credit hours must be earned in mathematics courses.
6. A Master's thesis option is available. As described later in detail, this option involves satisfactorily completing six (6) credit hours in the Master's thesis course and writing a thesis.
7. A student who completes a Master's thesis may apply at most three (3) credit hours in research, seminar and directed study courses to the Master's degree, over and above the six (6) credit hours in the Master's thesis course.
8. A student who does not complete a Master's thesis may apply at most four (4) credit hours in research, seminar and directed study courses toward the Master's degree.
- 9. The course grade must be B- or better for the credit hours received in any course to be counted towards any Master's requirement (including the 30 total credit hours.)**
- 10. The Grade Point Average (GPA) in EECS course work must be at least 5.000 (B), based on Rackham's 9.0 scale. (In addition, Rackham requires the overall GPA among all courses applied to the Master's degree to be at least 5.0.)**
11. Courses with insufficiently advanced content and level, or which substantially duplicate in content and level courses already completed by the student may not be counted as meeting any Master's requirement.

12. In the EE Program, the following courses may not be counted towards any Master's requirement: MATH 404, MATH 448, and MATH 450.
13. A student must satisfy both the General Master's Degree Requirements of the Rackham School of Graduate Studies as specified in Section 7 of the Rackham Student Handbook, and the College of Engineering Regulations as specified in the College of Engineering Bulletin. Both of these publications are accessible on the Internet (see below).

1.3 Major Areas (Kernels)

The EE Master's Programs require each student to choose a major area and to satisfy all requirements. For the EE Program, the major area must be one of the following:

- Applied Electromagnetics and RF Circuits
- Circuits and Microsystems
- Optics and Photonics
- Solid State
- VLSI

In addition to the major areas, students may find courses from the following list useful:

- Biosystems
- Communications
- Computers
- Control Systems
- Signal Processing

For each designated major area, there is a set of courses called the "kernel." The major area requirements are to be satisfied by taking courses from the respective kernels. The kernels are listed in Appendix A.

1.4 Cognates

In order to ensure sufficient breadth of study, the Rackham School of Graduate Studies requires Master's and Doctoral students to satisfy a cognate requirement of at least two graduate courses for a minimum of two hours of credit each in areas outside one's own field. Ordinarily, these courses would be from departments other than the student's. However, due to the diversity of curricula within the department, it is possible to use EECS courses that are not associated with one's own program to satisfy the cognate requirement.

Specifically, for each division (CSE, EE, EES), there is a list of associated graduate courses that may **not** be used as cognates by the students of that division. All other graduate courses offered by EECS or other Departments may be used except those listed under a non-EE Division major kernel if the student selected that kernel. The usual provisions about needing the approval of the appropriate Advisor or Graduate Chair must be emphasized. Courses in other departments cross-listed with EECS courses associated with the student's major program may not be used to fulfill the cognate requirement.

A list of associated graduate courses that may **not** be used as cognates by EE Division students is given in Appendix B. This list includes all of the kernel courses in the EE Division, plus a few "high EE-content" courses from the other divisions. Students in VLSI may not use the courses listed under Appendix D in the VLSI kernel list, but they can use any of the non-EE Division courses listed there under "Other Recommended Courses".

1.5 Course Transfer and Equivalency

Graduate credit hours **transferred** from other programs may be applied to meet any Master's requirement except the 12 credit hours of 500 level EECS course work required in item 3 above. (Rackham specifies limitations to the circumstances under which credits may be transferred. See the Rackham Student Handbook for limitations on credit transfer.)

Graduate courses taken from another university or department that are **equivalent** in level and content to the designated courses **in a kernel** may be counted towards meeting the major area content requirement if their equivalence is confirmed by the Graduate Chair. (It is not necessary that such courses be officially transferred, and they will not count towards the credit hour requirement, only the content requirement.)

1.6 Policy for Dropping Courses

After the eighth week of a full term (fourth week of a half term), courses may be dropped or changed to Visit status only under exceptional circumstances and with the approval of the course instructor and the program chair. The Rackham Graduate School rules for dropping courses also apply (see the Rackham Student Handbook).

1.7 Internet Resources

Many of the requirements documented here are also available on the Internet. The Rackham Student Handbook and the Engineering College Bulletin are among the numerous UM publications available on the WWW. To get this on-line information, refer to the EECS Web Pages at:

<http://www.eecs.umich.edu/>

and click on "Grad Program." Please also make use of the additional graduate information on this page, and of the information regarding the department on the other EECS Web Pages.

1.8 Master's Thesis Option

The option of writing a Master's thesis is available to Master's students in good academic standing. A student wishing to exercise this option may initiate the process through three steps. He/she must:

1. find an EECS faculty member willing to serve as Thesis Advisor,
2. enroll in the Master's thesis course with an initial enrollment of from one to six credit hours; and
3. arrange for a Master's Thesis Committee to be appointed by the Program Graduate Committee.

The Thesis Advisor is responsible for supervising the work of the Master's thesis project. The Master's Thesis Committee shall consist of the thesis advisor, as chair, and two additional faculty members. The committee members will be available for consultation and will evaluate the thesis.

The student must satisfactorily complete the Master's thesis course for a total of six (6) credit hours. These credit hours may be spread over more than one term. The course may be taken for one to six credit hours per term and shall be graded on an S/U basis.

The student must write a report that is substantially consistent with the Rackham format for theses. Each member of the Master's Thesis Committee must submit a written evaluation of the thesis. Approval of the thesis by all committee members is required. In addition to the thesis, an oral report may be requested by the Master's Thesis Committee.

DEADLINES: The student must elect the thesis option within thirteen months of first enrolling in the Master's program, and the student must complete the thesis within twelve (12) months of the initial election of the thesis course.

2. Plan of Study for the Master's Degree

The *Plan of Study* is intended to help you and will assure that you have an academic program that meets the degree requirements. The *Plan* will also make it easier for you and your Program Advisor to plan a sequence of courses that meets your professional objectives. To help you get the best possible counseling, you will see the same Program Advisor each time you need to work out your program, make election changes or simply need advice on your academic work or your career. There is at least one Program Advisor for each major EE area, so that you will have a chance to counsel with someone familiar with your intended area of specialization.

Each Master's student must submit for approval a "Plan of Study" (see page 8) at the beginning of the first term of enrollment. This plan must contain a listing of the courses the student intends to take to satisfy the degree requirements and must constitute a coherent program at an appropriate level. It is the student's responsibility to ensure that all requirements are met. **Any departure must be explicitly requested by written petition to the Electrical Engineering Graduate Committee.**

You must have a rough draft version of your *Plan of Study* when you counsel with your Advisor, who will discuss your intended Plan with you.

The *Plan of Study* is amenable to changes. For instance, you may decide to drop a course, be enrolled in courses at conflicting time, or be stimulated to elect additional courses in an area new to you. You should consult with your Program Advisor to be absolutely certain that your revised *Plan of Study* will still enable you to meet the degree requirements by your desired graduate date.

The *Plan of Study* is intended only as a guide to the student and Program Advisor. Final responsibility for ensuring that the student's course work meets requirements rests with the student. Your Program Advisor is available to help you in this task, and to answer any questions you may have. If the student so desires, the Advisor can draw up a Degree Contract, which will be signed by the student, the Advisor, and the Chairman of the Graduate Committee. The Degree Contract is an official agreement that if the student successfully completes the course work indicated, then the student will have satisfied all the requirements for the Master's degree.

If you change your course selections, you should submit a revised *Plan of Study*. Do this before you discuss the next Term's election with your Program Advisor. By discussing your course selections and any changes to these selections with your Program Advisor, you can be assured of meeting graduation requirements.

Please use the Master's Degree Requirements above and the list of kernel courses in Appendix A to make out your *Plan of Study*. Read the Requirements carefully to assure that your *Plan of Study* is acceptable for the degree and reflects your professional interests. The Master's Degree Requirements provide an overall summary of the totality of the requirements for the degree. By following the *Plan of Study* format, you will meet the requirements for the degree. The Master's Degree Requirements should answer any detailed questions you may have on what is acceptable.

