



GRADUATE STUDENT HANDBOOK

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Department of Electrical and Computer Engineering
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1. Introduction

The faculty and students of the graduate program in Electrical and Computer Engineering are divided into six specialization areas:

Communications Engineering
Computer Engineering
Digital Signal Processing
Software Engineering
Solid State Electronics
Systems and Controls

This information guide describes the degree requirements in these areas and clarifies the procedures used for admission into the M.S. and Ph.D. programs.

The School of Graduate Studies catalog should be consulted for additional information regarding the general policies and procedures of the School of Graduate Studies.

2. Admission Requirements

Deadline for all M.S. applicants is *December 1* for fall term admission. Deadlines for Ph.D. applicants are *December 1* for fall term admission and *October 1* for spring term admission. Admission materials are available from the Office of Graduate and Professional Admissions, 56 College Avenue, Rutgers University, New Brunswick, NJ 08901-8541, U.S.A. An online application is available at <http://gradstudy.rutgers.edu>.

Admission is competitive. Some applicants who meet or surpass the minimum requirements may be denied admission. Admission is recommended by the Electrical and Computer Engineering Graduate Admissions Committee and must be approved by the Dean of the School of Graduate Studies. All applicants must identify on their application material (personal statement, resume) one out of five areas for graduate study in this department: (1) Communications, (2) Computer Engineering, (3) Digital Signal Processing, (4) Software Engineering, (5) Solid State Electronics, and (6) Systems and Controls

Foreign nationals can only have full-time student status. US Citizens or Permanent Residents may have either full-time or part-time student status. Part-time students are subject to the same admission requirements as that for full-time students.

2.1. M.S. Program

The requirements for admission into the master's degree program are:

1. A bachelor's degree in Electrical and/or Computer Engineering with a minimum grade point average (GPA) of 3.2 on a 4.0-point scale.
2. Three letters of recommendation
3. The general Graduate Record Examination (GRE). The minimum expected scores are: **Verbal 500** (= **153** new test score), **Quantitative 730** (= **157** new test score), and **Analytical Writing 4.5**. The subject GRE in engineering is not required.

In addition, the Test of English as a Foreign Language (TOEFL) is required of all foreign applicants whose native language is not English unless an undergraduate degree was received in the USA. A

minimum score of 250 is expected. Students who obtain a TOEFL score below 250 may be accepted in exceptional cases, but will be required to attend classes in the Program in American Language Studies (PALS). This score corresponds to the new TOEFL Scores: Writing 22, Speaking 23, Reading 21, and Listening 17.

Students with bachelor's degrees in closely related areas such as Physics, Computer Science, Applied Mathematics or Engineering Technology may be considered for admission if they have outstanding GPA's and GRE's and after the following undergraduate electrical engineering courses are completed with a grade of B or better:

332:221,222	Principles of Electrical Engineering I,II
332:231	Digital Logic Design
332:252	Programming Methodology I
332:321	Probability and Random Processes
332:322	Principles of Communication Systems
332:331	Computer Architecture and Assembly Language
332:345	Linear Systems and Signals
332:346	Digital Signal Processing
332:361	Electronic Devices
332:362	Analog Electronics
332:366	Digital Electronics
332:382	Electromagnetic Fields
332:415	Introduction to Automatic Control

2.2 Combined BS/MS Degree(s) in Electrical and Computer Engineering

The requirements for admission in the combined BS/MS degree are:

1. Electrical and Computer Engineering undergraduate students in a good academic standing with a GPA of 3.2 and above will be eligible for admission to the Electrical and Computer Engineering graduate program.
2. The interested student will submit a regular School of Graduate Studies application at the beginning of the Fall semester *directly* to the Electrical and Computer Engineering Graduate Director together with a personal statement, three letters of recommendation and an official undergraduate transcript. The GRE requirement will be waived. The deadline for BS/MS applicants is December 1.
3. Students must complete the number of credits required for the Electrical and Computer Engineering B.S. degree before starting the M.S. graduate program. The requirements for the M.S. degree are identical to the requirements in effect for regular Electrical and Computer Engineering M.S. students:
 - (a) 24* credits of course work plus the master thesis.
 - (b) 30* credits of course work plus the master technical paper and its public presentation.

* See the School of Graduate Studies Policy on Double Counting of Credits (graduate and undergraduate credits). In general, any graduate course taken beyond 120 credits counts for both degrees B.S. and M.S.

2.3. Ph.D. Program

The requirements for admission into the Ph.D. degree program are:

1. A master's degree in Electrical and/or Computer Engineering with a minimum GPA of 3.5 on a 4.0-point scale and an undergraduate GPA of 3.2 or better.
2. Three letters of recommendation.
3. GRE examination with the same minimum scores as for the M.S. program.

Foreign applicants whose native language is not English and who have not received either a B. S. or M. S. degree in the USA (or any other English speaking county) must also submit their TOEFL scores.

Students with masters degrees in closely related areas such as Physics, Computer Science, or Applied Mathematics may be accepted on the condition that some or all of the undergraduate EE courses listed in Section 2.1 be completed with a grade of B or better.

Students who have completed the M.S. degree requirements at Rutgers and wish to continue for the Ph.D. must meet the 3.5 GPA requirement and submit a *change of status* form to the graduate director for approval. Foreign students are also required to obtain the approval of the Financial Aid Office regarding their financial status. Final approval is made by the School of Graduate Studies.

2.4. Non-Degree Students

Qualified students may apply to the Electrical and Computer Engineering graduate program for nonmatriculated (nondegree) status. Students must have academic credentials that are comparable to those required for regular admission. Transcripts are *required*. Initial application is made through the Electrical and Computer Engineering program. The completed application materials are then submitted to the Nondegree Graduate Study program. Nondegree students must either be US Citizens or Permanent Residents.

The course schedules of nonmatriculated students *must be approved* by the graduate director. After completing 12 credits of relevant graduate courses with a grade of B or better, a nonmatriculated student may apply for matriculated (degree) status. Only 12 credits of non-degree study are allowed.

The criteria for admission into the regular degree programs for nonmatriculated students are the same as for regular degree students. The graduate program coordinator can provide more information to interested students.

3. M.S. Degree Requirements

Master of Science degree candidates may follow either a thesis or a nonthesis program of study.

The thesis program requires 24 credits of course work, 6 credits of research leading to a master's thesis, and the final defense of the thesis.

In the nonthesis program, the candidate must complete 30 credits of course work with a minimum grade point average of 3.0, and write a Technical Paper which must be approved by at least three members of the ECE Graduate Faculty.

3.1. Course Requirements

At least 15 credits for the thesis option and 21 credits for the nonthesis option, must be fulfilled by the required and elective courses that are *relevant* to the student's area of specialization. The computer engineering option has some additional requirements explained below. All M.S. Students are required to take 2 semesters of 16:332:699 Colloquium in Electrical and Computer Engineering. In order to be graded "Satisfactory" you must attend 80% of the lectures (attendance is taken). *Online and short courses (winter break, spring break, two week courses) can not be used to satisfy the course requirements for any degree (M.S. or Ph. D.).*

The elective courses must be *approved* by the student's advisor or the Graduate Director before registration. A list of recommended electives is provided under each area of specialization.

3.1.1 Communications Engineering

Required courses:

- 332:541 Stochastic Signals and Systems
- 332:542 Information Theory and Coding
- 332:543 Communication Networks I
- 332:544 Communication Networks II
- 332:545 Digital Communication Systems
- 332:546 Wireless Communications Technologies
- 332:548 Error Control Coding
- 332:549 Detection and Estimation Theory
- 332:559 Advanced Topics in Communications Engineering

Recommended elective courses:

- 332:501 System Analysis
- 332:505 Control System Theory
- 332:506 Applied Controls
- 332:521 Digital Signals and Filters
- 332:525 Optimum Signal Processing
- 640:501 Theory of Functions of a Real Variable
- 640:503 Theory of Functions of a Complex Variable
- 640:515 Ordinary Differential Equations
- 642:550 Linear Algebra and Applications
- 642:573 Topics in Number Theory I
- 642:574 Topics in Number Theory II
- 642:591 Topics in Probability and Ergodic Theory
- 642:621 Financial Mathematics I
- 642:622 Financial Mathematics II
- 960:580 Basic Probability and Statistics
- 960:582 Introduction to Methods and Theory of Probability

3.1.2 Computer Engineering

- I.) Students taking the THESIS option will take:
- * 3 core courses
 - * 3 courses from the Computer Engineering group courses
 - * 2 additional courses of their choice
- II.) Students taking the NON-THESIS option will take:
- * 3 core courses
 - * 4 courses from the Computer Engineering group courses
 - * 3 additional courses of their choice

Required core courses:

332:563 Computer Architecture I
332:573 Data Structures and Algorithms
or 198:513 Design and Analysis of Data Structures and Algorithms)
One math elective

Note: If any of the following undergraduate courses are missing in the student's undergraduate transcripts, they must be made up:

332:231 Digital Logic Design
332:331 Computer Architecture and Assembly Language
332:351 Programming Methodology II or 198:112 Data Structures
198:416 Operating Systems (required for software track)

Computer engineering courses:

332:560 Computer Graphics
322:561 Machine Vision
332:562 Visualization and Advanced Computer Graphics
332:564 Computer Architecture II
332:566 Introduction to Parallel and Distributed Computing
332:567 Software Engineering I
332:568 Software Engineering Web Applications
332:569 Database System Engineering
332:570 Robust Computer Vision
332:571 Virtual Reality Technology
332:574 Computer Aided Digital VLSI Design
332:576 Testing of ULSI Circuits
332:577 Analog and Low-Power Digital VLSI Design
332:579 Advanced Topics In Computer Engineering
332:542 Information Theory and Coding
332:544 Communication Networks II
198:515 Programming Languages and Compilers
198:519 Operating Systems

Mathematical electives (one course required):

332:501	System Analysis
198:510	Numerical Analysis
198:521	Linear Programming
198:522	Network and Combinatorial Optimization Algorithms
198:524	Nonlinear Programming Algorithms
198:528	Parallel Numerical Computing
642:550	Linear Algebra and Applications
642:573	Topics in Number Theory I
642:587	Selected Topics in Discrete Mathematics
642:621	Financial Mathematics I
642:622	Financial Mathematics II

3.1.3 Digital Signal Processing

Required courses:

332:521	Digital Signals and Filters
332:525	Optimum Signal Processing
332:527	Digital Speech Processing
332:529	Image Coding and Processing
332:533	Computation Methods for Signal Recovery
332:535	Multi-Dimensional Signal Processing Algorithms
332:541	Stochastic Signals and Systems
332:561	Machine Vision
332:570	Robust Computer Vision

Recommended elective courses:

332:501	System Analysis
332:505	Control System Theory
332:506	Applied Controls
332:565	Neurocomputer Systems Design
640:501	Theory of Functions of a Real Variable
640:503	Theory of Functions of a Complex Variable
642:550	Linear Algebra and Applications
642:573	Topics in Number Theory I
642:574	Topics in Number Theory II
642:621	Financial Mathematics I
642:622	Financial Mathematics II

3.1.4 Software Engineering

- I.) Students taking the THESIS option (6 credits of research) will take:
- * 3 core courses
 - * 3 courses from the Software Engineering group of elective courses
 - * 2 additional courses of their choice

II.) Students taking the NON-THESIS option will take:

- * 3 core courses
- * 5 courses from the Software Engineering group of elective courses
- * 2 additional courses of their choice

Required Core Courses for Software Engineering:

332:563	Computer Architecture
332:567	Software Engineering
332:568	Software Engineering of Web Applications
332:573	Data Structures and Algorithms

If any of the following undergraduate courses are missing in the student's undergraduate transcripts, they must be made up:

332:252	Programming Methodology I
332:351	Programming Methodology II

ECE Software Engineering Elective Courses:

332:507	Security Engineering
332:543	Communication Networks I
332:544	Communication Networks II
332:560	Computer Graphics
322:561	Machine Vision
332:562	Visualization and Advanced Computer Graphics
332:566	Introduction to Parallel and Distributed Computing
332:569	Database System Engineering
332:571	Virtual Reality
332:572	Parallel and Distributed Computing
332:579	Advanced Topics in Computer Engineering (Cyber Physical Systems, Mobile Apps Engineering and User Experience, Cloud Computing, Big Data)
332: 601	Special Problems

Elective Courses from Other Graduate Programs: (up to 9 credits):

