Department of Electrical and Computer Engineering

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ECE Graduate Handbook

Containing information pertinent to the rules and the requirements for obtaining Masters and Doctoral degrees in the graduate program as established by the Department of Electrical and Computer Engineering

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I. General Information for All ECE Graduate Students

A. Sources of Important Information

This handbook provides information that is crucial to ECE graduate students as they proceed toward completing their degree requirements. ***It is expected that all students in the ECE department have read this handbook and are familiar with its contents.***

Information is also available on the ECE Department's Graduate Programs Web Page: http://www.binghamton.edu/ece/grad/current/current.html.

Another important source of information is the ***Graduate Student Handbook for the Watson School of Engineering and Applied Science*** – it provides details on rules and procedures that are common among the departments within the Watson School. For example, it contains information about full-time status, course registration procedures, grades and academic policies, etc. There is a link to it on the ECE Department web page (http://www.binghamton.edu/ece/grad/current/current.html).

The rules of the Graduate School can be found in the ***Graduate School Manual***, which can be found at http://www2.binghamton.edu/grad-school/resources/policies-procedures/manual/index.html
This is where you look for the high-level rules that cover all graduate students: registration, graduation, etc.

B. Graduate Degrees in Electrical Engineering

The Department of Electrical and Computer Engineering currently offers opportunities leading to the following graduate degrees:

1. The *Master of Science in Electrical and Computer Engineering* (MSEE).

2. The *Doctor of Philosophy* (PhD) in Electrical and Computer Engineering.

(Note: We had formerly offered a *Masters of Engineering* (MEng) in Electrical and Computer Engineering Degree Program), but admissions to that program were suspended in Sept. 2015. If you are currently in that program and have a question, please see the Graduate Director).

Information for students in each of these programs is included below.

C. Graduate Courses in Electrical and Computer Engineering

The Electrical and Computer Engineering (ECE) Department offers a range of graduate courses that cover major areas within the discipline. See the "Tentative Plan of Future Graduate Course Offerings" list (available on the ECE Dept Website) for a current listing of courses and when they are likely to be offered. Note that: (i) a relatively small portion of the total course list is offered each academic semester; (ii) courses are usually offered once a year (either Fall or Spring Semesters), or once every two years either on even or odd years); (iii) courses are offered in accordance with the availability of full-time or adjunct faculty with expertise in the field; (iv) additional courses are offered when there is a perceived need, and the requisite minimum enrollment (typically ten or more students) is satisfied. A small number of graduate courses may be offered during the Summer, but this is not common.

Course Numbering Scheme

Graduate courses at the Masters and PhD level are labeled in the 500s or 600s; those labeled in the 600s are more advanced graduate courses and typically have a 500-level course as a prerequisite. Courses numbered 590 – 599 and 690 – 699 are special courses that are discussed below. To a large degree, the center digit of a course indicates the specialization area in which the course falls (see list of specialization areas below), although there is some overlap between areas.

Graduate Courses Cross-Listed With Undergraduate Courses

Some of the 500 level courses are cross-listed with numbers in the 400s. These cross-listed courses require graduate students to complete additional work beyond that required of the undergraduates. *The following restrictions apply to cross-listed courses*:

- they may not be counted if the student has taken a similar course as an undergraduate;
- they may not be counted after taking a course that has the cross-listed course as a prerequisite.

EngiNet Distance Learning Courses

Although most of the graduate courses are taught as conventional on-campus classes, some are offered through *EngiNet*, where on-campus students meet in a video classroom, which facilitates delivery of these courses to distance learners. A handbook explaining *EngiNet* is available from the *EngiNet* office (800-478-0718 or 607-777-4965).

Transfer Courses

A maximum of two courses taken by a graduate student outside Binghamton University may be accepted as valid transfer courses into the Masters programs. Transfer courses require approval by the ECE Graduate Director and the Graduate School. Transfer of courses for PhD students is not applicable since the requirement for the PhD is to complete 24 residency credits at Binghamton University.

D. Special Course Types in the ECE Department

EECE 597 & 697 Independent Study

A graduate course which deserves special mention is the *Independent Study*, labeled as EECE 597 at the Masters level and EECE 697 at the PhD level. The independent study is a course with variable credit, which is available every semester. The arrangement for an independent study consists of a mutual agreement between a professor and a student whereby the professor supervises a study undertaken by the student for the equivalent of 1, 2, or 3 credits. Independent studies of 3 credits are considered the equivalent of a regular graduate course, and are expected to entail an equivalent amount of work. A 3-credit independent study fulfills an elective course in the Masters requirements. In some cases, an independent study may be the result of an otherwise canceled regular course (due to lack of enrollment, for instance) being taught by the instructor as an "independent study" to a small number of students. In all cases, registration for an independent study requires filling out special "**Watson School Independent Study Course Registration Form**" form in addition to a "**Independent Study Agreement**" form (available in the Department Office and on the ECE Graduate web site), which describes the independent study and how it will be graded. The necessary approvals must be obtained on both forms.

EECE 598 Masters Project

This variable-credit course, labeled EECE 598, is required of MSEE students who choose the Project option. For project completion, a minimum of 3 credits is required. Other special provisions pertinent to this course are described later in this document.

EECE 599 Research Thesis

This variable-credit course, labeled EECE 599, is required of all Masters students pursuing an MSECE with thesis option. For completion, a minimum of 6 credits is required. The details of the course may be found in the University Bulletin. Other provisions pertinent to this course are described later in this document.

EECE 698 & 699 Dissertation

These variable-credit courses, labeled EECE 698 and EECE 699, are required for research in preparation of the PhD dissertation. Students register for EECE 698 before admission to candidacy and EECE 699 after admission. Further details are given later in this document.

EECE 700 Continuous Registration

This 1-credit course, labeled as EECE 700, is offered Fall and Spring semesters, and is available to graduate students who have otherwise completed their course requirements but need to maintain their matriculated status. ***In the event that such status is not maintained, the student must reapply for admission and adopt the newest degree requirements.***

EECE 701 Practicum for Research and Teaching Assistants

This is a variable-credit course, labeled EECE 701, is open to all funded graduate students involved in research and/or teaching under the supervision of a faculty advisor.

E. Financial Aid

For detailed information regarding financial aid, students should consult the University Bulletin, and visit the Binghamton University web site at http://www2.binghamton.edu/grad-school/cost-aid-funding/financial-support/. In addition to University-wide scholarships and fellowships, the Department of Electrical and Computer Engineering also offers a small number of teaching assistantships (TAs) to eligible graduate students. Individual faculty members in the program with available research funds may also offer research project assistantships (RPAs) to students on a highly competitive basis.

Teaching Assistantships

A limited number of assistantships are available for graduate students who qualify for them on a competitive basis. The teaching assistantships typically consist of a stipend along with a tuition waiver. The duties of a teaching assistant may include a combination of laboratory instruction, grading, proctoring, conducting discussion sections, giving tutorials, and other activities as considered appropriate by the instructor of the course to which a TA is assigned. TA positions are awarded after a review of applicants based on the following criteria:

(i) Outstanding undergraduate record
(ii) Binghamton GPA
(iii) GRE score
(iv) Domestic applicants
(v) PhD applicants
(vi) Fit of background to existing research

Note that a TA appointment is not indefinitely renewable; typically, the program will support a Masters student with a TA for up to one academic year. In special cases, PhD students may receive a TA award for two academic years. Maintaining a TA appointment requires maintaining an excellent academic record after an award has been made. *It must be noted that as a rule new international students are not considered for TA positions, although a few offers are made to truly exceptional new international students. After an international student has demonstrated their ability during their first semester, receiving a TA appointment in subsequent semesters is more likely.*

Research Assistantships

Note that the Electrical and Computer Engineering Department does not play any role in the RPA selection process. An RPA is selected by an individual faculty member with available funds. To inquire about and apply for an RPA appointment, an applicant must establish individual contact with a faculty member directly. The availability of research project assistantships (RPAs) is dependent on research funds individual faculty may have via research grants and contracts. Since faculty are generally anxious to find talented graduate students to work on research projects, any research funding available to a faculty member is likely to be quickly allocated to a suitable applicant. Promptness is therefore of the essence to ensure success. A potential applicant may first wish to browse the Department's web page; it has much information about general research areas in the department as well as individual faculty research interests. There are videos on our web page that describe many of the professors' research interests. Most faculty have links to their personal web pages with detailed descriptions of their research and publications. Browsing a professor's web page will familiarize a student with the faculty research interests, and enable him/her to decide if there is a match of interest. The student may thereafter correspond (by email or otherwise) with the faculty member directly to inquire if any RPA funding is available. The amount, and terms and conditions for RPA funding are similar to those for TA funding, although the amounts in dollar terms may vary within university guidelines.

