Rochester Institute of Technology

Department of Electrical and

Microelectronic Engineering

Kate Gleason College of Engineering

EME Graduate Program Guide

2020-2021

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 strong, rigorous curricula 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 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. They are the following

- Master of Science in Electrical Engineering (EEEE-MS)
- Master of Science in Microelectronic Engineering (MCEE-MS)
- Master of Engineering in Microelectronic Manufacturing Engineering (MCEMANU-ME)

This document is intended to provide 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**.**

https://www.rit.edu/engineering/electrical-and-microelectronic-engineering/student-resources

The KGCOE Student booklet which contains all resources and policies related to computer networking, Student Information System (SIS), grades, probation and suspension and Ethics can be found in the link provided below:

https://www.rit.edu/engineering/sites/rit.edu.engineering/files/docs/resources/Graduate%20Student%20Handbook%202019-2020.pdf

Table of Contents

		Page
1.	**Contact Information**	**5**
2.	**Master of Science in Electrical Engineering (EEEE-MS)**	**6**
2.1	General steps towards earning the MSEE degree	6
2.2	Admission requirements	7
2.3	Graduation requirements	7
2.4	Focus areas of Specialization	7
2.5	Graduate student advising	7
2.6	Plan of study and policies	7
2.7	Transfer credits	8
2.8	Graduate Teaching and Research assistantships	8
2.9	Good academic standing	9
2.10	MSEE Graduate Paper	9
2.11	MSEE Thesis	9
2.12	MSEE Comprehensive exam	9
2.13	Graduate Internships in the MSEE Program	10
2.14	EE Graduate Course Offerings by Focus Areas	11
3.	**Master of Science in Microelectronic Engineering (MCEE-MS)**	**12**
3.1	General steps towards earning the degree	12
3.2	MCEE-MS Microelectronic Engineering Admission requirements	12
3.3	MCEE-MS Microelectronic Engineering Program	13
3.4	MCEE-MS Core Courses	13
3.5	MCEE-MS Elective Courses	13
3.6	MCEE-MS Microelectronic Engineering Plan of study	13
3.7	MCEE-MS Microelectronic Engineering Graduate student advising	13
3.8	Assistantships and Fellowships	14
3.9	Thesis Proposal and Thesis Work	14
3.10	Typical schedule for non BS MicroE	14
3.11	Typical schedule for BS MicroE	15
4.	**Master of Engineering in Microelectronic Manufacturing Engineering (MCEMANU-ME)**	**16**
4.1	General steps towards earning the **MCEMANU-ME** degree	16
4.2	MCEMANU-ME Admission requirements	16
4.3	MCEMANU-ME Program requirements	16
4.4	Microelectronics Courses	17
4.5	Microlithography Courses	17
4.6	Manufacturing Courses	17

Page

4.7 MCEMANU-ME Typical schedule 18
4.8 On-Line Master of Engineering in Microelectronic Manufacturing Engineering 16

5. Graduate Paper and Thesis Procedures for all EME Graduate Programs 19

5.1 Requirements 19
5.2 Registration 19
5.3 Procedures 19
5.4 Graduate Paper: Format and Formalities 20
5.5 Graduate Thesis: 21
5.5.1 Thesis format 21
5.5.2 Thesis Defense 21
5.5.3 Permissions: Copyright and Embargoes 22
5.5.4 Thesis submission on ProQuest 22

Appendix A –Electrical and Microelectronic Engineering Faculty 23

Appendix B - Recent MS Electrical Engineering Thesis Titles 26

Appendix C - Recent MS Microelectronic Engineering Thesis Titles 27

Appendix D – Electrical Engineering (EEEE) Graduate Course Descriptions 28

Appendix E – Microelectronic Engineering (MCEE) Graduate Course Description 39

Appendix F - Sample MSEE Thesis Title Page and Signature Page 42

Appendix G - Sample MSEE Graduate Paper Title Page 44

Appendix H- Sample MS MicroE Thesis Title Page and Signature Page 45

Appendix J – Sample Table of Contents for Thesis and Graduate Paper 47

1. Contact Information

Department of Electrical and Microelectronic Engineering
Rochester Institute of Technology
79 Lomb Memorial Drive
Rochester, NY 14623
Phone (585) 475-2164
http://www.rit.edu/kgcoe/electrical/
http://www.rit.edu/kgcoe/microelectronic

Dr. Ferat Sahin, Professor and Department Head
Electrical and Microelectronic Engineering
79 Lomb Memorial Drive
Rochester, NY 14623
Phone (585) 475-2164
Email: feseee@rit.edu

Ms. Patricia Vicari, Graduate Sr. Staff Specialist
79 Lomb Memorial Drive
Rochester, NY 14623
Phone (585) 475-2164
Email: pmveee@rit.edu

Dr. Jayanti Venkataraman, Graduate Program Director (MSEE)
Professor Department of Electrical and Microelectronic Engineering
Rochester Institute of Technology
Building 09, Office 3091
79 Lomb Memorial Drive
Rochester, NY 14623
Phone (585) 475-2143
Email: jnveee@rit.edu
http://www.rit.edu/kgcoe/eta/

Dr. Sean Rommel, Microelectronic Engineering Program Director
Electrical and Microelectronic Engineering
82 Lomb Memorial Drive
Rochester, NY 14623
Phone (585) 475-4723
Email: slremc@rit.edu
http://www.rit.edu/kgcoe/microelectronic

2 Master of Science in Electrical Engineering (EEEE-MS)

2.1 General Steps towards earning the MSEE Degree

- The MSEE Program requirements which is a total of 30 credits can be completed by one of the following options
  - Graduate Thesis (6 credit hours) and 8 courses (3 credits each)
  - Graduate Paper (3 credit hours) and 9 courses (3 credits each)
  - Comprehensive Exam (No credit) and 10 courses (3 credits each)

  Details are provided in section 2.3.

- MSEE students are required to select a focus area prior to registering for their first semester of studies upon which a faculty advisor in that area will be assigned who will assist the student with course selections. The focus area, however, can be changed to meet educational needs. Details are provided in Section 2.4 and 2.6. The MSEE course outlines are provided in Appendix D.

- During the first semester, MSEE 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 abstracts of faculty publications in Appendices A, B, and K, which may assist you in determining a specific thesis or graduate paper advisor. While completing the remaining credits, students are encouraged to continue to develop their paper or thesis ideas and discuss their thoughts with their faculty advisor.

- Graduate thesis (6 credit) can be split in increments of 3 credits per semester. AFTER you have registered for all six credits, you must KEEP REGISTERING on a semester-by-semester-basis for one credit each time, for as long as your work is still in progress. This allows you to stay current in the system. You are allowed one free credit in which to complete your thesis. After that, you will be charged for one credit per semester until you complete your thesis. Summer semesters are free. Upon completion, students are required to obtain the proper approvals for their thesis and provide the necessary copies to the Electrical and Microelectronic Engineering department. Details are described in Section 2.11 and Section 5.