The Cognate Requirements define a cognate course. Note that there are some courses of insufficiently high level (e.g., MATH 404, 448, 450) that may not be used either for a cognate or to satisfy any other degree requirement. There are other courses (not listed) that are likewise unacceptable, such as those on elementary programming or statistics in other units of the University. In addition, you may not elect any course that essentially duplicates material you have studied elsewhere.

In planning your program of studies, be sure that you have the necessary prerequisites for selected courses; these are listed both in the time schedules and the University bulletins. Many courses are offered only once per year (as indicated in the "kernels" section of this document and in the College of Engineering Bulletin) so construct your *Plan of Study* realistically according to what will actually be offered in each term. If you fail to take course scheduling into account, you may have a course election problem part-way through your projected program! If you fail to follow an acceptable *Plan of Study*, you could receive a disagreeable surprise when you apply for the degree in your last term and a final audit by the Program Chair finds an unsatisfied requirement.

3. Master's Degree Plan of Study Template Electrical Engineering

Name (Print) _____ Signature _____ Date: _____

email: _____ Student ID # _____

Date of Admission _____ Advisor Approval _____ Date: _____

Category	Requirements	Level	Courses Selected	Credit Hrs
Major kernel: Check one: Applied Electromagnetics and RF Circuits _____ Circuits & Microsystems _____ Optics & Photonics _____ Solid State _____ VLSI _____	≥ 9 hours total; includ. ≥ 6 hours at ≥ 500 level	400 ≥ 500	_____	
Other EECS courses:	≥ 12 hours total EECS courses at \geq 500 level (include above) Total _____ Hrs.	400 ≥ 500	_____	
Directed study, seminar, or research	≤ 4 hours (≤ 3 hrs if thesis elected)			
Master's thesis	6 hours			
Cognate courses (courses outside major kernel area) <i>See Master's requirements for definition and instructions</i>	≥ 2 courses include. ≥ 3 hours math (excluding 404, 448, 450)	Math cognate Second cognate	_____ _____	
Other technical courses _____	≥ 24 hours for all technical courses, including above Total: _____ hrs		_____	
Non-technical courses				

Total hours (≥ 30) _____

ALL courses must be graduate level

4. THE DOCTORAL PROGRAMS OF THE EECS DEPARTMENT

The Department of Electrical Engineering and Computer Science has three Graduate Programs; they are Computer Science and Engineering (CSE), Electrical Engineering: Systems (EES), and Electrical Engineering (EE). Each graduate program has its own Doctoral Program and comprises several technical areas. However, the three Doctoral Programs are governed by the same general rules and guidelines under the Rackham Graduate School. This document describes the general and specific rules and guidelines that apply to the EE Doctoral Program. The program is administered by a Graduate Committee representing the EECS faculty in that program (the “EE faculty”). Doctoral qualification decisions are made by the Doctoral Qualification Committee comprised of all EE faculty members.

5. OVERVIEW OF DOCTORAL REQUIREMENTS

The Doctoral degree (Ph.D.) is conferred by the Rackham Graduate School in recognition of marked ability and scholarship in some relatively broad field of knowledge, plus the demonstrated ability to carry out independent research yielding significant original results.

The Doctoral Program proceeds in three stages:

- (1) Qualification, marked by completion of the Preliminary Exam Part I: Qualification
- (2) Candidacy, marked by completion of coursework and Preliminary Exam Part II: Research, and
- (3) Proposing, writing, and defending the Dissertation, marked by the Thesis Proposal Presentation and the Final Oral Defense.

Qualification marks the beginning of the doctoral program; *Candidacy* signifies that coursework is essentially completed and that a specific research area has been selected; successful definition, completion and defense of the doctoral dissertation in the *Final Oral Defense* mark the completion of the requirements for the Ph.D. degree.

5.1 INTERNET RESOURCES

Many of the requirements documented here are also available on the Internet. The Rackham Student Handbook and the Engineering College Bulletin are among the numerous UM publications available on-line. The “Rackham Student Handbook” gives details about the Ph.D. degree requirements imposed by the Graduate School, and should be consulted by all Ph.D. students, particularly in regard to questions about residency, fees, cognates, and dissertation committee eligibility.

To get this information on-line, refer to the EECS Web Pages at:

<http://www.eecs.umich.edu/>

and click on “Grad Program.” Please also make use of the additional graduate information on this page, and of the information regarding the department on the other EECS Web Pages.

6. DOCTORAL QUALIFICATION

To qualify for the EE Doctoral Program a student must do the following:

- (a) Satisfactorily complete the Doctoral Qualification Coursework (see Section 6.1),
- (b) Initiate and make satisfactory progress in a Research-Oriented Directed Study project or Master's thesis (see Section 6.2),
- (c) Take the Doctoral Preliminary Examination Part I (see Section 6.3),
- (d) Be accepted by the Doctoral Qualification Committee as qualified for doctoral study. (See the paragraph below.)

The decision to approve a student for doctoral study is made by the Doctoral Qualification Committee, which meets for this purpose after each offering of the Preliminary Examination Part I. All students who have just taken the

examination are considered. The decision is based on the performance in the Doctoral Qualification Coursework, satisfactory progress on the Research-Oriented Directed Study (or Master's thesis), the performance on the Preliminary Examination Part I, the overall academic record as measured by the graduate GPA, and English proficiency (see Section 6.4). For each student the possible outcomes of the decision are:

- (a) Qualified for the Doctoral Program. (For students with minor deficiencies in English proficiency, there may be a requirement to satisfactorily complete certain English language courses.),
- (b) Not Qualified for the Doctoral Program, but allowed to retake the Preliminary Examination Part I. (The Committee will normally encourage or discourage such students.),
- (c) Not qualified for the Doctoral Program, and not allowed to retake the Preliminary Examination Part I.

A student may take the Preliminary Examination Part I and be considered for acceptance at most twice. It is offered three times per year: in the second and third full weeks of classes in the Fall and Winter terms, and in May during the Spring half term. The Doctoral Qualification Coursework (Section 6.1) must be completed before taking the examination. The Research-Oriented Directed Study (Section 6.2) must be started at least one full term prior to taking the exam, but need not be completed before taking the exam. It is permissible to complete the Directed Study or Thesis before taking the exam if time allows, but lack of completion is not an acceptable reason for postponing the exam.

Students entering the EE graduate program with a Bachelor's degree are strongly encouraged to take the exam within seventeen (17) months of their entry and **must qualify** for the Doctoral program within twenty-five (25) months. Students entering the Ph.D. program with a relevant Master's degree are encouraged to take the Preliminary Examination Part I within thirteen (13) months of their entry and **must qualify** for the Doctoral program within seventeen (17) months. These time periods include all terms: Fall, Winter, and Spring/Summer, and apply regardless of the term in which graduate study begins. Additional timetable details are given in Section 9.

6.1 Doctoral Qualification Coursework Overview

As part of the qualifying process, a doctoral student must satisfactorily complete a set of courses known collectively as the Doctoral Qualification Coursework. This coursework is a subset of the Doctoral Coursework required for Candidacy (See Section 7.2).

Students who enter the graduate program in the EECS Department with a Bachelor's degree and who are planning to work toward the Ph.D. are encouraged to plan their Doctoral Qualification coursework in concert with their Master's degree coursework.

Major Areas (Kernels)

To satisfy the Doctoral Qualification Coursework requirement, the student must choose a major area from the lists of areas given at the end of this section, and must satisfactorily complete sufficient courses in the chosen major areas to satisfy certain requirements. These courses and requirements are stated in the "kernels" that appear in APPENDIX A. Within the kernels, there may be required courses, group requirements, and electives.