The university also has certain tuition scholarships and fellowships for which announcements are made from time to time. Information about these resources may be obtained via the Graduate Admissions Office and the office of the Vice-Provost and Dean of the Graduate School.

F. Advising

Graduate advising within the ECE programs is carried out at the following levels:

(a) For matters pertaining to appropriateness of course structure, interpretation of certain rules (at the Watson and Departmental level), and other structural issues, a student may consult the ECE Graduate Director and/or the Watson School Graduate Coordinator.

(b) For matters pertaining to university rules and policies, a student may consult the Watson Graduate Coordinator, or the University Graduate Office directly.

(c) For matters pertaining to financial aid and scholarships, a student may consult the ECE Department Chair and/or the ECE Graduate Director.

(d) For *all* matters pertaining to graduate research (dissertation, thesis, or project), and associated processes such as selection of coursework and evaluation committees, a student must consult his/her thesis/project advisor. *Note that the thesis/project advisor is the person with whom a student needs to establish a close professional relationship, and interact with frequently.*

G. Graduation Requirements for Degree Completion

Early in the semester in which you are planning to graduate it is essential that you visit the Graduate School's **Degree Completion/Graduation Web Site** at

http://www2.binghamton.edu/grad-school/resources/graduation/index.html

At that site you will find important information about:

- Degree Completion Deadlines… If you miss these deadlines you can't graduate that semester!
- Commencement Information
- Thesis/Dissertation Preparation & Submission Information… These are the requirements you MUST follow to submit your MS thesis or PhD dissertation
    - An MS Thesis or PhD Dissertation must be submitted to and defended in front of your committee
    - The MS project need only be approved by your advisor.

Timing of MS *Thesis* or *PhD Dissertation* Completion: Please note that you must allow ample time ***BEFORE*** the deadlines posted by the graduate school for submission of your thesis/dissertation in order for: (i) your committee to read it, (ii) the thesis/dissertation defense, and (iii) completion of any revisions requested by your committee. Consult early with your advisor regarding his/her timing requirements.

Timing of MS *Project* Completion: Please note that you must allow ample time ***BEFORE*** the deadlines posted by the graduate school for submission of your Recommendation of Degree form in order for your advisor to read and approve your project report… keep in mind that your advisor may require revisions prior to approving the report.

Completion of a graduate degree requires submission of:

(i) Complete the ***Graduate Application for Degree (GAFD)***. Masters degree students must complete this online ***EARLY*** *in the semester in which they plan to graduate* ***(see the Grad School's Deadlines for the date)***. This serves as a declaration of intent to graduate and an application for degree completion. It can be accessed through Grad School's Degree Completion/Graduation Web Site (http://www2.binghamton.edu/grad-school/resources/graduation/graduate-application-for-degree.html). If a student completes the GAFD but fails to graduate, she or he must submit a new GAD during the semester in which they will actually graduate.

(ii) A ***Proposed Course of Study and Graduation Check*** form – only for MS & MEng. It is available in .pdf format via a link on the ECE Graduate Forms web page (http://www.binghamton.edu/ece/resource/resources-current.html#graduate). This form, when completed, will indicate the details of the student's coursework and other associated academic requirements which must all be fulfilled before candidacy for the degree can be finalized. For MS students, this form requires the signature from the thesis or project advisor. For MEng students, this form requires the ECE Graduate Director's signature.

(iii) A ***Recommendation For Award of Degree*** form. This form is available on the ECE Graduate Forms web page (http://www.binghamton.edu/ece/resou999999rce/resources-current.html#graduate). There is one form for Masters degrees and one form for PhD. For MS & PhD students, this form requires the signature from the student's advisor and then the ECE Graduate Director's signature. For MEng students, only the ECE Graduate Director's signature is required.

II. Requirements for Masters Degrees

This section provides details on the Masters degree programs and ***details on requirements for degree completion.***

A. Areas of Specialization for Masters Degrees

The Department of Electrical and Computer Engineering currently has seven areas of specialization, shown in Table 1, where *an **x** in the course number represents any of the digits 0, 1, 2, … 9*.

Students pursuing a specific specialization area should consult with a faculty member in that area for advice on course selection to ensure an effective set of courses to meet the student's professional goals.

Table 1: ECE Degree Areas of Specialization

DSP & Communication	**Computer Architecture and Networks**
EECE 513,520,521,522,523,527,542	EECE 552,553,560,570
EECE 545. 549,580G, 580H, 629,642	EECE 573,575,580E,580F,657
Control Systems	**Information Assurance**
EECE 509X,510,513,515,517,518	EECE 527,560,562,566
EECE 503, 504,616,619,680B	EECE 580F,580X,657
	EECE 658
Physical Electronics & Electro-Optics	**Power & Energy**
EECE 501, 504, 505, 508,516	EECE 502, 503, 504, 508, 509X
EECE 530,532,549	EECE 511X,512X,513, 516
EECE 578X,580J	
VLSI	
EECE 570, 573, 574, 575	

B. Requirements for the MSEE Degree

The University Bulletin at http://bulletin.binghamton.edu/ posts the official current MSEE program requirements. The degree requirements for an individual student are those in effect at the time of the student's matriculation; for these requirements, see the online Bulletin for the year of matriculation. A

student who matriculated under older requirements may elect to adopt the requirements that are in affect for the current Bulletin.

The **MS program** prepares students for development-oriented engineering careers and/or continuation onto doctoral studies by providing:

- Increased depth in an area of specialization
- Expanded breadth in supporting areas
- Focused study of recent advances in your area of specialization

The MS program provides a balance of advanced theory and practical engineering knowledge necessary to prepare its graduates for professional practice and/or for continuation into a PhD program. The program culminates with either a thesis or a project report through which students develop their ability to perform independent investigation of recent advances and present the results in a written document. The typical time for completion is 18 – 24 months of full-time study.

MSEE Program

The student must maintain at least a B average in the following plan of study:

- Specialization Courses:
  - 3 courses in a single area of specialization (see list of areas in Table 1);
  - Only in very special circumstances can EECE 597 Independent Study be used
- Breadth Courses:
  - For *Thesis Option*: 2 ECE Courses in two areas other than specialization
  - For *Project Option*: 2 ECE Courses in at least two areas other than specialization
- Math Methods Course:
  - EECE 506 Mathematical Methods in EE *or*
  - EECE 507 Mathematical Methods in Computer Engineering, *or*
  - Another approved relevant mathematical methods course.
- Electives:
  - For *Thesis Option*: 2 Courses or for *Project Option*: 3 Courses, which may be either ECE courses or from other departments
  - Any regular ECE Graduate Course not used above
  - EECE 597 Independent Study (can be used for both electives)
    - To count toward the degree an Independent Study must be done on a regular grade basis (rather than S/U or P/F).
  - Certain Out-of-Department Graduate Courses (see details below):
    - Other Engineering, Math & Science Departments
    - Business School
- Thesis Option *or* Project Option (See Details Below):
  - EECE 599 Research Thesis (6 credits) *and* successful defense of MS Thesis, *or*
  - EECE 598 Project (3 credits) *and* acceptance of MS Project Report

Thesis vs. Project

The ***thesis option*** consists of 6 credits of thesis research culminating in the writing of and oral defense of a thesis. Students pursuing this option are expected to perform research to answer some open question in their chosen area of specialization. *Some* examples of suitable MS thesis research are: (i) improve an existing method and verify the performance gain, (ii) compare and contrast two or more existing methods and determine which is better, (iii) characterize the performance of an existing method under new conditions.