- Graduate paper (3 credits) needs to be completed in one semester, upon which a letter grade will be awarded by the faculty advisor. This grade will be counted for the cumulative grade point average (CGPA). Students are required to provide the necessary copies to the Electrical and Microelectronic Engineering department. Details are in Section 2.10 and Section 5.

- The Comprehensive exam is offered twice a year in January and June. Details are provided in section 2.12.

- 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.

- Internships are permitted during any semester, upon approval of the graduate paper / thesis faculty advisor and the Graduate Program Director. Details are provided in Section 2.13.

2.2 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.

MSEE can be pursued both on a full time or part time basis.

2.3 Graduation Requirements

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.

2.4 Focus Areas of Specialization

For the MSEE degree, the student can select and specialize in one of the following eight areas.

- Communications
- Control Systems
- Digital Systems
- Electromagnetics, Microwaves and Antenna
- Integrated Electronics
- MEMS
- Robotics
- Signal & Image Processing

2.5 Graduate Student Advising

All incoming students will be assigned an academic faculty advisor who is in the focus area of their choice. 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.

2.6 Plan of Study and Policies

Every matriculated student must arrange to have a Plan of Study prepared in consultation with his/her faculty advisor *at the beginning of the program*

The following general rules apply to all MSEE students:

- 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.

- Those students who have selected the following focus areas: Control Systems, Communications, Electromagnetics, Robotics and Signal & Image Processing, must also complete EEEE-602: Random Signals and Noise.

- Students must take three courses in their chosen focus area from the Electrical and Microelectronic Engineering department and expected to perform the research needed for a graduate paper or thesis in the same area.

- Student may take the remaining courses from a related area within the College of Engineering, the Center for Imaging Science and the Computer Science Department with approval from the Graduate Program Director.

- A maximum of 2 courses are allowed as electives from programs outside the above listed Colleges / Departments. These must be approved by the Graduate Program Director.

- All courses must be 600 level or above.

- MSEE students can select one of the following options to complete the degree requirement.

    - Graduate Thesis (6 credit hours) and 8 courses.

    - Graduate Research Paper (3 credit hours) and 9 courses.

    - Comprehensive Examination (NO Credit) and 10 courses.

- 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.

2.7 Transfer Credits

For students transferring credits from other universities, a maximum of 2 graduate courses (6 credits) are allowed with approval from the Graduate Program Director.

2.8 Graduate Teaching and Research Assistantships

The Electrical and Microelectronic Engineering Department offers teaching assistantships to a limited number of outstanding incoming first year graduate students. During the second year, students are encouraged to seek support as research assistants (RA) from a faculty member.

2.9 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 and KGCOE 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 'C-', 'D' or 'F' grades do not count toward the fulfillment of the program requirements for a graduate degree." However, they are calculated in the CGPA and will remain on the student's transcript permanently. Students placed on probation may have their scholarship reduced or totally eliminated at the discretion of the Graduate Program Director and in accordance with RIT policies.

2.10 MSEE Graduate Paper

The MSEE graduate paper is 3 credits. It is treated as a regular course that is required to be completed in one semester. Letter grades A through F will be assigned by the Faculty advisor. This grade will count towards the CGPA. Students are required to provide the necessary copies to the Electrical and Microelectronic Engineering department. Details of the format of the paper is given in Section 5.

2.11 MSEE Thesis

Graduate thesis (6 credits) can be split in increments of 3 credits per semester. AFTER you have registered for all six credits, you must KEEP REGISTERING on a semester-by-semester-basis for one credit each time, for as long as your work is still in progress. This allows you to stay current in the system. You are allowed one free credit in which to complete your thesis. After that, you will be charged for one credit per semester until you complete your thesis. Summer semesters are free. Upon completion, students are required to obtain the proper approvals for their thesis and provide the necessary copies to the Electrical and Microelectronic Engineering department. Details of the thesis defense and thesis format are provided in Section 5.

2.12 MSEE Comprehensive Exam

- There are two parts to the exam.
  - Part I: Based on the two Mandated Courses
    - EEEE707 Engineering Analysis
    - EEEE709 Advanced Engineering Mathematics
  - Part II: Based on the Student's Focus Area

- Students are allowed to take the exam after a successful completion of 7 to 8 EE courses.

- The exam will be conducted twice every academic year: Mid-June and January (during the Intersession)

- Sign up for the exam is in early May and early December

- The duration of the exam is 3 hours for each part.

- The exam is written, held in class and proctored.
- Part I is closed book.
- Part II is closed book or open book, depending on the focus area and the instructor.
- In case of a failing grade a maximum of two more attempts are permitted (total 3 attempts).

2.13 Graduate Internships in the MSEE Program

A maximum of one year is permitted for Graduate internships. Following is the approval process.

- Student should have an offer letter from a company with start and end dates.
- Students should be registered for courses in the semester following the duration of the internship.
- Approval is required by the student’s graduate paper/thesis faculty advisor stating that upon return of student to RIT, the faculty will continue to work with student to ensure that the graduate paper /thesis will be completed in a timely manner.
- Upon approval by the MSEE Program coordinator, the student will be registered in EEEE699-Graduate Co-op.
- Students accepted for Co-op by a company who fail to report for work or who quit the internship before the designated date, will not be permitted to accept any other Co-op during their duration in the MSEE program at RIT.

2.14 EE Graduate Course Offerings by Focus Area

Core Courses	Fall	Spring
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 Course for all Focus Areas except #3,5,6	EEEE-602 Random Signal and Noise	EEEE-602 Random Signal and Noise
Focus Area		
1 - Communication	EEEE 692 Communications Networks EEEE-629 Antenna Theory and Design EEEE-718 Des & Characterization of Microwave Systems EEEE-793 Error Detect/Error Correction EEEE-797 Wireless Communication	EEEE-693 Digital Data Communication. EEEE-694 Sensor Array Processing for Wireless Communications EEEE-617 Microwave Circuit Design EEEE-710 Advanced EM Theory EEEE-794 Information Theory
2 - Control Systems	EEEE-661 Modern Control Theory EEEE-663 Real-Time Embedded Systems	EEEE-664 Performance Engineering of Real-time & Embedded Systems EEEE-765 Optimal Control
3 - Digital Systems	EEEE-620 Design of Digital Systems EEEE-621 Design of Computer Systems EEEE 722 Complex Digital Systems Verification	EEEE-620 Design of Digital Systems EEEE-720 Advanced Topic in Digital Sys Design EEEE-721 Advanced Topics in Computer Sys Design
4-Electromagnetics, Microwaves and Antenna	EEEE-629 Antenna Theory & Design EEEE-718 Des & Characterization of Microwave Systems	EEEE-617 Microwave Circuit Design EEEE-710 Advanced Electromagnetic Theory
5- Integrated Electronics	EEEE-610 Analog Electronics EEEE-711 Advanced Carrier-Injection Devices EEEE-713 Solid State Physics MCEE-601 Micro Fabrication	EEEE-712 Advanced Field Effect Devices EEEE-726 Mixed Signal IC Design 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-622 Electric Power Transmission & Distribution **(Elective)**	EEEE-646 Power Electronics EEEE-787 MEMs Evaluations EEEE-624 Advances in Power Systems **(Elective)** EEEE-631 Biomed Sensors & Transducers I **(Elective)**
7- Robotics	EEEE-685 Principles of Robotics EEEE-647 Artificial Intelligence EEEE-661 Modern Control Theory	EEEE-636 Bio-robotics/ Cybernetics EEEE-784 Advanced Robotics
8- Signal & Image Processing	EEEE-678Digital Signal Processing EEEE-695 Optimization Methods for Engineers EEEE-794 Information Theory	EEEE-670 Pattern Recognition EEEE-694 Sensor Array Processing for Wireless Communications EEEE-768 Adaptive Signal Processing EEEE-779 Digital Image Processing EEEE-781 Image and Video Compression

