Rochester Institute of Technology

Department of Electrical and Microelectronic Engineering
Kate Gleason College of Engineering
Graduate Program Guide for 2014-2015
(Intended for students who have a Bachelor of Science Degree)

Welcome

Welcome to the Electrical and Microelectronic Engineering Department at the Rochester Institute of Technology. Our exciting profession is at the forefront of many transformational innovations including cell phones, media players, lasers, medical diagnosis systems, and multimedia workstations to name but a few. We provide a strong, rigorous curriculum that prepares students to enter the professional workforce and/or pursue further graduate studies in their field of interest. Our graduates are highly sought after by leading employers and top graduate and professional schools in the country. Surveys consistently confirm that an advanced degree in engineering provide significantly more career opportunities than a standard four year program. The Electrical and Microelectronic Engineering Department offers a number of full and part time graduate programs and is supported by a wide range of highly experienced, internationally renowned faculty and staff; and world class laboratories and facilities. We offer numerous graduate courses in multiple disciplines and concentrations. Furthermore, our faculty conduct state of the art sponsored research for government agencies and industrial partners. Our work is routinely cited in leading journals and periodicals.

The objective of this document is to provide guidance for students who already have a Bachelor of Science degree and are pursuing a Master's degree in the Department of Electrical and Microelectronic Engineering. There are three separate degrees within the department for which this guide applies. The Master of Science Degree in Electrical Engineering, which includes both a thesis and a graduate paper option. The Master of Science Degree in Microelectronic Engineering which is thesis-only, and the Master of Engineering in Microelectronic Manufacturing Engineering, which does not require a thesis or a paper but does require an industrial internship. The Master of Engineering in Microelectronic Manufacturing Engineering degree can also be done as an on-line degree.

This document is intended to provide students and faculty pertinent information concerning each of these degrees. It also contains multiple sections devoted to common issues such as thesis formats and binding etc. These guidelines outline the expectations of the Department of Electrical and Microelectronic Engineering and the Rochester Institute of Technology as well as the responsibilities of the student, thesis supervisor, and committee members**.**

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I.   Contact Information

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General Steps Towards Earning your Master's Degree

➢ Master of Science in Electrical Engineering students are required to select a focus area prior to registering for their first semester of studies. The focus area, however, can be changed to meet educational needs. Master of Science and Master of Engineering in Microelectronics students do not have to declare a focus area but should meet with their initially assigned graduate advisor before registering for their first semester of studies.

➢ After completing approximately 12 credits, Master of Science students should begin to consider a topic for their graduate paper or thesis. This document contains recent thesis titles as well as up to date faculty publications which may assist you in determining a specific thesis or graduate paper advisor. Master of Engineering students should begin to search for a company at which they can complete their internship. They should register at the RIT Co-op and Placement office and begin the interview process.

➢ While completing the remaining credits, students are encouraged to continue to develop their paper or thesis ideas and discuss their thoughts with their advisor of choice.

Master of Science students are required to register for a graduate paper (*minimum of 3 credits*) or thesis (*minimum of 6 credits*) credits. You may register for the paper in increments of one, two, or all three at once. Registering for all three credits at once means that you will be charged for the total amount of credits and have only one semester to complete your paper. However, if you register one credit at a time, you will be charged accordingly.

➢ Once you have registered for your graduate paper or thesis, you must KEEP REGISTERING for the paper or thesis on a semester by semester basis for as long as your work is still in progress. This allows you to stay current in the system. You are allowed one free semester in which to complete your paper or thesis AFTER you have registered for all three or six credits respectively. For example, if you are completing a graduate paper, and you have already registered for all three credits, you must then register for **Completion of Graduate Paper (EEEE-796)** for one credit. You will be allowed one free credit for which you will not be charged. After that, you will be charged for one credit per semester until you complete your thesis or paper. Summer semesters are free.

➢ During the semester prior to the one you intend to graduate in, you are required to complete and submit an application for graduation to the Electrical and Microelectronic Engineering department.

➢ Master of Science students are required to obtain the proper approvals for their thesis or graduate paper and provide the necessary copies to the Electrical and Microelectronic Engineering department.

III.   Master of Science in Electrical Engineering

III.1 Admission Requirements

Admission into graduate studies leading to an MS degree in Electrical Engineering requires a Bachelor of Science degree from an accredited program in Electrical Engineering (note that a BS degree in Microelectronic Engineering qualifies). An applicant with a strong undergraduate record and a Bachelor of Science degree in another branch of engineering (mechanical, computer, industrial, etc) will also be considered for admission. In this case, the student must complete a certain number of undergraduate courses in order to bridge over to Electrical Engineering. Additional information in this regard is available from the department.

A combined Bachelor of Science and Master of Science program in Electrical Engineering exists with separate admission requirements. Please refer to documents describing that program for admission requirements. These guidelines apply once a student has been accepted into the combined BS/MS EE program.

Since many of the Electrical Engineering graduate courses are scheduled in the late afternoons or early evenings, the Master of Science in Electrical Engineering can be pursued both on a full time and/or part time basis with minimal impact to work assignments or other career opportunities. Students employed full-time in industry can register for two courses six credits each semester). A student who wishes to register for more than six credits while employed full-time must obtain the permission of his or her advisor and the approval of the department head. It is possible for a part time student to earn a Master of Science in Electrical Engineering in two academic years by taking courses in late afternoons or early evening only.

III.2 Graduation

The Master of Science degree in Electrical Engineering is awarded upon the successful completion of an approved graduate program consisting of a minimum of 30 credit hours. Under certain circumstances, a student s required to complete more than the minimum number of credits.

III.3 Focus Areas

Within Electrical Engineering, a student can specialize in eight separate areas for the MS degree.

These areas are:
  ➢ Control Systems
  ➢ Communications
  ➢ Digital Systems
  ➢ Electromagnetics
  ➢ Integrated Electronics
  ➢ MEMS
  ➢ Robotics
  ➢ Signal & Image Processing

The differences between some of the areas are not always distinct. Therefore, students are urged to discuss the significance of their choices with graduate advisors in the department.

III.4 Plan of Study

Every matriculated student must arrange to have a Plan of Study prepared in consultation with the student's advisor *at the beginning of the program.*

III.5 Policies

The following general rules apply to all MSEE students:

1. All students seeking the MSEE degree must satisfactorily complete two core courses, EEEE-707: Engineering Analysis and EEEE-709: Advanced Engineering Mathematics. Students will be expected to take the required core courses immediately upon entering the program since these courses are prerequisites to several other graduate courses.

2. Those students who have selected the following focus areas: Control Systems, Communications, Signal & Image Processing, MEMS, and Robotics must also complete EEEE-602: Random Signals and Noise. Students who want to develop a minor in any of the above areas are also encouraged to take Random Signals and Noise.

3. Each student must take four core courses from the Electrical and Microelectronic Engineering department in their chosen focus area. The student is expected to perform the research needed for a graduate paper or thesis in the same area.

4. Each student may take three courses from a related area within the Electrical and Microelectronic Engineering department.

5. The academic student advisor must approve all course selections. All courses must be 600 level or above.

6. MSEE students are required to complete 30 credit hours of graduate work by selecting one of the following options:

    ➢ Graduate Thesis (6 credit hours) and 8 courses

    ➢ Graduate Research Paper(3 credit hours) and 9 courses

    ➢ Comprehensive Examination (NO Credit) and 10 courses

7. All graduate work must be completed within a seven-year period starting from the first course applied towards the MSEE degree. Also, a student who is pursuing the thesis/graduate paper options may be required to register for a continuation of thesis credits if he or she is not enrolled for any credits in a given semester. For complete details, please consult the Continuation of Thesis credit requirements discussed in the beginning section of the RIT Graduate Catalog.

III.6 Transfer Credits

A maximum of 6 credit hours can be earned from courses available from other departments within RIT with the prior approval of the faculty/department advisor. For students transferring credits from other universities, the total number of credits transferred from outside the Electrical and Microelectronic Engineering Department from all sources may not exceed six credits.

III.7 Graduate Student Advising

All incoming students will be assigned an academic faculty advisor. The student is encouraged to generate a plan of study in consultation with his or her advisor. He/she will continue to be the student's academic advisor until a research topic has been chosen. At that time, the thesis/paper advisor assumes the role of academic advisor.

III.8 Graduate Teaching Assistant

The Electrical and Microelectronic Engineering Department offers teaching assistantships to a limited number of students during the student's first academic year of study. Subsequently, however, students are encouraged to seek support as research assistants (RA) from one of the research faculty. Full time graduate teaching assistant (TA) are awarded to limited number of outstanding incoming first year graduate students.

III.9 Good Academic Standing

A 3.0 GPA or higher is required to graduate. ALL graduate courses taken after matriculating into an MS program at RIT are counted toward your grade point average (GPA). To be in good academic standing, a graduate student must maintain a cumulative GPA of 3.0/4.0 or better throughout their program of study. Students would be placed on probation or may be suspended at the discretion of the Graduate Program Director and in accordance with RIT policies if the cumulative GPA falls below 3.0. If placed on probation, students are given one semester to elevate their GPA to 3.0 or be suspended indefinitely from the program. Please note that RIT institute policy states "'D' or 'F' grades do not count toward the fulfillment of the program requirements for a graduate degree." However, they are calculated in the GPA and will remain on the student's transcript permanently. Students place on probation may have their scholarship reduced or totally eliminated at the discretion of the Graduate Program Director and in accordance with RIT policies.

Core Courses	Fall 2014-1	Spring 2014-5
Required Courses for all focus areas	EEEE-707 Engineering Analysis EEEE-709 Adv. Engineering Mathematics	EEEE-707 Engineering Analysis EEEE-709 Adv. Engineering Mathematics
Required Courses for Focus Areas 1, 2, 4, 6, 7 and 8 only.	EEEE-602 Random Signal and Noise	EEEE-602 Random Signal and Noise
Focus Area		
1 - Communication	EEEE-593/693 Digital Data Communication. EEEE-629 Antenna Theory and Design EEEE-710 Adv. Electromagnetic Theory EEEE-793 Error Detect/Error Correction	EEEE 592/692 Communications Networks EEEE-617 Microwave Circuit Design EEEE-718 Des & Charac Microwave Sys EEEE-794 Information Theory EEEE-797 Wireless Communication
2 - Control Systems	EEEE-661 Modern Control Theory EEEE-669 Fuzzy Logic & Applications	EEEE-765 Optimal Control EEEE-766 Multivariable Modeling
3 - Digital Systems	EEEE-520/620 Design of Digital Systems EEEE521/621 Design of Computer Systems	EEEE-720 Adv Topic in Digital Sys Design EEEE-721 Adv Topics in Computer Sys Design
4-Electromagnetics	EEEE-629 Antenna Theory & Design EEEE-710 Adv. Electromagnetic Theory	EEEE-617 Microwave Circuit Design EEEE-718 Des & Charac Microwave Sys
5- Integrated Electronics	EEEE-510/610 Analog Electronics EEEE-711 Adv Carrier-Injection Devices EEEE-713 Solid State Physics MCEE-601 Micro Fabrication	EEEE-712 Advanced Field Effect Devices EEEE-726 Mixed Signal IC Design (2nd year standing) MCEE-732 CMOS Mfg.
6-MEMS	EEEE-661 Modern Control Theory EEEE-689 Fundamentals of MEMs MCEE-601 Micro Fabrication MCEE-770 MEMs Fab	EEEE-786 Microfluidic MEMs EEEE-787 MEMs Evaluations
7- Robotics	EEEE 585/685 Principles of Robotics EEEE-547/ 647 Artificial Intelligence(2nd year standing) EEEE-661 Modern Control Theory	EEEE-536/636 Biorobotics/ Cybernetics EEEE-784 Adv Robotics (2nd year standing)
8- Signal & Image Processing	EEEE-678Digital Signal Processing EEEE-779 Digital Image Processing	EEEE-670 Pattern Recognition EEEE-780 Digital Video Processing EEEE-781 Image and Video Compression

1. A selected number of 500, 600 and 700 level courses are usually made available during the summer semester. Please consult the Electrical and Microelectronic Engineering Department for up to date course offerings.
2. Graduate level courses taken in Microelectronic Engineering or Computer Engineering can be counted towards the four course requirement in the Digital Systems, Integrated Electronics or MEMs focus areas.
3. Robust control is offered on a yearly basis by either the EME or the Computer Engineering department. Either version is accepted for the control focus area.
4. Pattern recognition is offered on a yearly basis by either the EME or the Imaging Science Department. Either version is accepted in the Signal Processing focus area.