137:560	Introduction to Systems Engineering for Engineering Management (Fall semester)
137:602	Enterprise Software Architecture (Spring semester)
198:536	Machine Learning
198:541	Database Systems
198:544	Computer Security
198:546	Computer System Security
198:547	Security and Dependability of Distributed Systems

3.1.5 Solid State Electronics

Required courses:

332:580	Electric Waves and Radiation
332:581	Introduction to Solid State Electronics
332:583	Semiconductor Devices I
332:584	Semiconductor Devices II
332:587	Transistor Circuit Design

Recommended elective courses:

332:588	Integrated Transistor Circuit Design
332:589	RF Integrated Circuit Design
332:591	Opto-Electronics I
332:592	Opto-Electronics II
332:594	Solar Cells
150:522	Electron Microscopy
642:516	Applied Partial Differential Equations
642:527	Methods of Applied Mathematics I
642:528	Methods of Applied Mathematics II
642:575	Numerical Solutions of Partial Differential Equations
635:501	Theory of Solid State Materials
750:501	Quantum Mechanics I
750:601	Solid State Physics I
750:602	Solid State Physics II

3.1.6 Systems and Controls

Required courses:

332:501	System Analysis
332:505	Control System Theory
332:506	Applied Controls

Recommended elective courses:

332:508	Digital Control Systems
332:510	Optimal Control Systems
332:512	Nonlinear and Adaptive Control
332:514	Stochastic Control Systems
332:519	Advanced Topics in Systems Engineering
332:521	Digital Signals and Filters
332:526	Robotic Systems Engineering
332:541	Stochastic Signals and Systems
332:545	Digital Communication Systems
332:563	Computer Architecture I
640:501	Theory of Functions of a Real Variable
640:503	Theory of Functions of a Complex Variable

640:515	Ordinary Differential Equations
642:516	Applied Partial Differential Equations
642:527	Methods of Applied Mathematics I
642:528	Methods of Applied Mathematics II
642:550	Linear Algebra and Applications
642:573	Topics in Number Theory I
642:575	Numerical Solutions of Partial Differential Equations
642:621	Financial Mathematics I
642:622	Financial Mathematics II

3.2. Master's Thesis

Students writing a master's thesis must choose a thesis advisor who will supervise their research project. In consultation with the graduate director, a thesis committee will be appointed consisting of at least *three* members, including the thesis advisor who will chair the committee.

All members of the thesis committee must be members or associate members of the graduate faculty of the Electrical and Computer Engineering graduate program. One additional non-program member is permitted if appropriate, but must be approved by the graduate director. Substitutions in the committee membership may be made only by the graduate director and will occur only if a member is unable to serve or if a student's thesis topic changes requiring modification of the committee.

A final draft of the thesis (with all figures and references included) must be given to all committee members and the graduate director at least *three* weeks before the thesis defense date. The thesis must be approved by the thesis advisor and accepted by the other members of the student's committee. A final version of the thesis in unbound format must be submitted to the graduate director along with the degree candidacy form after successfully defending the thesis.

If a student fails his/her final thesis defense examination, the student will be allowed one more attempt to rewrite and defend the thesis. Alternatively, at the recommendation of his/her committee, the student may switch to the nonthesis option and take the master's comprehensive examination plus additional courses to raise his/her course credits to 30. In such cases, the comprehensive examination may be taken only once. Failure to pass the repeated thesis or comprehensive examinations will result in a recommendation for dismissal from the Electrical and Computer Engineering Graduate Program.

Teleconferencing is permitted with the thesis presentation being held at Rutgers University.

3.3. M.S. Technical Paper

The MS Technical Paper constitutes a substitution for the Master Comprehensive Exam. The topic of the Master Technical Paper must be chosen in consultation with an ECE graduate faculty member who serves as the student's advisor for the technical paper. The paper must ultimately be approved by three ECE graduate faculty members, of which the student advisor serves as the lead reader for the paper. The student and advisor select the additional two members of the ECE graduate faculty who will serve as readers of the technical paper. The students may use as the M. S. technical paper any term paper done in any graduate class, assuming the paper is endorsed by three ECE graduate faculty.

In order to streamline the process and improve the quality of M.S. Technical Papers, it is recommended that the papers be written through course term papers or projects, including Special Problems courses, excluding courses taught by part-time faculty. The course instructor will serve as the mentor. For each such course, during the semester, a reader will be appointed by the Graduate Director in consultation with the class instructor. The Graduate Director will serve as the third reader.

The student must incorporate feedback from the readers, revise the technical paper and ultimately achieve the approval of all three readers before the MS candidacy form submission deadline. A student is given two chances to successfully pass the evaluation of his/her technical paper.

3.4. Candidacy Forms/Deadlines

The Master of Science *candidacy form* should be completed *several weeks* before the student's anticipated graduation. The completed form must be first submitted to the Graduate Director for approval, and then brought to the School of Graduate Studies for verification of credits and grades. Upon completion of either Master Thesis or M. S. Technical Paper and collection of all required signatures the form must be submitted to the School of Graduate Studies (Barbara Sirman's Office, 848-932-8122). Please see dates included in table below.

The Diploma Application is available online at Registrar: <http://registrar.rutgers.edu> and it must be filed according to the schedule provided in the table below.

Graduation	Diploma Application Submission Deadline	Candidacy Form Submission Deadline
October 2018	October 1, 2018	October 3, 2018
January 2019	January 6, 2019	January 11, 2019
May 2019	April 1, 2019	April 12, 2019

3.5. Checklist for M.S. Degree - Thesis Option

THESIS FORMAT GUIDE: You may obtain a style guide for thesis available online at the School of Graduate Studies: grad.rutgers.edu, or pick up print copies from the School of Graduate Studies (25 Bishop Place) or from the graduate program coordinator. It contains information regarding style, format, paper, margins, footnotes, etc. It should be followed explicitly. Any questions regarding tables, graphs, photos, etc., can be directed to Barbara Sirman at (848) 932-8122 or email at sirman@grad.rutgers.edu.

CANDIDACY FORM AND THESIS:

1. The candidacy form should be picked up (downloaded) either at the School of Graduate Studies (website) or from the Electrical and Computer Engineering Graduate Program Coordinator in the Electrical Engineering Building.
2. Complete the form and [have the Graduate Director sign](#) the front of the form. The ECE Graduate Program Coordinator will verify credits and grades.
3. Have the members of your thesis committee sign the form on the back ([Section A and Section C](#)), as well as the title page. The Graduate Director must also sign the back of the candidacy form at this time ([Section E](#)).
4. Submit [one](#) copy of the final version of the thesis with signed (photocopy) title page, unbound, single-sided on photocopy paper to the Graduate Director along with the candidacy form signed by the thesis committee. Please note that the committee must sign also the Comprehensive Exam section ([Section C](#)).

5. Submit thesis electronically (<https://edt.libraries.rutgers.edu/login.php>) to the School of Graduate Studies. **One** original title page must have the original signatures (**in black ink**); also submit your candidacy form. **Three (3)** additional signed, (photocopies are acceptable) title pages, and **three (3)** additional abstracts are also required.
6. THE DEADLINE FOR FINAL SUBMISSION OF ALL MATERIALS TO THE SCHOOL OF GRADUATE STUDIES IS: **October 3, 2018** for an October-dated degree; **January 11, 2019** for a January-dated degree; **April 12, 2019** for a May-dated degree.

DIPLOMA APPLICATION FORM:

1. Diploma Application form is available online at: Registrar: <http://registrar.rutgers.edu>.
2. Contact the Graduate Registrar's Office, Administrative Services Building - Room 200F, Busch Campus (848-445-3557) regarding diploma application questions.
3. The deadline for submission of this form is given in Section 3.4.

PLEASE BE SURE THAT YOU ARE CONSISTENT IN THE USE OF YOUR NAME ON THE DIPLOMA APPLICATION, AND TITLE PAGE OF YOUR DISSERTATION. YOUR NAME SHOULD BE THE SAME ON THE TITLE PAGE AND THE DIPLOMA APPLICATION.

3.6. Checklist for M.S. Degree - Non-Thesis Option

CANDIDACY FORM:

1. The candidacy form should be picked up (or downloaded) from your program or at the School of Graduate Studies (website), 25 Bishop Place, College Avenue Campus.
2. Complete the form and **have the Graduate Director sign the front of the form**. The ECE Graduate Program Coordinator will verify credits and grades.
3. A total of **three** committee signatures are required for **Sections B and C**. The Graduate Director must also sign **Section E** on the back of the candidacy form after the results of the final examination are known.
4. THE DEADLINE FOR FINAL SUBMISSION OF ALL MATERIALS TO THE SCHOOL OF GRADUATE STUDIES IS: **October 3, 2018** for an October-dated degree; **January 11, 2019** for a January-dated degree; **April 12, 2019** for a May-dated degree.

DIPLOMA APPLICATION FORM:

1. Diploma Application form is available online at Registrar: <http://registrar.rutgers.edu>.
2. Contact the Graduate Registrar's Office, Administrative Services Building - Room 200F, Busch

- Campus (848-445-3557) regarding diploma application questions.
3. The deadline date for submission of this form is given in Section 3.4.
 4. Any questions may be directed to either the graduate secretary or Barbara Sirman, at 848-932-8122.

4. Ph.D. Degree Requirements

The Ph.D. degree requires a total of at least 72 credits. The credit requirements for the Ph.D. degree must consist of at least 36 credits in graduate course work, 24 credits of research leading to the Ph.D. dissertation, and an additional 12 credits that may come from either course work or research. In addition, all Ph.D. Students are required to take 4 semesters of 16:332:699 Colloquium in Electrical and Computer Engineering. In order to be graded "Satisfactory", you must attend 80% of the lectures (attendance is taken).

The student who has been admitted to the Ph.D. program must pass the Ph.D. qualifying examination taken within the first two years of entering the Ph.D. program. Finally, the student must successfully defend his/her Ph.D. dissertation in a final public examination.

There are no foreign language requirements for the Ph.D.; however, a student must demonstrate proficiency in English.

Students who decide to continue beyond the M.S. degree and pursue a Ph.D. must submit a Change of Status form, and must adhere to the GPA requirements of the Ph.D. degree.

The purpose of the Ph.D. qualifying examination is to assess the student's creative ability, depth of knowledge, and potential for independent research. Students admitted into the Ph.D. program must *pass* this examination within their first two years of entering the program. Students not yet admitted into the Ph.D. program may take the qualifying exam only if they have a GPA of 3.5 or better and 12 graduate credits at Rutgers.

[Students may take the qualifying exam only twice.](#) Failure to pass the exam for the second time will result in a recommendation for dismissal from the Ph.D. program.

Students who passed the Ph.D. Qualifying Exam should complete the Ph.D. Candidacy form, get the signatures of four faculty examiners and the Graduate Director. The form must be submitted to the School of Graduate Studies for the change of status from a prequalifying to a post-qualifying doctoral student.

4.1. Ph.D. Qualifying Examination

Goal: Make the qualifier exam a constructive component in the development of a student's research skills and use the course work requirements to distinguish between potential doctoral students and master students.

Exam Structure: The Ph. D. Qualifying Exam has two parts: I) GPA requirement on selected courses, and II) Research potential assessment.

Part I. GPA Course Requirements

- A. *ECE Course Requirement:* Prequalified doctoral students are required to pass **four courses** selected from a list of *relevant doctoral courses* ("core courses") with a **GPA of at least 3.75**.

- B. Mathematics/Physics/Statistics Course Requirement:** Prequalified doctoral students are required to pass **one** course in mathematics/physics/statistics with the grade of a **B+** and above.

Each research group (Communications, Computational Sensing, Computer Engineering, Control Systems, Cybersecurity, Digital Signal Processing, Networks, Software Engineering, and Solid State Electronics) has its own list of “core courses” and mathematics/statistics courses.

Part II. Research Potential Assessment Oral Qualifier

Following completion of the course requirements for specified research group, a student will be eligible to take the research potential assessment examination. In this exam, the student will prepare a written report and make a 45-minute oral presentation of his/her own independent research to a Ph.D. Qualifying Committee of four members of the ECE graduate faculty (but excluding a student’s advisor). The oral presentation will be followed by an open-ended question and answer session that may include questions specific to the research project as well as questions generally relevant to the research area.