For the EE Program the designated major areas are:

- Applied Electromagnetics and RF Circuits
- Circuits and Microsystems
- Optics and Photonics
- Solid State
- VLSI

In addition to the major areas, students may find courses from the following list useful:

- Biosystems
- Communications
- Computers
- Control Systems

Signal Processing

The Academic and Research Advisors

The Academic Advisor is determined by the major area of the student, and is particularly important for assistance in course planning at the beginning of a student's Ph.D. program. Each major area has at least one faculty member advisor, who will have extra office hours at the time of registration for classes for the next term and will be available to the student to help plan for course registration and to answer other academic questions. As the student progresses and becomes more involved with research, the Research Advisor will play a greater role in choosing courses and advising the student, but the student should continue to see the Academic Advisor to be sure that all degree requirements will be met.

Equivalency

Graduate courses taken in other departments or universities that are equivalent in level and content to courses in a kernel may be counted towards that kernel. This is called "Equivalency" and is not a transfer of credit hours. It is recognition that course content has been covered previously. The decision to accept such courses is made by the EE Graduate Committee upon petition by the student. Students entering with a Master's degree must submit such petitions as part of the planning and counseling process at the beginning of their first term in the graduate program. Courses taken as an undergraduate are eligible for Equivalency provided they can be taken for graduate credit at the host institution. Please see Section 10 for Equivalency requirements and a list of material to be submitted when applying for Equivalency. Equivalent courses do not count toward the doctoral coursework credit-hour requirement (Section 7.2).

Students entering graduate studies in the EECS Department with a Master's degree may satisfy the Doctoral Qualification coursework requirements by petitioning to have courses taken elsewhere counted towards their major kernel (through equivalency as described above) and by taking the necessary courses at the University of Michigan. Regardless of the number of equivalent courses granted, such students shall complete:

at least 9 credit hours of graded University of Michigan (Ann Arbor) graduate courses prior to taking the Preliminary Examination Part I.

It is important for such students to obtain Equivalency for previous courses so that they will be able to meet the Ph.D. timetable requirement.

GPA Requirements

"Satisfactory" performance in the Doctoral Qualification Coursework means that the student must achieve at least a B grade in each course of the Doctoral Qualification Coursework, at least a 6.66 grade point average in the courses he or she selects to satisfy the major kernel requirement.

The student may take more courses than are necessary, and is free to select the subsets of kernel courses that satisfy the kernel grade requirements for Preliminary Exam Part I.

Special Courses

New graduate courses are often offered initially under the course number EECS 598. If you wish to use one of these to satisfy a kernel requirement, you must obtain written approval from the instructor and the Academic Advisor in the kernel area of the course. This approval must be turned in to the Graduate Secretary before submitting the *Ph.D. Plan of Study* for the Qualification Exam or for Candidacy, and it will be placed in your graduate file.

Course Status Changes

After the eighth week of a full term (fourth week of a half term), courses may be dropped or changed to Visitor status only under exceptional circumstances and with the approval of the course instructor and EE Graduate Committee Chair.

Ph.D. Plan of Study for Qualification and Candidacy

The Ph.D. Plan of Study (see Section 12 for the form) is intended to help you select courses and will ensure that you have an academic program that meets the Ph.D. coursework requirements. The Plan of Study will also make it easier for you and your advisors to plan a sequence of courses that meets your professional objectives. To help you get the best possible counseling, you will see the same Academic Advisor each time you need to work out your program, make election changes, or simply need advice on your academic work or your career. There is at least one Academic Advisor for each EE major area, so you will have a chance to counsel with someone familiar with your intended area of specialization. As you get more involved with research, you should also consult with your Research Advisor about course planning. For students who enter with a Bachelor's degree, the Ph.D. Plan of Study will be a continuation of their Master's Degree Plan of Study.

Each Ph.D. student must initiate a Ph. D. Plan of Study at the time when the student begins the Ph.D. program, and an up-to-date copy must be submitted when the student signs up to take the Preliminary Examination Part I. The Plan of Study must contain a listing of the courses the student has taken or intends to take to satisfy the Qualification Coursework Requirements and must constitute a coherent program at an appropriate level. In addition, election worksheets for registration must be signed by the student's Academic Advisor. The web (Wolverine Access) registration system enables a student to register without the advisor's signature, but it is the student's responsibility to ensure that all requirements are met and seeing the advisor will guarantee that no requirements are overlooked. Any departure from the requirements must be explicitly requested by written petition to the Electrical Engineering Graduate Committee.

You must have a rough draft version of your Ph.D. Plan of Study when you counsel with your Academic Advisor. Your Advisor will discuss your intended plan with you.

The Ph.D. Plan of Study is amenable to changes. It can be started while working on your Master's degree. You should consult with your advisors to be absolutely certain that your Plan of Study will enable you to meet the coursework requirements by your desired timetable date.

Please use the major kernel requirements in APPENDIX A to make out your Ph.D. Plan of Study. Read the kernel requirements carefully to assure that your Ph.D. Plan of Study is acceptable and reflects your professional interests. Consider the frequency of course offerings as you plan. These are given in Appendices B, C, and D. The most up-to-date EECS Department timetable is available on the EECS web pages, in the EE Graduate Office, and the nearby hallway bulletin board, and should be consulted before registration for EECS course offerings. It is more current than Appendices B, C, and D of this document.

The cognate requirements in Section 11 define a cognate for you. The cognates must be graduate-level courses. Note that there are some courses of insufficiently high level (e.g., Math 404, 448, 450) that may not be used either for a cognate or to satisfy any other degree requirement. There are other courses (not listed) that are likewise unacceptable, such as those on elementary programming or statistics which are taught at the graduate level in other units of the University. You may use graduate-level cognate courses taken elsewhere if they are graded courses. These courses do not have to be formally transferred, but they must appear on the official copy of your graduate transcript from the other school. The school name and course number should be entered on the Plan of Study.

The Ph.D. Plan of Study is used by the Program Chair to determine if the student has satisfied the kernel course requirements and the cognate requirement at the time the student wishes to advance to Candidacy. At that time, the student must submit a "clean" copy of the Ph.D. Plan of Study for evaluation.

6.2 Research-Oriented Directed Study/Master's Thesis

A Ph.D. aspirant must demonstrate his/her potential for conducting original research. This may be accomplished by completing a Master's thesis for 6 credit hours, or by doing a Research-Oriented Directed Study project for a least 3 credit hours. Either must be completed in the EECS Department of the University of Michigan. Work on either must be started at least one full term prior to taking the Preliminary Exam Part I **by taking one or more credit hours of directed study/thesis registration in the EECS Department**. The project need not be finished before taking Preliminary Exam Part I. If it is not finished, then at least three weeks prior to taking the exam the student is required to submit a **one-page progress report**, and the faculty advisor submits a separate evaluation

to the Doctoral Qualification Committee indicating if the project is progressing satisfactorily. If the project is completed before taking Preliminary Exam Part I then, at the student's option, a formal written report may be submitted for the directed study project or a formal thesis for the Master's thesis option (see additional details about the the thesis in the "Master's Degree Requirements" pamphlet) in lieu of the one-page progress report.

When the project is completed, a formal written report is required with the directed study option and a formal thesis is required for the Master's thesis option. The supervisory faculty member provides a final written evaluation to the Graduate Committee.

The completed project report and final faculty evaluation are required for admission to Candidacy (see Section 7.3).

6.3 Doctoral Preliminary Examination Part I: Qualification

The Preliminary Examination Part I is an oral examination whose purpose is to evaluate the student's ability to inter-relate various topics and concepts, to analyze problems, and to synthesize solutions.

The Preliminary Examination Part I is offered in the second and third full week of classes in the Fall and Winter terms and in May during the Spring term. At least 10 weeks prior to the Examination, the student must indicate in writing his/her intention to take the Examination. The Preliminary Examination Part I will be administered by an Examining Committee consisting of Faculty members appointed by the Graduate Committee. In the VLSI kernel, at least one examiner will be chosen from each of the EE and CSE divisions. Following the Examination, each member of the Examining Committee will submit an evaluation of the student's performance to the Doctoral Qualification Committee.