- A selected number of Graduate courses are usually available during the summer semester.
- Graduate level courses taken in Microelectronic Engineering, Computer Engineering or Mechanical Engineering can be counted towards the 3-course requirement in the Controls, Digital Systems, Integrated Electronics or MEMs focus areas.
- Related area courses may be taken from the College of Engineering, the Center for Imaging Science and the Computer Science Department

3 Master of Science in Microelectronic Engineering (MCEE-MS)

3.1 General Steps towards earning the Degree

- Master of Science in Microelectronics students typically have a default schedule for their first semester. If a student has transfer credit or other academic issues they should meet with the Microelectronic Engineering graduate program director (currently Dr. Rommel) before registering for their first semester of studies.

- During the first semester, Master of Science students should begin to consider a topic for their graduate thesis. This document contains recent thesis titles (appendix C). Abstracts of faculty publications which may assist you in determining a specific thesis advisor can be found on individual faculty web pages. Students are required to interact with program faculty and declare a thesis advisor by the beginning of April of the spring semester.

- While completing the remaining degree credits, students are encouraged to continue to develop their thesis ideas and discuss their thoughts with their faculty advisor.

- MCEE students can register for thesis in increments of 3 credits per semester. A total of six credits of thesis are required. AFTER you have registered for all six credits, you must KEEP REGISTERING on a semester-by-semester-basis for one credit each time, for as long as your work is still in progress. This allows you to stay current in the system. You are allowed one free credit in which to complete your thesis. After that, you will be charged for one credit per semester until you complete your thesis. Summer semesters are free.

- Students are required to obtain the proper final approvals for their thesis document and provide the necessary **electronic copy to ProQuest**. The electronic receipt must be sent via email to the EME graduate coordinator.

- Microelectronic Engineering continues to **require a bound paper copy** be submitted to the program director.

- 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.

3.2 MCEE-MS Microelectronic Engineering 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 typically 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 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.

3.3 MCEE-MS Microelectronic Engineering 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 in Microelectronic Engineering two core courses (MCEE-704 and MCEE-732) courses and six elective courses are required. In addition, all graduate students in this program are required to take one credit seminar/research course for their first two semesters. Up to 2 seminar/research credits will be allowed to count toward the required 32 hours. A six-credit thesis proposal, written thesis 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 32.

3.4 MCEE-MS Core Courses

MCEE-601	Micro Fabrication
MCEE-602	Semiconductor Process Integration
MCEE-603	Thin Films
MCEE-605	Lithographic Materials and Processes
MCEE-615*	Nanolithography Systems
MCEE-732	Microelectronic Manufacturing
MCEE-704**	Physical Modeling Semiconductor Devices

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

3.5 MCEE-MS Elective Courses

The following is a subset of the elective courses offered for graduate credits. See the degree audit function in Student Information Services (SIS) or the program website for a complete list http://www.rit.edu/kgcoe/microelectronic/ms/curriculum

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
MCEE-730	Metrology Failure Analysis & Yield
MCEE-770	MEMS Fabrication
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.

3.6 MCEE-MS Microelectronic Engineering Plan of Study

As previously stated, new incoming students receive a default schedule for their first semester. Students should initially discuss this schedule with the Program's Graduate Director. Students also usually take a default schedule in the spring semester as well and wait until their second year to take electives.

The second semester each student should seek out a thesis advisor based on common interests. Students are required to declare an advisor by April of the spring semester (both student and advisor have to sign-off). Then, in consultation with his or her academic advisor – a plan of study is formulated 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. The plan of study should be revised with the recommendation of the advisor at start of each semester in the second year of study.

3.7 MCEE-MS Microelectronic Engineering Graduate Student Advising

Dr. Sean Rommel is the initial graduate advisor for all students with a MS in Microelectronics.

3.8 Assistantships and Fellowships

A limited number of assistantships and fellowships may be available for full-time (or full-time equivalent) MS students. Appointment **in the second year of study** as a teaching/lab assistant typically carries a 8-10 hour-per-week commitment to a laboratory teaching function and permits a student to take graduate work at the rate of 10 credits per semester. Students in the MS program may also eligible for research fellowships. Appointment as a research assistant also permits taking up to 10 credits per semester while the remaining time is devoted to the research effort, which often serves as a thesis subject. Appointments provide hourly pay. Applicants for research assistantships should contact the program director or individual faculty members for details.

3.9 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 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 from the Microelectronic Engineering Graduate Director 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).

3.10 Typical Schedule for a non BS MicroE student

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-795 (1 cr) Seminar/Research	1. MCEE-602 (3 cr) Semiconductor Process Integration **CORE** 2. MCEE-732 (4 cr) Microelectronic Manufacturing & Lab **CORE** 3. Graduate Professional Elective (3 cr) 4. MCEE-795 (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)	1. MCEE-790 (3 cr) Thesis 2. Full Time Equivalency (6 cr) Research
Total of 32 credits: 2 Seminar, 6 thesis and 24 course credits (8 courses). Transition courses may be required which do not count towards the degree credits.			

3.11 Typical Schedule for a BS MicroE student

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-795 (1 cr) Seminar/Research	1. Graduate Professional Elective (3 cr) 2. MCEE-732 (3 cr)Microelectronic Manufacturing, Lab **CORE** 3. Graduate Professional Elective (3 cr) 4. MCEE-795 (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)	1. MCEE-790 (3 cr) Thesis 2. Full Time Equivalency (6 cr) Research
Total of 32 credits: 2 Seminar, 6 thesis and 24 course credits (8 courses).			

4 Master of Engineering in Microelectronic Manufacturing Engineering (MCEMANU-ME)

4.1 General Steps towards earning the MCEMANU-ME Degree

- Master of Engineering in Microelectronics Manufacturing students typically have a default schedule. New students with transfer credit or other possible issues should meet with the Microelectronic Graduate program director (Dr. Rommel) before the start of the first semester. Students will be automatically enrolled in the typical fall courses. If changes need to be made they can be done during the first week of the semester (add/drop).