IV.   Master of Science in Microelectronic Engineering

IV.1 Admission Requirements

The objective of the Master of Science in Microelectronic Engineering program is to provide an opportunity for students to perform graduate level research as they prepare for entry into the semiconductor industry or a Ph.D. program. The program requires strong preparation in the area of microelectronics. The program takes two years to complete and requires a thesis. Applicants must hold a baccalaureate degree in Electrical Engineering, Chemical Engineering, Materials Science and Engineering, Physics or the equivalent, from an accredited college or university in good academic standing. An undergraduate grade point average of 3.0 or better on a 4.0 scale or strong academic advisor/supervisor endorsements are required. Graduate Record Exam (GRE) scores are not mandatory but may support the candidacy.

The prerequisites include a BS in engineering (such as electrical or microelectronic engineering), and an introductory course in device physics. Students from RIT's BS in microelectronic engineering meet these prerequisites. Students who do not have the prerequisite device physics can take a course during their first year of study at RIT and still complete the Master of Science program in two years. The prerequisite course will not count toward the 24 credits worth of graduate courses required for the MS degree.

IV.2 Program

The program consists of eight graduate level (600 level or higher) courses, including six core courses and two elective courses for students with BS degree in a discipline other than Microelectronic Engineering. Two core courses and six elective courses are required for students with BS in Microelectronic Engineering. In addition, all graduate students in this program are required to take one credit seminar/research course for three semesters. Up to 3 seminar/research credits will be allowed to count toward the required 33 hours. A six-credit thesis that includes dissertation submission and oral defense will be required of all students in this program. The total number of credits needed for the Master of Science in Microelectronics Engineering is 33.

IV.3 Core Courses

MCEE-601	Micro Fab
MCEE-602	VLSI Process Modeling
MCEE-603	Thin Films
MCEE-605	Lithography Materials and Processes
MCEE-615*	Nanolithography Systems
MCEE-732	CMOS Manufacturing
MCEE-704**	Phy Modeling Semicon Dev

*Required for ME not MS
**Required for MS not ME

V.   Master of Science in Microelectronic Engineering

IV.4 Elective Courses

The following elective courses are offered for graduate credits:

MCEE-706	SiGe and SOI Devices and Technology
MCEE-615*	Microlithography Systems, Lab
MCEE-620	Photovoltaics
MCEE-704**	Physical Modeling of Semi Devices
MCEE-732	Microelectronics Manufacturing II, Lab
MCEE-730	Metrology Failure Analysis & Yield
MCEE-770	Microelectromechanical Systems
MCEE-789	Special Topics

*Required for ME elective for MS
**Required for MS elective for ME

Based on the student's particular needs, he or she may, with the approval of the program director, choose electives from other programs at RIT.

IV.5 Plan of Study

The student - in consultation with his or her academic advisor - formulates a plan of study based on the student's academic background, program objectives, degree requirements and course offerings and submits it to the program director within the first year. If necessary, the plan of study may be requested for revision with the recommendation of the advisor.

Initial Faculty Advisors
Dr. Karl Hirschman is the initial advisor for students with a BS in Microelectronics.
Dr. Sean Rommel is the initial advisor for students with a BS in other engineering disciplines.

IV.6 Assistantships and Fellowships

A limited number of assistantships and fellowships may be available for full-time students. Appointment as a teaching assistant carries a 12-hour-per-week commitment to a teaching function and permits a student to take graduate work at the rate of 9 credits per semester. Appointment as a research assistant also permits taking up to 9 credits per semester while the remaining time is devoted to the research effort, which often serves as a thesis subject. Students in the MS program are eligible for research fellowships. Appointments provide full or partial tuition and stipend. Applicants for financial aid should contact to the program director for details.

IV.7 Thesis Proposal and Thesis Work

A process and set of requirements have been created for the thesis proposal for the Master of Science degree in Microelectronic Engineering. The thesis proposal should occur in the fall or early spring of the second year of MS study. Key features of the proposal are the make-up of the committee, the literature search, presentation of the problem/issues, research plan and thesis timetable. A copy of a sample proposal can be obtained to illustrate the proper format and content. The expectation of the Microelectronic Engineering program is that the master's thesis will involve an *empirical* component. While theoretical frameworks or conceptual models may (and should in many cases) guide the research questions, or be the subject of empirical testing, a strictly theoretical paper is not acceptable for a master's thesis. The thesis may involve research in

device, circuit or process design, development and validation and evaluations through modeling and *analysis within the realm of microelectronic engineering discipline.*

In some cases, the thesis may be developed in conjunction with ongoing projects or extension of existing processes. In other cases, the thesis may involve original or new devices, circuits, and/or processes. The thesis may involve quantitative data, qualitative data, or a combination of both types of data. Details about the thesis defense, thesis preparation, binding etc. can be found in a later section of this document (section VII).

A *typical* schedule for a Master of Science in Microelectronic Engineering student where the student does *not* hold a BS in Microelectronic Engineering			
Fall (year 1)	**Spring (year 1)**	**Fall (year 2)**	**Spring (year 2)**
1. MCEE-601 Micro Fab, Lab **CORE** 2. MCEE-605 (3 cr) Microlithography Materials & Processes, Lab **CORE** 3. MCEE-603 (3 cr) Thin Films, Lab **CORE** 4. MCEE-794 (1 cr) Seminar/Research	1. MCEE-602 (3 cr) VLSI Process Modeling, Lab **CORE** 2. MCEE-732 (4 cr) CMOS Manufacturing I, Lab **CORE** 3. Graduate Professional Elective (3 cr) 4. MCEE-794 (1 cr) Seminar/Research	1. MCEE-704 (3 cr) Physical Modeling of Semi. Devices, Lab **CORE** 2. MCEE-790 (3 cr) Thesis 3. Graduate Professional Elective (3 cr) 4. MCEE-794 (1 cr) Seminar/Research	1. MCEE-790 (3 cr) Thesis 2. Full Time Equivalency (6 cr) Research
Total of 33 credits: 3 Seminar, 6 thesis and 24 course credits (8 courses). Transition courses may be required which do not count towards the degree credits.			

A *typical* schedule for a Master of Science in Microelectronic Engineering student who already holds a BS in Microelectronic Engineering			
Fall (year 1)	**Spring (year 1)**	**Fall (year 2)**	**Spring (year 2)**
1. Graduate Professional Elective (3 cr) 2. Graduate Professional Elective (3 cr) 3. Graduate Professional Elective (3 cr) 4. MCEE-794 (1 cr) Seminar/Research	1. Graduate Professional Elective (3 cr) 2. MCEE-732 (3 cr) CMOS Manufacturing I, Lab **CORE** 3. Graduate Professional Elective (3 cr) 4. MCEE-794 (1 cr) Seminar/Research	1. MCEE-704 (3 cr) Physical Modeling of Semi. Devices, Lab **CORE** 2. MCEE-790 (3 cr) Thesis 3. Graduate Professional Elective (3 cr) 4. MCEE-794 (1 cr) Seminar/Research	1. MCEE-790 (3 cr) Thesis 2. Full Time Equivalency (6 cr) Research
Total of 33 credits: 3 Seminar, 6 thesis and 24 course credits (8 courses).			

V. Master of Engineering in Microelectronic Manufacturing Engineering

V.1 Admission Requirements

The Master of Engineering in Microelectronics Manufacturing Engineering program offered by the department of Electrical and Microelectronic Engineering at Rochester Institute of Technology provides a broad based education to students with a bachelor's degree in traditional engineering or science disciplines interested in a career in the semiconductor industry.

V.2 Program Requirements

The Master of Engineering degree is awarded upon successful completion of an approved graduate program consisting of a minimum of 30 credit hours. The program consists of a possible transition course, six core courses, two elective courses, two credits of the research methods course and a minimum of 4 credits of internship. Under certain circumstances, a student may be required to complete more than the minimum number of credits. The transition course is in an area other than that in which the BS degree was earned. For example, a chemistry major may be required to take a two-course sequence in circuits and electronics. The core courses are divided into three areas, the first is microfabrication MCEE 601, 602 and 603; the second is microelectronics manufacturing MCEE 732, and the third is microlithography materials and processes (MCEE605) and microlithography systems MCEE 615 (see the typical course schedule listed below). The two elective courses are graduate-level courses in a microelectronics related field. Elective courses may be selected from a list that includes courses such as defect reduction and yield enhancement, semiconductor process and device modeling. See the program director for a more complete list of elective courses.

The program requires an internship, which is at least three months of full time successful work employment in the semiconductor industry or academia. The internship can be completed in industry or at RIT. It will involve an investigation or a study of a problem or process directly related to microelectronics manufacturing engineering. This is not a thesis but requires a report and completion of a survey at the end of the project. A sample internship report and format guide can be obtained from the Microelectronic Engineering Program Director.

V.3 Microelectronics

The Microelectronics sequence (MCEE 601, 602, 603) covers major aspects of integrated circuit manufacturing technology such as oxidation, diffusion, ion implantation, chemical vapor deposition, metallization, plasma etching, etc. These courses emphasize modeling and simulation techniques as well as hands-on laboratory verification of these processes. Students use special software tools for these processes. In the laboratory students design and fabricate silicon MOS integrated circuits. They learn how to utilize most of the semiconductor processing equipment and how to develop and create a process, manufacture and test their own integrated circuits.

V.4 Microlithography

The microlithography courses are advanced courses in the chemistry, physics and processing involved in microlithography. Optical lithography will be studied through diffraction, Fourier and image assessment techniques. Scalar diffraction models will be utilized to simulate aerial image formation and influences of imaging parameters. Positive and negative resist systems, as well as

processes for IC application, will be studied. Advanced topics will include chemically amplified resists; multiple layer resist systems; phase shift masks, and electron beam, x-ray and deep UV lithography. Laboratory exercises include projection system design, resist materials characterization, process optimization, electron beam lithography and excimer laser lithography.

V. 5 Manufacturing

The manufacturing course include topics such as scheduling, work-in-progress tracking, costing, inventory control, capital budgeting, productivity measures and personnel management. Concepts of quality and statistical process control are introduced to the students. The laboratory for this course is the student-run factory functioning in the department. Important issues that include measurement of yield, defect density, wafer mapping, control charts and other manufacturing measurement tools are introduced to the students in the lecture and laboratory. Computer integrated manufacturing is also studied in detail. Process modeling, simulation, direct control, computer networking, database systems, linking application programs, facility monitoring, expert systems applications for diagnosis and training and robotics are all introduced and supported by laboratory experiences in the integrated circuit factory at RIT. An online (distance delivery) version of this program exists for engineers employed in the semiconductor industry. Please refer to the RIT Part-time/Online Guide for details.