The ***project option*** consists of 3 credits of study culminating in the writing of a project report. Students pursuing this option are expected to demonstrate the application of knowledge drawn from the

study of recent literature (papers or advanced books). ***Some*** examples of suitable MS project work are: (i) take an existing paper, implement its method and test it, (ii) write a critical survey of a few existing papers in a specific area.

Thesis Option

Masters thesis research is supervised by a full-time ECE faculty member (although in some cases, the primary advisor may be a non-ECE faculty; however, this is relatively rare). Non-ECE faculty may serve as research co-advisors, with a full-time faculty being the other co-advisor. The conduct and completion of the thesis research, and in particular, the defense of the thesis research is supervised by a Thesis Committee, which is chaired by the Thesis Advisor. A Thesis Committee is made up of *at least* three (3) members, including *at least two* (2) full-time ECE faculty. The written thesis is submitted to the committee and is then presented orally during an open seminar; acceptance of the thesis by the committee is required for completion of this degree option. See the Watson School's Graduate Handbook for the requirements on submission of theses. It is required that the thesis acceptable for public disclosure (i.e., made available for University or Department archives, and also be eligible for journal publication); in view of this, thesis work cannot be subject to a non-disclosure agreement.

Project Option

Masters project work is supervised by a full-time ECE faculty member (although in some cases, the primary advisor may be a non-ECE faculty; however, this is relatively rare). Non-ECE faculty may serve as a project co-advisor, with a full-time faculty being the other co-advisor. The written project report is submitted for acceptance to the project advisor(s). It is required that the project report be acceptable for public disclosure (i.e., made available for University or Department archives, and also be eligible for journal publication). In view of this, project work cannot be subject to a non-disclosure agreement.

Advisor

MSECE students should seek to obtain an advisor as soon as possible. Your advisor is the professor who will be guiding your thesis/project work. A student asks a professor in their area of interest if they will serve as their advisor; thus, this is usually done once a student has enrolled in such a professor's class.

Full-Time Status

An MS student who has completed fewer than 24 graduate credits* at Binghamton ***must enroll for 12 graduate credits to maintain full-time status***. Once an MS student has completed at least 24 credits graduate credits* at Binghamton, then they need only enroll in 9 graduate credits to maintain full-time status. However, near the end of their program it is possible (under certain conditions) for an MS student to be "certified" for full-time status despite registering for fewer than 9 credits; this is useful for Immigration and/or loan-deferral purposes. See the section on Full-Time Certification for more details.

* Only courses that have been ***completed*** count towards this 24 credits – grades of Incomplete (I), Failure (F), and Unsatisfactory (U) do not count towards this 24 credits.

Full-Time Status & Immigration Rules

Immigration rules require that international students maintain full-time status. Please be aware that if an international student withdraws from a course without replacing those credits with some other course then they risk being in violation of immigration rules. International student who receive an Incomplete (I) grade may also be at risk of violating immigration rules. International students who are in either of these

two situations must *immediately* see the Office of International Student & Scholar Services http://www.binghamton.edu/isss/for help in these matters.

In some situations there are means to allow international students to Request a Reduced Course Load:

- Due to Academic Difficulty – for one of the following reasons:
  - initial difficulty with the English language
  - initial difficulty with reading requirements
  - unfamiliarity with American teaching methods
  - improper course level placement
- Due to Completion of Study (used only in your last semester)
  - **Warning! This form states: "**A student who registers for less than a full course load because he or she intends to graduate in that semester, and ***then does not graduate, will then be considered to be out of status***. The student risks losing all F-1 benefits, including employment, unless the student's department is able to certify that the student is making satisfactory academic progress towards his or her degree."
  - see also "Certify Full Time"
- Due to Medical Condition

To Request a Reduced Course Load:

(i) *First*, discuss the details of your situation with the ISSS office to ensure that you are eligible,

(ii) *Second*, obtain the correct "Request for Reduced Course Load" from at http://www.binghamton.edu/isss/essential-forms/index.html, and

(iii) *Third*, have your advisor sign the form and return the form to the ISSS office (if you do not yet have an advisor the ECE Graduate Director should sign this).

Full-Time Certification

Immigration rules require that international students maintain full-time status. Domestic students may also desire to maintain full-time status for loan deferral purposes. Full-time certification can be used under certain conditions to allow a student to maintain full-time status at the end of the program.

In order to qualify, students must meet the following criteria:

- International Masters students must be officially course-complete (meaning they ONLY have thesis or project work left and have taken all required non-thesis/project courses).
- Domestic Masters students must be within one academic semester of degree completion, if not already course complete (meaning that they can be certified full time even if they have non-thesis/project courses remaining).
- All students must have completed 24 or more graduate credits in residency.

The ECE Department's form for full-time certification is available on our Graduate Forms page (http://www.binghamton.edu/ece/resource/resources-current.html#graduate).

Note: There is an important distinction between "Full-Time Certification" and "Request for a Reduced Load Due to Completion of Study": (i) the latter has a risk involved if the student does not complete the program that semester but (ii) the former can only be used if the only degree requirements left to complete are thesis/project credits.

Continuous Registration

All students who have been admitted into a degree-granting program must maintain continuous registration each semester for a minimum of 1 credit hour of EECE700. Students who do not maintain registration are severed and may not return unless they reapply for admission, paying a new application fee. Students who are readmitted are required to register and pay for one credit for each semester they have not registered, plus one credit for the semester they re-enter, up to a maximum of four credits. Graduate students are not required to maintain matriculation during the summer unless they intend to complete their final degree requirements during this period. However, students graduating in the summer must be registered for at least 1 credit in one (=any) summer session.

Typical MSECE Course Plan of Study

A typical new full-time MS student will register for 12 credits in each of their first two semesters (see section on Full-Time Status). Keep in mind that not all courses are offered each year (and most are only offered in either Fall or Spring but not both). Thus, careful planning is required to ensure requirements can be met in a timely manner. To aid the student in this planning a "Tentative Plan of Future Graduate Course Offerings" is posted in the Graduate Programs section of the ECE Department web page. It is advisable to take courses in the selected area of specialization early in the course of study so that they can support subsequent thesis/project work. It is also advisable to take breadth course and the ECE math course early in your studies. Leaving Electives and thesis/project till the end allows students maximum flexibility in meeting all degree requirements in a timely fashion.

***Typical MSECE-Thesis Plan* (Based on Fall start)**

Fall Year #1	Spring Year #1	Summer	Fall Year #2
3 cr Specialization	3 cr Specialization	3 cr Thesis*	3 cr Thesis
3 cr Specialization	3 cr Breadth Course		Full-Time Certification**
3 cr EECE 506 or 507	3 cr Elective		
3 cr Breadth Course	3 cr Elective		

* If thesis work is not done in the summer then there are two options: (i) take 3 credits of thesis in Fall Y2 and another 3 cr of thesis in Spring Y2, or (ii) take 6 credits of thesis in Fall Y2 (although this is not recommended).

** Note the FTC can NOT be used if the student takes anything other than Thesis credit.

***Typical MSECE-Project Plan* (Based on Fall start)**

Fall Year #1	Spring Year #1	Summer	Fall Year #2
3 cr Specialization	3 cr Specialization	3 cr Elective*	3 cr Project
3 cr Specialization	3 cr Breadth Course		Full-Time Certification**
3 cr EECE 506 or 507	3 cr Elective Course		
3 cr Breadth Course	3 cr Elective		

* Electives taken in summer are typically Independent Studies. If an elective is not taken in the summer then it would need to be taken in Fall Y2 and the full-time certification form would not be applicable (must be taking *only* thesis/project). However, see discussion above about Request a Reduced Course Load.