- If interested in a summer internship, Master of Engineering students should begin to search for (interview with) companies at which they can complete their internship. This can begin as early as the fall semester. We require you to register at the RIT Co-op and Placement office and begin the interview process.

- 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.

4.2 MCEMANU-ME 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. The GRE exam is not required but may give the admission committee additional insight into the candidate's qualifications. A TOEFL score of 85 or greater is preferred.

4.3 MCEMANU-ME 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 (which does not count toward the degree), six core courses, two elective courses, three credits of the research methods course and a minimum of 3 credits of internship or an additional graduate course elective if a student does not do an 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, consisting of 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 in section 4.7 below).

The following is a subset of the elective courses offered for graduate credit. See the degree audit function in Student Information Services (SIS) or the program website for a complete list http://www.rit.edu/kgcoe/microelectronic/ms/curriculum

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
MCEE-730 Metrology Failure Analysis & Yield
MCEE-770 MEMS Fabrication
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.

The program allows for 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 possibly at RIT. Students must pay a reduced tuition for internship credits. 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 Graduate Director. If a student does not do an internship they can choose to take an additional elective course.

4.4 Microelectronics Courses

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.

4.5 Microlithography Courses

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.

4.6 Manufacturing Course

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.

4.7 MCEMANU-ME Typical Schedule

<table>
<tr><th colspan="4">A <u>typical</u> schedule for a Master of Engineering in Microelectronic Manufacturing Engineering</th></tr>
<tr><th>Fall (year 1)</th><th>Spring (year 1)</th><th>Summer (year 1)</th><th>Fall (year 2)</th></tr>
<tr>
<td>• MCEE-601 Micro Fab, Lab CORE
• MCEE-605 (3 cr) Microlithography Materials & Processes, Lab CORE
• MCEE-603 (3 cr) Thin Films, Lab CORE
• MCEE-795 (1 cr) Seminar/Research</td>
<td>• MCEE-602 (3 cr) Semiconductor Process Integration CORE
• MCEE-732 (4 cr) Microelectronic Manufacturing CORE
• MCEE-615 CORE
• MCEE-795 (1 cr) Seminar/Research</td>
<td>• Internship (3 cr) optional</td>
<td>• Graduate elective (3 cr)
• Graduate Professional Elective (3 cr)
• Independent study (1 cr)</td>
</tr>
<tr><td colspan="4">Total of 30 credits: 2 Seminar, 1 independent study, 3 internship (optional) and either 24 or 27 course credits (8 or 9 courses) depending on internship. Transition courses may be required which do not count towards the degree credits.</td></tr>
</table>

4.8 On-line Master of Engineering in Microelectronic Manufacturing Engineering

On-Line MCEMANU-ME students would take the same core courses but do not have to take the three MCEE-795 Seminar/Research credits since that course is only offered on-campus. On-line students substitute an additional (3^{rd}) graduate elective for these three credits. On-line students may use their normal jobs for their internship if they work in the semiconductor industry or they may work at RIT for a period of time (typically in the summer) or they may choose to take an additional (4^{th}) elective course.

5 Graduate Paper and Thesis: Policies and Procedures for all EME Graduate Programs

5.1 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 thesis or Graduate Paper.

In order to obtain a Master of Science degree in Microelectronic Engineering students must complete a Graduate Thesis. Of the minimum 32 credit hours needed to earn the degree, a typical student earns 24 credit hours from course work and the remaining 6 credit hours from the Thesis and the remaining two credit hours from the graduate seminar.

Thesis 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.

5.2 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 MCEE-790 section 1 for Microelectronics Masters students).

Graduate paper (3 credits) needs to be completed in one semester, upon which a letter grade will be awarded by the faculty advisor. This grade will be counted for the cumulative grade point average (CGPA).

Graduate thesis (6 credits) can be split in increments of 3 credits per semester. AFTER you have registered for all six credits, you must KEEP REGISTERING on a semester-by-semester-basis for one credit each time, for as long as your work is still in progress. This allows you to stay current in the system. You are allowed one free credit in which to complete your thesis. After that, you will be charged for one credit per semester until you complete your thesis. Summer semesters are free.

5.3 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.

5.4 Graduate Paper: Format and Formalities

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 need 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.

5.5 Graduate Thesis

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.

5.5.1 Thesis Format

- The default style format for your thesis is the *Chicago Manual of Style*. Your thesis must meet the minimum requirements for correct sentence structure, spelling, punctuation and technical accuracy.
- The Library requests that you leave a margin of 1 inch on all sides of the paper to accommodate the bindery process.
- The thesis should be 1.5 or double-spaced. Footnotes and long quotations should be single-spaced.
- The font style must be a serif style-serif fonts have additional structural details that enhance the readability of printed text. One popular serif font is *Times New Roman*
- 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.

5.5.2 Thesis Defense

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.

Notification of Thesis Defense: At least a week prior to the actual defense dates an electronic thesis defense notification email must be distributed to the EME faculty, staff and graduate students. This is done by supplying the graduate staff coordinator with a one page copy of the defense announcement. The title, date, location, student's name and advisor's name must appear along with an abstract of the defense

5.5.3 Permissions, Copyright, & Embargoes Permissions

Permission statements are no longer required.

Copyright:

Your work is automatically copyrighted once written. If you wish to add another layer of protection, you may register your work with the U.S. Copyright Office directly (http://www.copycerts@loc.gov). There are fees associated with this service. You also have the option for ProQuest to file for copyright with the U.S. Copyright Office on your behalf for a $55 fee. For more information on copyright, see: http://www.proquest.com/documents/copyright_dissthesis_ownership.html.

Embargoes:

Any student who desires an embargoed thesis must make a request through the Office of Graduate Education. Contact the Office of Graduate Education at (585) 475-2127 OR bdogs@rit.edu for more information.

The Thesis/Dissertation Author Limited Embargo Notification form must be completed. This form states that an embargo has been approved by the Office of Graduate Education: http://infoguides.rit.edu/ld.php?content_id=15221363

5.5.4 Thesis Submission on ProQuest

Your thesis should include the following:

- **The title page** Title
- Author's name
- Type of degree
- Name of department and college
- Date approved: month, day, year

Committee Signature page

- The printed names and signatures of the committee members
- The thesis must be signed and dated by the Department Chair and/or your Graduate Advisor before binding takes place.
- An unsigned thesis will not be processed.

Abstract

The abstract should summarize the entire manuscript and its arguments for readers. It should be a single typed page, approximately 300 words.

Appendix A: 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, Professor, biosensors (electromagnetic and chemical), biomedical Instrumentation, MEMs fabrication, systems engineering

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

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

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.

Jamison Heard, Ph.D., Vanderbilt University, Assistant Professor, robotics, artificial intelligence, control systems

Karl D. Hirschman, Ph.D., University of Rochester, 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

Jason Hoople, Ph.D., Cornell University, Visiting Lecturer, RF MEMs, Software Defined Radio

Mark Indovina, MSEE, Rochester Institute of Technology, Lecturer, mixed-signal and digital circuit design, VLSI design, embedded systems, systems engineering, signal processing for various applications including professional audio and sensor conditioning

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.