A *typical* schedule for a Master of Engineering in Microelectronic Manufacturing Engineering			
Fall (year 1)	**Spring (year 1)**	**Summer (year 1)**	
• MCEE-601 Micro Fab, Lab **CORE** • MCEE-605 (3 cr) Microlithography Materials & Processes, Lab **CORE** • MCEE-603 (3 cr) Thin Films, Lab **CORE** • Graduate elective (3 cr) • MCEE-794 (1 cr) Seminar/Research	• MCEE-602 (3 cr) VLSI Process Modeling, Lab **CORE** • MCEE-732 (4 cr) CMOS Manufacturing I, Lab **CORE** • Graduate Professional Elective (3 cr) • Graduate Elective (3 cr) • MCEE-794 (1 cr) Seminar/Research	• Internship (4 cr)	
Total of 30 credits: 2 Seminar, 4 internship and 24 course credits (8 courses). Transition courses may be required which do not count towards the degree credits.			

VI. Graduate Paper and Thesis: Policies and Procedures

VI.1 REQUIREMENTS

In order to obtain a Master of Science degree in Electrical Engineering, students must complete a Graduate Paper or a Graduate Thesis. Of the minimum 30 credit hours needed to earn the degree, a typical student earns 24 to 27 credit hours from course work and the remaining credit hours from the Paper or Thesis.

In order to obtain a Master of Science degree in Microelectronic Engineering students must complete a Graduate Thesis. Of the minimum 33 credit hours needed to earn the degree, a typical student earns 24 credit hours from course work and the remaining credit hours from the Thesis.

Thesis and Graduate Paper credits do not affect the GPA. A grade of 'R' is given upon registration. At completion, the advisor approves the paper with his or her signature.

VI.2 REGISTRATION

If you are registering for a Graduate Paper, register for course EEEE-792, Section 1, the same way you would register for a course. If you are registering for a Thesis, register for EEEE-790 Section 1 (or section 1 for Microelectronics Masters students). The Graduate Paper mandates a minimum of 3 credits while the Thesis requires 6 credits. You may register for these all at once or by increments of 1 credit.

NOTE: If you register for your Paper or Thesis one credit at a time, you will only be charged for one credit. . If you register for the total amount of credits all at once, you will be charged for the total amount of credits and will have only two semesters to complete the Paper or Thesis. After you register for the three credits allotted for the graduate paper, you are allowed 1 free semester in which you can register for EEEE-796: Continuation of Graduate Paper. You register for 1 or 0 credit hours. Note Microelectronics Masters students will follow the same procedure except that the course number will be.

After this free semester, if you are still not done with your paper, you must register for EEEE-796: Continuation of Graduate Paper for 1 or 0 credit hours. You will be charged for one credit hour. You are not charged for summer semesters. Always register for EEEE-796: Continuation of Graduate Paper after you have already registered for your three credits and have not completed your paper. This is to ensure that you stay in the system. Once your work has been completed and your Thesis/Paper is approved and accepted, the Electrical and Microelectronic Engineering department will certify you for graduation internally, provided all other graduate requirements have been met.

VI.3 PROCEDURES

When to Start? The most advantageous time to start thinking about the research work is when you have completed about two thirds of the course work. Planning for the thesis, however, should begin as early as possible. Normally, full-time students should complete all their degree requirements, including thesis defense, within 2 years (four academic semesters and one summer) from the date of entry.

Your thesis is the culmination of your graduate work and an opportunity to apply the knowledge and skills that you have acquired through course work and research assistantships, etc. It is intended as a guided, constructive learning experience. It is an opportunity for you to work in collaboration with a number of faculty members on a research project of mutual interest and to publish manuscripts resulting from the thesis.

How to Get Started? First, you need to explore possible topics and areas of mutual interest through talking with faculty members and reading the relevant published literature. You may become interested in certain areas as a result of course topics or papers. Your advisor or other faculty members may describe research projects they are currently working on that you might be interested in. *Since the masters degree time line is quite short, it is important to start exploring and discussing possible thesis topics as early as possible, no later than the end of the first year of the program for full-time students*. While students often conduct their thesis research in conjunction with their academic advisor (who then becomes their thesis supervisor), this is not always the case. There are many factors that influence the choice of thesis topics and the selection of a supervisor, including: mutual interest, projected costs and time line for the research, faculty availability during the anticipated thesis period, and a comfortable working relationship. You may not always be able to do exactly what you want to do; however, every attempt is made to match student and faculty interests. Faculty members may discourage ideas that are not suitable or

feasible for a master's thesis. They are trying to assist you in choosing a project that is within your capabilities and available facilities and can be completed in a timely manner.

Thus, the initiation of ideas for possible thesis can come from either the student or from faculty members. You can bounce ideas off various faculty members, but you should keep your academic advisor appraised. Once an agreement is reached, in principle, to pursue a specific topic (on the part of both the student and a faculty member), you are ready to proceed to the proposal and committee selection phase of the process.

Who is on the Master's thesis committee? RIT guidelines stipulate that for degree programs requiring a Master's thesis, the committee must consist of three faculty members: *the supervisor from within the home department, and two committee members (at least one of whom has an academic appointment in the home department).* Your supervisor will assist you in selecting and approaching potential committee members for your thesis.

Once your thesis topic has been determined and your committee has been chosen, you can proceed with the development of the thesis proposal. You need to complete the *Declaration of Topic and Committee Form*, have it signed by your thesis supervisor, and return it to the Department Office. If you have a topic that you would like to explore, please give the office a call. We will match you with a professor who has similar interests. Before approaching the professor, prepare a one to two page summary of your ideas. This can be presented to the professor.

Upon mutual agreement on the topic and the scope of your work, the professor becomes your advisor. If you do not have a firm idea about a topic, please call us; we will be able to arrange a professor to talk to you. The professor may have a research topic that you could be interested in.

VI.4 Format for Graduate Paper

You must write a final report describing your research work. The Graduate Paper differs from the Thesis mostly in formatting requirements. It must be printed double-spaced on one side of a standard 8-1/2 x 11 sheet of paper. You are encouraged to bind the document. The final document need not be leather bound, but should have a soft binding (Comb Binding is available at the Hub Crossroads). A copy is not kept in the library.

You must work out a plan for frequent interactions and consultations with your advisor during the course of the research. A document generated without such consultation faces almost certain rejection.

What Are The Formalities?

The Graduate Paper is complete when your advisor approves it. A Paper, unlike a Thesis, need not be approved by a faculty committee; the Advisor alone approves or disapproves the paper. He or she may ask you to give a presentation before faculty and students or may simply accept the written document. The final copy must also be signed by the Department Head.

How Many Copies?

One copy of the final document, signed by your advisor and department head, must be submitted to the Electrical Engineering office. Your advisor and you should each retain a copy as well. Thus, the minimum number of copies is three though your supervisor at work or colleagues may want a copy as well.

VII. THESIS

VII.1 Filing of Subject

The candidate must select the subject of the Thesis in consultation with a faculty member who agrees to act as the Thesis advisor. The candidate must report the subject of the Thesis and the name of his advisor to the graduate-committee chairman.

VII.2 Style Format for the Thesis

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- Font size must be no smaller than 10-point or larger than 12-point.
- All preliminary pages should be numbered with Roman numerals.
- The main text, illustrations, appendices and bibliography should use Arabic numbering.

VII.3 Presentation to Committee

The advisor for the Masters candidate submits the final thesis to a Faculty Committee for examination and approval. This committee is appointed by the thesis advisor and consists of three members of the graduate committee of the Department of Electrical and Microelectronic Engineering. Its approval is indicated by signatures on the title page of the original and the two required copies of the thesis.

The thesis must be defended and accepted in final form at least 30 days before the completion of the semester in which it is expected the degree will be conferred. The original and two copies must be given to the Department Office after signed approval by the student's advisor. Two of these copies are for transmittal to the Institute Library and one to the faculty advisor.

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Appendix A: Representative Electrical Engineering Research Thesis

DATE	AUTHOR	TITLE	ADVISOR
2013	Girish Chandrashekar	Fault Analysis Using State-of-the-Art Classifiers	Dr. Sahin
2013	Matt De Capua	Current Sensing Feedback for Humanoid Stability	Dr. Sahin
2013	Kevin Fronczak	Stability Analysis of Switched DC-DC Boost Converters for Integrated Circuits	Dr. Bowman
2013	Matthew Ryan	FPGA Hardware Accelerators-Case Study on Design Methodologies and Trade Offs	Dr. Lukowiak
2014	Michael Ostertag	Reconstructing Electrocardiogram Leads from a Reduced Lead Set through the use of Patient-Specific Transforms and Independent Compnent Analysis	Dr. Tsouri
2014	Hanfeng Wang	Switched-Capacitor Voltage Double Design Using 0.5 am Technology	Dr. Bowman
2014	Andrew Phillips	A Study of Advanced Modern Control Techniques Applied To a twin Rotor MIMO System	Dr. Sahin
2014	Jamison Whitesell	Design for Implementation of Image Processing Algorithms	Dr. Patru
2014	Steven Ladavich	An Atrial Activity Based Algorithm for the Single-Beat Rate-Independent Detection of Atrial Fibrillation	Dr. Ghoraani
2013	Survi Kyal	Constrained Independent Component Analysis for Non-Obtrusive Pulse Rate Measurements Using a Webcam	Dr. Tsouri
2013	Matthew Sidley	Calibration for Real-Time Non-Invasive Blood Glucose Monitoring	Dr. Venkataraman
2012	Luis Gan Chau	A MEMs Viscosity Sensor for Conductive Fluids	Dr. Fuller
2012	Primit Modi	Charge Pump Architecture with High Power-Efficiency and Low Output Ripple Noise in 0.5 um CMOS Process Technology	Dr.Bowman
2012	Matthew Cappello	A Model Order Reduction Method for Lightly Damped State Space Systems	Dr. Hopkins
2012	Mohammed Yousefhussien	Three-dimensional Quantification and Visualization of Vascular Networks in Engineered Tissues	Dr. Helguera
2012	Jean-Jacque Delisle	Design and Analysis of a UHF Transmission Line Coupler for Telemetry and Power Harvesting in a Passive Sensor System	Dr. Bowman
2012	Eric Welch	A Study of the use of SIMD Instructions for Two Image Processing Algorithms	Dr. Patru
2012	Ahmed Almradi	Signal to Noise Ratio Estimation using the Expectation Maximization Algorithm	Dr. Dianat
2012	Brent Josefiak	Multi-Mission Radar Waveform Design via a Distributed SPEA2 Genetic Algorithm	Dr. Amuso
2012	Jordon Hibbits	An Evaluation of the Application of Partial Evaluation on Color Lookup Table Implementations	Dr. Patru
2012	Ryan Toukatly	Dynamic Partial Reconfiguration for Pipelined Digital Systems A Case Study Using A Color Space Conversion Engine	Dr. Patru
2012	Mark Bailly	A Coarse Imaging Sensor for Detecting Embedded Signals in Infrared Light	Dr. Moon
2012	Nicholas Liotta	An Industrial Fluid Multi-Sensor	Dr. Fuller
2012	Prafull Purohit	Ripple Clock Schemes for Quantum-dot Cellular Automata Circuits	Dr. Peskin
2011	Jeffrey Abbott	Modeling the Capacitive Behavior of Coplanar Striplines and Coplanar Waveguides Using Simple Functions	Dr. Bowman
2011	Mustafa Erkilinc	Page Layout Analysis and Classification for Complex Scanned Documents	Dr. Saber
2011	Alan Olson	Towards FPGA Hardware in the Loop for QCA Simulation	Dr. Patru
2011	Jeff Wilczewski	Experimental Investigation into Novel Methods of Reliable and Secure On-Body Communications with low System Overheads	Dr. Tsouri
2011	Ruslan Dautov	Efficient Collision Resolution Protocol for Highly Populated Wireless Networks	Dr. Tsouri
2011	Benjamin Freer	Feasibility of a Non-Invasive Wireless Blood Glucose Monitor	Dr. Venkataraman
2011	Thomas Keane	Weighted and Filtered Mutual Information a Metric for the Automated Creation of Panoramas from Views of Complex Scenes	Dr. Saber
2010	Mike Pecoraro	A PCA Based Method for Image and Video Pose Sequencing	Dr. Venkataraman
2010	Eyup Cinar	A Study of Recent Classification Algorithms And A Novel Approach for Biosignal Data Classification	Dr. Sahin