It is strongly recommended (although not required) that the student have a faculty advisor before taking the oral qualifier. Students who have no academic advisors must register for Special Problems in the second year of their doctoral studies and conduct preliminary research with a faculty member in their research area of interest. The subject of the oral exam is to be chosen by the student. It is recommended that this choice be made in consultation with a faculty advisor and the ECE graduate director. A suitable basis for the examination may include, but is not restricted to:

- A conference paper submission based on research under the supervision of a faculty advisor.
- An M.S. thesis in preparation or previously completed thesis (either at Rutgers or any other university.)
- A final project report derived from an ECE graduate Special Problems independent study course. (The student who does not have a faculty research advisor must take the Special Problems class in the second year with an ECE graduate faculty in student’s research area of interest).

Unlike the PhD thesis proposal defense, this examination will occur in the early stages of research and the presented paper need not lead to a Ph.D. thesis proposal. For the examination committee, evaluation of the originality and novelty of the research contribution will be secondary to an evaluation of the student’s critical thinking skills. Specifically, the committee will focus on the student’s ability to analyze, interpret and articulate both strengths and weaknesses of the work.

Nine Areas of the Ph. D. Qualifying Exam

- Communications
- Computational Sensing¹
- Computer Engineering
- Control Systems
- Cybersecurity
- Digital Signal Processing
- Networking
- Software Engineering
- Solid State Electronics

¹ for students interested in computer vision, robotics (cloud-assisted, swarm), devices/circuits for imaging, sensor networks, tele-rehabilitation, integration of sensing with communications and computing, mobile agents, computational photography.

General Rules:

- The exam must be taken within two years from the time the student starts the Ph.D. Program.
- The student will be allowed two chances to take the Ph.D. Qualifying Exam. The second attempt must be taken within one year.
- The student must apply to the graduate director to take the Ph.D. Qualifying Exam. In this application, the student selects the research group for the exam and identifies how the core course requirements for that group have been met.
- The written report to accompany the oral presentation must be submitted to the graduate director with the application.
- The Ph.D. Qualifying Committee will be composed of four ECE Graduate Program faculty. The student advisor cannot serve on the student's Qualifying Committee.
- Based on the subject of the submitted written report and the student's selected research group, the examination committee will be chosen by the graduate director in consultation with the student and his/her advisor.
- Each member of the Ph. D. Qualifying committee votes. The vote of 3:1 or 4:0 is needed for the student to pass the Ph. D. Qualifying Exam.
- The new format of the Ph. D. Qualifying Exam is offered year around. For scheduling the Ph.D. Oral Qualifying exam please contact the ECE Graduate Director one month before the exam.

Ph.D. Exam Application and Scheduling Policy (Effective Fall 2016):

- 1) Applications with the list of the core courses taken should be submitted by the student electronically to the Graduate Director, Dr. Zoran Gajic. The application form can be found in front of office EE 134.
- 2) Upon approval of the list of the selected core courses, the student will be requested to submit a paper to the Graduate Director to be presented and discussed with the Ph. D. Committee.
- 3) The Ph. D. Committee will be formed based on the student and the advisor's recommendation in consultation with the Graduate Director. **As of October 24, 2016 the School of Graduate Studies allows that the fourth committee member does not need to be a member of the student's graduate program.**
- 4) **Scheduling of the oral exam will be done by the ECE Graduate Program Coordinator, Ms. Christy Lafferty.** The exam will be scheduled roughly one month from the time the paper is submitted to the Office of the Graduate Director. At the same time, Dr. Gajic will email the exam paper to the Committee members and Ms. Lafferty will email the Ph. D. Qualifying Exam Evaluation Form to the Committee members.
- 5) The Ph. D. Qualifying Exam Committee should return the Evaluation Form to the ECE Graduate Office upon the completion of the exam with their comments and pass/no recommendation.
- 6) If the student passes the exam, they will receive a letter from the Graduate Director stating that the Ph. D. Qualifying Exam was successfully completed and they will be provided the Ph. D. Candidacy Form. If a student does not pass the exam, they will receive a letter from the Graduate Director indicating they failed to pass and are permitted only one more chance to take and pass the exam during the listed time frame.
- 7) The student who passes the exam is required to get four signatures (from each of the Ph. D. Qualifying Exam Committee members) and then a signature from the Graduate Director.

- 8) When all signatures are acquired on the Candidacy Form, the student must submit the Candidacy Form to the School of Graduate Studies and their status will be changed from prequalified to post-qualified doctoral student.

CORE COURSE REQUIREMENTS

Students wishing to take an alternative to these options outside the department may petition the Graduate Director, who will consult the appropriate committees.

COMMUNICATIONS

Faculty Members: Bajwa, Chen, El Rouayheb, Foschini, Frenkiel, Gajic, Mandayam, Martin, Petropulu, Pompili, Sarwate, Soljanin, Spasojevic, Trappe, Wu, Yates

Core Courses:

332:509 Convex Optimization
332:521 Digital Signals and Filters
332:541 Stochastic Signals and Systems
332:542 Information Theory
332:543 Communications Networks I
332:544 Communications Networks II
332:545 Digital Communications
332:546 Wireless Communication Technologies
332:548 Error Control Coding
332:549 Detection and Estimation Theory

Mathematics/Statistics Courses:

642:527 Methods of Applied Mathematics I
642:528 Methods of Applied Mathematics II
642:550 Linear Algebra and Applications
642:551 Applied Algebra
960:592 Theory of Probability
960:593 Theory of Statistics
640:411 Mathematical Analysis I

COMPUTATIONAL SENSING

Faculty Members: Bajwa, Dana, Petropulu, Pompili, Meer, Sarwate, Trappe, Yates

Core Courses:

332:504 Sensor-based Systems
332:509 Convex Optimization
332:521 Digital Signals and Filters
332:525 Optimal Signal Processing
332:526 Robotic System Engineering
332:541 Stochastic Signals and Systems
332:561 Machine Vision
332:591 Optoelectronics
332:539 Advanced Topics in DSP (Statistical Learning; Deep Learning)
332:579 Advanced Topics in Computer Engineering (Advanced Computer Vision)
198:534 Computer Vision
198:536 Machine Learning
198:535 Pattern Recognition: Theory and Applications

Mathematics/Statistics courses: Any graduate level course in mathematics or statistics.

COMPUTER ENGINEERING

Faculty Members: Burdea, Chen, Dana, Dehnavi, Gruteser, Jha, Lindqvist, Marsic, Ortiz, Rodero, Parashar, Pompili, Silver, Wei, Zhang

Core Courses:

Must choose three core courses out of the following five courses (if the student had some of these courses at any other graduate school, the student may take additional courses from the next list)

332:563 Computer Architecture

332:567 Software Engineering I

332:573 Data Structure and Algorithms

332:566 Intro Parallel & Distributed Computing

332:543 Communication Networks I

Take one course from the list:

332:544 Communication Networks II

332:560 Computer Graphics

332:562 Visualization and Advanced Computer Graphics

332:568 Software Engineering of Web Applications

332:572 Parallel & Distributed Computing

332:579 Advanced Topics in Computer Engineering (Cyber-Physical Systems; High-Performance Distributed Computing; Cloud Computing; Computing Principles for Mobile Embedded Systems; Malware Analysis and Reverse Engineering; Embedded Systems II: Application Development; Intro to Computer Systems; Applied Parallel Computing)

Mathematics/Statistics courses: Any graduate level course in mathematics or statistics.

CONTROL SYSTEMS

Faculty Members: Baruh, Gajic, Li, Orfanidis, Shoane, Sontag, Yi, Zou

Core courses:

332:501 System Analysis

332:505 Control System Theory

332:506 Applied Controls

332:509 Convex Optimization for Engineering Applications

332:510 Optimal Control Systems

332:512 Nonlinear and Adaptive Control

332:519 Advanced Topics in Systems Engineering (Kalman filtering, Game theory, Energy Systems, Information Security)

332:521 Digital Signals and Filters

Mathematics courses:

642: 527 Methods of Applied Mathematics I

642:528 Methods of Applied Mathematics II

642 550 Linear Algebra and Applications

642:573 Numerical Analysis

CYBERSECURITY

Faculty Members: Chen, El Rouayheb, Gruteser, Lindqvist, Ortiz, Petropulu, Sarwate, Trappe, Wei, Zhang, Zonouz

Core courses:

332:507 Security Engineering

332:542 Information Theory and Coding

332:544 Communication Networks II
332:567 Software Engineering
332:573 Data Structures & Algorithms
332:519 Advanced Topics in Systems Engineering (Network security)
332:579 Advanced Topics in Computer Engineering (Information and Network Security; Malware Analysis and Reverse Engineering; Network Centric Programming; Mobile Apps Engineering and User Experience, Methods in Human-Computer Interaction, Foundations of Cyber-Physical Systems)
198:544 Computer Security
198:596 Introduction to Cryptography
Mathematics/Statistics courses: Any graduate level course in mathematics or statistics.

DIGITAL SIGNAL PROCESSING

Faculty Members: Bajwa, Dana, Hanson, Mammone, Meer, Najafizadeh, Orfanidis, Petropulu, Patel, Sarwate

Core courses:

332:509 Convex Optimization
332:521 Digital Signals and Filters
332:527 Digital Speech Processing
332:539 Advanced Topics in DSP (Deep Learning, Biometrics)
332:541 Stochastic Signals and Systems
332:542 Information Theory and Coding
332:545 Digital Communication Systems
332:549 Detection and Estimation Theory
332:561 Machine Vision

Mathematics/Statistics courses:

640:411 Mathematical Analysis I
960:554 Applied Stochastic Processes
960:565 Applied Time Series Analysis
960:567 Applied Multivariate Analysis
960:592 Theory of Probability
960:593 Theory of Statistics
Any course in Mathematics at the 500 level or above

NETWORKING

Faculty Members: Chen, Gruteser, Mandayam, Marsic, Petropulu Pompili, Raychaudhuri, Sarwate, Spasojevic, Trappe, Yates, Zhang

Core Courses:

332:509 Convex Optimization
332:541 Stochastic Signals and Systems
332:543 Communications Networks I
332:544 Communications Networks II
332:546 Wireless Communication Technologies
332:568 Software Engineering Web Applications
332:573 Data Structures and Algorithms
198:512 Introduction to Data Structures and Algorithms
198:513 Design and Analysis of Data Structures and Algorithms
332:519 Advanced Topics in Systems Engineering (Information and Network Security)

Mathematics/Statistics Courses:

642:527 Methods of Applied Mathematics I
642:528 Methods of Applied Mathematics II
642:550 Linear Algebra and Applications
642:551 Applied Algebra
960:592 Theory of Probability
960:593 Theory of Statistics
640:411 Mathematical Analysis I

SOFTWARE ENGINEERING

Faculty Members: Gruteser, Jha, Lindqvist, Marsic, Silver, Zhang, Zonouz

Core courses:

332:563 Computer Architecture
332:567 Software Engineering
332:568 Software Engineering of Web Applications
332:573 Data Structures and Algorithms
332:560 Computer Graphics
322:561 Machine Vision
332:562 Visualization and Advanced Computer Graphics
332:566 Introduction to Parallel and Distributed Computing
332:569 Database System Engineering
332:571 Virtual Reality
332:572 Parallel and Distributed Computing
332:543 Communications Networks I
332:544 Communications Networks II
332:579 Advanced Topics in Computer Engineering (Cyber Physical Systems; Big Data Analytics; Cloud Computing; Mobile Apps Engineering and User Experience; Network Centric Programming; Games and Virtual Reality; Computing Principles for Mobile Embedded Systems)

Mathematics/Statistics courses: Any graduate level course in mathematics or statistics.

SOLID STATE ELECTRONICS

Faculty Members: Caggiano, Cheong, Chhowala, Feldman, Godrich, Hassan, Javanmard, Jeon, Lu, McAfee, Najafizadeh, Oh, Wu, Zhao

Core courses:

The student needs to take four core courses, in a combination of 3+1, within the broad SSE areas (if the student had some of the fundamental courses at any other graduate school, the student may take additional courses from the list of “advanced” courses).