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

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

Panos P. Markopoulos, Ph.D., University at Buffalo, Assistant professor, communication and signal processing

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

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, Assistant Professor, MEM's, micro-fabrication, circuits and sensors.

Majid Rabbani, Ph.D., University of Wisconsin-Madison, Visiting Professor, Information Theory and Coding, Signal and Image processing, Image and Video Analysis.

Sean L. Rommel, Ph.D., University of Delaware, 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 and Department Head, 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, Bangalore, India, - Professor, Electromagnetics, microstrip antennas and integrated microwave circuits, Metamaterials and applications, Wireless Interconnects, Bbioelectromagnetics.

Bing Yan, Ph.D., University of Connecticut, Assistant Professor, Power system planning and scheduling, robust renewable integration to the grid Operation and design optimization microgrids, and distributed energy systems

Jing Zhang, BS, Huazhong University of Science and Technology (China), Ph.D., Lehigh University,Associate 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 B: Recent Electrical Engineering Research Thesis Titles

DATE	AUTHOR	TITLE	ADVISOR
2020	Justin Kon	Gait Generation for Damaged Hexapods using Genetic Algorithm	Dr. Ferat Sahin
2020	Rohini Gillela	Design of Hardware CNN Accelerator for Audio and Image Classification	Prof. Indovina
2020	Vu Le	All-Pssive Composite Right/Left-Handed (CRLH) Antenna Array For Sum and Difference Patterns	Dr. Venkataraman
2020	Steven Jacobson	Wearable Antennas Backed by Artificial Magnetic Conductor for Enhanced Gain and Reduced Back Radiation	Dr. Venkataraman
2020	Douglas Bean	Gain Enhancement of On-Chop Wireless interconnects at 60 GHz Using an Artificial Magnetic Conductor	Dr. Venkataraman
2020	Rashmi Ballamajalu	Turn and Orientation Sensitive A* for Autonomous Vehicles in Intelligent Material Handling Systems	Dr. Ferat Sahin
2019	Sarthak Arora	Perception Methods for Speed and Separation Monitoring Using Time-Of-Flight Sensor Arrays	Dr. Ferat Sahin
2019	Prasanna Pulakurthi	Shadow Detection in AEtial Images using Machine Learning	Dr. Emmett Ientilucci
2019	Pallavi Mayekar	Design and Verification of a DFI-AXI DDR4 Memory PHY Bridge Suitable for FPGA Based RTL Emulation and Prototyping	Prof. Mark Indovina
2019	Tuly Hazbar	Task Planning and Execution for Human Robot Team Performing a A Shared Tash in a shared Workplace	Dr. Sahin
2019	Krushal Kyada	Structure Preserving regularizer for Neural Style Transfer	Dr. Saber
2019	Sajeed Shahriat	Global Congestion and Fault Aware Wireless Inerconnection Framework for Multicore Systems	Dr. Ganguly
2019	Odysseus Adamides	A Time of Flight on-Robot Proximity Sensing System for Collaborative Robotics	Dr. Sahin
2019	Jonathan McClure	A low-Cost Search-and-Rescue Drone Platform	Dr. Sahin
2018	Benjamin Stewart	Cryogenic Operation of sCMOS Image Sensors	Dr. Patru
2018	Felisa Sze	Simulation and Framework for the Humanoid Robot TigerBot	Dr. Sahin
2018	Abdullah Alzahrani	Convex Optimization Approach to the Optimal Power Flow Problem in DC-Microgrids with Energy Storage	Dr. Cockburn
2018	Mayur Dhanaraj	Inremental and Adaptive l1-NORM Principal Component Analysis: Novel Algorithms and Applications	Dr. Markopoulos
2018	Tucker Graydon	Novel Detection and Analysis Using Deep Variational Autoencoders	Dr. Sahin
2018	Tanmay Shinde	Design, Fault Modeling and Testing of a Fully Integrated Low Noise Amplifier (LNA) in 45 nm CMOS Technology for Inter and Intra-Chip Wireless Interconnects	Dr. Ganguly
2018	Ian Tomeo	Covariance Estimation from Limited Data: State-of-the-Art. Algorithm Implementation and Application to Wireless Communication	Dr. Markopoulos
2018	Kevin Wilson	Modeling and Extraction of Transport Parameters to Simulate Drug Delivery in the Murine Cochlea2018	Dr. Borkholder
2018	Meenakshy Iyer	Compact Antenna with Artificial Magnetic Conductor for Noninvasive Continuous Blood Glucose Monitoring	Dr. Venkataraman
2018	Akram Marseet	Applications of Convolution Neural Network Framework om Generalizes Spatial Modulation for next Generation Wireless Networks	Dr. Sahin
2018	Yansong Liu	Measurement of Blood Flow Velocity in Vivo Video Sequences using Motion Estimation Methods	Dr. Saber
2017	Matthew Haywood	A Novel 3D printed leg design for a Biped Robot	Dr. Sahin
2017	Abhishek Vashist	Using Proportional-Integral-Differential Approach for Dynamic Traffic Prediction in Wireless Network-on-Chip	Dr. Ganguly
2017	Ggassab Dharb	PaSE: Parallel Speedup Estimation Framework for Network-on-Chip Based Multi-Core systems	Dr. Ganguly
2017	Mazin Ali	360 View Camera Based Visual Assistive Technology for Contextual Scene Information	Dr. Sahin
2017	Abhijeet Walke	Design Strategies for Ultralow Power 10nm FinFETs	Dr. Kurinec
2017	Mark Pitonyak	A Novel Hexapod Design with flight Capability	Dr. Sahin
2017	Lucas Prilenski	Bandgap Reference Design at the 14-Nanometer FinFET Node	Dr. Mukund
2017	Rounak Singh Narde	Wireless Interconnects for Intra-chip & Inter-chip Transmission	Dr. Venkataraman
2016	Vajpey, Divya	Energy Dispersion Model Using Tight Binding Theory	Dr. Rommel
2016	Jairo Hemandez Guzman	Cardiac Inter Beat Internal and Atrial Fibrillation Detection using Video Plethysmography	Dr. Tsouri
2016	Mohamed Maafa	Frequency Doubling of RF-Over-Fiber Signal Based on Mach Zehnder Modulator	Dr. Maywar
2016	Xing Lei	Development of Nanosphere Lithography for Semiconductor Device Applications	Dr. Zhang