Appendix B: Representative Microelectronic Research Thesis

DATE	AUTHOR	TITLE	ADVISOR
2014	Samarth Parikh	Manufacturing Design and Fabrication of 100 mm(leff)CMOS Devices	Dr. Pearson
2014	Christopher Maloney	Compensation of Extreme Ultraviolet Lithography Image Field Edge Effects Through Optical Proximity Correction	Dr. Pearson
2013	Brian Romanczyck	Fabrication and Characterization of III-V Tunnel Field-Effect Transistors for Low Voltage Logic Applications	Dr. Rommel
2013	Qinglong Li	Investigation on Solid-Phase Crystallization (SPC) techniques for low-temperature poly-Si thin-film transistor applications	Dr. Hirschman
2013	Seth Slavin	Thermal & Electrical Simulation for the Development of Solid-Phase Polycrystalline Silicon TFT's	Dr. Hirschman
2013	Nan Xiao	Thin-Film Transistors Fabricated Using Sputter Deposition of ZnO	Dr. Hirschman
2013	Ketan Deshpande	Simulation and Implementation of Moth-eye Structures as a Broadband Anti-Reflective Layer	Dr. Ewbank
2013	Shaurya Kumar	Investigation of Bolometric and Resistive Properties of Nickel Oxide	Dr. Fuller
2012	Daniel Smith	Multi-Sensor MEMS for Temperature, Relative Humidity, and High-G Shock Monitoring	Dr. Fuller
2012	Lydia Alvarez-Camacho	Fabrication of Jet Printed Interdigitated Back Contact Solar Cells	Dr. Pearson
2012	Shaoting Hu	Exploring Si/SiGe Quantum-Well Thin-Film Thermoelectric Devices using TCAD Simulation	Dr. Hirschman
2012	Chris Shea	A Silicon P-I-N Detector for a Hybrid CMOS Imaging System	Dr. Hirschman
2011	Daiji Kawamura	Investigating Block Mask Lithography Variation Using Finite-Difference Time-Domain Simulation	Dr. Hirschman
2011	Michael Barth	Development of a Deep Sub-Micron Fabrication Process for TFETs	Dr. Rommel
2011	Ryan Rettmann	Development of Low Temperature Oxidation for Crystalline Silicon TFT Applications	Dr. Hirschman
2010	Heidi Purrington	A Multi-Sensor Chip for Monitoring the Quality of Drinking Water	Dr. Fuller
2010	Paul Thomas	Developing Germanium on Nothing (GON) Nanowire Arrays	Dr. Rommel
2010	Murat Baylav	Ion Sensitive Field Effect Transistor (ISFET) for MEMS Multisensory Chips at RIT	Dr. Fuller
2010	Andrew McCabe, MS(μE)	High Field Induced Stress Suppression of GIDL Effects in TFTs	Dr. Hirschman
2010	Jacob Leveto, MS(μE)	Development of a Three-Axis MEMS Accelerometer	Dr. Fuller
2010	Tushara Pasupuleti, MS(μE)	Design and Fabrication of Structured Roughness in Microchannels with Integrated MEMS Pressure Sensors	Dr. Kandlikar
2010	Germain Fenger, MS(μE)	Development if Plasma Enhanced Cehemical Vapor Deposition (PECVD) Gate Dielectrics for TFT Applications	Dr. Hirschman
2010	Meng Zhao, MS(μE)	Exploration of non-chemically amplified resist bas on dissolution inhibitors for 193nm Lithography	Dr. Tom Smith
2010	Bhurat Veeramachaneni, MS(μE)	Oxidized Porous Silicon for Localized Formation of SOI Active Regions	Dr. Hirschman
2010	Fred Ogah, MS(μE)	Free-Carrier Effects in Polycrystalline Silicon-on-Insulator Photonic Devices	Dr. Preble
2010	Burak Baylav, MS(μE)	Exploration of Non-CAR Systems based on Dissolution Inhibitors fro 193 nm Lithography	Dr. Bruce Smith
2009	Patrick Whiting, MS(μE)	Investigation of Defects Formed by Ion Implantation of H2+ into Silicon	Dr. Hirschman
2009	Amandeep Saluja	A parametric study of gas sensing response of ZnO nanostructures and carbon nanotubes	Dr. Raffaelle

Appendix C: Electrical Engineering (EEEE) Graduate Course Descriptions

EEEE- 602   Random Signals & Noise
In this course the student is introduced to random variables and stochastic processes. Topics covered are probability theory, conditional probability and Bayes theorem, discrete and continuous random variables, distribution and density functions, moments and characteristic functions, functions of one and several random variables, Gaussian random variables and the central limit theorem, estimation theory , random processes, stationarity and ergodicity, auto correlation, cross-correlation and power spectrum density, response of linear prediction, Wiener filtering, elements of detection, matched filters. (Graduate Standing) Class 3, Lab 0, Credit 3 (F, S)

EEEE-605   Modern Optics for Engineers
This course provides a broad overview of modern optics in preparation for more advanced courses in the rapidly developing fields of optical fiber communications, image processing, super-resolution imaging, optical properties of materials, and novel optical materials. Topics covered: geometrical optics, propagation of light, diffraction, interferometry, Fourier optics, optical properties of materials, polarization and liquid crystals, and fiber optics. In all topics, light will be viewed as signals that carry information (data) in the time or spatial domain. After taking this course, the students should have a firm foundation in classical optics. (EEEE-473) Class3, Credit 3 (S) Class 3, Lab 0, Credit 3 (Fall or Spring)

EEEE-610   Analog Electronics
This is a foundation course in analog integrated electronic circuit design and is a perquisite for the graduate courses in analog integrated circuit design EEEE-726 and EEEE-730. The course covers the following topics: (1)CMOS Technology (2) CMOS active and passive element models (3) Noise mechanisms and circuit noise analysis (4) Current mirrors (5) Differential amplifiers, cascade amplifiers (6) Multistage amps and common mode feedback (7) Stability analysis of feedback amplifiers; (8) Advanced current mirrors, amplifiers, and comparators (9) Band gap and translinear cells (10) Matching. (EEEE-482 Electronics II or equivalent background, or Graduate Standing) Class 2, Lab 3, Credit 3 (F)

EEEE-617   Microwave Circuit Design
The primary objective is to study the fundamentals of microwave engineering with emphasis on microwave network analysis and circuit design. Topics include microwave transmission lines such as wave-guides, coax, microstrip and stripline, microwave circuit theory such as S- matrix, ABCD matrices, and even odd mode analysis, analysis and design of passive circuits and components, matching networks, microwave resonators and filters. Microwave circuit design projects will be performed using Ansoft's Designer software. (EEEE-374) Class 3, Lab 0, Credit 3 (S)

EEEE-620   Design of Digital Systems
The purpose of this course is to expose students to complete, custom design of a CMOS digital system. It emphasizes equally analytical and CAD based design methodologies, starting at the highest level of abstraction (RTL, front-end)), and down to the physical implementation level (back-end). In the lab students learn how to capture a design using both schematic and hardware description languages, how to synthesize a design, and how to custom layout a design. Testing, debugging, and verification strategies are formally introduced in the lecture, and practically applied in the lab projects. Students are further required to choose a research topic in the area of digital systems, perform bibliographic research, and write a research paper following a prescribed format. (EEEE-420) Class 3, Lab 3, Credit 3 (F)

EEEE-621   Design of Computer Systems
The purpose of this course is to expose students to the design of single and multicore computer systems. The lectures cover the design principles of instructions set architectures, non-pipelined data paths, control unit, pipelined data paths, hierarchical memory (cache), and multicore processors. The design constraints and the interdependencies of computer systems building blocks are being presented. The operation of single core, multicore, vector, VLIW, and EPIC processors is explained. In the first half of the semester, the lab projects enforce the material presented in the lectures through the design and physical emulation of a pipelined, single core processor. This is then being used in the second half of the semester to create a multicore computer system. The importance of hardware/software co-design is emphasized throughout the course. Students are further required to choose a research topic in the area of computer systems, perform

bibliographic research, and write a research paper following a prescribed format. (EEEE-420) Class 3, Lab 3, Credit 3 (S)

EEEE-629   Antenna Theory
The primary objective is to study the fundamental principles of antenna theory applied to the analysis and design of antenna elements and arrays including synthesis techniques and matching techniques. Topics include antenna parameters, linear antennas, array theory, wire antennas, microstrip antennas, antenna synthesis, aperture antennas and reflector antennas. A significant portion of the course involves design projects using some commercial EM software such as Ansoft Designer, Ansoft HFSS and SONNET and developing Matlab codes from theory for antenna synthesis and antenna array design. The measurement of antenna input and radiation characteristics will be demonstrated with the use of network analyzers, and spectrum analyzers in an anechoic chamber. (EEEE-374) Class 3, Lab 0, Credit 3 (F)

EEEE-636   Biorobotics/Cybernetics
Cybernetics refers to the science of communication and control theory that is concerned especially with the comparative study of automatic control systems (as in the nervous system and brain and mechanical-electrical communications systems). This course will present material related to the study of cybernetics as well as the aspects of robotics and controls associated with applications of a biological nature. Topics will also include the study of various paradigms and computational methods that can be utilized to achieve the successful integration of robotic mechanisms in a biological setting. Successful participation in the course will entail completion of at least one project involving incorporation of these techniques in a biomedical application. Students are required to write an IEEE conference paper on their projects. (Graduate Standing) Class 3, Lab 0, Credit 3 (S)

EEEE-647   Artificial Intelligence Explorations
The course will start with the history of artificial intelligence and its development over the years. There have been many attempts to define and generate artificial intelligence. As a result of these attempts, many artificial intelligence techniques have been developed and applied to solve real life problems. This course will explore variety of artificial intelligence techniques, and their applications and limitations. Some of the AI techniques to be covered in this course are intelligent agents, problem-solving, knowledge and reasoning, uncertainty, decision making, learning (Neural networks and Bayesian networks), reinforcement learning, swarm intelligence, Genetic algorithms, particle swarm optimization, applications in robotics, controls, and communications. Students are expected to have any of the following programming skills listed above. Students will write an IEEE conference paper. (Graduate Standing) Class 3, Lab 0, Credit 3 (F)

EEEE-661   Modern Control Theory
This course deals with a complete description of physical systems its analysis and design of controllers to achieve desired performance. The emphasis in the course will be on continuous linear systems. Major topics are: state space representation of physical systems, similarities/differences between input-output representation (transfer function) and state spate representations, conversion of one form to the other, minimal realization, solution of state equations, controllability, observability, design of control systems for desired performance, state feedback, observers and their realizations. (co-requisite: EEEE-707 Engineering Analysis Class 3, Lab 0, Credit 3 (F)