The time at which the Examination is taken is independent of the completion of the Master's degree and the Directed Study/Thesis project. The time is determined by the time of completion of the Qualification Coursework and it must satisfy the timetable given in Section 9.

Part II of the Preliminary Examination is related to completion of the Directed Study project or Master's thesis, and is described in Section 7.3.

6.4 English Proficiency

As part of the qualifying process, the student's English proficiency will be evaluated, based on the performance in the Preliminary Examination Part I and the Research-Oriented Directed Study or Master's thesis. Students deemed to have minor deficiencies in English, but who are otherwise qualified for the Doctoral Program, will be judged Qualified for the Doctoral Program but will be required to perform satisfactorily in specified English language courses. Students deemed to have major deficiencies in English will be judged Not Qualified for the Doctoral Program. Non-native English speakers are urged to achieve proficiency in English as early in their studies as possible.

6.5 The Research Advisor

Shortly after a student has qualified for the Doctoral Program, the EE Graduate Committee shall appoint a Research Advisor who will guide the student towards Candidacy. This includes completion of the directed study project or Master's thesis, and therefore, in many cases, the Advisor will be the Directed Study Advisor. It is the responsibility of the student to find a faculty member willing to serve in this role and to propose him/her to the Graduate Committee for approval. In most cases the Advisor will eventually become the Dissertation Advisor. Note: This advisor is distinct from the Academic Advisor associated with the student's major area. The Academic Advisor must still be consulted at the beginning of each term, and is the person who must sign all Election Worksheets.

7. CANDIDACY

7.1 Admission Criteria and Procedures

A student will be admitted to Candidacy when the following requirements have been met:

- (a) The student has completed all essential coursework including the Doctoral Candidacy Coursework described in Section 7.2.
- (b) The student has completed the Directed Study or Master's Thesis Project. (See Section 7.3 below).
- (c) The student has satisfied all other Rackham Candidacy requirements. These concern items such as fee credit hours, residence requirements, and cognate coursework. (See Section 11 for a statement on the cognate requirement, and Appendices B, C, and D for a partial list of courses which may be used to complete the requirement.)

7.2 Doctoral Candidacy Coursework

As part of the process of achieving Candidacy, a doctoral student must complete a set of courses known as the Doctoral Candidacy Coursework. This is a continuation of the Qualification Coursework. It includes at least 36 credit hours of relevant graduate coursework beyond the Bachelor's Degree, of which at least 18 credit hours must have been earned at the University of Michigan, Ann Arbor. Credit for individual study, research and seminar courses may not be counted toward the 18 or 36 hour requirement. These credits are often indicated by "S" grades. The Graduate School requires that at least two post-Bachelors cognate courses be included. These courses can be included in the Candidacy hour requirement unless an "S" grade was used or the course is non-technical (e.g., business, writing, etc.) In particular, math courses can be included. Students who enter the Ph.D. with a relevant Master's degree from another school will generally have had approximately 18 hours of relevant graded coursework which gives a total of 36 hours when combined with the required 18 hours at UM.

In addition the student must take sufficient courses from the kernel of his/her chosen major area to satisfy certain requirements. These courses and requirements are stated in the "kernels" that appear in APPENDIX A. The major kernels specify 5 or 6 courses.

Students who change their major area from those used for their Master's degree to new areas for their Ph.D. degree may have to take more than 36 hours to fulfill the kernel course requirements.

Courses taken from other departments or universities that are equivalent in level and content to courses in a kernel may be counted towards that kernel. The decision to count such courses is made by the Graduate Program Committee upon petition by the student. See Section 6.1 and Section 10 for more information about "Equivalency". Courses for which Equivalency is given do not count toward the 18 or 36 hour requirement.

The cognate requirement must be completed before advancement to Candidacy. Consult Section 11 and the Rackham Student Handbook for additional information.

A "clean" copy of the Ph.D. Plan of Study in Electrical Engineering must be completed and submitted to the Graduate Chair at the time the student applies for Candidacy. This Plan of Study is used to verify that the Candidacy coursework and hour requirements are satisfied. A Plan of Study template is included in Section 12. A student may apply for Candidacy as soon as the coursework and directed study/Master's thesis are complete.

The same policy as for the Doctoral Qualification Coursework on Course Status Changes applies (see Section 6.1).

7.3 Doctoral Preliminary Examination Part II: Research

A student who has passed the Preliminary Exam Part I may proceed to Candidacy as soon as the Coursework for Candidacy and the Directed Study/Master's Thesis project are completed. The Directed Study project requires a total registration of at least 3 credit hours, which may be spread over one or more terms. The Master's thesis requires 6 credit hours. To complete the Directed Study project, a formal written report is submitted to the supervisory faculty member (the Research Advisor) who supervises the project. The faculty member will provide a written evaluation to the Graduate Committee along with a copy of the report. The Master's thesis option will proceed in the same way, but will follow the formal thesis procedure outlined in the Master's Degree Requirements. A final grade of S or U will be given to the project by the Research Advisor.

In the event of an unsatisfactory grade in the project or thesis, the Graduate Committee will appoint a project review committee of three faculty members in the research area of the project but not including the Research Advisor. This committee will independently review the written report and examine the student's understanding of it in an oral exam. The committee may agree with the evaluation of the Advisor, in which case the student is not advanced to Candidacy, or it may disagree and the student is given time to improve the project or to do a second project with a different advisor. Failure to complete this within the required timetable (see Section 9) may result in disqualification from the Ph.D. program. It is the student's responsibility to find a faculty member to supervise a second project.

8. DISSERTATION

8.1 The Thesis Proposal Presentation and Dissertation Committee

After admission to Candidacy, it is the responsibility of the student to find an eligible faculty member willing to serve in this role and to propose him/her to the Graduate Committee for approval. In most cases the Dissertation Chair will be the same person who supervised the Directed Study/Master's Thesis project.

After appointment of the Dissertation Chair, the student will write a dissertation research proposal under the guidance of the Dissertation Chair and give a *Thesis Proposal Presentation*.

Upon satisfactory completion of the proposal, the student, in consultation with the Dissertation Chair, will recommend a tentative Dissertation Committee to the Graduate Committee. The Dissertation Chair (or Co-Chair) will be the Chair (or Co-Chair) of the committee, which shall include at least three other members. The Dissertation Chair, or at least one of the Co-Chairs, must be from the EECS Department. In accordance with Rackham rules, at least one member must be from outside the EE Division of the EECS Department. Eligibility for service as a Dissertation Chair or as a Dissertation Committee member must be consistent with Rackham rules. The tentative Dissertation Committee may be changed completely or in part after the *Thesis Proposal Presentation* if so desired by the student, Dissertation Chair, or the Graduate Committee. The final decision on Dissertation Committee membership is made by the Graduate Committee, which must recommend the Committee to the Rackham Graduate School.

See the Graduate Coordinator for the thesis proposal form that you must complete and have approved by the Graduate Committee. When the Dissertation Committee is formed, the student will submit the dissertation research proposal to the Committee at least two weeks in advance of the *Thesis Proposal Presentation*.

The student will make an oral presentation of the proposed dissertation research, including relevant background material. During and after the presentation, the Committee will explore the research project with the student in order to provide guidance and make an evaluation of its suitability. They will report to the Graduate Committee one of two results:

- (1) The student has presented an acceptable thesis proposal.
- (2) The student does not have an acceptable proposal.

In the second case, the student is to take immediate steps to refine the proposal in consultation with the Chair and other Committee members. It is the responsibility of the student to work with the committee, possibly augmented by other faculty members, to obtain an acceptable proposal within the time period given in the Timetable (Section 9).

The *Thesis Proposal Presentation* requirement is completed when the Dissertation Committee Chair reports a successful proposal presentation to the Graduate Office.