** Note the FTC can NOT be used if the student takes anything other than Thesis credit.

A Special Note for Part-Time BAE MSEE Students

For BAE students who completed EECE 592 and EECE 593 (ELDP 1 and 2) the courses are fit into the MSECE degree requirements as follows:

(a) Ordinarily EECE 592 counts as two Electives Courses and EECE 593 fulfils a Breadth Course requirement;

(b) If one or more of the ELDP courses is/are deemed to be in the student's Specialization Area, point this out to the ECE Graduate Director, and provide the necessary evidence so the course can be counted in the Specialization Area;

(c) A full-time ECE faculty member must either serve as the Thesis/Project Advisor for the student, or for a work-related thesis, a full-time ECE faculty must serve as a co-adviser with a non-faculty member at the industry serving as the other co-advisor. The faculty member ensures that the thesis meets the expected rigor for the thesis whereas the industry co-adviser assures the work is the student's contribution, and does the day-to-day advising.

(d) It is required that the thesis or project report be acceptable for public disclosure (i.e., made available for University or Department archives, and also be eligible for journal publication). In view of this, thesis/project work cannot be subject to a non-disclosure agreement.

C. Out-of-Department Electives for MS Degrees

Certain regular courses from outside the ECE department are allowable electives; non-ECEE courses in the range 590-599 and 690-699 are not allowed as ECE electives. Registration in non-ECE courses may be subject to requirements and/or restrictions of the offering department and the ECE department can not ensure that an ECE student will be able to register in these courses – address such registration questions to the offering department. If a non-EECE graduate course has a reasonably equivalent EECE course, then the out-of-department course is not allowed as an ECE elective; see the pre-approved acceptable courses listed below.

The following is a list of non-ECE graduate courses that are acceptable as electives:

Bioengineering:

- All courses except those numbered 590 – 599 and 690 – 699.

Computer Science:

- The following courses are NOT allowed: CS514, CS515, CS522, CS524, CS528, CS558, CS622, CS624, and those numbered 590 – 599 and 690 – 699.
- All other courses are allowed and the following are recommended: CS527, CS529, CS532, CS535, CS552, CS553, CS554, CS557, CS565

Materials Engineering: All courses except those numbered 590 – 599 and 690 – 699.

Mechanical Engineering: All courses except those numbered 590 – 599 and 690 – 699.

System Science: All courses except those numbered 590 – 599 and 690 – 699.

School of Management: MGMT501 – MGMT508, MGMT 530, MGMT560, MIS523, MIS533, MIS586, MIS573

Graduate School: In the past the Graduate School has offered the following two courses (during summer & winter terms) that are acceptable (and encouraged) as electives:

- GRD530 Tools for Research & Scholars
- GRD593 Critical Skills for Graduate Success
- GRD594 Management Fundamentals for Scientists and Engineers
- GRD595 Fundamentals of Budget & Finance

Math & Science: Many courses are acceptable but the student should discuss selection with their advisor or the ECE Graduate Director.

III. Requirements for the PhD Degree

The PhD program meets the need of each student through an individualized learning program. For students who already hold an MS degree in an appropriate field, the PhD program requires a minimum of eight courses beyond the MS degree. For students who wish to pursue a direct-BS-to-PhD (without earning an MS along the way) the PhD program requires a minimum of 14 graduate courses. To meet the residency requirement, students must complete a minimum of 24 credits at Binghamton University.

Limitations on Independent Study Courses for PhD: Because the PhD program is highly individualized and research-focused it is natural that PhD students will want to tailor their studies to their research topic. Thus, PhD students' course of study may be best crafted through use of some number of Independent studies with the following limitations:

In some situations there are means to allow international students to Request a Reduced Course Load:

- For those students who have earned an MS degree (either at BU or elsewhere), all of the subsequent PhD coursework *may* be completed with independent studies if that is acceptable to the student's PhD advisor; however, most students do take some regular courses.
- Students who are pursuing the direct-BS-to-PhD path are limited to no more than four independent study courses (i.e., 12 credits) as part of the minimum of 14 graduate courses required for that path.

Note: To count toward the degree an Independent Study must be done on a regular grade basis (rather than S/U or P/F).

A. Full-Time Status and Continuous Registration

To maintain full-time status a post-MS PhD student must enroll for 9 graduate credits. A new PhD student who has not yet provided the graduate school with an official copy of a transcript showing the award of an MS degree must register for 12 credits to be full-time.

Full-Time Certification

Immigration rules require that international students maintain full-time status. Domestic students may also desire to maintain full-time status for loan deferral purposes. In addition, for PhD students full-time certification can be helpful in reducing the amount of financial support needed from their advisor. Full-time certification can be used under certain conditions to allow a student to maintain full-time status at the end of the program.

In order to qualify, students must meet the following criteria:

- International PhD students must be officially ABD (having completed their comprehensive exam: see III.C)
- Domestic PhD students must be within one academic year of ABD status or already course complete and ABD.
- All students must have completed 24 or more graduate credits in residency.

The ECE Department's form for full-time certification is available on our Graduate Forms page (http://www.binghamton.edu/ece/resource/resources-current.html#graduate).

Once a PhD student has completed all requirements except for defense of and submission of a dissertation only 1 credit of registration is needed for full-time status as long as the full-time certification form has been completed.

Continuous Registration

All students who have been admitted into a degree-granting program must maintain continuous registration each semester (except summer) for a minimum of 1 credit hour of EECE700. Students who do not maintain registration are severed and may not return unless they reapply for admission and pay a new application fee. Students who are readmitted are required to register and pay for one credit for each semester they have not registered, plus one credit for the semester they re-enter, up to a maximum of four credits. Graduate students are not required to maintain matriculation during the summer unless they intend to complete their final degree requirements during this period. But students graduating in the summer must be registered for at least 1 credit in one (=any) summer session.

B. PhD Advisor & Guidance Committee

The PhD student's research advisor is central in directing the student's development. Upon admission to the doctoral program, new students have the ECE Graduate Director as their advisor until an advisor is identified on the PhD Principal Advisor/Guidance Committee Form. As the initial academic advisor, the ECE Graduate Director is responsible for (a) explaining the Watson School regulations governing the doctoral program; (b) assisting the student in establishing a course of study and finding an advisor; and (c) assisting the student in forming a guidance committee. These actions should be completed during the first semester in residence.

As soon as the student finds a faculty member to serve as his/her Principal Advisor, the student and advisor should identify faculty members to serve on the student's guidance committee. Initially, ***the guidance committee must have a minimum of three members with at least two members (including the Principal Advisor) from ECE***. Each of these members is expected to take an active role in supervising the student's development. Members in addition to those mentioned above can be added to enhance the committee.

Only faculty with the formal rank of assistant, associate or full professor in an academic department offering advanced degrees may serve as members of graduate student dissertation committee. The Vice Provost and Dean of the Graduate School may approve exceptions to these restrictions in specific cases. Requests will not be considered without submission of a current curriculum vita and letters of endorsement from the chair or graduate director of the department offering the advanced degree and the dean of the school. Upon such approval, individuals who are not members of the graduate faculty may serve as members, but not as faculty advisors or chairs of graduate student dissertation committee.

When a proposed committee has been identified, the names and signatures are submitted on a Principal Advisor/Guidance Committee Form to the ECE Graduate Director. Once approved by the ECE Graduate Director, the forms are forwarded to the Graduate Coordinator in the Dean's Office. When the

guidance committee is approved, the forms will be placed on file in the Dean's Office. Any subsequent changes made to the membership of the guidance committee must be documented in a new copy of the Principal Advisor/Guidance Committee Form.

C. Steps to Complete a PhD

The major steps in the completion of the PhD program include the following sequence of items (a) through (g), which are described in detail below. Although the presented order is typical, it is not necessary; however, only small deviations from this sequence are possible. A graphical timeline is provided at the end of this section.