EEEE-669   Fuzzy Logic & Applications
In this course students are introduced to fuzzy systems and their applications in areas like control systems, signal and image processing, communications etc. Major topics are: Fuzzy sets and set operations, Evaluations of the rule sets using different implications, composition, aggregation and defuzzification methods. Applications in control systems: Development of fuzzy logic controllers for both linear and nonlinear systems & analysis and simulation studies of the designed systems. Function approximation using fuzzy systems. Students are also required to search published research works in other application areas like signal/image processing, communication, pattern recognition etc. and present their results to the class. (EEEE-414 or equivalent) Class 3, Lab 0, Credit 3 (F)

EEEE-670   Pattern Recognition
This course provides a rigorous introduction to the principles and applications of pattern recognition. The topics covered include maximum likelihood, maximum a posteriori probability, Bayesian decision theory, nearest-neighbor techniques, linear discriminant functions, and clustering. Parameter estimation and supervised learning as well as principles of feature selection, generation and extraction techniques, and utilization of neural nets are included. Applications to face recognition, classification, segmentation, etc. are discussed throughout the course. (EEEE-603, EEEE-602)   Class 3, Lab 0, Credit 3 (S)

EEEE-678   Digital Signal Processing
This course provides a rigorous introduction to the principles and applications of pattern recognition. The topics covered include maximum likelihood, maximum a posteriori probability, Bayesian decision theory, nearest-neighbor techniques, linear discriminant functions, and clustering. Parameter estimation and supervised learning as well as principles of feature selection, generation and extraction techniques, and utilization of neural nets are included. Applications to face recognition, classification, segmentation, etc. are discussed throughout the course. (EEEE-602, EEEE-707, EEEE-709)   Class 3, Lab 0, Credit 3 (S)

EEEE-685   Principles of Robotics
An introduction to a wide range of robotics-related topics, including but not limited to sensors, interface design, robot devices applications, mobile robots, intelligent navigation, task planning, coordinate systems and positioning image processing, digital signal processing applications on robots, and controller circuitry design. Pre- requisite for the class is a basic understanding of signals and systems, matrix theory, and computer programming. Software assignments will be given to the students in robotic applications. Students will prepare a project, in which they will complete software or hardware design of an industrial or mobile robot. There will be a two-hour lab additional to the lectures. Students are required to write an IEEE conference paper on their projects. (Graduate Standing) Class 3, Lab 2, Credit 3 (F)

EEEE-689   Fundamentals of MEMs
Microelectromechanical systems (MEMS) are widely used in aerospace, automotive, biotechnology, instrumentation, robotics, manufacturing, and other applications. There is a critical need to synthesize and design high performance MEMS which satisfy the requirements and specifications imposed. Integrated approaches must be applied to design and optimized MEMS, which integrate microelectromechanical motion devices, ICs, and microsensors. This course covers synthesis, design, modeling, simulation, analysis, control and fabrication of MEMS. Synthesis, design and analysis of MEMS will be covered including CAD. (Graduate Standing) Class 3, Lab 0, Credit 3 (F)

EEEE-692   Communication Networks
This course covers communication networks in general and the internet in particular. Topics include layers service models, circuit and packet switching, queuing, pipelining, routing, packet loss and more. A five-layer model is assumed and the top four levels are covered in a top-down approach: starting with the application layer, going down through the transport layer to the network layer and finally the data link layer. Emphasis is placed on wireless networks and network security. Students would perform a basic research assignment consisting of a literature survey, performance analysis and dissemination of results in written and oral presentation. (EEEE-353, MATH-251) Class 3, Lab 0, Credit 3 (F)

EEEE-693   Digital Data Communications
Principles and practices of modern digital data communication systems. Topics include pulse code transmission and error probabilities, M-ary signaling and performance, AWGN channels, band-limited and distorting channels, filter design, equalizers, optimal detection for channels with memory, synchonization methods, non-linear modulation, and introduction to multipath fading channels, spread spectrum and OFDM. Students would perform a basic research assignment consisting of a literature survey, performance analysis and dissemination of results in written and oral presentation. (EEEE-484, EEEE-602) Class 3, Credit 3 (F)

EEEE-707   Engineering Analysis
This course trains students to utilize mathematical techniques from an engineering perspective, and provides essential background for success in graduate level studies. An intensive review of linear and nonlinear ordinary differential equations and Laplace transforms is provided. Laplace transform methods

are extended to boundary-value problems and applications to control theory are discussed. Problem solving efficiency is stressed, and to this end, the utility of various available techniques are contrasted. The frequency response of ordinary differential equations is discussed extensively. Applications of linear algebra are examined, including the use of eigenvalue analysis in the solution of linear systems and in multivariate optimization. An introduction to Fourier analysis is also provided. Class 3, Lab 0, F, S

EEEE-709   Advanced Engineering Mathematics
Advanced Engineering Mathematics provides the foundations for complex functions, vector calculus and advanced linear algebra and its applications in analyzing and solving a variety of electrical engineering problems especially in the areas of control, circuit analysis, communication, and signal/image processing. Topics include: complex functions, complex integration, special matrices, vector spaces and subspaces, the nullspace, projection and subspaces, matrix factorization, eigenvalues and eigenvectors, matrix diagonalization, singular value decomposition (SVD), functions of matrices, matrix polynomials and Cayley-Hamilton theorem, state-space modeling, optimization techniques, least squares technique, total least squares, and numerical techniques. Electrical engineering applications will be discussed throughout the course. (F, S)

EEEE-710   Advanced Electromagnetic Theory
The primary objective is to provide the mathematical and physical fundamentals necessary for a systematic analysis of electromagnetic field problems. Topics included: electromagnetic theorems and principles, scattering and radiation integrals, TE and TM in rectangular and circular waveguides, hybrid LSE and LSM modes in partially filled guides, dielectric waveguides, the Green's function. The course will also include projects using advanced EM modeling software tools. (EEEE-617, EEEE-629) Class 3, Credit 3 (S)

EEEE-711   Advanced Carrier Injection Devices
A graduate course in the fundamental principles and operating characteristics of carrier-injection-based semiconductor devices. Advanced treatments of pn junction diodes, metal-semiconductor contacts, and bipolar junction transistors form the basis for subsequent examination of more complex carrier-injection devices, including tunnel devices, transferred-electron devices, thyristors and power devices, light-emitting diodes (LEDs), and photodetectors. Topics include heterojunction physics and heterojunction bipolar transistors (HBT). (Graduate Standing) Class 3, Lab 0, Credit 3 (S)

EEEE-712   Advanced Field Effect Devices
An advanced-level course on MOSFETs and submicron MOS devices. Topics include MOS capacitors, gated diodes, long-channel MOSFETs, subthreshold conduction and off-state leakage, short-channel effects, hot-carrier effects, MOS scaling and advanced MOS technologies. (Graduate Standing) Class 3, Lab 0, Credit 3 (S)

EEEE-713   Solid State Physics
An advanced-level course on solid-state physics, with particular emphasis on the electronic properties of semiconductor materials. Topics include crystal structure, wave propagation in crystalline solids, lattice vibrations, elements of quantum mechanics, elements of statistical mechanics, free-electron theory of metals, Boltzmann transport equation, quantum-mechanical theory of carriers in crystals, energy band theory, equilibrium carrier statistics, excess carriers in semiconductors, carrier transport. (Graduate Standing) Class 3, Lab 0, Credit 3 (S)

EEEE-718   Design & Characterization of Microwave Systems
There are two primary course objectives.   Design of experiments to characterize or measure specific quantities, working with the constraints of measurable quantities using the vector network analyzer, and in conjunction with the development of closed form analytical expressions. Design, construction and characterization of microstrip circuitry and antennas for specified design criteria obtaining analytical models, using software tools and developing measurements techniques. Microwave measurement will involve the use of network analyzers, and spectrum analyzers in conjunction with the probe station. Simulated results will be obtained using some popular commercial EM software for the design of microwave circuits and antennas. (EEEE-617, EEEE-629) Class 2, Lab 3, Credit 3 (F)

EEEE-720   Advanced Topics in Digital Systems Design
In this course the student is introduced to a multitude of advanced topics in digital systems design. It is expected that the student is already familiar with the design of synchronous digital systems. The lecture introduces the operation and design principles of asynchronous digital systems, synchronous and asynchronous, pipelined and wave pipelined digital systems. Alternative digital processing paradigms are then presented: data flow, systolic arrays, networks-on-chip, cellular automata, neural networks, and fuzzy logic. Finally, digital computer arithmetic algorithms and their hardware implementation are covered. The projects reinforce the lectures material by offering a hands-on development and system level simulation experience. (Graduate standing) Class 3, Credit 3 (F)

EEEE-721   Advanced Topics in Computer System Design
In this course the student is introduced to advanced topics in computer systems design. It is expected that the student is already familiar with the design of a non-pipelined, single core processor. The lectures cover instruction level parallelism, limits of the former, thread level parallelism, multicore processors, optimized hierarchical memory design, storage systems, and large-scale multiprocessors for scientific applications. The projects reinforce the lectures material, by offering a hands-on development and system level simulation experience. (Graduate standing) Class 3, Lab 0, Credit 3 (S)

EEEE-726   Mixed –Signal IC Design
This is the first course in the graduate course sequence in analog integrated circuit design EEEE-726 and EEEE-730. This course covers the following topics: (1)Fundamentals of data conversion (2) Nyquist rate digital-to-analog converters (3) Quantization noise and analysis (4) Nyquist rate analog-to-digital converters (5) Sample and hold circuits (6) Voltage references (7) Static and dynamic testing of digital-to-analog converters (8) Cell based design strategies for integrated circuits (9)Advanced topics in data conversion. (Graduate Standing) Class 3, Lab 0, Credit 3 (S)

EEEE-730   Advanced Analog IC Design
This is the second course in the graduate course sequence in analog integrated circuit design EEEE-726 and EEEE-730. This course covers the following topics: (1) Fundamentals of Filter Design (2) Filter Approximations (3) Frequency and Impedance Scaling (4) Delay Equalization (5) Sensitivity Analysis (6) Sampled Data Theory (7) CMOS Integrated Filters including Switched Capacitor and gm-C Filters (8)Phase Locked Loops (EEEE-726) Class 3, Lab 0, Credit 3 (F)

EEEE-733   Robust Control
This course will provide an introduction to the analysis and design of robust feedback control systems. Topics covered: overview of linear algebra and linear systems, H2 and H (spaces, modeling and paradigms for robust control; internal stability; nominal performance (asymptotic tracking); balanced model reduction; uncertainty and robustness; H2 optimal control; H (control; H (loop shaping; controller reduction; and design for robust stability and performance. (EEEE-661) Class 3, Lab 0, Credit 3 (S)

EEEE-765   Optimal Control
The course covers different optimization techniques, as applied to feedback control systems. The main emphasis will be on the design of optimal controllers for digital control systems. The major topics are: Different performance indices, formulation of optimization problem with equality constraints, Lagrange multipliers, Hamiltonian and solution of discrete optimization problem. Discrete Linear Quadratic Regulators (LQR), optimal and suboptimal feedback gains, Riccati equation and its solution, linear quadratic tracking problem. Dynamic Programming - Bellman's principle of optimality - Optimal controllers for discrete and continuous systems - Systems with magnitude constraints on inputs and states. (EEEE-661) Class 3, Lab 0, Credit 3 (S)