Following acceptance of the Thesis Proposal, the Dissertation Committee is finalized. This must be done within the timetable given in Section 9 for the *Thesis Proposal Presentation*. The student submits a written request to the Graduate Committee with a proposed committee. Upon approval by the Graduate Committee, its membership is submitted to Rackham for approval. *Failure to finalize this committee until just before the Final Oral Defense may result in serious delays of the defense.* It is expected that the Dissertation Committee will regularly review the student's progress.

A person who is not a member of the graduate faculty of the University of Michigan may serve on the Dissertation Committee with prior approval of the Graduate Committee. Such a person must have an earned doctorate or the equivalent. See the Rackham Student Handbook for details about eligibility for the Dissertation Committee.

It is expected that work on the thesis proposal will be done concurrently with the completion of coursework for Candidacy.

8.2 The Dissertation and Its Defense: Final Oral Defense

Upon completion, the dissertation must receive a written evaluation from each member of the Dissertation Committee and must be defended orally in an open examination before the Committee in accordance with Rackham rules. Following the successful *Final Oral Defense*, the student must consult with the Dissertation Chair(s) about any changes required by the Committee, and must make these changes before final submission of the thesis to Rackham.

9. SUMMARY OF THE TIMETABLE FOR THE Ph.D. PROGRAM

The following time periods include Fall, Winter, and Spring/Summer terms. They apply to all students regardless of the term (Fall, Winter, or Spring/Summer) in which they begin graduate studies at the University of Michigan. **Any departure from the timetable must be explicitly requested by written permission.**

Students entering the Graduate Program with a Bachelor's degree must

1. Qualify for the Doctoral Program within twenty-five (25) months of entry, (for satisfactory progress students are strongly encouraged to take the Preliminary Examination Part I within seventeen (17) months).
2. Complete Part II of the Preliminary Examination and achieve Candidacy within 36 months of entry. (For satisfactory progress, Candidacy should be achieved within 32 months.)
3. Complete the Thesis Proposal Presentation within 40 months of entry. (For satisfactory progress, the proposal should be completed within 36 months).
4. Complete the dissertation and Final Oral Defense within six years of entry. (Under normal conditions the dissertation should take an average of five years from entry to complete.)

Students entering the Graduate Program with a relevant Master's degree must

1. Qualify for the Doctoral Program within seventeen (17) months of entry, (for satisfactory progress, such students are strongly encouraged to take the Preliminary Examination Part I within thirteen (13) months).
2. Complete Part II of the Preliminary Examination and achieve Candidacy within 28 months of entry. (For satisfactory progress, Candidacy should be achieved within 24 months.)
3. Complete the Thesis Proposal Presentation within 32 months of entry. (For satisfactory progress, the proposal should be completed within 28 months).
4. Complete the dissertation and Final Oral Defense within five years of entry. (Under normal conditions the dissertation should take an average of four years from entry to complete.)

Experience has shown that successful doctoral students devote a majority of their time to their academic program. Consequently, this Timetable applies to all students, including those with TA or RA appointments, as well as to students carrying outside obligations. Any departure from the Timetable must be explicitly requested by written

petition. Each petition will be reviewed by the Graduate Committee of the EE Program, and each decision will be made on the individual merits of the petition. The Department may terminate the enrollment of any student who fails to follow these procedures and the timetable.

10. Equivalency Information

For students entering with a Bachelor's degree, the kernel requirements are generally met over the standard Ph.D. timetable through appropriate Master's degree course selections. Students who enter a Master's degree must be prepared for the Preliminary Exam Part I after a shorter time period, and therefore must use "equivalent" courses from their Master's degree to meet the kernel requirements.

Because of the limited time available for course work prior to the exam, students with a Master's degree are usually unable to complete the kernel course requirements through courses taken at Michigan. The purpose of equivalency is to recognize that these students have already acquired considerable background as part of their Master's degree course work. Thus courses completed previously are recognized as equivalent to the EECS kernel courses. Equivalency is not a formal transfer of courses and will not appear on the student's University of Michigan transcript. Students entering with a Master's degree must submit any petition for equivalency as part of the planning and counseling process at the beginning of their first term in the graduate program.

While equivalency is a necessity for students entering with a Master's degree, it can also be used by students entering with a Bachelor's degree if they have taken graduate-level courses as an undergraduate or as a non-degree student at another school.

Requesting Equivalency

A student wishing to request equivalency for course work prior to taking the Preliminary Exam Part I should petition the Graduate Program Chair in the first term of study. A long lead time is necessary in case expected equivalency is not obtained and additional course work must be taken. Entering students should bring the requested equivalency material (see below) with them to Ann Arbor, and discuss equivalency with their Academic Advisor in their first meeting. Students entering with a Master's degree must submit such petitions as part of the planning and counseling process at the beginning of their first term in the graduate program.

The material requested for deciding equivalency is listed on the form "Request for Equivalency Evaluation." A copy of this form is included. It is recognized that the student may not have all of the requested material, but it is the student's responsibility to present sufficiently convincing evidence to justify approval of equivalency.

The student is informed about the equivalency decision, usually within four weeks of receipt of the petition and materials. If the petition is submitted early enough, this will allow time to register for course work in the following term in case equivalency is not obtained.

Guidelines for Determining Equivalency

The general policy is that student's Ph.D. timetable should not be delayed because they received their Master's degree at another school, provided that they took a rigorous program of relevant course work and request equivalency early enough.

The following condition must always be satisfied:

The course(s) or parts of courses used for equivalency must be at an intellectual and content level commensurate with the corresponding courses in EECS at Michigan, and must be of similar duration and intensity. The student must have earned a grade of B (or its equivalent) or higher in the courses proposed for equivalency.

In addition, the following guidelines apply:

1. If a course taken elsewhere includes at least 60% of the kernel course material then equivalency is given.

2. If a combination of material from two or more courses taken elsewhere cover at least 75% of the kernel course material then equivalency is given.
3. If a course taken elsewhere does not match any kernel course but is judged to be suitable for the student's major area if it were offered at Michigan, then this course will reduce by one the number of kernel courses required to satisfy the Ph.D. kernel requirements.
4. Students entering with a Master's degree must submit any petition for equivalency as part of the planning and counseling process at the beginning of their first term in the graduate program.

Courses not in the kernels and non-EECS courses such as math do not have to be considered for equivalency.

10.1 Request for Equivalency Form:

REQUEST FOR EQUIVALENCY EVALUATION

Students entering with a Master’s degree must submit any petition for equivalency as part of the planning and counseling process at the beginning of their first term in the graduate program.

Date: _____

Please furnish the information requested below for equivalency evaluation. Use a separate form for each course that you are submitting for evaluation.

Name: _____ Major: _____
email: _____

1. University where course was taken: _____
2. Year & term taken: _____ 3. Letter grade earned: _____
4. Course title: _____
5. Course number: _____ 6. No. of weekly meetings: _____
7. Number of weeks of course duration: _____
8. Proposed UM equivalent course number: _____
9. UM faculty member who is teaching course in present term or previous term (time schedules are available on the EECS website with this information): _____

In addition to this form, please furnish the following:

- a) Course outlines or syllabus.
- b) Catalog course description.
- c) Names of texts used (furnish a copy of the text if it is not universally available).
- d) Lecture notes, homework problems, and tests.
- e) Any other material indicative of the coverage and level of the course.
- f) A copy of the transcript showing the course and grade. (It does not need to be a certified copy; normally, the EE Graduate Office will have a transcript or copy on file from admissions, but check to be sure).

For department use only. Circle one.

Equivalence for course no. _____ is / is not approved.

EE Graduate Chair: _____ Date _____

11. Cognate Requirement For the Ph.D. Degree

In order to ensure sufficient breadth of study, the Rackham Graduate School requires graduate students to satisfy a cognate requirement of at least two graduate-level courses for a minimum of two credit hours each in areas outside of one's own field. Ordinarily, these courses should be from departments other than EECS, but because of the diversity of courses within EECS it is permissible (but not required) to use EECS courses that are not associated with the student's own program to satisfy the cognate requirement.