Three courses from the following list of “fundamental” courses:

332:580 Electric Wave and Radiation
332:581 Introduction to Solid State Electronics
332:583 Semiconductor Devices I
332:587 Transistor Circuit Design

One course from the following list of “advanced” courses, based on the research topic:

332:574 CAD Digital and VLSI Design
332:584 Semiconductor Devices II
332:589 RF Integrated Circuit Design
332:591 Optoelectronics I
332:597 Material Aspects of Semiconductor

332:599 Advanced Topics in SSE (Biosensing and Bioelectronics; Wearable and Implantable Electronic Systems; Microelectronic Processing; Microgrid Concepts and Distributed Generation Technology; Smart Grid: Fundamental Elements of Design)

Mathematics courses:

642:516 Applied Partial Differential Equations

642:527 Methods of Applied Mathematics I

642:528 Methods of Applied Mathematics II

642:550 Linear Algebra and Applications

642:573 Numerical Analysis

960:565 Applied Time Series Analysis

4.2. Ph.D. Proposal Presentation

The proposal presentation examination is conducted by a committee consisting of the student's thesis advisor and at least *three* other members or associate members of the electrical engineering graduate faculty. Normally, the thesis advisor, at least two other members of this committee, and an outside member, will later serve as the student's thesis committee.

The examination consists of a one-hour presentation and defense of a *thesis research proposal* by the student, followed by an *oral examination* by the committee. The thesis proposal presentation is *not* public; however, any faculty member of the School of Graduate Studies may attend.

The student should provide each member of his/her committee and the graduate director with a copy of the thesis proposal *at least three weeks* before the examination. The proposal should include a review of previous work on the subject, a description of the proposed research project, and preliminary research results, such as experimental, theoretical, or simulation results indicating that the project can be successfully undertaken.

4.2.1 ECE Ph.D. Proposal Presentation Policy

The Doctoral Dissertation Proposal presentation will be announced at least *three weeks* before the presentation.

It is the *advisor responsibility* to inform the Graduate Director Office, either via email or a hard copy memo (preferred), that the student is ready to present his/her proposal, and provide the list of at least four (at least three ECE Graduate Program members including the advisor) committee members, time and place of the presentation. The committee may include one or two “outside ECE Graduate Program” members. The outside committee members are appointed by the Graduate ECE Program Director in consultation with the student’s advisor.

It is the *student responsibility* to provide the Graduate Director office with a copy of the dissertation proposal and an electronic version of the proposal abstract at least *three weeks* before the presentation.

Teleconferencing is permitted with the proposal presentation being held at Rutgers University. The proposal presentation is closed to public (Rutgers University regulation). The ECE faculty members are allowed to attend the proposal presentation and/or examine the written copy of the proposal.

For a successful proposal presentation only one non-approval is permitted. A student is given *two* chances to successfully present his/her doctoral dissertation proposal.

4.3. Dissertation Requirements

The dissertation topic is agreed upon by the student and the thesis advisor. The dissertation

committee, which consists of the dissertation advisor, at least *two* other members or associate members of the electrical engineering faculty, and an *outside* member, is selected by the student and the thesis advisor, in consultation with the graduate director.

Substitutions in the committee membership may be made only by the graduate director and will occur only if a member is unable to serve or if a student's dissertation topic changes requiring modification of the committee. In cases other than these, approval rests with the Dean of the School Graduate Studies.

The dissertation committee must be kept informed of the student's progress and must agree to follow the student's work and assist in its development. The committee shall also agree to give ample and early warning of any reservations regarding the student's progress and must specify in writing the changes required for dissertation acceptance.

The Ph.D. dissertation should be submitted to the dissertation committee and the graduate director at least *four* weeks before the final dissertation defense examination. The dissertation should be in final form with all figures and references.

The final dissertation defense must be announced and is open to the public. *Teleconferencing* is permitted with the dissertation presentation being held at Rutgers University. The dissertation advisor and all but one of the other committee members must approve in order for the student to pass the examination. In the case of two or more dissenting members, an attempt should be made to reconcile the differences. If resolution of the differences is not possible, the dissertation must be judged unsatisfactory. Appeals may be referred to the Dean of the School of Graduate Studies. The committee members must sign the student's Ph.D. candidacy form, the title page of the thesis if the dissertation is approved. If approval is not unanimous, a letter from the dissenting members indicating the reasons for disapproval must be sent to the Dean of the School Graduate Studies and copies sent to the graduate director, the other committee members, and to the student.

A final version of the dissertation in unbound format must be submitted to the graduate director along with the degree candidacy form after successfully defending the dissertation. After the final signature from the graduate director has been obtained on the candidacy form, the form and the two copies of the dissertation required by the School of Graduate Studies must be hand-delivered by the student.

4.4 Checklist for Ph.D. Degree

STYLE GUIDE FOR THESIS AND DISSERTATION PREPARATION: A thesis style guide is available online at the School of Graduate Studies: grad.rutgers.edu, or pick up print copies from the graduate secretary or from the School of Graduate Studies (25 Bishop Place-CAC). This booklet presents the requirements governing the physical form of the thesis doctoral dissertation. Any questions should be directed to Barbara Sirman at (848) 932-8122, or email at sirman@grad.rutgers.edu.

CANDIDACY FORM AND DISSERTATION:

1. The candidacy form should be picked up at the School of Graduate Studies prior to your defense. **Note:** The last page of the form, listing both your course and research credits, should be completed right after your taking the Ph.D. Qualifying Examination.
2. At that time, you will be given other forms for completion: (i.e.) payment fee, microfilming, survey, questionnaires, etc.
3. Take the candidacy form to your defense and have your committee members and the Graduate Program Director sign page 3. They should also sign the title page of your dissertation. An

outside member is required for the dissertation committee. If the person is from outside the University, a resume is required by the Graduate Director such that formal permission can be obtained from the School of Graduate Studies.

4. Submit **one** copy of the final version with photocopy of signed title page, unbound, single-sided on photocopy paper to the graduate director along with the candidacy form signed by the dissertation committee.
5. Submit to the School of Graduate Studies **electronically** copy of the dissertation <https://etd.libraries.rutgers.edu/login.php> . Submit **ONE (1)** original title page with signatures **in black ink**). Also submit your candidacy and other forms.

Note: Three (3) additional signed (photocopies are acceptable) title pages and three (3) additional abstracts are also required.

7. THE DEADLINE FOR FINAL SUBMISSION OF ALL MATERIALS TO THE SCHOOL OF GRADUATE STUDIES IS: **October 3, 2018** for an October-dated degree; **January 11, 2019** for a January-dated degree; and **April 12, 2019** for a May-dated degree.

DIPLOMA APPLICATION FORM:

1. Diploma Application form is available online at Registrar: <http://registrar.rutgers.edu>.
2. Contact the Graduate Registrar's Office, Administrative Services Building - Room 200F, Busch Campus (848-445-3557) regarding diploma application questions.
3. The deadline for submission of this form is: **October 1, 2018** for an October-dated degree; **January 6, 2019** for a January-dated degree; and **April 1, 2019** for a May-dated degree.

PLEASE BE SURE THAT YOU ARE CONSISTENT IN THE USE OF YOUR NAME ON THE DIPLOMA APPLICATION, AND TITLE PAGE OF YOUR DISSERTATION. YOUR NAME SHOULD BE THE SAME ON THE TITLE PAGE AND THE DIPLOMA APPLICATION.

5. Scholastic Standing

The academic progress of masters students, Ph.D. students who have not yet selected a thesis advisor, and of all students on academic probation is monitored by the Electrical and Computer Engineering Graduate *Scholastic Standing Committee*, which reviews student performance twice a year.

Master's degree students must maintain a GPA of 3.0 or higher and Ph.D. students a GPA of 3.5 or higher. A student who's GPA falls below the corresponding threshold will be placed on *academic probation* for two semesters. Failure to raise the GPA above the threshold within the next two semesters will result in a recommendation for dismissal from the graduate program.

In addition, **students may not use more than one grade of C/C+ towards any degree.** Students receiving two grades of C/C+ or below will be sent an academic probation letter and if, subsequently, they receive a third such grade they will be recommended for dismissal from the program.

The academic progress of post-qualifying Ph.D. students who have selected a thesis advisor is monitored, on a regular basis, by their thesis advisor and thesis committee.

All graduate students are encouraged to become familiar with the Rutgers University POLICY ON ACADEMIC INTEGRITY. A copy of the policy statement can be obtained from the graduate program coordinator.

5.1. Academic Probation

The following events will automatically trigger Academic Probation for a student:

1 F in a course

2 C's in graduate courses

The following events may trigger Academic Probation for a student:

An Incomplete that is not made up in the immediately following semester.

The following events will trigger a hearing to determine whether to dismiss a student from the Electrical and Computer Engineering Department:

2 F's in graduate courses

3 C's in graduate courses

Repeated problems in maintaining a full-time student course load of 9 credits.

5.2. Degree Time Limits

MS Degree

There is a time limit of 2 years to complete a full-time MS degree in the Electrical and Computer Engineering Department. Students who take longer than that time interval will normally not be admitted to the PhD program.

PhD Degree

There is a time limit of 5 years after the MS degree to complete the PhD degree. Students who take longer than that time interval may be discontinued in the PhD program.

Normally, PhD students who have not initiated research activity will be dismissed after 2 years in the PhD program. Research activity means that the student has a doctoral advisor, has pursued an original thesis topic, and has completed some research.

5.3. Incomplete Grades

Incomplete (IN) grades must be completed within *one* semester. A student who has more than one IN grade will be allowed one semester to reduce the number to one (or none), after which he/she will not be allowed to register for additional courses until the IN's are completed. The School of Graduate Studies will not allow students with IN's to graduate. The graduate director will not give TA/Fellowship support or Practical Training letters to students with Incompletes.

5.4. Full-Time Student Status Visa Requirements

Our Department considers 9 academic credits (consisting of undergraduate remedial courses, graduate courses, or graduate research 332:701 and 332:702) to be full-time study. **The special TA and GA courses**

do not count towards the academic credits. We do not accept undergraduate course credits toward the MS and PhD graduate degrees. We also will not allow students to take fewer than 9 academic credits and retain full-time enrollment status, except in these situations:

- I. The student is in the last term of his/her degree, and has completed all degree course requirements, in which case fewer than 9 credits is permitted.
- II. The student is studying for the PhD Qualifying Examination, in which case 6 credits is permitted, either during the semester of the examination, during the semester preceding the examination, or both. The preparation time for this examination is significant, and judged to be equivalent to two 3 credit graduate courses.

In all other situations, we expect students to carry 9 academic credits. If remedial English courses are required, then a student must still carry 9 academic credits. Student's who do not satisfy this policy will be reviewed by the Scholastic Standing Committee of the Electrical and Computer Engineering Department, and also jeopardize their full-time enrollment status.

5.5. Lead-time for Processing of Student Forms

The ECE graduate program is a very large program with research and faculty in many different areas. In order to adequately process the applications and documents of all students in a fair and proper manner, the ECE Graduate Office requests that students provide forms, such as Visa and OPT/CPT forms, at least three weeks in advance of any deadline. The ECE Graduate Office will do its best to accommodate any emergencies that might arise and which necessitate very fast processing of documents. However, students must understand that many deadlines are known significantly in advance of the deadline, e.g. Visa renewal deadlines, and thus it is the responsibility of the student to properly plan their schedules accordingly. Additionally, students should also submit requests for documents related to employment opportunities (e.g. support letters) at least three weeks to properly process. Finally, students should also refer to the Rutgers Center for International Faculty and Student Services for any other deadlines and guidelines.

6. New Graduate Student Information

As a new graduate student it is highly recommended that you spend your first semester in the program familiarizing yourself with the faculty with the aim of identifying a faculty research advisor. Establishing a research path is the most critical step in your graduate career. A timely goal would be to establish a broad idea of the research area that interests you and meet with potential thesis advisors.

7. Ethics

If you are a TA, a GA, or a Fellow, then you are an employee at Rutgers University. The salary, tuition, and fringe benefits that you receive are in return for work, and it is expected that the work will be done very well. If you are a TA, it is expected that you will do an outstanding job of teaching and grading, and of communicating with the undergraduate students. If you are either a TA, a GA, or a Fellow, it is expected that you will achieve excellent grades, and will complete the graduate program requirements in a timely fashion. It is also expected that you will promptly initiate your own research program with a faculty advisor, and will soon become productive in conducting research and writing papers.

TAs are reviewed after one semester in the program. They are expected to make satisfactory academic progress, and to have a research advisor by the end of their first semester. TAs and Fellows are reviewed again after the end of the spring term. In order to continue as a TA, you must be rated by the Professor and the students in the course as an excellent teacher, you must be making satisfactory academic progress in the graduate program, and you must have a research advisor who indicates that your research is proceeding well. In order to continue as a Fellow, you must have outstanding academic progress in the graduate program, you must have a research advisor who says that your research is proceeding well, and you must have a record of service to either the Electrical or Computer Engineering Department or to the School of Graduate Studies. It is considered a distinct honor to be a Fellow of the Electrical and Computer Engineering Department.