EEEE-766   Multivariable Modeling
This course introduces students to the major topics, methods, and issues in modeling multiple-input multiple-output (MIMO) linear systems. The course covers methods of creating models and refining them. Modeling topics include model-order determination, canonical forms, numerical issues in high-order models, creating frequency-response models from time-domain measurements, creating state-space models from frequency-response data, model-order reduction, model transformations and information loss, and

estimating model accuracy of MIMO models. Use of MIMO models in controller design will be discussed. (EEEE-707; Co-requisite: EEEE-661) Class 3, Lab 0, Credit 3 (F)

EEEE-768   Adaptive Signal Processing
An introduction to the fundamental concepts of adaptive systems; open and closed loop adaptive systems; adaptive linear combiner; performance function and minimization; decorrelation of error and input signal. Adaptation algorithms such as steepest descent, LMS and LMS/Newton algorithm. Noise and misadjustments. Applications will include system identification, deconvolution and equalization, adaptive arrays and multipath communication channels. (EEEE-603, EEEE-707, EEEE-709) Class 3, Lab 0, Credit 3 (F, S)

EEEE-779   Digital Image Processing
This is an introductory course in digital image processing. The course begins with a study of two dimensional (2D) signal processing and transform methods with applications to images. Image sampling is discussed extensively followed by gray level description of images and methods of contrast manipulation including linear/nonlinear transformations, histogram equalization and specification. Image smoothing techniques are considered including spatial and frequency domain low pass filtering, AD-HOC methods of noise removal and median filtering. Following this, methods of image sharpening are studied including derivatives and high pass filtering. Edge and line detection algorithms are discussed using masks and Hough transforms. Finally, methods of image segmentation, restoration, compression and reconstruction are also discussed. Several extensive computer lab assignments are required. (EEEE-678) Class 3, Lab 0, Credit 3 (S)

EEEE-780   Digital Video Processing
In this graduate level course the following topics will be covered: Representation of digital video - introduction and fundamentals; Time-varying image formation models including motion models and geometric image formation; Spatio-temporal sampling including sampling of analog and digital video; two dimensional rectangular and periodic Sampling; sampling of 3-D structures, and reconstruction from samples; Sampling structure conversion including sampling rate change and sampling lattice conversion; Two-dimensional motion estimation including optical flow based methods, block-based methods, Pel-recursive methods, Bayesian methods based on Gibbs Random Fields; Three-dimensional motion estimation and segmentation including methods using point correspondences, optical flow & direct methods, motion segmentation, and stereo and motion tracking. (EEEE-779) Class 3, Lab 0, Credit 3 (S)

EEEE-781   Image and Video Compression
This course studies the fundamental technologies used in image and video compression techniques and international standards such as JPEG and MPEG. At the highest level, all visual data compression techniques can be reduced to three fundamental building blocks: transformation or decomposition (examples are discrete cosine transform or DCT, wavelets, differential pulse code modulation or DPCM and motion compensation), quantization (strategies include scalar vs. vector quantization, uniform vs. nonuniform, Lloyd-Max and entropy-constrained quantization) and symbol modeling and encoding (the concept of Markov source and its entropy, context modeling, variable length coding techniques such as Huffman and arithmetic coding and Golomb-Rice coding). This course studies all of these fundamental concepts in great detail in addition to their practical applications in leading image and video coding standards. The study cases include a comprehensive review of the JPEG lossless compression standard (based on pixel prediction and Huffman coding), the JPEG lossy compression standard (based on DCT and Huffman coding), a detailed study of wavelet decomposition and a brief overview of the MPEG family of standards (employing motion compensation in addition to aforementioned techniques). (EEEE-779) Class 3, Credit 3

EEEE-784   Advanced Robotics
This course explores advance topics in mobile robots and manipulators. Mobile robot navigation, path planning, room mapping, autonomous navigation are the main mobile robot topics. In addition, dynamic analysis of manipulators, forces and trajectory planning of manipulators, and novel methods for inverse kinematics and control of manipulators will also be explored.   The pre-requisite for this course is Principles of Robotics. However, students would have better understanding of the topics if they had Control Systems and Mechatronics courses as well. The course will be a project based course requiring exploration

of a novel area in Robotics and writing an IEEE conference level paper. (Graduate Standing) Class 3, Lab 0, Credit 3 (S)

EEEE-787   MEMS Evaluation
This course focuses on evaluation of MEMS, microsystems and microelectromechanical motion devices utilizing MEMS testing and characterization. Evaluations are performed using performance evaluation matrices, comprehensive performance analysis and functionality. Applications of advanced software and hardware in MEMS evaluation will be covered. (Graduate standing) Class 3, Credit 3 (S)

EEEE-789   Special Topics
Topics and subject areas that are not regularly offered are provided under this course. Such courses are offered in a normal format; that is, regularly scheduled class sessions with an instructor. (Graduate Standing) Class 3, Credit 3 (F, S,)

EEEE-790   Thesis
An independent engineering project or research problem to demonstrate professional maturity. A formal written thesis and an oral defense are required. The student must obtain the approval of an appropriate faculty member to guide the thesis before registering for the thesis. A thesis may be used to earn a maximum of 6 credits. (Graduate Standing and department approval required) Class 0; Credit 1-6 (F, S, Su)

EEEE-792   Graduate Paper
This course is used to fulfill the graduate paper requirement under the non-thesis option for the MS degree in electrical engineering. The student must obtain the approval of an appropriate faculty member to supervise the paper before registering for this course. (Department approval required) Class 0, Credit 0-3 (F, S, SU)

EEEE-793   Error Detection & Error Correction
This course covers linear algebraic block codes, convolutional codes, turbo codes, and low-density parity-check codes. The fundamental structure of linear block code will be developed and applied to performance calculations. The structure of cyclic codes will be developed and applied to encoders and decoders. The major error correction methods, including error trapping, majority logic decoding and the BCH encoder and decoder algorithms will be developed. The Viterbi and sequential decoding algorithms will be studied. Questions of system performance, speed and complexity will be examined. Class 3, Credit 3 (F)

EEEE-794   Information Theory
This course introduces the student to the fundamental concepts and results of information theory. This is a very important course for students who want to specialize in signal processing, image processing, or digital communication. Topics include definition of information, mutual information, average information or entropy, entropy as a measure of average uncertainty, information sources and source coding, Huffman codes, run-length constraints, discrete memoryless channels, channel coding theorem, channel capacity and Shannon's theorem, noisy channels, continuous sources and channels, coding in the presence of noise, performance bounds for data transmission, rate distortion theory. (EEEE-602) Class 3, Lab 0, Credit 3 (S)

EEEE-795   Graduate Seminar
The objective of this course is to introduce full time Electrical Engineering BS/MS and incoming graduate students to the graduate programs, campus resources to support research. Presentations from faculty, upper division MS/PhD students, staff, and off campus speakers will provide a basis for student selection of research topics, comprehensive literature review, and modeling effective conduct and presentation of research. All first year graduate students enrolled full time are required to successfully complete two semesters of this seminar. Class 1, Credit 0 (F, S)

EEEE-797   Wireless Communication
The course will cover advanced topics in wireless communications for voice, data and multimedia. Topics covered are: 1) Channel modeling: Overview of current wireless systems, modeling wireless channels, path loss for different environments, log-normal shadowing, flat and frequency-selective multipath fading, LS estimation of channel parameters, and capacity limits of wireless communication channels. 2) Transmission over fading channels, 3) Techniques to improve the speed and performance of wireless inks (adaptive

modulation and diversity techniques such as maximum gain combining to compensate for flat-fading). 4) Techniques to combat frequency-selective fading (adaptive equalization, space time coding, multicarrier modulation (OFDM), and spread spectrum). 5) Applications for these systems, including the evolution of cell phones and PDAs, sensor networks will be discussed. (EEEE-602, EEEE-693) Class 3, Lab 0, Credit 3 (S)

EEEE-799   Independent Study
This course is used by students who plan to study a topic on an independent study basis. The student must obtain the permission of the appropriate faculty member before registering for the course. Class 0, Credit 1-3 (F, S, SU)

Appendix D: Microelectronic Engineering (MCEE) Course Descriptions

600 & 800 Level Courses in Microelectronic Engineering (all courses earn 3 credits unless otherwise noted)

MCEE-601   Microelectronic Fabrication
This course introduces the beginning graduate student to the fabrication of solid-state devices and integrated circuits. The course presents an introduction to basic electronic components and devices, lay outs, unit processes common to all IC technologies such as substrate preparation, oxidation, diffusion and ion implantation. The course will focus on basic silicon processing. The students will be introduced to process modeling using a simulation tool such as SUPREM. There is a lab for the on campus section (01), and a discussion of laboratory results and a graduate paper for the distance learning-section (90). The lab consists of conducting a basic metal gate PMOS process in the RIT clean room facility to fabricate and test a PMOS integrated circuit test ship. Laboratory work also provides an introduction to basic IC fabrication processes and safety. (Graduate standing or permission of the instructor) Class 3, Lab 3, Credit 3 (F)

MCEE-602   VLSI Process Modeling
This is an advanced level course in silicon process technology. A detailed study of several of the individual processes utilized in the fabrication of VLSI circuits will be done, with a focus on engineering challenges such as shallow-junction formation and ultra-thin gate dielectrics. Front-end silicon processes will be investigated in depth including diffusion, oxidation, ion implantation, and rapid thermal processing. Particular emphasis will be placed on non-equilibrium effects. Device design and process integration details will also be emphasized. SUPREM-IV (Silvaco Athena) will be used extensively for process simulation. A project will involve the complete simulation of a twin-well CMOS process. (MCEE-601 Microelectronic Fabrication) Class 3, Lab 2, Credit 3 (F, S)

MCEE-603   Thin Films
This course focuses on the deposition and etching of thin films of conductive and insulating materials for IC fabrication. A thorough overview of vacuum technology is presented to familiarize the student with the challenges of creating and operating in a controlled environment. Physical and Chemical Vapor Deposition (PVD & CVD) are discussed as methods of film deposition. Plasma etching and Chemical Mechanical Planarization (CMP) are studied as methods for selective removal of materials. Applications of these fundamental thin film processes to IC manufacturing are presented. (MCEE-601 Microelectronic Fabrication) Class 3, Lab 3, Credit 3 (F, S)

MCEE-605 Lithography Materials and Processes
Microlithography Materials and Processes covers the chemical aspects of microlithography and resist processes. Fundamentals of polymer technology will be addressed and the chemistry of various resist platforms including novolac, styrene, and acrylate systems will be covered. Double patterning materials will also be studied. Topics include the principles of photoresist materials, including polymer synthesis, photochemistry, processing technologies and methods of process optimization. Also advanced lithographic techniques and materials, including multi-layer techniques for BARC, double patterning, TARC, and next generation materials and processes are applied to optical lithography. (CHMG-131 Gen Chemistry for Engineers or equivalent) Class 3, Lab 3, Credit 3 (F, S)

MCEE-615   Nanolithography Systems
An advanced course covering the physical aspects of micro- and nano-lithography. Image formation in projection and proximity systems are studied. Makes use of optical concepts as applied to lithographic systems. Fresnel diffraction, Fraunhofer diffraction, and Fourier optics are utilized to understand diffraction-limited imaging processes and optimization. Topics include illumination, lens parameters, image assessment, resolution, phase-shift masking, and resist interactions as well as non-optical systems such as EUV, maskless, e-beam, and nanoimprint. Lithographic systems are designed and optimized through use of modeling and simulation packages. (MCEE-605 Lithographic Materials and Processes) Class 3, Lab 3, Credit 3 (F, S)