(a) Successful completion of a ***qualifying examination***
(b) Satisfactory completion of a ***learning contract***
(c) Demonstration of ***teaching proficiency***
(d) Completion of ***course work***
(e) Successful completion of a ***comprehensive examination***
(f) Advancement to ***Candidacy (also known as "ABD" status)***
(g) Acceptance of ***prospectus*** outlining dissertation research & Presentation of ***colloquium***
(h) Submission of ***Dissertation*** & oral defense of Dissertation

(a) PhD Qualifying Exam: Students are encouraged to attempt this examination as early as possible in their program, preferably within the first three semesters. The qualifying exam is given on the second Friday of the Fall and Spring Semesters. Details on the exam can be found in the appendix of this handbook.

The qualifying exam is used to assess the background of beginning PhD students and identify any areas of weakness that should be addressed early in the PhD program. On the qualifying examination, a student must demonstrate quantitative skills and subject knowledge within key areas of ECE.

Based on a student's Qualifying Exam results the possible recommendations of the Graduate Committee are: (1) satisfactory progress has been demonstrated; (2) the examination should be re-taken (can be taken only two times); (3) the student should withdraw from the PhD program.

(b) Learning Contract: The new doctoral student should start to work immediately (even prior to taking the qualifying exam) with his/her advisor to develop a learning contract. The learning contact should be completed as early as possible in the student's PhD studies. The purpose of the learning contract is to define the knowledge and skills required in order to pass the comprehensive examination. Toward that, the learning contract will identify core courses and concepts, which must be mastered in order to provide breadth of background, as well as specialized courses and concepts that are germane to the proposed area of research. The learning contract may be modified later if additional knowledge is required, or if the field of research is changed. There is a template for the learning contract available at http://www.binghamton.edu/watson/student-services/advising/pdfs/Learning-Contract.pdf.

Once completed, a copy of the learning contract, with signatures indicating approval of the guidance committee, is placed in the student's file in the Dean's Office.

(c) Evidence of Proficiency in Teaching: In addition to the coursework and research, doctoral candidates must demonstrate proficiency in teaching. Doctoral students must meet a teaching requirement in one of the following ways:

(i) Be an instructor of record in an undergraduate course. Note, however, that generally full-time faculty are expected to be the primary instructor of undergraduate courses.
(ii) Completion of a teaching methods course (these are available on-line through the Graduate School) and the teaching of one or more seminars or a portion of a course.

(iii) History of teaching experience comparable to choices (a) or (b) above, approved by the guidance committee.

In this context, it is also important to note that all ECE graduate students are eligible for a *Certificate for College Teaching*, which cites a student's special accomplishments as a teacher/instructor of electrical and computer engineering. Note that this certificate may be especially useful to doctoral students who wish to pursue an academic career. A description of the certificate may be found at: http://gradschool.binghamton.edu/cs/teachcolluniv.asp

(d) Completion of Coursework: For students who already hold an MS degree in an appropriate field, the PhD program requires a minimum of eight courses beyond the MS degree. For students who wish to pursue a direct-BS-to-PhD (without earning an MS along the way) the PhD program requires a minimum of 14 graduate courses. To meet the residency requirement, students must complete a minimum of 24 credits at Binghamton University. See the section titled "Limitations on Independent Study Courses for PhD".

(e) Comprehensive Examination: After completion of the coursework, and before completion of a significant portion of the dissertation research, a student must complete the Comprehensive Examination. This is an individual examination with the responsibility for the content given to the student's guidance committee. The ECE Graduate Director is an ex-officio member of the comprehensive examination to assure uniformity in the level of examinations within the Department. Once the members of the guidance committee have agreed on the examination content and format, it will be clearly explained to the student and the examination date set.

(f) Admission to Candidacy: After successfully completing the comprehensive examination, and any additional requirements such as the development of communication skills, the student can be admitted to candidacy for the doctorate. The Graduate Office is notified of the satisfactory completion of the comprehensive examination and the student's admission to candidacy on the Recommendation for Admission to Candidacy for Doctoral Degree Form. The student has six months from completion of the comprehensive requirement to submit an approved prospectus to the Watson School Graduate Coordinator. ***Note that the candidate is required to defend the dissertation within five years of admission to candidacy.***

(g) Prospectus Submission & Colloquium Presentation: Upon completion of the comprehensive examination and admission to candidacy, the candidate prepares a written prospectus that identifies: (i) the research topic to be undertaken, (ii) the relevance of the results-to-date, and (iii) a proposed approach for completing the dissertation project. The prospectus is presented and defended in an open colloquium. Upon acceptance of the prospectus by the guidance committee, a copy is filed with the Watson School Graduate Coordinator. The written prospectus should conform to IEEE manuscript guidelines, and be at least ten pages in length.

(h) Outside Examiner: An "outside examiner" must be appointed, who serves as the representative of the Graduate School to ensure that the Dissertation Defense is properly conducted in accordance to the rules of the Graduate School. The outside examiner is either a Binghamton faculty member from a related area outside the student's major program, department or division, or someone from a related discipline outside the University; the outside examiner must be tenured and have supervised graduate research as faculty advisor, served on a number of doctoral committees, and served on at least several doctoral defenses prior to appointment as an outside examiner for BU. The ECE Graduate Director makes a request to the Graduate School for the appointment of the outside examiner; the student's advisor should contact the ECE Graduate Director to initiate the appointment of the outside examiner.

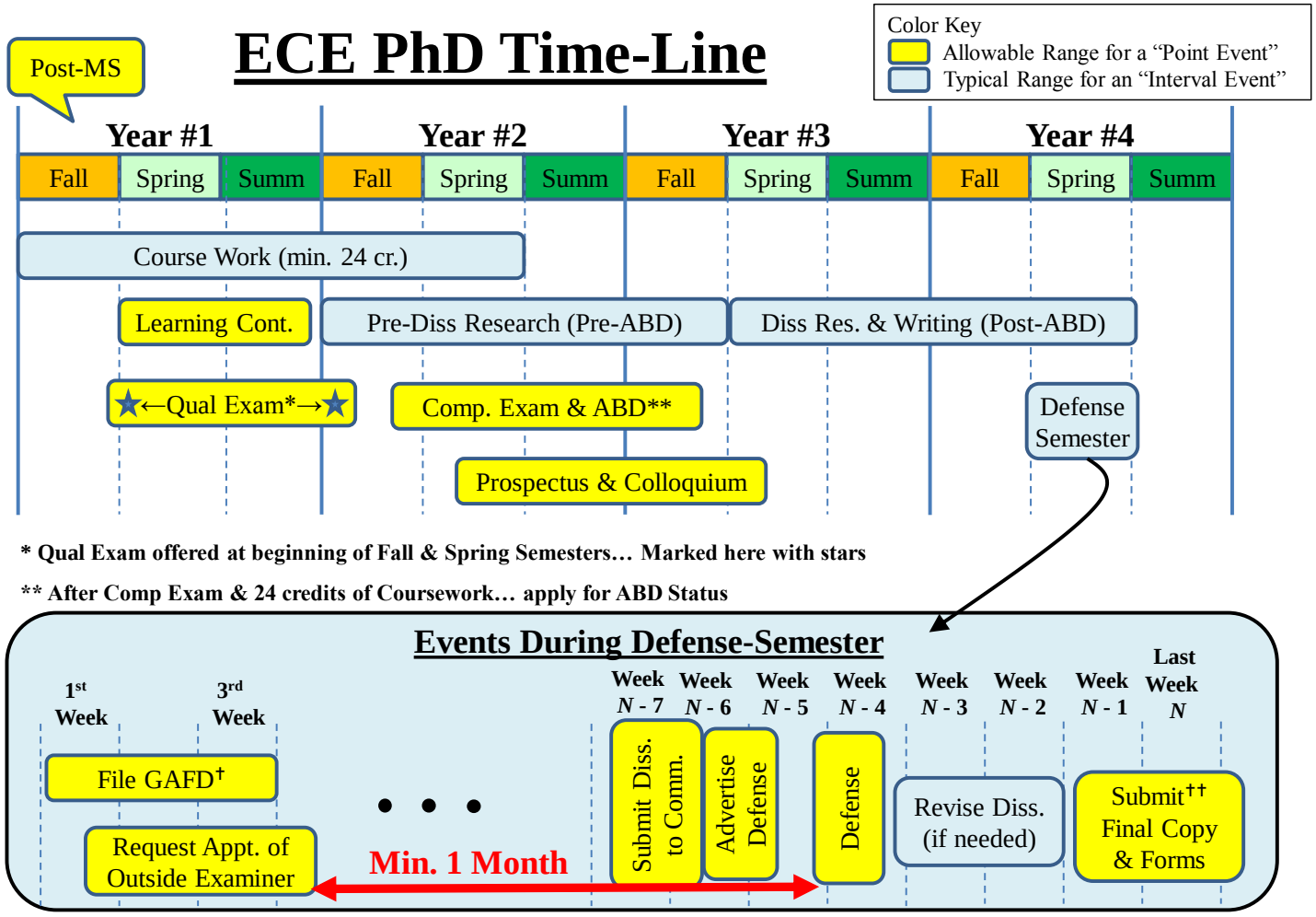
(i) Dissertation and Defense: With the guidance of the dissertation advisor, the student completes the research and prepares a dissertation, which is an original written contribution demonstrating originality and competence in the chosen field of research. The guidance committee has direct charge of all matters pertaining to the dissertation, which must have the committee's unanimous approval before arrangements are made for the final examination for the degree. The dissertation is to comply with the format and filing requirements set forth in the *Graduate School Student Handbook*; please see the following link: http://www2.binghamton.edu/grad-school/new-and-current-students/graduate-school-manual/index.html#thesis-or-dissertation