For EE Division students, courses in the EE Division are not acceptable as cognates, nor are courses in other EECS divisions if they are associated with the student's program. All other graduate courses offered by EECS or other departments may be used, although the necessity of obtaining approval of the Academic Advisor must be especially emphasized in the case of cognates. Courses in other departments that are cross-listed with EECS courses associated with the student's program may not be used for cognates.

Courses taken elsewhere as part of a Master's degree program or other graduate studies may be used providing they are outside the student's major area, are of graduate level, appear on the student's official graduate school transcript, and were graded by a letter grade of B (or the equivalent) or higher. These courses do not have to be formally transferred.

Appendices B, C, and D list all EECS graduate-level courses and classify them as to acceptability for the cognate requirement, subject to the restrictions given above.

12. Ph.D. Plan of Study Template Electrical Engineering

Name (Print) _____ Signature _____ Date _____

email: _____ Student ID # _____

Date of Admission _____ Advisor Approval _____ Date _____

Research Advisor Name _____ Research Advisor INDI # _____

Category	Requirements	Level	Courses Selected	Credit Hrs
Major kernel: Check one: Applied Electromagnetics and RF Circuits _____ Circuits & Microsystems _____ Optics & Photonics _____ Solid State _____ VLSI _____	Pre-Qualification (Circle courses chosen to qualify, GPA \geq 6.66, all with grade \geq B)	Equivalency or Transfer from BSE/MSE (give U-M Course Number) _____ 400 \geq 500		
	Post-Qualification	400 \geq 500		
Other graded EECS courses not needed for kernels				
Directed study, Seminars, or Research (S-graded courses)	Do not count these credits toward the hour requirement			
Other technical courses (non-EECS), Math, Science, etc., not used for Cognates:				
Cognate courses (courses outside major kernel area & EE Division)	2 courses, \geq 2 hours each	Cognate No. 1: _____ Cognate No. 2: _____		
TOTAL CREDIT HOURS FOR CANDIDACY: (\geq 18 hrs. if entering with Master's degree, \geq 36 hours if entering with bach. Degree)		Cognates may be counted if technical Total credit hours: _____		
Nontechnical courses (credit hours do not count toward hour requirement)		Course No. _____ Credit Hrs _____ Course No. _____ Credit Hrs _____ Course No. _____ Credit Hrs _____		

13. APPENDIX A: The EE Program Master's and Ph.D. Kernels

The latest revision of the kernels at the term you are first enrolled will apply. However, you are encouraged to satisfy the most recent revisions as far as is possible. If in doubt, consult your advisor.

Offering Code: I=Fall Term, II=Winter Term, IIIa=Spring-Half Term; EY=Even Years, OY=Odd Years, AY=Alternate Years (Offering times are subject to change; consult the current Time Schedule)

Applied Electromagnetics and RF Circuits

Master's Degree

Four courses from the entire list at the 500 level or above with at least three of the four courses from the "Applied Electromagnetics and RF Circuits" list.

Ph.D. Degree

For Qualification: EECS 530, plus three other courses from the entire list below, with at least two of the three courses from the "Applied Electromagnetics and RF Circuits" list of which at least one course is at the 500 level or above, and one course at the 500 level or above from the entire list.

For Candidacy: EECS 530, plus five other courses from the entire list below, with at least three of the five courses from the "Applied Electromagnetics and RF Circuits" list of which at least two courses are at the 500 level or above, and two courses at the 500 level or above from the entire list.

Entire List:

Applied Electromagnetics and RF Circuits:

EECS 411 (4) (I) Microwave Circuits I
 EECS 430 (4) (II) Radiowave Propagation and Link Design
 EECS 503 (3) (I) Intro. To Numerical Electromagnetics
 EECS 517 (3) (II) Physical Processes in Plasmas
 EECS 519 (4) (II) Plasma Gen. And Diagnostic Lab.
 EECS 525 (3) (I) Advanced Solid-State Microwave Circuits
 EECS 530 (3) (I) Electromagnetic Theory I
 EECS 531 (3) (II) Antenna Theory and Design
 EECS 532 (3) (OY) Microwave Remote Sensing I: Radiometry
 EECS 533 (3) (II) Microwave Measurement Lab.
 EECS 598 (1-4) Special Topics in Electrical Engineering and Computer Science
 EECS 631 (3) (AY) Electromagnetic Scattering
 EECS 632 (3) (IIEY) Microwave Remote Sensing II: Radar
 EECS 633 (3) (AY) Numerical Methods in Electromagnetics

Aerospace and Oceanic Studies

AOSS 401 Geophysical Fluid Dynamics
 AOSS 422 Micrometeorology I
 AOSS 467 Biogeochemical Cycles
 AOSS 524 General Circulation
 AOSS 532 Radiative Transfer
 AOSS 565 Planetary Atmospheres
 AOSS 585 Introduction to Remote Sensing and Inversion Theory

Aero 729 Introduction to Electric Propulsion
 AOSS 597(Aero 597) Fundamentals of Space Plasma Physics
 NERS 471 Introduction to Plasmas
 NERS 571 Intermediate Plasma Physics I
 NERS 572 / Appl Phys 672 Intermediate Plasma Physics II
 NERS 576 Charged Particle Accelerators and Beams

Circuits, Microsystems and MEMS

EECS 413 Monolithic Amplifier Circuits
 EECS 414 Introduction to MEMS
 EECS 421 Properties of Transistors
 EECS 425 Integrated Microsystems Laboratory
 EECS 514 Advanced MEMS Devices and Technologies
 EECS 515 Integrated Microsystems
 EECS 522 Analog Integrated Circuits (RFIC)
 EECS 598 Special Topics in Electrical Engineering and Computer Science

ME 420 Fluid Mechanics II
 ME 541 Mechanical Vibration
 ME 553 MEMS (need to see overlap with 4xx and 5xx)
 ME 559 Smart Materials and Structures
 ME 560 Modeling of Dynamic Systems

Wireless Communications and Remote-Sensing Related Courses

EECS 451 Digital Signal Processing and Analysis
 EECS 452 Digital Signal Processing Design Laboratory
 EECS 455 Digital Communication Signals and Systems
 EECS 501 Probability and Random Processes
 EECS 502 Stochastic Processes
 EECS 550 Information Theory
 EECS 551 Mathematical Methods for Signal Processing
 EECS 554 Introduction to Digital Communication and Coding
 EECS 555 Digital Communication Theory
 EECS 556 Image Processing
 EECS 559 Advanced Signal Processing
 EECS 564 Estimation, Filtering, and Detection

Biomedical Engineering and Biosystems

BiomedE 434 Microbiology for Engineers
 BiomedE 495 Introduction to Bioengineering
 BiomedE 518 Engineering Fund. In Biological Systems
 BiomedE 525 Cellular and Molecular Networks
 BiomedE 583 Biocompatibility of Materials

EECS 458 Biomedical Instrumentation and Design
 EECS 516 Medical Imaging Systems

Material Science and Engineering

MSE 501 Structure and Proc. Of Electrical Materials

Fundamental Science (Physics, Biology, Chemistry)

Any course at the 400-level and above in the above areas, with the approval of the program advisor.

Circuits and Microsystems***Master's Degree:***

At least three courses from the following groups, including at least two courses at the 500 level or above.

Ph.D. Degree:

Recommended for all in the Ph.D. program: Tech Com 610 (Thesis Writing)

For QUALIFICATION: At least four courses from the following groups, including at least three courses at the 500 level or above.

For CANDIDACY: At least six courses from the following groups, including **four** at the 500 level or above.