MCEE-699   Graduate Co-op
Up to six months of full-time, paid employment in the microelectronic engineering field. See the graduate program coordinator or RIT's Office of Cooperative Education for further details. (Department approval) Credit 0 (F, S, SU)

MCEE-704   Physical Modeling of Semiconductor Devices
MCEE-704 is a senior or graduate level course on the application of simulation tools for physical design and verification of the operation of semiconductor devices. The goal of the course is to provide a more in-depth understanding of device physics through the use of simulation tools. Technology CAD tools include Silvaco (Athena/Atlas) for device simulation. The lecture will explore the various models that are used for device simulation, emphasizing the importance of complex interactions and 2-D effects as devices are scaled deep-submicron. Laboratory work involves the simulation of various device structures. Investigations will explore how changes in the device structure can influence device operation. (Permission of Instructor)   Class 3, Lab 2, Credit 3 (F)

MCEE-706   SiGe and SOI Devices and Technologies
This course introduces students to the fundamentals of SiGe and Silicon on Insulator (SOI) devices and fabrication technologies. The course will first discuss the band structure of the SiGe material system, and how its properties of band structure and enhanced mobility may be utilized to improve traditional Si devices. Basic heterojunciton theory is introduced to students. Some specific applications that are introduced include heterojunction bipolar transistors (HBTs), SiGe-channel MOS devices, and high-electron mobility transistors (HEMTs). Fabrication technologies for realizing SOI substrates that include SIMOX and SMART CUT technologies are described. The physics of transistors built on SOI substrates will be discussed. At the completion of the course, students will write a review paper on a topic related to the course. (Permission of instructor) Class 3, Lab 3, Credit 3 (F)

MCEE-713   Quantum and Solid-State Physics for Nanostructures
This course describes the key elements of quantum mechanics and solid state physics that are necessary in understanding the modern semiconductor devices. Quantum mechanical topics include solution of Schrodinger equation solution for potential wells and barriers, subsequently applied to tunneling and carrier confinement. Solid state topics include electronic structure of atoms, crystal structures, direct and reciprocal lattices. Detailed discussion is devoted to energy band theory, effective mass theory, energy-momentum relations in direct and indirect band gap semiconductors, intrinsic and extrinsic semiconductors, statistical physics applied to carriers in semiconductors, scattering and generation and recombination processes. (Graduate Standing) Class 3, Lab 0, Credit 3 (F)

MCEE-714   Micro/Nano Characterization
This microelectronic engineering elective is taught by mechanical engineering with a weekly lab component focuses on tools and techniques for micro- and nano-characterization of materials, surfaces and thin films. The course covers the principles and applications of four experimental techniques: quantitative imaging, x ray diffraction, scanning probe microscopy, and micro- and nano-indentation. Students will learn the physics of interaction processes used for characterization, quantification and interpretation of collected signals, and fundamental detection limits for each technique.   (An introductory materials science course such as: MECE-305 Materials Science and Applications OR MCEE-360 Semiconductor Devices OR MTSE-701 Introductory Materials Science) Class 2, Lab 2, Credit 3 (F)

MCEE-717   Memory Systems
This course targets the overlapping areas of device physics, VLSI Design, advanced processes, electrical characterization and circuit architecture as it applies to modern memory systems. While there are no specific set of pre-requisite courses, students should be willing to work on problems involving the previously mentioned topics. Course work will trace the design, development, fabrication, packaging and testing of SRAM, DRAM and Flash Memory, and then branch off into MRAM, FRAM and PRAM technology. The course wraps up with an exploration of future memory system candidates such as quantum, molecular and optical memory systems. Students will write a term paper on an aspect of memory systems of particular interest to them (proposed topic must still be approved by the instructor).)Graduate Standing or Permission of Instructor) Class 3, Lab 0, Credit 3 (F)

MCEE-720   Photovoltaic Science and Engineering
This course focuses on the principle and engineering fundamentals of photovoltaic (PV) energy conversion. The course will cover modern silicon PV devices, including the basic physics, ideal and non-ideal models, device parameters and design, and device fabrication. The course will discuss crystalline, multi-crystalline, amorphous thin films solar cells and their manufacturing. Students will be made familiar on how basic semiconductor processes are employed in solar cells manufacturing. The course will further introduce third generation advanced photovoltaic concepts including compound semiconductors, spectral conversion, and organic and polymeric devices. PV applications, environmental, sustainability and economic issues will also be discussed. Evaluation will include in addition to assignments and exams, a research/term paper on a current PV topic. (Permission of Instructor) Class 3, Lab 3, Credit 3 (S)

MCEE-730   Metrology for Failure Analysis and Yield of IC's
Successful IC manufacturing must detect defects (the non-idealities) that occur in a process), eliminate those defects that preclude functional devices (yield enhancement), and functionality for up to ten years of use in the field (reliability). Course surveys current CMOS manufacturing to compile a list of critical parameters and steps to monitor during manufacturing. This survey is followed with an in depth look at the theory and instrumentation of the tools utilized to monitor these parameters. Tool set includes optical instrumentation, electron microscopy, surface analysis techniques, and electrical measurements. Case studies from industry and prior students are reviewed. Students are required to perform a project either exploring a technique not covered in class, or to apply their course knowledge to a practical problem. (MCEE-201 IC Technology or Equivalent MCEE-360 Semiconductor Devices or Equivalent Permission of Instructor) Class 3, Lab, Credit 3 (F)

MCEE-732   Evaluation of Microelectronics Manufacturing
This course focuses on CMOS manufacturing. Topics include CMOS process technology, work in progress tracking, CMOS calculations, process technology, long channel and short channel MOSFET, isolation technologies, back-end processing and packaging. Associated is a lab for on-campus section (01) and a graduate paper/case study for distance learning section (90). The laboratory for this course is the student-run factory. Topics include Lot tracking, query processing, data collection, lot history, cycle time, turns, CPK and statistical process control, measuring factory performance, factory modeling and scheduling, cycle time management, cost of ownership, defect reduction and yield enhancement, reliability, process modeling and RIT's advanced CMOS process. Silicon wafers are processed through an entire CMOS process and tested. Students design unit processes and integrate them into a complete process. Students evaluate the process steps with calculations, simulations and lot history, and test completed devices. (MCEE-701 Microelectronics Fabrication) Class 3, Lab 3, Credit 3 (S)

MCEE-770   Microelectromechanical Systems
This course will provide an opportunity for the student to become familiar with the design, fabrication technology and applications of Microelectromechanical systems. This is one of the fastest growing areas in the semiconductor business. Today's MEMS devices include accelerometers, pressure sensors, flow sensors, chemical sensors, energy harvesting and more. These devices have wide variety of applications including automotive, consumer, military, scientific, and biomedical. Students will select a MEMS device/project to be made and then design, fabricate, test, prepare a project presentation and final paper. (Senior/Graduate level engineering student or permission of the instructor.) Class 3, Lab 3, Credit 3 (F)

MCEE-777   Master of Engineering Internship
This course number is used to fulfill the internship requirement for the master of engineering degree program. The student must obtain the approval of the department head before registering for this course. (Advisor approval) Class 0, Lab 0, Credit 4 (F, S, S)

MCEE-789   Special Topics
This is a variable credit, variable special topics course that can be in the form of a course that is not offered on a regular basis. (Advisor approval) Class 1-3, Lab 0, Credit 1-3 (F, S, S)

MCEE-790   MS Thesis
The master's thesis in microelectronic engineering requires the student to prepare a written thesis proposal for approval by the faculty; select a thesis topic, adviser and committee; present and defend thesis before a

thesis committee; submit a bound copy of the thesis to the library and to the department; prepare a written paper in a short format suitable for submission for publication in a journal; complete course work and thesis within a seven-year period; register for one credit of Continuation of Thesis each school term (except summer) after the 30 credits required for the master's degree until the thesis is completed. (Graduate standing in MS in microelectronic engineering, Advisor approval) Class 1; Credit 1-6 (F, S)

MCEE-795   Microelectronics Research Methods
Weekly seminar series intended to present the state of the art in microelectronics research. Other research-related topics will be presented such as library search techniques, contemporary issues, ethics, patent considerations, small business opportunities, technical writing, technical reviews, effective presentations, etc. Required of all MS microelectronic engineering students for one credit up to a total 3 credits.   Class 1, Lab 0, Credit 1 (F, S)

MCEE-799   Graduate Independent Study
This course number should be used by students who plan to study a topic on an independent basis under the guidance of a faculty member. A written proposal with an independent study form is to be submitted to the sponsoring faculty member and approved by the department head prior to the commencement of work. (Advisor approval) Credit 1-3 (F, S, S)

Appendix E: Electrical and Microelectronic Engineering Department Faculty

Mustafa A. G. Abushagur, Ph.D., California Institute of Technology, President of RIT Dubai. optical communications, computing, interconnects, MEMS, and optical signal processing, fiber bragg grating and sensors.

David Borkholder, Ph.D., Stanford University, Associate Professor, biosensors (electromagnetic and chemical), biomedical Instrumentation, MEMs fabrication, systems engineering

Robert J. Bowman, Ph.D., University of Utah, Professor, analog Integrated circuit design semiconductor physics, biomedical Instrumentation

Edward Brown, Ph.D., Vanderbilt University, Associate Professor, rehabilitation, robotics, control systems, biomechatronics

Sohail A. Dianat, Ph.D., George Washington University, Professor and Department Head, control systems, communications, signal/ Image processing

Dale E. Ewbank, Ph.D., Rochester Institute of Technology, Senior Lecturer, microlithography and electro-optics.

Lynn F. Fuller, Ph.D., State University of New York at Buffalo, Professor, IEEE Fellow, Microsystems MEMS (micro-electro-mechanical systems) with integrated CMOS electronics (digital and analog) for a wide variety of applications including biomedical and remote sensing.

Karl D. Hirschman, Ph.D., University of Rochester, Associate Professor, integration of novel device structures (e.g. sensors, optoelectronic devices) with silicon microelectronics, and the integration of silicon devices with non-traditional substrates.

Christopher Hoople, Ph.D., Cornell University, Senior Lecturer, power electronics, device physics

Mark Hopkins, Ph.D., Virginia Polytechnic, Professor, control systems, system identification

Michael A. Jackson, Ph.D., State University of New York at Buffalo, Associate Professor, photovoltaics, defect analysis and metrology, thin film processes, optics and fields.

Mehran Mozaffari Kermani, Ph.D., Western University, London, Ontario Canada, Assistant Professor, cryptographic hardware architectures, embedded systems security, reliable and secure low-power FPGA and ASIC designs, and fault diagnosis and tolerance in VLSI crypto-systems.

Santosh K. Kurinec, Ph.D. in Physics, University of Dehli – India, Professor, photovoltaics, novel materials, device integration, tunnel diodes, magnetic tunnel junctions (MTJ), magnetic materials and devices, silicon-carbide devices.

Zhaolin Lu, B.A. Chongqing University (China), MS, Michigan Technological University, Ph.D., University of Delaware-Associate Professor

Sergey Lyshevski, Ph.D., Kiev, Polytechnic Institute, Professor, microsystems

A.V. Mathew, Ph.D., Queens University (Ontario), Professor, control systems, robotic vision

James Moon, Ph.D., University of California at Berkeley, Associate Professor, solid state devices, VLSI Design, semiconductor physics, integrated circuit design, electronic & photographic imaging systems

Sildomar Takahashi Monteiro, Ph.D., Tokyo Institute of Technology, Tokyo, Japan, Assistant Professor, robotics, machine learning, statistical signal and image processing, remote sensing, biomedical imaging.