After distributing the dissertation for review to the guidance committee and the outside examiner, an oral defense of the PhD dissertation is scheduled. The PhD candidate is required to present an oral defense of his/her dissertation in an open colloquium. Upon satisfactory defense of the dissertation, the ECE Graduate Director submits a signed copy of the Recommendation for Award of Doctoral Degree Form to the Graduate Coordinator in the Dean's Office.

Note that before signing the Recommendation for Award of Doctoral Degree Form, the ECE Graduate Director needs to ascertain that all the necessary milestones defined above for the completion of the doctoral degree, including the learning contract, coursework, qualifying and comprehensive examinations, presentation of prospectus, and admission to candidacy have been passed satisfactorily.

After verification of completion of the program of study, the Graduate Coordinator forwards the recommendation form to the Graduate Office. Note that all the forms and other paperwork for the graduate program are available in the Watson School Graduate Advising Office.

ECE PhD Time-Line



*** Qual Exam offered at beginning of Fall & Spring Semesters… Marked here with stars**

**** After Comp Exam & 24 credits of Coursework… apply for ABD Status**

† GAFD = "Graduate Application for Degree" available on Grad School Web Page

†† Check Grad School Web Page for Official Deadlines and Procedures!!!

Appendix: Ph.D. Qualifying Exam Overview

The following outlines the details for the Qualifying Exam:

- The exam is given at the beginning of each semester.
- The exam is 4 hours long.
- The exam consists of 4 questions on math topics (2 CoE-oriented and 2 EE-oriented) as well as 2 questions in each of 8 areas (See below for a list of areas)
- Students are required to complete 2 of the 4 math questions and 4 of 18 other questions
    - The expected scenario is: Student would do 2 from one area and 2 from a second area
    - But student can do any combination as long as they do 4 out of the 18 area questions
- Grading will consist of the following
    - Each answered question is graded on the basis of 10 points
    - Thus, the maximum total achievable is 60 points
    - The ECE Grad. Studies Committee will review graded results and decide Pass/Fail for each student
- Students are allowed 2 attempts to pass
    - If they fail the first time they must retake the entire exam
- Students are allowed to bring:
    - One 8.5”x11” sheet of notes (both sides)
    - A Calculator
    - Reference tables will be provided if needed (e.g., Fourier transforms, etc.)
- Areas of the Exam
    - Mathematics (Required)
    1. Digital Signal Processing
    2. Communications
    3. Controls
    4. Digital Design
    5. Computer Architecture and Networks
    6. Electronics
    7. Semiconductors
    8. Electro-Magnetics/Optics

Details on the topics covered in each area of the exam are provided below.

Topics for Math Area of ECE Ph.D. Qualifying Exam

Below is an outline of the topics that the exam questions could be drawn from. A list is provided of some suggested textbooks suitable for preparing for the exam – there is no single book that the exam will be based on, but each of the suggested books covers all the topics listed.

Some topics are oriented toward computer engineering and some are oriented toward electrical engineering. Any student may prepare for any of the topics.

CoE-Oriented Topics

1. Logic and reasoning
   a. Connectives, Propositional Equivalence, Implication, Rules of Inference, Predicates and Quantifiers, Methods of Proof, Mathematical Induction, Proof Techniques, Recursion
2. Set Theory and Enumeration
   a. Set Operations, Products, Laws, Pigeonhole Principle, Counting Techniques, Binomial Theorem, Permutations, Combinations
3. Probability Theory (See also the EE-Oriented Section)
   a. Discrete Probability, Probability Theory, Conditional Probability, Discrete Random Variables
4. Relations and Functions
   a. Relations, Functions, Composition and Inversion, Zero-One-Matrices, Partial Orders, Hasse Diagrams, Equivalence Relations, Partitions, Lattices
5. Graph Theory
   a. Graphs and Trees, Subgraphs, Paths and Cycles, Shortest Path
6. Modern Algebra
   a. Rings, Modular Arithmetic, Groups

Suggested Books
(not in any particular order)

1. *"Discrete Math and its Applications,"* Rosen, 7th Ed., ISBN-13: 978-0073229720
2. *"Discrete and Combinatorial Mathematics: An Applied Introduction,"* Grimaldi, 5th Ed, ISBN-13: 978-0201726343.

EE-Oriented Topics

1. 1. Linear algebra and matrix theory
   - Vector Space, Norms and Inner Products, Linear Independence, Span, Basis, ON Basis, Matrix Rank, Matrix Inverse, Null Space, Range Space, Solutions of Linear Systems of Equations, Determinants, eigenvectors and eigenvalues.
2. Vector Calculus
   - Cross Product, Vector and Scalar Functions and Fields, Derivatives, Grad, Div, Curl, Theorems of Green, Gauss, and Stokes.
3. Probability Theory (See also the CoE-Oriented Section)
   - Continuous Random Variables, Probability Density Functions, Cumulative Density Functions, Conditional Density Functions, Conditional Probability, Common Continuous RVs (e.g., Gaussian, Chi-Square, Laplacian, etc.), Mean, Variance, Correlation, Covariance, Independence

Suggested Books
(not in any particular order)

1. *"Advanced Engineering Mathematic ,"* Kreyszig, any recent edition should be fine.
2. *"Discrete and Combinatorial Mathematics: An Applied Introduction,"* Grimaldi, 5th Ed, ISBN-13: 978-0201726343.

Topics for Digital Communications Ph.D. Qualifying Exam

Below is an outline of the topics that the exam questions could be drawn from. A list is provided of some suggested textbooks suitable for preparing for the exam – there is no single book that the exam will be based on, but each of the suggested books covers all the topics listed.