8. Appeals Procedures

Appeals of a decision to recommend dismissal from the graduate program must be made in writing to the Graduate Scholastic Standing Committee. The committee will consider the appeal and vote to sustain or rescind the original recommendation.

Student grievances concerning grades on the Ph.D. qualifying exam should be addressed to the Graduate Director. If the matter is not resolved satisfactorily, the student may appeal in writing to the Graduate Scholastic Standing Committee for a formal review.

Student grievances concerning course grades should be addressed to the instructor of the course. If the matter is not resolved satisfactorily, the student may appeal to the graduate director, who will attempt to resolve the dispute informally. If this attempt is unsuccessful, the student may appeal in writing to the Graduate Scholastic Standing Committee.

Students may appeal decisions of the Graduate Director, Graduate Scholastic Standing Committee, or graduate faculty, in writing, to the Dean of the School of Graduate Studies if they feel that the process by which the electrical and computer engineering graduate program reached its decision was unfair.

9. Financial Aid

Teaching assistantships (TA's) are available to full time graduate students. TA awards are competitive. Candidates are expected to have excellent undergraduate grades, high GRE scores, and a thorough command of the English language. TA application forms, available from the graduate program coordinator, must be submitted at least four months prior to the desired starting semester.

Graduate assistantships (GA's) are also available. These positions are supported by research grants of individual faculty members. The faculty members should be contacted directly. A list of the faculty and their research interests is given in Appendix B.

Students holding TA/GA positions may not accept employment outside the department without permission of the graduate director and the Dean of the School of Graduate Studies.

There are also a number of fellowships, loans, and employment opportunities. The School of Graduate Studies catalog may be consulted for more information.

Information and forms regarding benefits for TA/GA's, such as health insurance, can be obtained from the Department Administrator.

10. Transfer of Credits

Credits may not be transferred from other institutions until 12 credits of graduate courses with

grades of B or better have been completed at Rutgers. Only courses in which grades of B or better were received can be considered for transfer. (B- in not transferable.) Research credits are not transferable. *Online courses are not transferable.* It is the departmental policy that short courses (winter break, spring break, two week courses) cannot be used to satisfy the course requirements for any degree.

A maximum of 12 credits may be transferred towards the M.S. degree. A maximum of 24 course credits may be transferred towards the Ph.D. degree. These credits are normally transferred from the student's M.S. degree.

Application forms for transfer of credit are available from the graduate program coordinator. The forms are to be submitted to the graduate director for approval and then to the School of Graduate Studies for final approval. They must be accompanied by official transcripts unless the transcripts are already available in the student's file. Catalog descriptions and/or syllabi indicating texts used must also be submitted.

11. Registration Questions

11.1. Matriculation Continued

A student who wishes to take a leave of absence under extraordinary circumstances may apply for Matriculation Continued status. The student must complete a *Matriculation Continued Application* available from the graduate program coordinator and submit it to the graduate director for approval.

Pre-qualifying Ph.D. students who have finished all course requirements may register for matriculation continued until they take their qualifying examination. Post-qualifying Ph.D. students are not permitted to register for Matriculation Continued. They must register for [one](#) credit of research each semester until they complete their degree.

Master's degree students who have completed all course requirements must register for Matriculation Continued until they complete the M.S. Technical Paper, unless they are engaged in thesis research on campus, in which case they must register for at least one credit of research.

11.2. Application for Readmission

A student who has missed one or two semesters of registration must complete an *Application for Readmission* and submit it to the graduate director for approval. Students who have missed *more* than two semesters without registration must file a *new Application for Admission* through the Graduate Admissions Office.

11.3. Assistantship Registration

Students with TA/GA's must register their assistantship appointments using the "E" credit prefix. Registration is 6 credits per term for full-time TA/GA's and 3 credits for half-time appointments.

11.4. Special Problems Courses

A student taking a *Special Problems* course must make arrangements with a faculty member to supervise the project and must submit a completed *application* form to the graduate program coordinator before registering for the course. The student must fill out the "By Arrangement" column on the registration form. The student receives a regular letter grade for the course.

No more than 6 credits of Special Problems will be credited towards the Master's degree and no

more than 9 credits towards the Ph.D. degree.

11.5. Undergraduate Courses

No graduate credit is given for undergraduate courses. To register for undergraduate courses, the student must enter the prefix "E" in the credit prefix column of the registration form, and must submit an *application form*, available from the graduate program coordinator, to the graduate director for approval.

11.6. Non-Credit Courses

Courses taken on a "not for credit" basis require an "N" prefix on the registration form. The student will complete all course work except the final exam and will receive a grade of "S" or "U". Graduate students in the program are not permitted "Pass/Fail" grades for course work.

12. Communication with Students

All graduate students are provided with mailboxes in the Electrical Engineering Building. It is the student's responsibility to inform the graduate program and the School of Graduate Studies of any changes in address and/or telephone number.

This handbook is subject to amendment at any time. Therefore, students should make sure they have the most recent version.

Any questions not covered in this handbook may be addressed to the graduate program coordinator, Mrs. Christy Lafferty, Electrical Engineering Building, Room 134, Busch Campus, (848) 445-2577, or to the graduate director: Professor Zoran Gajic, Electrical Engineering Building, Room 134A, Busch Campus, (848) 445-2578. Consultations with Professor Gajic are normally by appointment only.

13. Practical Training

Two types of practical training are offered by the Electrical and Computer Engineering Department:

1. Optional Practical Training (OPT). This is available to any student who is in good academic standing, and has no more than 1 Incomplete, provided that the Incomplete only occurred during the immediately preceding semester. This training counts against your 1-year time limit of Practical Training after obtaining your degree from Rutgers. In order to apply for OPT, please supply these items to the Graduate Program Coordinator:
 - a.) A memo to the Graduate Director requesting OPT.
 - b.) A complete OPT form (which you obtain from Global Services).

2. Curricular Practical Training (CPT). This is available to PhD students and to Master's Thesis students who have completed 2 semesters of study in the Department. The CPT is semester based. The students must be full-time registered during CPT. The conditions for CPT are:
 - a.) You, your advisor, and the company that is employing you must be participating in a joint research project, *which will become part of your MS thesis/PhD dissertation*. Your advisor's letter must

indicate the research topic and state that this research work will be an essential part of your MS thesis/PhD dissertation. The company letter must have the job description consistent with your advisor's letter.

- b.) You must register for at least 1 credit of 16:332:701 or 16:332:702 (Graduate Research) during the period of your CPT.
- c.) You must write a technical report about your CPT research and submit it to the Graduate Director. The report will be reviewed by your advisor and the Graduate Director.

If you meet these criteria, you may apply for CPT in the following way:

- a.) Attend a workshop on CPT at the International Center at Rutgers.
- b.) Bring the job offer letter, the advisor's letter and the form requesting CPT (which you obtain from the International Center) to the Graduate Director.

Appendix A --- Faculty Research Areas

- I. Androulakis** *Biomedical Engineering*, (848) 445-6561, ioannis.androulakis@rutgers.edu; BME 212.
Systems biology. Functional links between cellular events, such as signaling transcription and translation. Interactions that include bidirectional links between cells, tissues, organs, environmental signals, and physiological responses.
- W. Bajwa** *Digital Signal Processing*, (848) 445-8541, waheed.bajwa@rutgers.edu; CoRE 723.
Digital signal processing, high-dimensional inference and inverse problems, compressed sensing, wireless communications.
- H. Baruh** *Mechanical and Aerospace Engineering*, (848) 445-3680, baruh@rutgers.edu; ENG B242.
Structural dynamics, control of structures using piezoelectric component, impact dynamics, control of systems describing constrained coordinates, autonomous vehicle control, structural damage detection.
- G. Burdea** *Computer Engineering*, (848) 445-5309, burdea@rutgers.edu; CoRE 721.
Virtual reality systems, force feedback interfaces, medical applications of virtual reality. Telemedicine.
- M. Caggiano**, *Professor Emeritus of Electrical and Computer Engineering*, (848) 445-0678, cagg@rutgers.edu; EE-111.
High performance and microwave IC device packaging. Electronic circuits.
- Y. Chen**, *Cybersecurity, Networking, Computer Engineering*, (848) 445-9151, yingying.chen@rutgers.edu; CoRE 506.
Mobile healthcare, Internet of Things (IoT), Cyber Security and Privacy, Connected vehicles, Mobile Computing and Sensing.
- M. Chhowalla** *Material Science and Engineering*.
Graphene oxide, copper, organic electronics, optoelectronics, solar cells.
- S-W. Cheong** *Physics and Astronomy*, (848)445-9023, sangc@physics.rutgers.edu; W123.
Experimental condensed-matter physics and material science.
- D. L. Comaniciu**, *Siemens Corporate Technology*, Princeton, NJ, Ph. D. Rutgers University.
Medical imaging, scanner automation. Cardiac modeling, image-guided surgery, biomedical, computer vision, and machine learning.
- K. Dana** *Computer Engineering*, (848) 445-5253, kristin.dana@rutgers.edu; CoRE 514.
Computational models for image texture with applications in pattern recognition and scene rendering. Physics-based methods for vision and graphics. Stochastic processes for surface modeling and texture analysis. Medical image processing using image registration, fusion and change detection. Optical imaging models for microscopy.
- M. M. Dehnavi** *Computer Engineering*.
Numerical analysis, machine learning, high-performance computing, compiler and library design, cloud computing.

- F. Javier Diez-Garias** *Mechanical & Aerospace Engineering*, (848)445-3665, f.javier.diez@rutgers.edu; ENG B236.
Experimental thermal and fluid sciences, fire safety, sprays, microfluidics, flow diagnostics, turbulence, combustion and energy.
- S. El Rouayheb** *Communications, Cybersecurity*, (848) 445-9154, salim.elrouayheb@rutgers.edu; CoRE 717.
Information theory, Coding theory, and their applications to data security and privacy.
- T.N. Farris** *Engineering*, (848) 445-2212, tfarris@rutgers.edu; RWH 405.
Aerospace structures and materials. Tribology, manufacturing, fatigue and fracture.
- L. C. Feldman** *Institute of Advanced Materials, Devices and Nanotechnology*, (848) 445-4524, l.c.feldman@rutgers.edu.
The chemical formation and structure of thin film materials and their applications to problems of semiconductor science and engineering and applications associated with energy. Included in the latter are the fundamentals of photon interactions with solids, and radiation effects in semiconductor materials.
- G.J. Foschini**
Wireless and optical communications.
- R.H. Frenkiel** *Communications*, (732) 446-7992, frenkiel@winlab.rutgers.edu; WLTC C111.
Wireless systems architecture.
- Z. Gajic** *Systems and Control*, (848) 445-3415, zgajic@rutgers.edu; EE 134A.
Singular perturbation methods in control system analysis. Linear stochastic estimation and control. Bilinear control systems. Matrix Lyapunov and Riccati equations. Control of power in optical and wireless networks, fuel and solar cells, and energy systems.
- H. Godrich** (848) 445-0606, godrich@rutgers.edu; EE 122.
Statistical and array signal processing, distributed detection and estimation with application in radar systems, wireless sensor networks, and smart power grids.
- M. Gruteser** *Communications*, (848)932-0993; gruteser@winlab.rutgers.edu; WLTC C114.
Pervasive computing architectures and prototyping; location tracking, location-aware systems and applications; information privacy and security for wireless networks and sensor-based systems.
- M. Gurbuzbalaban** *Management Science and Information Systems*, (617)324-0645; mgurbuzbalaban@business.rutgers.edu.
Optimization and computational science driven by applications in large-scale information, decision and infrastructure systems, convex optimization, probability and robust control.
- S. J. Hanson** *Physiology Newark (Brain Imaging Center)* (973) 353-5440 x 3952, jose@psychology.rutgers.edu; Smith Hall 324.
Learning theory and experiment, connectionist models of human characterization and object recognition, brain imaging – predictive decoding/MVPA and graphical models, event perception, language supporting functions.
- U. Hassan** *Bioelectrical Engineering, Bioelectronics*, (848)445-2164, umer.hassan@rutgers.edu; EE 215.
Micro/nano sensing for biomedical applications, disease diagnostics and Therapeutics for

personalized medicine, BioMEMS & microfluidics and immuno-engineering, predictive prognostics, healthcare systems, point-of-care devices for global health applications.