P.R. Mukund, Ph.D., University of Tennessee, Professor, VLSI design, analog circuit design and electronics packaging

Dorin Patru, Ph.D., Washington State University, Associate Professor, mixed-signal and digital integrated circuits

Robert E. Pearson, Ph.D., State University of New York at Buffalo, Associate Professor, device physics, semiconductor processing, device simulation, electrical testing and characterization.

Daniel Phillips, Ph.D., University of Rochester, Associate Professor, biomedical instrumentation, signal processing & visualization, and embedded systems.

Ivan Puchades, Ph.D., Rochester Institute of Technology, Research Faculty, MEM's, micro-fabrication, circuits and sensors.

Sean L. Rommel, Ph.D., University of Delaware, Associate Professor, nanoelectronic devices and circuits, photonic/optoelectronic devices/circuits, and advanced semiconductor fabrication techniques. Specializes in experimental demonstration of tunneling devices.

Eli S. Saber, Ph.D., University of Rochester, Professor, signal, image & video processing communications, biomedical, computer vision

Ferat Sahin, Ph.D., Virginia Polytechnic Institute, Professor, robotics, artificial intelligence, control systems

Gill Tsouri, Ph.D., Ben-Gurion University, Associate Professor, digital and wireless communications, signal processing for biomedical applications

Jayanti Venkataraman, Ph.D., Indian Institute of Science, India, - Professor, electro-magnetics, theoretical modeling and measurement of microstrip antennas and integrated microwave circuits, CRHL transmission line metamaterials, RF Microsystems, bioelectromagnetics.

Jing Zhang, Ph.D., Lehigh University, Assistant Professor, Various aspects of computational/advanced simulations, MOCVD growths (epitaxy), and device fabrication of III-Nitride semiconductors for photonics, thermoelectric, and solid state lighting applications.

Appendix F: Representative Publications

Dr. Mustafa A. G. Abushagur

- "*Efficiently squeezing near infrared light into a 21nm-by-24nm nanospot,*" Ruoxi Yang, Mustafa A. Abushagur and Zhaolin Lu, Optics Express Vol. 16, Iss. 24, pp. 20142–20148 (2008).
- "*Broadband Silicon Electro-Optic Absorption Modulator,*" A. W. Elshaari, S. F. Preble, and M. A. Abushagur, Laser Science XXIV, OSA Technical Digest (Optical Society of America, 2008).
- "*Efficient Couplers and Splitters from Dielectric Waveguides to Plasmonic Waveguides,*" R. A. Wahsheh, Z. Lu, and M. A. Abushagur, Frontiers in Optics, OSA Technical Digest (Optical Society of America, 2008).
- "*Cross Talk Reduction by Photonic Crystal Cavities,*" R. A. Wahsheh, Z. Lu, S. F. Preble, and M. A. Abushagur, Frontiers in Optics, OSA Technical Digest (Optical Society of America, 2008).
- "*Optical Multi-Level Logic on a Silicon Chip,*" K. Narayanan, S. F. Preble, Z. Lu, and M. A. Abushagur, Frontiers in Optics, OSA Technical Digest (CD) (Optical Society of America, 2008).

Dr. David Borkholder

- David A. Borkholder, XiaoXia Zhu, Robert D. Frisina, "*Round Window Membrane* Intracochlear *Drug Delivery Enhanced by Induced Advection,*" Journal of Controlled Release, 174:171-176 (2013).
- Jessica L. Snyder, Jirachai Getpreecharsawas, David Z. Fang, Thomas R. Gaborski, Christopher C. Striemer, Philippe M. Fauchet, David A. Borkholder, and James L. McGrath, "*High-performance, low-voltage electroosmotic pumps with molecularly thin silicon nanomembranes,*" Proceedings of the National Academies of Sciences, 110(46):18425-18430 (2013).
- Haghpanahi M, Gladstone MB, Zhu XX, Frisina RD, Borkholder DA, "*Noninvasive Technique for Monitoring Drug Transport Through the Murine Cochlea using Micro-Computed Tomography,*" Ann Biomed Eng, 41:2130-2142 (2013) DOI 10.1007/s10439-013-0816-4.
- Conn, Nicholas J, Borkholder, David A**.** "*Wavelet based photoplethysmogram foot delineation for heart rate variability applications,*" *Signal Processing in Medicine and Biology Symposium (SPMB), 2013 IEEE*, pp.1,5, 7-7 Dec. 2013 doi: 10.1109/SPMB.2013.6736782
- Ostertag MH, Kenyon M, da Silva U, Lee G, Kamimori G, Borkholder DA, "*The Blast Gauge System as A Research Tool to Quantify Blast Overpressure in Complex Environments.*" *Proceedings of the ASME 2013 International Mechanical Engineering Congress & Exposition*, November 13-21, San Diego, CA (2013).

Dr. Robert Bowman

- Christopher James Nassar, Joseph Revelli, and Robert John Bowman, "*Application of the Homotopy Analysis Method to Poisson-Boltzmann Equation for Semiconductor Devices",* Communications in Nonlinear Science and Numerical Simulations, Elsevier, June 2011
- S. A. Marshall, C. J. Nassar, J. W. Choi, J. Jang, C. A. Kosik Williams, E. J. Mozdy, T. J. Tredwell, R.J. Bowman, "*The 1/f Noise Performance for TFTs Fabricated in Three TFT Technologies: Monocrystalline Silicon on Glass, Low Temperature Polysilicon on Glass, and Silicon on Insulator",* Proceedings of the Electrochemical Society Transactions Volume 33, Issue 5, October, 2010
- C. J. Nassar, T. J. Tredwell, C. A. Kosik Williams, J. F. Revelli, and R. J. Bowman, Z"*A Charge Based Compact Modeling Technique for Monocrystalline TFTs on Glass",* Proceedings of the Electrochemical Society Transactions Volume 33, Issue 5. October, 2010
- Chris Nassar, Carlo Kosik-Williams, Dave Dawson-Elli, Robert J. Bowman, Single Fermi Level, Thin Film CMOS on Glass: "*The Behavior of Enhancement Mode PMOSFETs from Cutoff through Accumulation",* IEEE Transactions on Electron Devices, September, 2009.
- Knausz and R. Bowman, "*A Low Power, Scalable, DAC Architecture for Liquid Crystal Display Driver"s,* IEEE Journal of Solid State Circuits, September, 2009.

Dr. Edward Brown

- Gebregiorgis, A. L., and Brown, Jr., E. E., "*Using Hidden Markov Models to Track Upper Extremity Arm Motions for Surface Electromyographic Based Robot Teleoperation,*" 5th IEEE Biosignals and Biorobotics Conference (ISSNIP*),* Salvador, Brazil, May 26-28, 2014.

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- Howard, A. M., Brooks, D. A., Brown, E. E., Gebregiorgis, A., and Chen, Y-P., "*Non-Contact Versus Contact-Based Sensing Methodologies for In-Home Upper Arm Robotic Rehabilitation*," *13th* International Conference on Rehabilitation Robotics (ICORR2013), Seattle, WA, June 24-26, 2013.
- Smith, A., and Brown, Jr., E. E., "*Myoelectric Control Techniques for a Rehabilitation Robot*," Applied Bionics and Biomechanics, Vol. 8, No. 1, May 2011.
- Brown, Jr., E. E., "*A Multicontextual Model for Broadening Participation in STEM Related Disciplines*," Journal of U.S./China Education Review, Vol. 8, No. 3, March 2011.
- Brown, Jr., E. E., "*A Multicontextual Model for Increasing Participation and Graduation Rates in STEM Related Disciplines*," 2010 International Technology, Education, and Development Conference (INTED2010*)*, Valencia, Spain, March 8-10, 2010.

Dr. Sohail Dianat
- G. Tsouri, S. Kyal, S. Dianat, and L. K. Mestha, "*Constrained-ICA Approach to Non-Obtrusive Pulse Rate Measurements*", Journal of Biomedical Optics, August 2012.
- H. Peng, R. Rao, S. A. Dianat, "*Optimized Vector Bilateral Filter for Multispectral Image Denoising*", 19th IEEE International Conference on Image Processing, Orlando, Florida, September 2012.
- H. Peng, R. Rao, S. A. Dianat, " *Nonnegative Matrix Factorization with Deterministic Annealing for Unsupervised Unmixing of Hyperspectral Imagery*", 19th IEEE International Conference on Image Processing, Orlando, Florida, September 2012.
- M. Almradi, and S. A. Dianat, "*NDA SNR Estimation over MISO with STBC Channels for BPSK Modulated Signals using the EM Algorithm*", The 2nd International Conference on Communications and Information Technology (ICCIT): Wireless Communications and Signal Processing, Hammamet, Tunisia, June 2012.
- M. Almradi, and S. A. Dianat, "'*Cramer-Rao Lower Bounds of NDA SNR Estimation for BPSK Modulated Signals over MISO with STBC Channels*", The 2nd International Conference on Communications and Information Technology (ICCIT): Wireless Communications and Signal Processing, Hammamet, Tunisia, June 2012.

Dr. Dale E. Ewbank
- D. E. Ewbank, "*Single Arm Interferometer System for Reflective Micro-Device Phase Measurement*," in *Optical Fabrication and Testing*, OSA Technical Digest (CD) (Optical Society of America, 2010), paper OWC2. http://www.opticsinfobase.org/abstract.cfm?URI=OFT-2010-OWC2.
- S. Kurinec*, et al.*, "*Summer Innovation Experience for undergraduates in semiconductor technology*," in Frontiers in Education Conference (FIE), 2010 IEEE, 2010, pp. T1J-1-T1J-2.
- D. E. Ewbank, "*Optical Test System for Reflective Electro-Optical Adaptive Micro-Device Phase Measurement*," in Frontiers in Optics, OSA Technical Digest (CD) (Optical Society of America, 2006), paper OFMC6. http://www.opticsinfobase.org/abstract.cfm?URI=OFT-2006-OFMC6.
- S. K. Kurinec*, et al.*, "*25 years of microelectronic engineering education*," in 2006 16th Biennial University/Government/Industry Microelectronics Symposium*,* 25-28 June 2006, Piscataway, NJ, USA, 2007, pp. 23-31.

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Appendix G: Specimen Title Page (Master of Science in Electrical Engineering - THESIS)

THE PURPLE PLAGUE

by

Chef Boyardee

A Thesis Submitted

in

Partial Fulfillment

of the

Requirements for the Degree of

MASTER OF SCIENCE

in

Electrical Engineering

Approved by:

PROF.
_____
(Thesis Advisor's Name, Printed)

PROF.
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PROF.
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PROF.
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(Department Head's Name, Printed)

DEPARTMENT OF ELECTRICAL AND MICROELECTRONIC ENGINEERING

COLLEGE OF ENGINEERING

ROCHESTER INSTITUTE OF TECHNOLOGY

ROCHESTER, NEW YORK

MAY, 2014

THE PURPLE PLAGUE

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(Graduate Paper Advisor's Name, Printed)

PROF.   _____
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MAY, 2014

Appendix I: Specimen Title Page (Master of Science in Microelectronic Engineering - THESIS)

THE PURPLE PLAGUE

by

Chef Boyardee

A Thesis Submitted

in

Partial Fulfillment

of the

Requirements for the Degree of

MASTER OF SCIENCE

in

Microelectronic Engineering

Approved by:

PROF. _____
(Thesis Advisor's Name, Printed)

PROF. _____

PROF. _____

PROF.

(Program Director's Name, Printed

PROF. _____
(Department Head's Name, Printed)

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Appendix J: Specimen Table of Contents for Graduate Paper and Thesis
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