Appendix C: Recent Microelectronic Research Thesis Titles

DATE	AUTHOR	TITLE	ADVISOR
2019	Veena Nundure	Monolayer Doping for Fabrication of Recessed Channel MOSFETs	Dr. Kurinec
2019	George Mc Murdy	Fabrication of A1:Hf)2 Gate Dielectric MOSFETs	Dr. Kurinec
2019	Rahnuma Chowdhury	Implant Activated Source/Drain Regions for Self-Aligned IGZO TFT	Dr. Hirschman
2019	Shreyas Choudhary	Improvements To A Thermally Actuated MEMs Viscosity Sensor	Dr. Puchades
2019	Harithshanmaa Sethupathi	A Study on Copper-Gate Integration with Titanium Interface Layers for IGZO TFT's	Dr. Hirschman
2019	Gildas Ouin	Etching Processes for GaN Nanowire Fabrication and Single Photon emitter Device Application	Dr. Jing Zhang
2019	Viraj Garg	Engineering Source/Channel/Drain Regions for PMOS TFT'S in Flash Lamp Annealed Polycrystalline Silicon	Dr. Hirschman
2019	Venkatesh Deenaadaylan	Fabrication of Resistive Thermo-Optic Heaters on Silicon Photonic Integrated Circuits	Dr. Preble
2019	Ky-El	Design, Fabrication and Test of a Graphene-Based THz modulator	Dr. Puchades
2019	Udita Kapoor	Atomistic Simulation for Transition Metal Dichalcogenides using NEMO5 and MedeA-VASP	Dr. Rommel
2018	Anish Bharadwaj	On the Reversible Effects of Bias-Stress applied to a-IGZO TFTs	Dr. Hirschman
2018	Chris O Connell	An Ethching Study for Self-Aligned Double Patterning	Dr. Pearson
2018	Andrew Burbine	Bayesian Analysis for Photolithographic Models	Dr. Smith
2018	Patricia Cadareanu	A Quantum Simulation Study of III-V Esaki Diodes and 2D Tunneling Field-Effect Transistors	Dr. Rommel
2017	Eli Powell	The Influence of Alternative Electrode Configurations And Process Integration Scemes on IGZO TFT operations	Dr. Hirschman
2017	Sanjna Lakshminarayanamurthy	Fabrication of Silocon Photonic Devices Using I-Line Lithography	Dr. Preble
2017	John Hughes	Sensitivity Enhancement of Metal_Oxide Chemical Sensors for Detection of Volatile Organic Compounds	Dr. Fuller
2017	Astha Tapriya	Ultra-Shallow Phosphorous Diffusion in Silicon using Molecular Monolayer Doping	Dr. Kurinec
2017	Jackson Anderson	Measurement of Ferroelectric Films in MFM and MFIS Structures	Dr. Kurinec
2017	Alexander Marshall	Nickel Silicide as a Contact and Diffusion Barrier for Copper Metallization in Silicon Photovoltaics	Dr. Kurinec
2016	Ankur Lamoria	Shallow Etch Recipe Design using DOE for Silicon Waveguides	Dr. Preble
2016	Kavya Duggimpudi	Characterization of Grid contacts for n-Si Emitter Solar Cells	Dr. Jackson
2015	Joshua Locke	CMOS Compatible 3-Axix Magnetic Field Sensor using Hall Effect Sensing	Dr. Fuller
2015	Karine Florent	Ferroelectric Hf02 for Emerging Ferroelctric Semiconductor Devices	Dr. Kurinec
2015	Anusha Aithal	Wireless Sensor Platform for Pulse Oximetry	Dr. Fuller
2015	Matthew Filmer	InAs/GaSb Tunnel Diodes	Dr. Rommel
2015	Abhinav Gaur	Surface Treatments to Reduce Leakage Current in Homojunction in 0:53Gao:47 asPin Diodes for TFET Applications	Dr. Rommel
2015	Joshua Melnick	Aluminum Nitride Contour Mode Resonators	Dr. Puchades
2014	Anthony Schepis	Alternative Lithographic Methods for Variable Aspect Ration Vias	Dr. Smith
2014	David Cabrera	Material Engineering for Phase Change Memory	Dr. Kurinec
2014	Idris Smaili	Design and Simulation of Short Channel Ferroelectric Field Effect Transistor	Dr. Kurince

Appendix D: Electrical Engineering (MSEE) 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 or equivalent background or Graduate Standing) 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 or equivalent background or Graduate Standing) Class 3, Lab 3, Credit 3 (F)

EEEE-622 Electric Power Transmission & Distribution
This course deals with the topics related to electric power transmission and distribution. Topics covered in this course include: Three Phase System-Wye and Delta connections, Transformers equivalent circuits-performance characteristics, Balanced and Unbalanced -624nalysis, Transmissions and Distribution Line Design considerations, Transmission Line Protection, Transmission Line Faults and Faulty Analysis. (EEEE-321) Class 3, Lab 0, Credit 3 (S)

EEEE-624 Advances in Power Systems
This course will introduce the details of electric power markets and the techniques to better use the available resources. Topics include the description of steam generation and renewable energy sources. Formulation of the cost associated with the generation and the optimization methods to minimize this cost in the economic dispatch problem. Unit commitment. Optimal power flow formulation and its solution methods. Introduction to smart grid technologies and challenges. (EEEE-622) Class 3, Lab 0, Credit 3

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-630 Biomedical Instrumentation
Study of fundamental principles of electronic instrumentation and design consideration associated with biomedical measurements and monitoring. Topics to be covered include biomedical signals and transducer principles, instrumentation system fundamentals and electrical safety considerations, amplifier circuits and design for analog signal processing and conditioning of physiological voltages and currents as well as basic data conversion and processing technology. Laboratory experiments involving instrumentation circuit design and test will be conducted. Class 3, Lab 3, Credit 3

EEEE-631 Biomed Sensors & Transducers I
Biological entities represent one of the most difficult environments in which to obtain or generate accurate and reliable signals. This course will discuss the techniques, mechanisms and methods necessary to transfer accurate and reliable information or signals with a biological target. Various biomedical sensor and transducer types including their characteristics, advantages, disadvantages and signal conditioning will be covered. Discussions will include the challenges associated with providing a reliable and reproducible interface to a biological entity, the nature and characteristics of the associated signals, the types of applicable sensors and transducers and the circuitry necessary to drive them. Class 3, Lab3, Credit 3

EEEE-632 Fundamental Electrophysiology
Investigation and study of the concepts and underlying mechanisms associated with electrical signals in mammalian biology and physiology with a significant emphasis on methods, techniques and understanding of electrical potential distribution and current flow derived from circuit analysis. Intended to provide engineers with insight into the relationship between the study of electricity and its applicability to a wide variety of physiological mechanisms ranging from intracellular communication and control to cognitive function and bodily movement. Successful completion of the course will require generation of a significantly in-depth analysis report on some electrophysiological phenomenon or mechanism. Class 3, Lab 3, Credit 3

EEEE-633 Biomedical Signal Processing
Discussion and study of the methods and techniques that may be optimally employed for the fixed and adaptive processing of information with biological and physiological origin. The challenges and unique features of these types of signals will be discussed and application of known signal processing techniques that accommodate linear, non-linear and stochastic signals for the purpose of analysis, detection and estimation, monitoring and control will be studied. Successful participation in the course will entail completion of a project involving incorporation of these techniques in a biomedical application. (Permission of instructor or graduate standing) Class 3, Lab 0, Credit 3

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-646 Power Electronics
The course involves the study of the circuits and devices used in the control and conversion of power. Devices include diodes, BJTs, power MOSFETS, IGBTs and thyristors. Power conversion includes rectifiers (ac-dc), dc-dc, ac-ac and inverters (dc-ac). DC circuit topologies include Buck Converter, Boost Converter, Buck-Boost Converter, and the Cuk converter.