- R. Howard** *Communications*, (848)932-0905, reh@winlab.rutgers.edu; WLTC A101.
Low energy sensors/networks, wireless PHY enhancements, HCI technology.
- M. Javanmard** *Electronics*, (848) 445-3382, mehdi.javanmard@rutgers.edu; EE 211.
Nanobiotechnology, BioMEMS, Microfluidics, Micro and Nanofabrication, Biosensing, Bioelectronics, Early Cancer Diagnostic Systems, Pathogen Detection, Diagnostics for the Developing World.
- J. Jeon** *Solid State Electronics*.
Nano-electro-mechanical relay devices, energy-efficient electronics, neural relay devices, neuromorphic systems, advanced materials and process technologies for energy-harvesting.
- S. Jha** *Computer Engineering*, (848) 445-8537, shantenu.jha@rutgers.edu; CoRE-705.
High-performance and distributed computing, scientific computation, large-scale cyberinfrastructure for supporting scientific and engineering computation.
- J. K-J. Li** *Biomedical Engineering*, (848) 445-6582, johnkjli@soe.rutgers.edu; BME 305.
Circulatory dynamics; instrumentation; physiological control.
- J. Lindqvist** *Communications/Computer Engineering*, (848) 445-0610, janne@winlab.rutgers.edu; CoRE 521.
Human behavior using computer systems, systems security and privacy, security for mobile systems and pervasive computing, automotive computing.
- Y. Lu** *Solid State Electronics*, (848) 445-3466, ylu@rutgers.edu; EE 236.
Wide band gap semiconductor (ZnO and GaN) materials and devices, tunable RF components, dielectric thin films, MOCVD growth.
- R. Mammone** *Digital Signal Processing*, (848) 445-5554, rmammone@rutgers.edu; CoRE 518.
Investigation and applications of new signal extraction algorithms, ultrasound and optical image restoration, speech parameter extraction, equalization of communication channels, machine vision, pattern recognition, expert systems and applications of neuro-networks.
- N. Mandayam** *Communications*, (848) 445-1494, narayan@winlab.rutgers.edu; EE 128.
Communication theory, spread spectrum, wireless system performance, multi-access protocols, multimedia communications over wireless systems, multiuser detection.
- I. Marsic** *Computer Engineering*, (848) 445-6399, marsic@rutgers.edu; CoRE 711.
Distributed Systems for Collaborative/Information Processing and Learning-(DISCIPLER), methods of object recognition in wavelet scale, image reconstruction, and machine vision.
- R. Martin** *Computer Science*, (848) 445-8304, rmartin@rutgers.edu; CoRE 304.
Sensor networks, wireless networks, internet, localization, ad-hoc communication networks.
- S. McAfee** *Solid State Electronics*, (848) 445-5247, sigridmcafee@aol.com; EE 213.
Fundamental properties of deep levels in semiconductors. Influence of deep levels on the growth parameters of molecular beam epitaxy silicon, metal-organic chemical vapor deposited Al(GaAs) and InGaAsP materials and devices. Semiconductor processing in silicon and III-V materials for

basic research and device applications. Fiber optics with emphasis on fiber optic coupling of lasers and waveguides. Electromagnetic field applications in materials and antennas.

P. Meer *Computer Engineering*, meer@rutgers.edu.

Application of modern statistical methods to computer vision and pattern recognition; robust techniques for image understanding; probabilistic algorithms for machine vision problems; representation of semantical visual information.

L. Najafizadeh *Nano and Microelectronics*, (848) 445-0593, laleh.najafizadeh@rutgers.edu; CoRE 520.
Brain imaging, microelectronics and circuits design, signal processing and biophotonics.

S. Oh *Physics and Astronomy*, (848) 445-8754, ohsean@physics.rutgers.edu; W121.

Molecular beam epitaxy of functional oxides and quantum materials, and low dimensional electronic properties.

S. Orfanidis *Digital Signal Processing*, (848) 445-5017, sophocles.orfanidis@rutgers.edu; EE 230.

Adaptive signal processing. Block processing and adaptive eigenvector methods for spectrum estimation, direction finding, and pole retrieval. Neural networks.

J. Ortiz *Computer Engineering*, (848) 445-5243, jorge.ortiz@rutgers.edu; CoRE 519.

IoT and cyber physical systems, machine learning, intelligent infrastructure and smart buildings, mobile health, sensor networks, machine learning at the edge, application of machine learning to cyber-physical systems in the context of sustainable systems and smart health applications, development of novel machine learning techniques motivated by real-world use cases in these application domains.

M. Parashar *Computer Engineering and Science*, (848) 445-5388, parashar@rutgers.edu; CoRE 628.

Parallel and Distributed Computing, Software Engineering, Scientific Computing, Computational Interaction and Steering, Network/Application Quality-of-Service, Active Networks, and Performance Evaluation and Prediction.

V. M. Patel *Electrical and Computer Engineering*, Johns Hopkins University, Maryland.

Computer vision, signal, image and video processing, biometrics, pattern recognition, mobile security and privacy, radar imaging, computational imaging, compressive sampling, image reconstruction.

A. Petropulu *Digital Signal Processing and Communications*, (848) 445-0414, athinap@rutgers.edu; CoRE 510.

Statistical signal processing – system identification; MIMO system estimation; blind source separation; higher-order statistics. Networking – cooperative protocols for wireless networks; high-speed wireline and wireless traffic modeling; cross-layer approaches. Wireless communications – blind channel estimation and equalization; CDMA systems; OFDM systems. Biomedical engineering – tissue characterization for breast cancer detection based on the ultrasound rf echo; resolution improvement of ultrasound images; Raman spectroscopy for tissue characterization.

D. Pompili *Computer Engineering*, (848) 445-8533, pompili@rutgers.edu; CoRE 615.

Sensor Networks, Underwater Acoustic Sensor Networks, Sensor and Actor Networks, Ad Hoc Networks, Wireless Internet, Wireless Mobile Networks, Overlay Networks, Traffic Engineering, Optimization, Multimedia Communications, Satellite Networks.

D. Raychaudhuri *Communications*, (848) 932-0941, ray@winlab.rutgers.edu; WINLAB WTC 103.

Network architecture, design and prototyping; Communication protocols/software; Quality-of-service, mobility management, and content delivery in mobile networks; Wireless system design, including spectrum management, radio MAC/link protocols & network management; Broadband network technologies.

I. Rodero *Computer Engineering*, (732)993-8837, irodero@rutgers.edu; CoRE 624.

Parallel and distributed computing; extreme-scale computing: energy/power efficiency, cloud and automatic computing, scalable data management and analytics, big data.

A. Sarwate *Signal Processing*, (848) 445-8516, anand.sarwate@rutgers.edu; CoRE 517.

Information processing in distributed systems, using tools from machine learning, signal processing, information theory, statistics, and optimization. I am interested in designing methods to learn from data, which is private or sensitive.

G. K. Shoane *Biomedical Engineering*, (848) 445-6583, shoane@soe.rutgers.edu; BME 306.

Binocular vision; vergence; accommodation model; amblyopia.

D. Silver *Computer Engineering*, (732)445-5117, dsilver@rutgers.edu; CoRE 709.

Computer graphics, scientific visualization, numerical analysis, computational geometry.

V. K. Singh *Library and Information Science*, (848) 932-7588, vivek.k.singh@rutgers.edu ; CI 334.

Data analytics-driven sensing and shaping of human behavior.

E. Soljanin *Communications and Computer Engineering*, (848) 445-5256; emina.soljanin@rutgers.edu; CoRE 511.

Mathematics of distributed systems, in particular concerning mechanisms for efficient, reliable, and secure distributed data storage that provide fast access, download, and streaming of big data files. Coding, information and queuing theory. Applications of probability, algebra, graph and number theory, and combinatorics to distributed systems.

E. D. Sontag *Mathematics*, (848) 445-7947, eduardo.sontag@gmail.com; HLL 422.

Linear and nonlinear control; neural networks; feedback design.

P. Spasojevic *Communications*, (848) 445-1372, spasojevic@winlab.rutgers.edu ; CoRE 504.

Wireless and wired digital communications, adaptive and statistical signal processing, sequence and channel estimation, multi-user detection; equalization and synchronization, iterative detection, and receiver implementation.

M. Striki *Software Engineering*, (848) 445-9145, maria.striki@rutgers.edu; EE 115.

Analysis/design/optimization of data algorithms, statistical analysis, mathematical modeling, big data, data analytics, social networks, information systems, cybernetics, wireless-mobile-ad-hoc-cellular networks, (secure) routing, mobile computing, network-computer security.

W. Trappe *Communications*, (848) 445-0611, trappe@winlab.rutgers.edu; CoRE 523.

Multimedia and multicast information security, signal, image and video processing, wireless networking, cryptography and network security.

M. Turilli *Software Engineering*, (848) 445-8540, matteo.turilli@gmail.com ; CoRE 707.

Parallel and Distributed Computing, Software Design for Distributed Infrastructures, Computer Science, Computer Ethics.

- S. Wei** *Computer Engineering, Cybersecurity*, (848) 445-5250, sheng.wei@rutgers.edu; CoRE 508.
Hardware security and trust, hardware-enabled system security, heterogeneous system architecture and security, mobile and multimedia systems.
- R. Wright** *Computer Science*, (848) 445-5931, rebecca.wright@rutgers.edu; CoRE 404.
Computer and communications security, particularly in the areas of privacy, cryptographic protocols, and fault-tolerant distributed computing. Designing protocols, systems, and services that perform their specified computational or communication functions even if some of the participants or underlying components behave maliciously.
- M. Wu** *Communications, Computational Sensing, Solid State Electronics*, (848) 445-5393, ctm.wu@rutgers.edu; EE 232.
Applied electromagnetics, antennas, passive/active microwave and millimeter-wave components, RF systems and metamaterials.
- R. Yates** *Communications*, (848) 445-8515, ryates@winlab.rutgers.edu; CoRE 515.
Power control, interference suppression and handoff for wireless networks, multiaccess protocols, discrete time queueing networks.
- J. Yi** *Mechanical and Aerospace Engineering*, (848) 445-3282, jgyi@rutgers.edu; ENG D157.
Autonomous robotic systems, dynamic systems and control; mechatronics, automation science and engineering.
- B. Yuan** *Computer Engineering, Signal Processing, Communications*, (848) 445-9152, bo.yuan@soe.rutgers.edu; CoRE 715.
Algorithm and hardware co-design and implementation for machine learning and signal processing systems, error-resilient low-cost computing techniques for embedded and IoT systems and machine learning for domain-specific applications.
- Y. Zhang** *Computer Engineering*, (848) 445-0608, yyzhang@winlab.rutgers.edu; CoRE 518.
Computer Architecture, Operating Systems, Parallel Computing, Cluster Computer, Performance Evaluation, Sensor Networks.
- J. Zhao** *Solid State Electronics* (848) 445-5240, jzhaoece@gmail.com; CoRE 512.
Silicon Carbide (SiC) Semiconductor Devices, SiC JFETs, BJTs, MOSFETS, GTOs, High Efficiency Smart Power Integrated Circuits, SiC Sensors, UV and EUV Detectors, SiC Single Photon Detectors, High Temperature Packaging, SiC Power Limiters/Protector/Circuit Breakers, SiC Inverters/Converters
- S. Zonouz** *Computer Engineering*, (848) 445-8508, saman.zonouz@rutgers.edu; CoRE 524.
Design and implementation for systems and networks security and privacy. Cyber-physical critical infrastructures, embedded systems, operating system security, intrusion detection and forensics analysis, and software reverse engineering.
- Q. Zou** *Mechanical and Aerospace Engineering*, (848)445-3268, qzzou@rutgers.edu; ENG D101.
Precision positioning, inversion-based control theory, scanning probe microscopy; nanofabrication.

Appendix B --- Graduate Courses

16:332:501 (F) SYSTEM ANALYSIS (3)

Fundamental system concepts, solution of linear differential and difference equations. Transform methods involving Fourier and Laplace transforms, double-sided Laplace transforms, Z-transforms, Hilbert Transforms, convolution in time and frequency domain. Complex variables and application of Residue Theorem for transform inversion. Review of Matrix algebra involving similarity transformations. Cayley-Hamilton theorem, state space concepts, controllability, observability, minimal realization.

16:332:502 (F) TECHNOLOGY ENTREPRENEURSHIP (3)

Structure and framework of entrepreneurial endeavors. Phases of a startup, business organization, intellectual property, financing, financial modeling, and business plan writing.