GROUPS:

Digital Circuits/VLSI: EECS 427, 478, 523, 627

Analog Circuits: EECS 411, 413, 430, 511, 522, 525

Microfabrication Technology: EECS 421, 423, 425, 512, 513, 517, 523, 528, 414, 514,515

MEMS: EECS 425, 503, 414, 509, 514,515,830 ME 553, Non-EECS Courses (See list below)

EECS Courses

EECS 411 (4) (I)	Microwave Circuits I
EECS 413 (4) (II)	Monolithic Amplifier Circuits
EECS 414 (4) (I)	Introduction to MEMS
EECS 421 (3) (I)	Properties of Transistors
EECS 423 (4) (I)	Solid-State Device Laboratory
EECS 425 (4) (II)	Integrated Microsystems Lab.
EECS 427 (4) (I,II)	VLSI Design I
EECS 430 (4) (II)	Radiowave Propagation and Link Design
EECS 478 (4) (I,II)	Logic Circuit Synthesis and Optimization
EECS 503 (3) (I)	Introduction to Numerical Electromagnetics
EECS 509 (3) (IIEY)	BioMEMS
EECS 511 (4) (II)	Integrated Analog/Digital Interface Circuits
EECS 512 (3) (I)	Amorphous and Microcrystalline Semiconductor Thin Films
EECS 513 (3) (II)	Flat Panel Displays
EECS 514 (4) (II)	Advanced MEMS and Device Technologies
EECS 515 (4) (I)	Integrated Microsystems
EECS 517 (3) (II,EY)	Physical Processes in Plasmas
EECS 522 (4) (II)	Analog Integrated Circuits (for RF communications)
EECS 523 (4) (I)	Digital Integrated Tech.
EECS 525 (3) (I)	Advanced Solid State Microwave Circuits
EECS 528 (3) (II)	Principles of Microelectronics Process Technology Circuits
EECS 627 (4) (II)	VLSI Design II

Non-EECS Courses

The following courses can be applied towards the MEMS group courses. Courses other than those listed below can also be taken upon approval of program advisor.

Aerospace Engineering

Aero 414	Structural Mechanics
Aero 420	Aerodynamics I
Aero 416	Theory of Plates and Shells
Aero 510	Finite Elements in Mechanical and Structural Analysis I
Aero 511	Finite Elements in Mechanical and Structural Analysis II

Applied Mechanics

AM 412 (ME 412)	Advanced Strength of Materials
AM 440 (ME 440)	Intermed. Dynamics and Vibration
AM 505 (ME 505)	Finite Element Methods in Mechanical Eng. and Applied Mechanics
AM 541 (ME 541)	Mechanical Vibrations

Biomedical Engineering

BiomedE 410	Biomedical Materials Considerations (MSE 410)
BiomedE 420	Introduction to Biomechanics
BiomedE 434	Microbiology for Engineers
BiomedE 456	Biomechanics (AM 456) (ME 456)
BiomedE 495	Introduction to Bioengineering (AM 495)
BiomedE 518	Engineering Fundamentals in Biological Systems (ChE 518)
BiomedE 525	Cellular and Molecular Networks (Microb 525)

BiomedE 583 Biocompatibility of Materials
(ChE 583)(MSE 583)

Chemical Engineering

ChE 412 Polymeric Materials
(MacroSE 412) (MSE 412)
ChE 414 Applied Polymer Processing
(MacroSE 414)(Mfg 414)(MSE 414)
ChE 511 Rheology of Polymeric Materials
(MacroSE 511)(MSE 511)
ChE 542 Intermediate Transport Phenomena
ChE 548 Electrochemical Engineering

Materials Science and Engineering

MSE 501 Structure and Proc. of Electrical Mat.

MSE 562 Electron Microscopy I

Mechanical Engineering and Applied Mechanics

ME 420 Fluid Mechanics II
ME 541 Mechanical Vibration
(AM541)
ME 553 Microelectromechanical Systems
(Mfg 553)
ME 559 Smart Materials and Structures
ME 560 Modeling Dynamic Systems
ME 583 Sensing and Modeling for
Manufacturing Control
(Mfg 583)

Optics and Photonics

Master's Degree

Major: At least three courses from the list below, with two or more courses at the 500 level or above.

Ph.D. Degree:

Major

For QUALIFICATION: EECS 537 and 538; plus at least two courses from the list below with at least one of these two courses at the 500 level or above.

For CANDIDACY: EECS 537, 538 and 539; plus at least two courses from the list below with at least one of these two courses at the 500 level or above.

EECS 434 (4) (I)	Principles of Photonics	EECS 538 (3) (I)	Optical Waves in Crystals
EECS 435 (3) (I,OY)	Fourier Optics	EECS 539 (3) (II)	Lasers
EECS 438 (4) (II)	Adv. Lasers and Optics Lab.	EECS 540 (3) (II)	Applied Quantum Mechanics I
EECS 530 (3) (I)	Electromagnetic Theory I	EECS 546 (3) (II)	Ultrafast Optics
EECS 535 (3) (II,OY)	Optical Information Processing	EECS 552 (3) (II)	Fiber Optical Communication
EECS 536 (3) (I,EY)	Classical Statistical Optics	EECS 634 (3) (I)	Nonlinear Optics
EECS 537 (3) (I)	Classical Optics	EECS 638 (3) (II,EY)	Quantum Theory of Light

Solid-State

Master's Degree:

Major: Three courses from the following groups, including at least one course at the 500 level or above from two groups, at least one course from each group, and not more than one two-hour laboratory course (EECS 528 cannot be used to satisfy both Theory and S-S Tech./Circuits):

GROUPS:

- Solid-State Theory: EECS 420, 517, 520, 528, 540
- Solid-State Technology/Circuits: EECS 423, 425, 513, 517, 523, 525, 528
- Solid-State Devices: EECS 421, 429, 434, 512, 521, 529, 552

Ph.D. Degree:

Major

For QUALIFICATION: Four courses from the following groups, including at least one course from each group, three courses at the 500 level or above from at least two groups, and not more than one laboratory course:

For CANDIDACY: Six courses from the following groups, including at least one course at the 500 level or above from each group, and not more than one laboratory course (EECS 528 cannot be used to satisfy both Theory and Technology/Circuits):

GROUPS:

- Solid-State Theory: EECS 420, 517, 520, 528, 540, 541
- Solid-State Technology/Circuits: EECS 423, 425, 513, 517, 523, 525, 528
- Solid-State Devices: EECS 421, 429, 434, 512, 521, 529, 552

EECS 420 (4) (I)	Phys. Princ. Underlying Smart Dev.		
EECS 421 (3) (I)	Properties of Transistors	EECS	EECS 523 (4) (I) Dig. Int. Tech.
EECS 423 (4) (I)	Solid-State Devices Laboratory		EECS 525 (3) (I) Advanced Solid State
EECS 425 (3) (II)	Integrated Microsystems Laboratory		Microwave Circuits
EECS 429 (4) (II)	Semiconductor Optoelectronic Dev.	EECS	528 (3) (II) Princ. of Microelectronics
EECS 434 (4) (I)	Principles of Photonics		Process Technology
EECS 512 (3) (I)	Amorphous and	EECS	529 (3) Semiconductor Lasers and
	Microcrystalline Semiconductor	(I,AY)	LEDs
	Thin-Film Devices	EECS	534 (4) Design and Characterization
EECS 513 (3) (II)	Flat Panel Displays	(I,OY)	of Microwave Devices and
EECS 517 (3) (II,EY)	Physical Processes in Plasma		Monolithic Circuits
EECS 520 (4) (II,OY)	Electronic and Optical Properties	EECS	540 (3) (I) Appl. Quantum Mechanics
	Of Semiconductors	EECS	552 (3) (II,OY) Fiber Optical
EECS EECS521 (3) (II)	High-Speed Transistors		Communications

VLSI

Master's Degree:

Major: EECS 427; 470 or 478; 511 or 522 or 523; 627 (4 courses total). A total of at least three 500 level or above (at least 12 credits) courses must be taken in EECS.

Ph.D. Degree:

For QUALIFICATION: EECS 427; 470 or 478; 511 or 522 or 523; 627 (4 courses total).