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-663 Real-Time & Embedded Systems
This first course in a graduate elective sequence will begin by presenting a general road map of real-time and embedded systems. The course will be conducted in a studio class/lab format with lecture material interspersed with laboratory work. This course will introduce a representative family of microcontrollers that will exemplify unique positive features as well as limitations of microcontrollers in embedded and real-time systems. These microcontrollers will then be used as external, independent performance monitors of more complex real-time systems. The majority of the course will present material on a commercial real-time operating system and using it for programming projects on development systems and embedded target

systems. Some fundamental material on real-time operating systems and multiprocessor considerations for real-time systems will also be presented. Examples include scheduling algorithms, priority inversion, and hardware-software co-design. (Graduate Standing) Class 3, Lab 0, Credit 3 (F)

EEEE-664 Performance Engineering of Real Time and Embedded Systems
This course discusses issues of performance in real-time and embedded systems. Techniques for profiling the resource usage of a system and for measuring the effect of increasing system requirements will be covered. The control of physical systems will motivate the need for performance tuning of a real-time system. Students will write programs running under a real-time operating system that can maintain control of a physical system. The course will discuss and experiment with performance trade-offs that can be made using hardware-software co-design. (EEEE-663 or equivalent) Class 3, Lab 0, Credit 3 (F, S)

EEEE-665 Modeling of Real Time Systems
This course introduces the modeling of real-time software systems. It takes an engineering approach to the design of these systems by analyzing system models before beginning implementation. UML will be the primary modeling methodology. Non-UML methodologies will also be discussed. Implementations of real-time systems will be developed manually from the models and using automated tools to generate the code. (EEEE-663 or equivalent) Class 3, Lab 0, Credit 3 (F, S)

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-602, EEEE-707, EEEE-709) Class 3, Lab 0, Credit 3 (S)

EEEE-678 Digital Signal Processing
In this course, the student is introduced to the concept of multi rate signal processing, Poly phase Decomposition, Transform Analysis, Filter Design with emphasis on Linear Phase Response, and Discrete Fourier Transforms. Topics covered are: Z- Transforms, Sampling, Transform Analysis of Linear Time Invariant Systems, Filter Design Techniques, Discrete Fourier Transforms (DFT), Fast Algorithms for implementing the DFT including Radix 2, Radix 4 and Mixed Radix Algorithms, Quantization Effects in Discrete Systems and Fourier Analysis of Signals. (Prerequisites: EEEE-602, EEEE-707 and EEEE-709)
Class 3, Lab 0, Credit 3 (F, S)

EEEE-679 Analog Filter Design
A study of the various techniques for the design of filters to meet the given specifications. The emphasis is on the design of active filters using op amps. The following topics are discussed in detail: Review of transfer functions, Bode diagrams and the analysis of op amp circuits; ideal filter characteristics, approximations to the ideal filter using Butterworth, Chebyshev and Bessel-Thompson polynomials; standard filter stages; magnitude and frequency scaling; low-pass filter design; design of high-pass, band-pass and band-reject filters; passive ladder filter network design; frequency dependent negative resistance networks; switched capacitor filters.

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 (S)

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-694 Sensor Array Processing for Wireless Communications
This course offers a broad overview of sensor-array processing, with a focus on wireless communications. It aims at providing g the students with essential and advanced theoretical and technical knowledge that finds direct application in modern wireless communication systems that employ multi-sensor arrays and/or apply user-multiplexing in the code domain (CDMA). Theory and practices covered in this course can be extended in fields such as radar, sonar, hyperspectral image processing, and biomedical signal processing. Topics covered: uniform linear antenna arrays (inter-element spacing and Nyquist sampling in space); linear beamforming, array beam patterns, array gain, and spatial diversity; interference suppression in the absence of noise (null-steering beamforming); optimal beamforming in AWGN (matched filter); optimal beamforming in the presence of colored interference; estimation of filters from finite measurements and adaptive beamforming (SMI and variants, RLS, LMS and variants, CMA, and AV); BPSK demodulation with antenna arrays (multiple users and AWGN); BPSK demodulation in CDMA (multiple users and AWGN); ML and subspace methods (MUSIC, root MUSIC, Minimum-norm, Linear Predictor, Pisarenko) for Direction-of-arrival estimation; BPSK demodulation with antenna arrays in CDMA systems (space-time processing).(S) Class 3 Credit 3

EEEE-695 Optimization Methods for Engineers
This course is designed to help the interested engineering students to develop working knowledge of optimization and, specifically, to develop the skills and background needed to recognize, formulate, and

solve convex optimization problems. Convex optimization problems emerge naturally in the design and analysis of systems across the entire engineering spectrum. First, the course will briefly review basic concepts of linear algebra and calculus. Second, students will be introduced to optimization (problem formulation, feasibility sets, etc.) and principles of convexity, including convex functions, convex sets, convex problems and properties thereof. Then, an array of algorithmic numerical methods will be studied for the solution of convex problems, covering, among other topics, gradient methods, coordinate descent, Lagrangian duality, saddle points, optimality conditions etc. Last, the course will focus on how to formulate and solve convex problems in engineering, including convex approximation of non-convex problems and regularization. Many practical application examples will be studied from diverse areas of engineering. Through a series of assignments and in-class examples, students will learn how to practically solve optimization problems in MATLAB, using state-of-the-art toolboxes. Class 3, Credit 3

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, Credit 3 (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. Class 3, Credit 3 (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. (EEEE621) 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 (F)

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. (EEEE620) Class 3, Credit 3 (S)

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. (EEEE-621) Class 3, Lab 0, Credit 3 (S)

EEEE-722 Complex Digital Systems Verification
Due to continually rising system complexity, verification has become the critical infection point for complex digital system success or failure. In this course students will study various concepts and technologies related to complex digital system verification, top down design flows and advanced methodologies. The class projects reinforce thelectures material by offering hands-on development of a verification environment for a complex digital systems. (Graduate Standing) Class 3, Lab 0, Credit 3 (F)

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-731 Integrated Optical Devices & Systems
This course discusses basic goals, principles and techniques of integrated optical devices and systems, and explains how the various optoelectronic devices of an integrated optical system operate and how they are integrated into a system. Emphasis in this course will be on planar passive optical devices. Topics include optical waveguides, optical couplers, micro-optical resonators, surface plasmons, photonic crystals, modulators, design tools and fabrication techniques, and the applications of optical integrated circuits. Some of the current state-of-the-art devices and systems will be investigated by reference to journal articles. (Graduate Standing) 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 (S)

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-602, EEEE-707, EEEE-709) Class 3, Credit 3 (F, S)

EEEE-771 Optoelectronics
To provide an introduction to the operating principles of optoelectronic devices used in various current and future information processing and transmission systems. Emphasis in this course will be on the active optoelectronic devices used in optical fiber communication systems. Topics include optical resonators, quantum states of light, semiconductor optics, fundamental of lasers, light-emitting diodes, laser diodes, semiconductor photon detectors, optical modulators, quantum wells, and optical fiber communication systems. (Graduate Standing) Class 3, Lab 0, Credits 3 (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 (F)

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 (S)

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. (EEEE-685) Class 3, Credit 3 (S)

EEEE-785 Comprehensive Exam
This class is restricted to degree-seeking graduate students or those with permission from instructor.