16:332:503 (F) PROGRAMMING METHODOLOGY FOR NUMERICAL COMPUTING AND COMPUTATIONAL FINANCE (3)

Fundamentals of object-oriented programming and C++ with an emphasis in numerical computing and computational finance. Design Oriented. Topics include: C++ basics, object oriented concepts, data structures, algorithm analysis and applications.

16:332:504 (F) SENSOR-BASED SYSTEMS AND APPLICATIONS (3)

Corequisite: 16:332:543

The course will develop skills in designing, programming, and testing self-configurable communication protocols and distributed algorithms for wireless sensor networks enabling environmental, health, and seismic monitoring, surveillance, reconnaissance, and targeting.

16:332:505 (S) CONTROL SYSTEM THEORY (3)

Prerequisite: 16:332:501.

Review of basic feedback concepts and basic controllers. State space and transfer function approaches for linear control systems. Concepts of stability, controllability, and observability for time-invariant and time-varying linear control systems. Pole placement technique. Full and reduced-order observer designs. Introduction to linear discrete-time systems.

16:332:506 (F) APPLIED CONTROLS (3)

Review of state space techniques; transfer function matrices; concepts of controllability, observability and identifiability. Identification algorithms for multivariable systems; minimal realization of a system and its construction from experimental data. State space theory of digital systems. Design of a three mode controller via spectral factorization.

16:332:507 (S) SECURITY ENGINEERING (3)

Essential principles, techniques, tools, and methods for systems security engineering. Students work in small collaborative design teams to propose, build, and document a project focused on securing systems. Students document their work through a series of written and oral proposals, progress reports, and final reports. Basics of security engineering, usability and psychology, human factors in securing systems, mobile systems security, intersection of security and privacy, security protocols, access control, password security, biometrics, and topical approaches such as gesture---based authentication.

16:332:508 (S) DIGITAL CONTROL SYSTEMS (3)

Prerequisite: 16:332:505.

Review of linear discrete-time systems and the Z-transform. Sampling of continuous-time linear systems

and sampled-data linear systems. Quantization effects and implementation issues. Computer controlled continuous-time linear systems. Analysis and design of digital controllers via the transfer function and state space techniques. Linear-quadratic optimal control and Kalman filtering for deterministic and stochastic discrete-time systems.

16:332:509 (S) CONVEX OPTIMIZATION FOR ENGINEERING APPLICATIONS (3)

The course develops the necessary theory, algorithms and tools to formulate and solve convex optimization problems that seek to minimize cost function subject to constraints. The emphasis of the course is on applications in engineering applications such as control systems, computer vision, machine learning, pattern recognition, financial engineering, communication and networks.

16:332:510 (S) OPTIMAL CONTROL SYSTEMS (3)

Prerequisites: 16:332:505 and 16:332:506.

Formulation of both deterministic and stochastic optimal control problems. Various performance indices; calculus of variations; derivation of Euler-Lagrange and Hamilton-Jacobi equations and their connection to two-point boundary value problems, linear regulator and the Riccati equations. Pontryagin's maximum principle, its application to minimum time, minimum fuel and "bang-bang" control. Numerical techniques for Hamiltonian minimization. Bellman dynamic programming; maximum principle.

16:332:512 (S) NONLINEAR AND ADAPTIVE CONTROL THEORY (3)

Prerequisite: 16:332:505.

Nonlinear servo systems; general nonlinearities; describing function and other linearization methods; phase plane analysis and Poincare's theorem. Liapunov's method of stability; Popov criterion; circle criterion for stability. Adaptive and learning systems; identification algorithms and observer theory; input adaptive, model reference adaptive and self-optimizing systems. Estimation and adaptive algorithms via stochastic approximation. Multivariable systems under uncertain environment.

16:332:514 (S) STOCHASTIC CONTROL SYSTEMS (3)

Prerequisite: 16:332:505.

Response of linear and nonlinear systems to random inputs. Determination of statistical character of linear and nonlinear filter outputs. Correlation functions; performance indices for stochastic systems; design of optimal physically realizable transfer functions. Wiener-Hopf equations; formulation of the filtering and estimation problems; Wiener-Kalman filter. Instabilities of Kalman filter and appropriate modifications for stable mechanization. System identification and modeling in presence of measurement noise.

16:332:519 ADVANCED TOPICS IN SYSTEMS ENGINEERING (3)

Prerequisite: Permission of instructor.

Advanced study of various aspects of automatic control system. Possible topics include identification, filtering, optimal and adaptive control, learning systems, digital and sampled data implementations, singular perturbation theory, large scale systems, game theory, geometric control theory, control of large flexible structures, etc. Topics will vary from year to year.

16:332:521 (F) DIGITAL SIGNALS AND FILTERS (3)

Corequisite: 16:332:501.

Sampling and quantization of analog signals; Z-transforms; digital filter structures and hardware realizations; digital filter design methods; DFT and FFT and methods and their application to fast convolution and spectrum estimation; introduction to discrete time random signals.

16:332:525 (F) OPTIMUM SIGNAL PROCESSING (3)

Prerequisites: 16:332:521 or Permission of instructor.

Block processing and adaptive signal processing techniques for optimum filtering, linear prediction, signal modeling, and high resolution spectral analysis. Lattice filters for linear prediction and Wiener filtering. Levinson and Schur algorithms and their split versions. Fast Cholesky factorizations. Periodogram and parametric spectrum estimation and superresolution array processing. LMS, RLS, and lattice adaptive filters and their applications. Adaptation algorithms for multilayer neural nets.

16:332:526 (S) ROBOTIC SYSTEMS ENGINEERING (3)

Introduction to robotics; robot kinematics and dynamics. Trajectory planning and control. Systems with force, touch and vision sensors. Telemanipulation. Programming languages for industrial robots. Robotic simulation examples.

16:332:527 (S) DIGITAL SPEECH PROCESSING (3)

Prerequisite: 16:332:521.

Acoustics of speech generation; perceptual criteria for digital representation of audio signals; signal processing methods for speech analysis; waveform coders; vocoders; linear prediction; differential coders (DPCM, delta modulation); speech synthesis; automatic speech recognition; voice-interactive information systems.

16:332:529 (S) IMAGE CODING AND PROCESSING (3)

Prerequisites: 16:332:521, 16:642:550, (16:332:535 recommended).

Visual information, image restoration, coding for compression and error control, motion compensation, advanced television.

16:332:533 (S) COMPUTATIONAL METHODS FOR SIGNAL RECOVERY (3)

Prerequisites: 16:332:521 and 16:332:541.

Computational methods for estimating signals in noise, for forecasting trends in noisy data, for clustering data for the recognition and detection of patterns in data. Kalman filtering, neural networks, support vector machines, and hidden Markov models. Applications in financial engineering and bioinformatics as well as in more traditional signal processing areas such as speech, image, and array processing, face recognition.

16:332:535 (F) MULTIREOLUTION SIGNAL PROCESSING ALGORITHMS (3)

Prerequisites: 16:332:521 or Permission of instructor. Corequisite: 16:642:550.

Wavelets and subband coding with applications to audio, image, and video processing. Compression and communications issues including low-bit-rate video systems. Design of digital filters for systems with 2 or more channels. Matlab and matrix algorithms for analysis, design, and implementation.

16:332:539 ADVANCED TOPICS IN DIGITAL SIGNAL PROCESSING (3)

Prerequisite: Permission of instructor.

The course deals with selected topics in digital signal processing. Emphasis is given to current research areas. Advanced treatment will be given to such topics as digital filter design, digital filtering of random signals, discrete spectral analysis methods, and digital signal processor architectures. Subject matter may change year to year.

16:332:541 (F) STOCHASTIC SIGNALS AND SYSTEMS (3)

Corequisite: 16:332:501 and 16:642:550.

Axioms of probability; conditional probability and independence; random variables and functions thereof; mathematical expectation; characteristic functions; conditional expectation; Gaussian random vectors; mean square estimation; convergence of a sequence of random variables; laws of large numbers and Central Limit Theorem; stochastic processes, stationarity, autocorrelation and power spectral density;

linear systems with stochastic inputs; linear estimation; independent increment, Markov, Wiener, and Poisson processes.

16:332:542 (S) INFORMATION THEORY AND CODING (3)

Prerequisite: 16:332:541.

Noiseless channels and channel capacity; entropy, mutual information, Kullback-Leibler distance and other measures of information; typical sequences, asymptotic equipartition theorem; prefix codes, block codes, data compression, optimal codes, Huffman, Shannon-Fano-Elias, Arithmetic coding; memoryless channel capacity, coding theorem and converse; Hamming, BCH, cyclic codes; Gaussian channels and capacity; coding for channels with input constraint; introduction to source coding with a fidelity criterion.

16:332:543 (F) COMMUNICATION NETWORKS I (3)

Prerequisite: 14:332:226 or equivalent or 16:332:541 or equivalent.

Introduction to telephony and integrated networks. Multiplexing schematics. Circuit and packet switching networks. Telephone switches and fast packet switches. Teletraffic characterization. Delay and blocking analysis. Queueing network analysis.

16:332:544 (S) COMMUNICATION NETWORKS II (3)

Prerequisite: 16:332:543.

Network and protocol architectures. Layered connection management, including network design, path dimensioning, dynamic routing, flow control, and random access algorithms. Protocols for error control, signaling, addressing, fault management, and security control.

16:332:545 (S) DIGITAL COMMUNICATION SYSTEMS (3)

Prerequisite: 16:332:541.

Signal space and Orthonormal expansions, effect of additive noise in electrical communications vector channels, waveform channels, matched filters, bandwidth and dimensionality. Digital modulation techniques. Optimum receiver structures, probability of error, bit and block signaling, Intersymbol interference and its effects, equalization and optimization of baseband binary and M-ary signaling schemes; introduction to coding techniques.

16:332:546 (S) WIRELESS COMMUNICATIONS TECHNOLOGIES (3)

Prerequisite: 16:332:545

Propagation models and modulation techniques for wireless systems, receivers for optimum detection on wireless channels, effects of multiple access and intersymbol interference, channel estimation, TDMA and CDMA cellular systems, radio resource management, mobility models.

16:332:548 (S) ERROR CONTROL CODING (3)

Prerequisite: 16:332:545.

Continuation of 16:332:545. Application of information-theoretic principles to communication system analysis and design. Source and channel coding considerations, rudiments of rate-distortion theory. Probabilistic error control coding impact on system performance. Introduction to various channel models of practical interest, spread spectrum communication fundamentals. Current practices in modern digital communication system design and operation.

16:332:549 (S) DETECTION AND ESTIMATION THEORY (3)

Prerequisite: 16:332:541.

Statistical decision theory, hypothesis testing, detection of known signals and signals with unknown parameters in noise, receiver performance and error probability, applications to radar and communications. Statistical estimation theory, performance measures and bounds, efficient estimators. Estimation of unknown signal parameters, optimum demodulation, applications, linear estimation,

Wiener filtering, Kalman filtering.

16:332:553 (S) WIRELESS ACCESS TO INFORMATION NETWORKS (3)

Prerequisites: 14:332:349 and 14:332:450 or equivalent.

Cellular mobile radio; cordless telephones; systems architecture; network control; switching; channel assignment techniques; short range microwave radio propagation; wireless information transmission including multiple access techniques, modulation, source coding, and channel coding.

16:332:556 (S) MICROWAVE COMMUNICATION SYSTEMS (3)

Prerequisite: 16:332:580 or equivalent.

Overview of modern microwave engineering including transmission lines, network analysis, integrated circuits, diodes, amplifier and oscillator design. Microwave subsystems including front-end and transmitter components, antennas, radar terrestrial communications, and satellites.

16:332:559 ADVANCED TOPICS IN COMMUNICATIONS ENGINEERING (3)

Prerequisite: Permission of instructor.

Topics such as source and channel coding, modern modulation techniques, wireless communication networks, networks security, and information processing. Subject matter changes from year to year.

16:332:560 (F) COMPUTER GRAPHICS (3)

Computer display systems, algorithms and languages for interactive graphics. Vector, curve, and surface generation algorithms. Hidden-line and hidden-surface elimination. Free-form curve and surface modeling. High-realism image rendering.

16:332:561 (F) MACHINE VISION (3)

Prerequisite: 16:332:501.

Image processing and pattern recognition. Principles of image understanding. Image formation, boundary detection, region growing, texture and characterization of shape. Shape from monocular clues, stereo and motion. Representation and recognition of 3-D structures.