For CANDIDACY: EECS 427; 470; 478; 511 or 522 or 523; 627; and one additional 500 level or above course from the kernel or recommended lists, below. At least four 500 level or above EECS courses total. Students are encouraged to take additional courses from the Recommended Courses listed below.

Kernel Courses

EECS 413 (4) (II)	Monolithic Amplifier Circuits
EECS 423 (4) (I)	Solid-State Devices Laboratory
EECS 425 (3) (II)	Integrated Microsystems Laboratory
EECS 427 (4) (I,II)	VLSI Design I
EECS 470 (4) (I,II)	Computer Architecture
EECS 478 (4) (I,II)	Logic Circuit Syntheses and Optimization
EECS 511 (4) (II)	Integrated Analog/Digital Interface Circuits
EECS 522 (4) (II)	Analog Integrated Circuits
EECS 523 (4) (I)	Digital Integrated Technology
EECS 527 (3) (II)	Layout Synthesis and Optimization
EECS 578 (3) (II)	Computer-Aided Design Verification of Digital Systems
EECS 579 (3) (I)	Digital System Testing
EECS 627 (4) (II)	VLSI Design II

Other Recommended Courses

VLSI: EECS 411, 525, 526

Solid-State: EECS 420, 421, 514, 515, 520, 521, 528, 540, 541

CAD/Software: EECS 477, 481, 482, 483, 574, 575, 581, 582, 583, 586

Architecture/Testing: EECS 570, 571, 573, 670

14. APPENDIX B: Courses Assoc. with the EE Graduate Program

(Not Acceptable for Cognates for EE Division Students)

EECS 411	Microwave Circuits I	EECS 528	Principles of Microelectronics Process Technology
EECS 413	Monolithic Amplifier Circuits	EECS 529	Semiconductor Lasers and LEDs
EECS 420	Physical Principles Underlying Smart Dev.	EECS 530	Electromagnetic Theory I
EECS 421	Properties of Transistors	EECS 531	Antenna Theory and Design
EECS 423	Solid-State Devices Laboratory	EECS 532	Microwave Remote Sensing I: Radiometry
EECS 425	Integrated Microsystems Laboratory	EECS 533	Microwave Measurements Laboratory
EECS 427	VLSI Design I	EECS 535	Optical Information Processing
EECS 429	Semiconductor Optoelectronic Devices	EECS 536	Classical Statistical Optics
EECS 430	Radiowave Propagation and Link Design	EECS 537	Classical Optics
EECS 434	Principles of Photonics	EECS 538	Optical Waves in Crystals
EECS 435	Fourier Optics	EECS 539	Lasers
EECS 503	Introduction to Numerical Electromagnetics	EECS 540	Applied Quantum Mechanics I
EECS 511	Integratd Analog/Digital Interface Circuits	EECS 541	Applied Quantum Mechanics II
EECS 512	Amorphous and Microcrystalline Semiconductor Thin-Film Devices	EECS 546	Ultrafast Optics
EECS 513	Flat Panel Displays	EECS 552	Fiber Optical Communications
EECS 514	Advanced MEMS Devices and Technology	EECS 627	VLSI Design II
EECS 515	Integrated Microsystems	EECS 631	Electromagnetic Scattering
EECS 517	Physical Processes in Plasmas	EECS 632	Microwave Remote Sensing II: Radar
EECS 519	Plasma Generation and Diagnostics Laboratory	EECS 633	Numerical Methods in Electromagnetics
EECS 520	Electronic and Optical Properties Of Semiconductors	EECS 634	Nonlinear Optics
EECS 521	High-Speed Transistors	EECS 638	Quantum Theory of Light
EECS 522	Analog Integrated Circuits	EECS 720	Special Topics in Solid-State Devices, Integrated Circuits and Physical Electronics
EECS 523	Digital Integrated Technology	EECS 730	Special Topics in Electromagnetics
EECS 525	Advanced Solid-State Microwave Circuits	EECS 731	Space Terahertz Technology and Applications
EECS 527	Layout Synthesis and Optimization	EECS 735	Special Topics In Optical Science
		EECS 820	Seminar in Solid-State Electronics

15. APPENDIX C: Courses Assoc. with the EES Graduate Program

(Acceptable for Cognates for EE Division Students)

EECS 401	Probabilistic Methods in Engineering	EECS 558	Stochastic Control
EECS 417	Electrical Biophysics	EECS 559	Advanced Signal Processing
EECS 451	Digital Signal Processing and Analysis	EECS 560	Linear System Theory
EECS 452	Digital Signal Processing Design Laboratory	EECS 561	Design of Digital Control Systems
EECS 455	Digital Communication Signals and Systems	EECS 562	Nonlinear Systems and Control
EECS 458	Biomedical Instrumentation and Design	EECS 564	Estimation, Filtering, and Detection
EECS 460	Control Systems Analysis and Design	EECS 565	Linear Feedback Control Systems
EECS 500	Tutorial Lecture Series in System Science	EECS 567	Introduction to Robotics: Theory and Practice
EECS 501	Probability and Random Processes	EECS 600	Function Space Methods in System Theory
EECS 502	Stochastic Processes	EECS 650	Channel Coding Theory
EECS 516	Medical Imaging Systems	EECS 651	Source Coding Theory
EECS 550	Information Theory	EECS 661	Discrete Event Systems
EECS 551	Mathematical Methods for Signal Processing	EECS 700	Special Topics in System Theory
EECS 554	Introduction to Digital Communication and Coding	EECS 750	Special Topics in Communication and Information Theory
EECS 555	Digital Communication Theory	EECS 755	Special Topics in Signal Processing
EECS 556	Image Processing	EECS 760	Special Topics in Control Theory
EECS 557	Communication Networks	EECS 765	Special Topics in Stochastic Systems and Control

16. APPENDIX D: Courses Assoc. with the CSE Graduate Program

(Acceptable for Cognates for EE Division Students if not VLSI Kernel Area)

EECS 427 VLSI Design I
EECS 442 Computer Vision
EECS 470 Computer Architecture
EECS 477 Introduction to Algorithms
EECS 478 Logic Circuit Synthesis and Optimization
EECS 480 Logic and Formal Verification
EECS 481 Software Engineering
EECS 482 Introduction to Operating System
EECS 483 Compiler Construction
EECS 484 Database Management Systems
EECS 485 Web Database and Information Systems
EECS 487 Interactive Computer Graphics
EECS 489 Computer Networks
EECS 492 Introduction to Artificial Intelligence
EECS 493 User Interface Development
EECS 497 EECS Major Design Projects
EECS 527 Layout Synthesis and Optimization
EECS 542 Vision Processing
EECS 543 Knowledge-Based Systems
EECS 545 Machine Learning
EECS 547 Electronic Commerce
EECS 557 Communication Networks
EECS 567 Introduction to Robotics: Theory and Practice
EECS 570 Parallel Computer Architecture
EECS 571 Principles of Real-Time Computing
EECS 574 Computational Complexity
EECS 575 Advanced Cryptography
EECS 579 Digital System Testing
EECS 580 Advanced Computer Graphics
EECS 581 Software Engineering Tools
EECS 582 Advanced Operating Systems
EECS 583 Advanced Compilers
EECS 584 Advanced Database Systems
EECS 586 Design and Analysis of Algorithms
EECS 587 Parallel Computing
EECS 589 Advanced Computer Networks
EECS 592 Advanced Artificial Intelligence
EECS 594 Introduction to Adaptive Systems
EECS 595 Natural Language Processing
EECS 627 VLSI Design II
EECS 661 Discrete Event Systems
EECS 670 Special Topics in Computer Architecture
EECS 682 Special Topics in Software Systems
EECS 695 Neural Models and Psychological Processes
EECS 767 Advanced Natural Language Processing and Information Retrieval
EECS 770 Special Topics in Computer Systems
EECS 892 Seminar in Artificial Intelligence