Topics

1. Formatting
   a. A/D conversion, noise, bit rate, symbol rate, error probability, BER, PAM signal
2. PCM and baseband modulation
   a. PCM signal and PCM system, binary PCM waveform, line code
   b. M-ary pulse modulation
   c. Baseband transmissions
3. Baseband demodulation
   a. Signal space: basis, projection, vector representation of communication signals
      i. Signal space representation & constellation of binary PAM, M-ary PAM, QPSK
      ii. Noise vector, noisy signal vector, SNR
   b. Matched filter
      i. Conventional design
      ii. Signal space representation
   c. Maximum likelihood detector and BER
      i. Minimum distance detection rule
      ii. Error probability: binary BER, use signal space to analyze error performance
   d. ISI and pulse-shaping
      i. ISI definition, ideal Nyquest filter for zero-ISI
      ii. Pulse-shaping by raised-cosine filter
      iii. Joint modulator/demodulator design, eye pattern
4. Bandpass modulation
   a. PSK signals, properties, modulator, demodulator
   b. QAM signals, properties, modulator, demodulator
   c. FSK signals, properties, modulator, demodulator
   d. Coherent detector, non-coherent detector, error performance
5. Channel coding
   a. Definition of FEC, power efficiency, channel models (BSC & Gaussian channel)
   b. Parity check codes, code rate
   c. Linear block code
      i. Code rate, generator matrix, parity checking matrix
      ii. Syndrome testing, standard array, decoding
      iii. Error detection and error correction capabilities
6. Convolutional code
   a. Code rate and parameters
   b. Trellis representation of convolutional code
   c. Convolutional encoding and decoding by trellis diagram
      i. Viterbi Algorithm
7. Spread spectrum techniques
   a. PN sequence, process gains
   b. Direct sequence spectrum spread systems
   c. Frequency hopping spread spectrum systems

Suggested Books

(not in any particular order – the 1st is the textbook we use, the other two are also good textbooks with introductions to signals, systems, and analog communications)

Digital Communications: Fundamentals and Applications, 2nd Ed., B. Sklar, Prentice Hall.
Communication Systems, 5th Ed., S. Haykin and M. Moher, Wiley.
Fundamentals of Communication Systems, J. Proakis and M. Salehi, Prentice Hall.

Topics for Computer Architecture and Networks Ph.D. Qualifier

Below is an outline of the topics from which the exam questions could be drawn. A list is provided of some suggested textbooks suitable for preparing for the exam. Note that each topic should be understood quantitatively and qualitatively.

Topics (Architecture)

- Performance metrics & Amdahl's Law
- Instruction Set Architectures
    - RISC vs. CISC
    - MIPS instructions & opcodes
    - Branches & jumps
    - Registers and stacks
- Arithmetic for computers
    - Signed/unsigned integers and floating point numbers
    - Binary arithmetic & logical operations
- Processor Datapath
    - Simple MIPS data path
        - Registers, program counters, I-memory, D-memory, ALU
        - Fetch, decode, execute, memory, writeback
- Pipelining
    - Control/pipeline registers
    - Hazards, forwarding, stalls, superscalar, bypass
    - Pipelined MIPS datapath
    - Branch prediction schemes and delay penalty
- Memory Hierarchy
    - Cache basics
        - Tag, data, associativity, multi-level hierarchy, banking
    - Virtual Memory vs. physical memory
        - Pages, TLB, page tables
    - Exclusivity vs. inclusivity, blocking vs. non-blocking
    - Victim caches
- Parallelism
    - Instruction-level parallelism
        - Unrolling, scheduling, scoreboarding, speculation
        - Tomasulo's algorithm
    - Data-level parallelism
        - SIMD, VLIW, vector architectures
    - Thread-level parallelism
        - Simultaneous multi-threading
        - Shared memory; distributed memory
        - Cache coherence protocols and state machines
        - Directory vs. Snoop-based coherence
        - Memory consistency
- I/O and peripherals
    - DMA, memory controllers, interrupts

Topics (Networking)

- Foundation
    - Layering and protocols
    - Performance evaluation
        - Bandwidth and latency
        - Delay x bandwidth product
- Data Link Layer

    - Encoding (NRZ, NRZI, Manchester, 4B/5B)
    - Framing techniques (Byte-oriented, Bit-oriented, clock-based)
    - Error Detection (Two-dimensional parity, checksum, CRC)
    - Reliable transmission (Stop-and-Wait, Sliding window)
    - CSMA/CD, CSMA/CA
- Internetworking
    - Switching/Bridging (Virtual Circuit Switching, Source Routing, Learning Bridge, Spanning Trees Algorithm)
    - IP (IPv4/IPv6 packet format, Fragmentation, Addresses, Subnetting, CIDR, ARP, DHCP)
    - Routing (Distance-Vector, Link State, Inter-Domain Routing)
    - Routing fabric (Crossbar, Banyan network)
    - Multicast (addresses, DVMRP, PIM, MSDP)
- End-to-End Protocols
    - UDP/TCP protocols (end-to-end issues, segment format)
    - TCP Connection establishment and termination (three-way handshake)
    - Sliding window, Adaptive retransmission (Karn/Partridge Algorithm)
- Congestion Control and Resource Allocation
    - Resource allocation (Fair Resource Allocation)
    - Queuing disciplines (FIFO, Fair Queuing, Weighted Fair Queuing)
    - TCP congestion control (AIMD, Slow Start, Fast Retransmit, Fast Recovery)
    - Congestion-Avoidance mechanisms (DECbit, RED, Source based congestion avoidance)
    - Quality of Service (QoS) (RSVP, Differentiated Services)
- Network Security Basic
    - Principles of Ciphers (Symmetric key ciphers, PKI, Key management)
    - Authentication (Kerberos, KDC, Diffie-Hellman Key Management)
    - SSH, TLS, SSL, IPSec
- Applications
    - Traditional protocols (SMTP, HTTP)
    - DNS
    - Overlay networks (Routing, Peer-to-Peer networks, Gnutella, Chord)

Recommended Books

- *Computer Organization & Design: The Hardware/Software Interface*, D.A. Patterson and J. L. Hennessy, **Morgan Kaufmann**
- *Computer Architecture: A Quantitative Approach*, J. L. Hennessy and D. A. Patterson, **Morgan Kaufmann**

Topics for Controls Ph.D. Qualifying Exam

Below is an outline of the topics that the exam questions could be drawn from. A list is provided of some suggested textbooks suitable for preparing for the exam. Since the material is standard, other similar textbooks can be used for this purpose as well.

Topics

1. Mathematical models of dynamic systems
   a. Modeling by first principle of electrical systems, simple mechanical and electro-mechanical systems
   b. Linear approximations of system models
   c. Conversion among common representations of linear systems (transfer functions, differential equations, state-space models, block diagram models)
2. Stability of linear feedback systems
   a. Concept of stability
   b. Stability tests using Routh-Hurwitz criterion, Bode plots, Nyquist criterion, state-space method
   c. Relative stability tests using root locus plot, Bode plots, Nyquist plot
3. Characteristics and performance of feedback control systems
   a. Sensitivity reduction, disturbance rejection, and tracking
   b. Transient and steady-state performance defined through step responses, especially through dominant 2^{nd} order systems
   c. Transient and steady-state performance of control systems
4. Design of feedback control systems
   a. Proportional, integral, and derivative control
   b. Phase-lead, -lag, -lead-lag designs using Bode diagram, and root-locus
   c. State-space methods
      i. Controllability and state-variable feedback
      ii. Observability and state observer
      iii. Output-feedback using combined state-variable feedback and state observer method
5. Basics in digital control systems
   a. Common methods for discrete-time equivalents of continuous-time models
   b. Sampling rate selection in digital control systems
   c. Stability and performance analysis of digital control systems in discrete-time domain
   d. Design of digital control systems using discrete-time domain methods (counter parts to 4 above)

Suggested Books (not in any particular order)

Modern Control Systems, (any edition), Richard. C. Dorf and Robert H. Bishop, Prentice Hall.
Feedback Control of Dynamic Systems, G. Franklin, J.D. Powell, and A. Emami-Naeini Prentice Hall.
Schaum's Outline of Feedback and Control Systems, (any edition) D. Stefano III, A. Stubberud,, and I. Williams, McGraw-Hill.
Introduction to Automatic Control: Volume I, Volume II, V. A. Skormin, Linus Publications

Topics for Digital Design Ph.D. Qualifier

Below is an outline of the topics from which the exam questions could be drawn. Typical textbooks for undergraduate courses in Digital Design are suitable sources for study. Note that each topic should be understood quantitatively and qualitatively.