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. (Department approval required) Class 0, Credit 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, Credit 3 (S)

EEEE-798 Software Defined Radio Communication
Learn the principles and practices of how to engineer and implement software digital radio signal processing systems. Technology advances have brought us into the age of completely programmable full radio systems on a chip. ADC/DAC and high speed low power digital circuitry advances allow engineers

to utilize digital signal processing techniques at RF and IF frequencies. By end of course students will understand how to statistically simulate receive and transmit fundamental digital radio modulations utilizing Matlab. As long as it is available by the time of the course and students/RIT can obtain equipment, exercises will be planned to implement some algorithms on a low cost educational digital radio kit (Analog Devices Educational Pluto Radio). Topics covered: OFDM, QAM, I/Q demod/mod, IF frequencies, encryption, channel interleavers, OSI Networking Layers 1 and 2. How to use iterative and non-iterative forward error correction (FEC) schemes. Efficient and proper utilization of RF spectrum, synchronization, radio channel equalization, understanding practical receive and transmit limitations, multipath channel models and an introduction to fixed point signal processing. The course will require much outside of class programming. (EEEE-602, EEEE-693) Class 3, 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 E: 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 Semiconductor Process Integration
This is an advanced level course in Integrated Circuit Devices and process technology. A detailed study of processing modules in modern semiconductor fabrication sequences will be done through simulation. Device engineering challenges such as shallow-junction formation, fin FETs, ultra-thin gate dielectrics, and replacement metal gates are covered. Particular emphasis will be placed on non-equilibrium effects. Silvaco Athena and Atlas will be used extensively for simulation. Class 3, Lab 2, Credit 3 (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-620 Photovoltaic Science and Engineering
This course focuses on the principle and engineering fundamentals of photovoltaic (PV) energy conversion. The course covers modern silicon PV devices, including the basic physics, ideal and non-ideal models,

device parameters and design, and device fabrication. The course discusses crystalline, multi-crystalline, amorphous thin films solar cells and their manufacturing. Students will become familiar with how basic semiconductor processes and how they are employed in solar cells manufacturing. The course further introduces 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. Evaluations include assignments and exams, a research/term paper on a current PV topic. (Permission of Instructor) Class 3, Lab 3, Credit 3 (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 Compound Semiconductor Devices

This course introduces students to the fundamentals of III-V, 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, high-electron mobility transistors (HEMTs) and tunnel FETS. 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-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 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-601) Class 3, Lab 3, Credit 3 (S)

MCEE-770 MEMs Fabrication

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. (MCEE601, EEEE587/EEEE787) 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 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 F:

Sample MSEE Thesis Title Page:

<u>Title of My Thesis</u>

by

John Doe

Thesis

Submitted in Partial Fulfillment of the Requirements for the Degree of

MASTER OF SCIENCE IN ELECTRICAL ENGINEERING

Department of Electrical and Microelectronic Engineering

Kate Gleason College of Engineering

Rochester Institute of Technology, Rochester, NY

Supervised by:

Dr. Jane Smith

May 8, 2021

Sample MSEE Thesis Signature Page

Title of My Thesis

Approved by:

____

Name (Print) Date

Thesis Primary Advisor: Rank, Department, College

____

Name (Print) Date

Committee Member: Rank, Department, College

____

Name (Print) Date

Committee Member: Rank, Department, College

____

Name(Print) Date

Department Head: Rank, Department, College

Appendix G:

Sample MSEE Graduate Paper Title Page

Title of My Graduate Paper

by

Jane Doe

Graduate Paper

Submitted in Partial Fulfillment of the Requirements for the Degree of

MASTER OF SCIENCE IN ELECTRICAL ENGINEERING

Department of Electrical and Microelectronic Engineering

Kate Gleason College of Engineering

Rochester Institute of Technology, Rochester, NY

Approved by:

____

_ Name (Print) Date
Advisor: Rank, Department, College

____

Name (Print) Date
Department Head: Rank, Department, College

May 8, 2021

Appendix F:

Sample MS MicroE Thesis Title Page

Title of My Thesis

by

John Brown

Thesis

Submitted in Partial Fulfillment of the Requirements for the Degree of

MASTER OF SCIENCE IN MICROELECTRONIC ENGINEERING

Department of Electrical and Microelectronic Engineering

Kate Gleason College of Engineering

Rochester Institute of Technology, Rochester, NY

Supervised by:

Dr. Jane Jones

May 8, 2021

Sample MS MicroE Thesis Signature Page

Title of My Thesis

Approved by:

____

Name (Print) Date

Thesis Primary Advisor: Rank, Department, College

____

Name (Print) Date

Committee Member: Rank, Department, College

____

Name (Print) Date

Committee Member: Rank, Department, College

____

Name (Print) Date

Department Head: Rank, Department, College

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

TABLE OF CONTENTS

LIST OF TABLES …………………………………………………………………v

LIST OF FIGURES………………………………………………………………vii

LIST OF SYMBOLS……………………………………………………………..viii

I. INTRODUCTION…………………………………………………………………..1

II. REVIEW OF LITERATURE ………………………………………………………8

A. Control Theory ……………………………………………………………….10

B. Control Devices ………………………………………………………………14

III. DESCRIPTION OF SYSTEM…………………………………………………..17

A. Control Apparatus…………………………………………………………...21

B. Process………………………………………………………………………....25

IV. EXPERIMENTAL PROCEDURE ……………………………………………...38

A. Calibration of Controller………………………………………………………42

1. Static calibration……………………………………………………...44

2. Dynamic operation…………………………………………………...48

B. System Operation ………………………………………………………..…52

1. Step input ……………………………………………………………....55

2. Sinusoidal input ……………………………………………...........61

C. Calculation Procedure …………………………………………….……...67

1. Frequency response ……………………………………..……...72

2. Optimization of system …………………………………..……….75

V. RESULTS

A. System Parameters …………………………………….………..…..80

B. Optimization Schedule …………………………………………….......86

VI. DISCUSSION…………………………………………………………..…….90

VII CONCLUSIONS…………………………………..………………….…...….96