16:332:562 (S) VISUALIZATION AND ADVANCED COMPUTER GRAPHICS (3)

Prerequisite: 16:332:560 or permission of instructor.

Advanced visualization techniques, including volume representation, volume rendering, ray tracing, composition, surface representation, advanced data structures. User interface design, parallel and object-oriented graphic techniques, advanced modeling techniques.

16:332:563 (F) COMPUTER ARCHITECTURE I (3)

Fundamentals of computer architecture using quantitative and qualitative principles. Instruction set design with examples and measurements of use, basic processor implementation: hardwired logic and microcode, pipelining; hazards and dynamic scheduling, vector processors, memory hierarchy; caching, main memory and virtual memory, input/output, and introduction to parallel processors; SIMD and MIMD organizations.

16:332:564 (S) COMPUTER ARCHITECTURE II (3)

Prerequisite: 16:332:563.

Advanced hardware and software issues in main-stream computer architecture design and evaluation. Topics include register architecture and design, instruction sequencing and fetching, cross-branch fetching, advanced software pipelining, acyclic scheduling, execution efficiency, predication analysis, speculative execution, memory access ordering, prefetch and preloading, cache efficiency, low power architecture, and issues in multiprocessors.

16:332:565 (F) NEUROCOMPUTER SYSTEM DESIGN (3)

Prerequisites: 16:332:563.

Principles of neural-based computers, data acquisition, hardware architectures for multilayer, tree and competitive learning neural networks, applications in speech recognition, machine vision, target identification and robotics.

16:332:566 (S) INTRODUCTION TO PARALLEL AND DISTRIBUTED COMPUTING (3)

Prerequisite: 16:332:563.

Introduction to the fundamental of parallel and distributed computing including systems, architectures, algorithms, programming models, languages and software tools. Topics covered include parallelization and distribution models; parallel architectures; cluster and networked meta-computing systems; parallel/distributed programming; parallel/distributed algorithms, data-structures and programming methodologies, applications; and performance analysis. A "hands-on" course with programming assignments and a final project.

16:332:567 (F) SOFTWARE ENGINEERING I (3)

Overview of software development process. Formal techniques for requirement analysis, system specification and system testing. Distributed systems. System security and system reliability. Software models and metrics. Case studies.

16:332:568 (S) SOFTWARE ENGINEERING WEB APPLICATIONS (3)

Prerequisite: 16:332:567.

The course focus is on Web software design with particular emphasis on mobile wireless terminals. The first part of the course introduces tools; Software component (Java Beans), Application frameworks, Design patterns, XML, Communication protocols, Server technologies, and Intelligent agents. The second part of the course presents case studies of several Web applications. In addition, student teams will through course projects develop components for an XML-Based Web, such as browsers, applets, servers, and intelligent agents.

16:332:569 (F) DATABASE SYSTEM ENGINEERING (3)

Relational data model, relational database management system, relational query languages, parallel database systems, database computers, and distributed database systems.

16:332:570 (S) ROBUST COMPUTER VISION (3)

Prerequisite: 16:332:561.

A toolbox of advanced methods for computer vision, using robust estimation, clustering, probabilistic techniques, invariance. Applications include feature extraction, image segmentation, object recognition, and 3-D recovery.

16:332:571 (S) VIRTUAL REALITY TECHNOLOGY (3)

Prerequisite: 16:332:560.

Introduction to Virtual Reality. Input/Output tools. Computing architectures. Modeling. Virtual Reality programming. Human factors. Applications and future systems.

16:332:572 (S) PARALLEL AND DISTRIBUTED COMPUTING (3)

Prerequisite: 16:332:563, 16:332:564 and 16:332:566.

Study of the theory and practice of applied parallel/distributed computing. The course focuses on advanced topics in parallel computing including current and emerging architectures, programming models

application development frameworks, runtime management, load-balancing and scheduling, as well as emerging areas such as autonomic computing, Grid computing, pervasive computing and sensor-based systems. A research-oriented course consisting of reading, reviewing and discussing papers, conducting literature surveys, and a final project.

16:332:573 (S) DATA STRUCTURES AND ALGORITHM (3)

The objective is to take graduate students in all graduate School of Engineering fields with a good undergraduate data structures and programming background and make them expert in programming the common algorithms and data structures, using the C and C++ programming languages. The students will perform laboratory exercises in programming the commonplace algorithms I C and C++. The students will also be exposed to computation models and computational complexity.

16:332:574 (F) COMPUTER-AIDED DIGITAL VLSI DESIGN (3)

Advanced computer-aided VLSI chip design, CMOS and technology, domino logic, pre-charged busses, case studies of chips, floor planning, layout synthesis, routing, compaction circuit extraction, multi-level circuit simulation, circuit modeling, fabrication processes and other computer-aided design tools.

16:332:575 (S) VLSI ARRAY PROCESSORS (3)

Prerequisite: 16:332:574

VLSI technology and algorithms; systolic and wavefront-array architecture; bit-serial pipelined architecture; DSP architecture; transputer; interconnection networks; wafer-scale integration; neural networks.

16:332:576 (S) TESTING OF ULTRA LARGE SCALE CIRCUITS (3)

Prerequisite: 16:332:563.

Testing of Ultra Large Scale Integrated Circuits (of up to 50 million transistors) determines whether a manufactured circuit is defective. Algorithms for test-pattern generation for combinational, sequential, memory, and analog circuits. Design of circuits for easy testability. Design of built-in self-testing circuits.

16:332:577 (S) ANALOG AND LOW-POWER DIGITAL VLSI DESIGN (3)

Transistor design and chip layout of commonly-used analog circuits such as OPAMPS, A/D and D/A converters, sample-and-hold circuits, filters, modulators, phase-locked loops, and voltage-controlled oscillators. Low-power design techniques for VLSI digital circuits, and system-on-a-chip layout integration issues between analog and digital cores.

16:332:578 (S) DEEP SUBMICRON VLSI DESIGN (3)

Prerequisite: 14:332:574 CAD Digital VLSI Design

Advanced topics in deep submicron and nanotechnology VLSI design and fabrication. Logic and state machine design for high performance and low power. Tree adders and Booth multipliers. Memory design. Timing testing for crosswalk faults. Design economics. Emerging nanotechnology devices.

16:332:579 ADVANCED TOPICS IN COMPUTER ENGINEERING (3)

Prerequisite: Permission of instructor.

In-depth study of topics pertaining to computer engineering such as microprocessor system design; fault-tolerant computing; real-time system design. Subject areas may vary from year to year.

16:332:580 (F) ELECTRIC WAVES AND RADIATION (3)

Prerequisite: A course in elementary electromagnetics.

Static boundary value problems, dielectrics, wave equations, propagation in lossless and lossy media, boundary problems, waveguides and resonators, radiation fields, antenna patterns and parameters, arrays, transmit-receive systems, antenna types.

16:332:581 (F) INTRODUCTION TO SOLID STATE ELECTRONICS (3)

Introduction to quantum mechanics; WKB method; perturbation theory; hydrogen atom; identical particles; chemical bonding; crystal structures; statistical mechanics; free-electron model; quantum theory of electrons in periodic lattices.

16:332:583 (F) SEMICONDUCTOR DEVICES I (3)

Charge transport, diffusion and drift current, injection, lifetime, recombination and generation processes, p-n junction devices, transient behavior, FET's, I-V, and frequency characteristics, MOS devices C-V, C-f and I-V characteristics, operation of bipolar transistors.

16:332:584 (S) SEMICONDUCTOR DEVICES II (3)

Prerequisite: 16:332:583.

Review of microwave devices, O and M-type devices, microwave diodes, Gunn, IMPATT, TRAPATT, etc., scattering parameters and microwave amplifiers, heterostructures and III-V compound based BJT's and FET's.

16:332:585 (S) SUSTAINABLE ENERGY (3)

The course develops the necessary analysis tools to assess different technologies in terms of cost, Efficiency and impact and uses them to assess all major non-renewable and renewable energy sources.

16:332:586 BIOSENSING AND BIOELECTRONICS (3)

This course covers state-of-the-art and emerging biosensors, biochips, microfluidics, which will be studied in the context of molecular diagnostics. Topics will include microfluidics and mass transfer limits, electrode-electrolyte interfaces, electrochemical noise processes, biosensor system level characterization, determination of performance parameters such as throughput, detection limit, and cost, integration of sensor with microfluidics, and electronic readout circuitry architectures, Novel nanobiosensors such as nanopores, nanowire FETS, surface plasmon resonance, surface enhanced Raman scattering, fluorescence and single molecule detection will also be covered.

16:332:587 (F) TRANSISTOR CIRCUIT DESIGN (3)

Design of discrete transistor circuits; amplifiers for L.F., H.F., tuned and power applications biasing; computer-aided design; noise; switching applications; operational amplifiers; linear circuits.

16:332:588 (S) INTEGRATED TRANSISTOR CIRCUIT DESIGN (3)

Prerequisite: 16:332:587.

Design of digital integrated circuits based on NMOS, CMOS, bipolar BiCMOS and GaAs FETs; fabrication and modeling; analysis of saturating and non-saturating digital circuits, sequential logic circuits, semiconductor memories, gate arrays, PLA and GaAs LSI circuits.

16:332:589 (S) RF INTEGRATED CIRCUIT DESIGN (3)

Basic concepts in RF design, analysis of noise, transceiver architectures, analysis and design of RF integrated circuits for modern wireless communications systems: low noise amplifiers, mixers, oscillators, phase-locked loops.

16:332:591 (F) OPTOELECTRONICS I (3)

Prerequisites: 16:332:580, and 581 or 583.

Waveguides and optical filters, optical resonators, principles of laser action, light emitting diodes, semiconductor lasers, optical amplifiers, optical modulators and switches, photodetectors, wavelength-division-multiplexing and related optical devices.

16:332:592 (S) OPTOELECTRONICS II (3)

Prerequisite: 16:332:591.

Photonic crystals: photonic bandgap, photonic crystal surfaces, fabrication, cavities, lasers, modulators and switches, superprism devices for communications, sensing and nonlinear optics, channel drop filters; advanced quantum theory of lasers: Fermi's golden rule for laser transition, noise, quantum well lasers, quantum cascade lasers. Nonlinear optics: parametric amplification, stimulated Raman/Brillouin scattering, Q-switching, mode-locked lasers.

16:332:594 (F) SOLAR CELLS (3)

Prerequisite: 16:332:583 or equivalent.

Photovoltaic material and devices, efficiency criteria, Schottky barrier, p-n diode, heterojunction and MOS devices, processing technology, concentrator systems, power system designs and storage.

16:332:597 (S) MATERIAL ASPECTS OF SEMICONDUCTORS (3)

Prerequisite: 16:332:581.

Preparation of elemental and compound semiconductors. Bulk crystal growth techniques. Epitaxial growth techniques. Impurities and defects and their incorporation. Characterization techniques to study the structural, electrical and optical properties.

16:332:599 ADVANCED TOPICS IN SOLID-STATE ELECTRONICS (3)

Prerequisite: Permission of instructor.

Semiconductor materials, surfaces and devices; opto-electronic devices; sensors; photovoltaics; fiber optics; and analog/digital circuit design. Subject areas may vary from year to year.

16:332:601, 602 SPECIAL PROBLEMS (BA, BA)

Prerequisite: Permission of instructor.

Investigation in selected areas of electrical engineering.

16:332:618 SEMINAR IN SYSTEMS ENGINEERING (1)

Presentation involving current research given by advanced students and invited speakers. Term papers required.

16:332:638 SEMINAR IN DIGITAL SIGNAL PROCESSING (1)

Presentation involving current research given by advanced students and invited speakers. Term papers required.

16:332:658 SEMINAR IN COMMUNICATIONS ENGINEERING (1)

Presentation involving current research given by advanced students and invited speakers. Term papers required.

16:332:678 SEMINAR IN COMPUTER ENGINEERING (1)

Presentation involving current research given by advanced students and invited speakers. Term papers required.

16:332:698 SEMINAR IN SOLID-STATE ELECTRONICS (1)

Presentation involving current research given by advanced students and invited speakers. Term papers required.

16:332:699 COLLOQUIUM IN ELECTRICAL & COMPUTER ENGINEERING (0)

Research presentations by distinguished lecturers.

16:332:701,702 RESEARCH IN ELECTRICAL ENGINEERING (BA, BA)

Research supervised by faculty in the Department of Electrical and Computer Engineering.
Typically 1 to 3 credits per semester.