Topics

1. Bit representations and Coding;

2. Boolean expressions, Boolean Gates, Boolean Functional

Representation and Expression minimization;

3. Truth Tables and K-Maps;

4. Flip-Flop/latch implementations and system level timing issues;

5. Data Registers;

6. Gated Clocking with and without a latch in the gating circuitry;

7. FIFOs, width and depth expansion;

8. Combinational logic such as adders, subtractors, multiplexers, and ROM;

9. Finite State Machine (FSM) design and analysis, Moore machine, Mealy machine;

10. Basic synchronous and asynchronous logic design and analysis;

11. Basic computer organization and design;

12. Basic VHDL/Verilog.

Topics for Electronics Ph.D. Qualifying Exam

Below is an outline of the topics that the exam questions could be drawn from. A list is provided of some suggested textbooks suitable for preparing for the exam – there is no single book that the exam will be based on, but each of the suggested books covers all the topics listed.

Topics

1. Basic Electronic Devices
   a. Diodes
      i. Ideal and non-ideal
      ii. Zener
      iii. Schottky
      iv. Photodiodes
      v. Light-emitting diodes (LEDs)
   b. BJTs
   c. MOSFETs
2. Device Characterization and Modeling
   a. PN junction basics (diodes and BJTs)
   b. I-V relationships (all devices)
   c. Large-signal and small-signal models
   d. Frequency response
3. Simple Amplifiers
   a. Characteristics and modeling
      i. Open-loop gain
      ii. Output range
      iii. Input biasing
      iv. Gain-bandwidth product
   b. Basic topologies
      i. Common-source (common-emitter)
      ii. Common-gate (common-base)
      iii. Common-drain (common-collector)
      iv. Source (emitter) degeneration
      v. Resistor and transistor loads
4. Operational Amplifiers
   a. Characteristics and modeling
      i. Open-loop gain
      ii. Output range
      iii. Input common-mode range
      iv. Gain-bandwidth product
   b. Feedback circuits
      i. Voltage follower
      ii. Inverting and non-inverting topologies
      iii. Positive and negative feedback
   c. Effects of non-idealities, such as finite gain

Suggested Books (in no particular order)

Microelectronic Circuits, A. S. Sedra and K. C. Smith, Oxford University Press.
Microelectronic Circuit Design, R. C. Jaeger, T. Blalock, and J. G. Tront, McGraw Hill.
Microelectronics Circuit Analysis and Design, D. A. Neamen, McGraw Hill.

Topics for Electromagnetics/Optics Ph.D. Qualifying Exam

Below is an outline of the topics that the exam questions could be drawn from. A list is provided of some suggested textbooks suitable for preparing for the exam – there is no single book that the exam will be based on, but each of the suggested books covers some of the topics listed.

Topics

1. Electromagnetic Fields
   a. Electric and Magnetic Fields
   b. Basic Laws of Electromagnetic Theory (Maxwell's equations)
   c. Electromagnetic Spectrum
   d. Electromagnetic Waves
2. Energy Characteristics
   a. Irradiance, Energy Density and Energy
   b. Momentum and Radiation pressure
   c. Blackbody Radiation Model
3. Transmission Lines
   a. Distributed-Parameter Model
   b. Characteristic Impedance, Lossless Lines
   c. Power Transmission
   d. Impedance Matching
4. Electrostatics and Magnetostatics
   a. Electric Field and Charges, Capacitors
   b. Conductors, Dielectrics and Boundary Conditions
   c. Magnetic Fields, Energy, and Inductance
   d. Magnetic Circuits
5. Electromagnetic Wave Propagation
   a. Wave Fronts and Wave Models
   b. Optical Path Length and Optical Path Difference
   c. Reflection and Refraction
6. Interference
   a. Interference by Amplitude Division
   b. Interference by Wave Front Division
   c. Fabry-Perot Cavity
   d. Anti-Reflective Coating
7. Diffraction
   a. Diffraction Orders
   b. Diffraction Limits
   c. Diffraction Gratings
8. Polarization
   a. Types of Polarization
   b. Polarizers and Wave Plates
9. Geometrical Optics
   a. Ray Tracing Analysis
   b. ABCD Formalism

Suggested Books

E. Hecht, *Optics, 4th Edition*. Addison Wesley, 2002. ISBN 0-8053-8566-5.
S. Wentworth, *Applied Electromagnetics: Early Transmission Lines Approach*, Wiley, 2007. ISBN 978-0-470-04257-1.

Topics for Semiconductors and Microelectronics Ph.D. Qualifying Exam

Properties, methods, and understanding of electronics on the solid state electronic level. The topic includes:

1. Fermi levels and quasi-Fermi levels
2. Band Structure and crystal structures
3. P-n junctions
4. Drift current
5. Diffusion current
6. Diode operation
7. Three-terminal devices: field effect transistors and bipoloar junction transistors
8. Interaction of photons with matter: photoelectric effect
9. Optical detectors and solar cells
10. LEDs and lasers
11. Metal semiconductor junctions
12. Fabrication technology

The material is covered in many junior/senior level books on solid state electronics. A good general book covering this material on the appropriate level is
Streetman and Banerjee, *Solid State Electronic Devices, 6th Edition*

Topics for Signal Processing Ph.D. Qualifying Exam

Below is an outline of the topics that the exam questions could be drawn from. A list is provided of some suggested textbooks suitable for preparing for the exam – there is no single book that the exam will be based on, but each of the suggested books covers all the topics listed.

Topics

1. Sampling of Lowpass Signals Continuous-Time Signals
   a. Sampling Theorem
   b. Aliasing
   c. Ideal Reconstruction
2. Discrete-Time (DT) Signals
   a. Standard DT Signals: Impulse, Unit step, Exponential, and Sinusoids (Complex & Real)
   b. Energy/Power of Discrete-Time Signals
   c. Frequency of digital sinusoids (i.e., ranges from $-\pi$ to π rad/sample)
3. Linear, Time-Invariant (LTI) Discrete-Time Systems
   a. Difference Equation Description
      i. Recursive solution of a difference equation
   b. Impulse Response and Convolution Description
      i. Using convolution to compute an output
   c. Transfer Function Description and Pole/Zero Plots
      i. See Z-Transform section below
   d. Relationships/Conversions among these three descriptions
4. Frequency Analysis of Discrete-Time Signals and Systems
   a. Fourier Transform of DT Signals (generally known as the DT Fourier Transform (DTFT))
   b. Properties of DTFT
   c. Frequency Response of LTI Systems
   d. Relationship of Frequency Response to Transfer Function, Impulse Response, and Difference Equation
5. Discrete Fourier Transform
   a. Definition and Relationship to DTFT
   b. Properties
   c. Interpretation of DFT Plots
6. Z-Transform
   a. Finding the Z-Transform of DT Signals
   b. Finding the Inverse Z-Transform
   c. Properties of Z-Transform
   d. Use of Z-Transform for Finding System Output
   e. Transfer Function of a System
      i. Poles, Zeros, Stability
7. Digital Filters
   a. Characterization of FIR vs. IIR via Difference Equation, Impulse Response, Transfer Function, Pole/Zero plot, and Block Diagram
   b. Frequency Response of Filters
   c. Lowpass, Highpass, Bandpass, Bandstop Types
   d. Characterization of Linear Phase FIR Filters

Suggested Books
(not in any particular order – the 1st two are textbooks, the 3rd is a good review book with examples of worked problems)

Digital Signal Processing: Principles, Algorithms, and Applications, J. G. Proakis and D. G. Manolakis, Prentice Hall.
Discrete-Time Signal Processing, A. V. Oppenheim and R. W. Schafer, Prentice Hall.
Schaum's Outline of Digital Signal Processing, M. H. Hayes, McGraw-Hill.