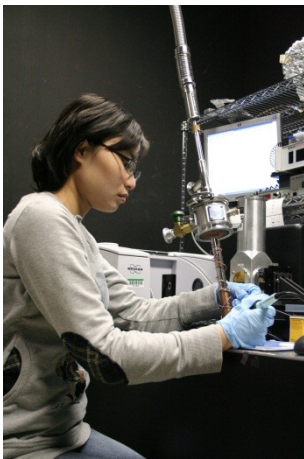




DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

DOCTORAL STUDENT HANDBOOK



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I. INTRODUCTION

The Department of Electrical and Computer Engineering (ECE) at the University of Massachusetts Lowell offers graduate programs leading to the Master of Science (M.S.), and the Doctor of Philosophy (Ph.D.) degrees. There are several active research areas in the ECE Department, including Communications, Computer Architecture, Control Systems, Digital Signal Processing, Distributed Networking, Embedded Systems, Metamaterials, Optoelectronic Devices, Power Distribution, Alternative Energy Sources, Nanotechnology. Specific information concerning each faculty member can be viewed on the individual faculty home pages as well as on Section V of this handbook. A list of the Research Groups within ECE Department can be found in Appendix B of this handbook. Details of the various research groups within the department can be viewed on the research homepage.

UMass Lowell is a comprehensive University with a national reputation in science, engineering and technology, and committed to educating students for lifelong success in a diverse world and conducting research and outreach activities that sustain the economic, environmental and social health of the region. UMass Lowell offers more than 120 degree choices, internships, bachelor's to master's programs and doctoral studies in the colleges of Fine Arts, Humanities and Social Sciences, Sciences, Engineering and Management, the School of Health and Environment, and the Graduate School of Education.

Financial Assistance

Financial assistance is an important issue during graduate school. Currently, both Full Research and Teaching Assistant-ships provide tuition waiver and a stipend. However, admission to the graduate program in ECE Department does not guarantee financial assistance. Admitted students without firm offers of financial support must be prepared to cover the full cost of tuition, supplies, room and board, etc., from personal sources.

- **Teaching Assistantships:** A limited number of teaching assistantships are available for matriculated, full-time (minimum of 9 credits/semester) graduate students. Assistantships are assigned by the student's department and are subject to the agreement between UMass Lowell and UAW/Graduate Employees Organization. Duties typically include teaching of undergraduate laboratories, grading, or other tasks related to undergraduate instruction. No teaching duties are required during the Summer session but the student is expected to progress significantly on his or her research during the summer. All interested in TA support, should complete the TA Application form. The form should be sent directly to the ECE Doctoral Coordinator by February 15 for students beginning of the Fall semester.
- **Research Assistantships:** Research assistantships (RA) are administered by individual faculty members, and thus selection for these requires a close match between the needs of the faculty member and the applicant's qualifications. In exceptional cases, RAs may be awarded to incoming students who have outstanding credentials. You are encouraged to contact faculty members via email to explore opportunities for RA funding. Details of each faculty members research can be viewed on the individual faculty home pages: <http://www.uml.edu/Engineering/Electrical-Computer/faculty/default.aspx>.

II. Ph.D. and D.Eng. PROGRAMS OVERVIEW

Objectives

The primary goal of the PhD in Electrical and Computer Engineering is to provide a research-intensive program with the rigorous course work to strengthen the student's knowledge in the fundamentals of Electrical and Computer Engineering.

1. Admission Requirements

Applicants must have a BS or MS degree in Electrical Engineering or Computer Engineering or their equivalent from a recognized college or university with an acceptable quality of prior academic work. Applicants must submit official transcripts of all prior undergraduate and graduate courses. Each applicant must submit an official report of Graduate Record Examination (GRE) General Test scores. The TOEFL exam is required for students from abroad whose native language is not English.

2. Plan of Study

Each student entering the program must develop a plan of study in consultation with his/her advisor.

3. Program Duration

The time for graduation for full-time students is expected to range from a minimum of three and a half years to a maximum of five years after BS and a minimum of two and a half years to a maximum of four years after MS.

4. Transfer Credit

Up to 24 semester credits in graduate courses in Electrical/Computer Engineering and allied subjects are transferable to the doctoral program upon approval by the Doctoral Committee of the Department of Electrical and Computer Engineering.

5. Candidacy Requirements

1. Qualifying Examination: The qualifying examination is a written exam which is conducted twice in the academic year: once in the beginning of the Fall Semester and once in the beginning of the Spring Semester. Students accepted to the Doctoral Programs must take the qualifying examination *within 1 year of their start in the Doctoral Program*. Detailed information on the Qualifying Exam is provided in Section 3.

2. Thesis Proposal and Oral Exam in Area of Concentration: Having passed the qualifying examination, a student may submit his/her dissertation proposal and defend the proposal before the Doctoral Committee. The proposal examination will also include an oral examination on topics connected with the student's area of research. On passing this examination, the student's name will be submitted to the College Doctoral Committee and the Registrar's Office for acceptance as a candidate for the Doctor of Philosophy or Doctor of Engineering Degree. Admission to candidacy status does not guarantee the obtaining of the degree.

6. Academic Requirements

A. Credit Requirement

- The Ph.D. degree must involve a traditional research-based dissertation, plus a total of 63 credit hours of graduate level courses are required for both the Ph.D. degree.
 - A minimum of 30 approved credit hours of graduate-level electrical and computer engineering courses.
 - A minimum of 21 credit hours of doctoral dissertation.
 - The balance of the remaining 12 credits can be a mix of graduate-level engineering including associated science and math course and dissertation credits at the discretion of the department, faculty advisor and dissertation committee.

A typical program consists of the following:

ECE and Allied Subjects: 30 credits

Thesis: 21 credits

ECE and Allied Subjects OR Thesis credits: 12

Total credit hours: 63

The student must have a minimum grade point average of 3.25 to graduate.

B. Core Requirement

The core courses are beginning graduate courses. They emphasize the fundamentals, concepts, and analytical techniques relevant to Electrical/Computer Engineering. They also help the student prepare for the qualifying examination. The student should consult with his/her Thesis Advisor on the appropriate course plan.

- i. **Required Core Courses for Ph.D. degree in Electrical Engineering.** Students in Electrical Engineering must take three of following courses:

16.507 Electromagnetic Materials and Waves

16.508 Quantum Electronics for Engineers

16.509 Linear Systems Analysis

16.513 Control Systems

16.515 Power Electronics

16.520 Computer-Aided Engineering Analysis

16.543 Communications Theory

16.584 Probability and Random Processes

16.595 Solid State Electronics

ii. Required Core Courses for Ph.D. degree in Computer Engineering. Students in Computer Engineering must take three of the following core courses:

- 16.553 Software Engineering
- 16.561 Computer Architecture and Design
- 16.562 VHDL/Verilog Synthesis and Design
- 16.573 Operating Systems and Kernel Design
- 16.574 Advanced Logic Design

7. Grade-Point Average (GPA) Requirement

To successfully complete the program, a student must achieve a cumulative grade-point average (CGPA) of at least 3.25 in all course work.

III. Information on Qualifying Examination

1. Qualifying Examination Policies

The examination is a written one of the closed book variety, and will be of four hours duration.

The problems are not restricted to material from specific courses but are chosen to test the student's understanding of fundamental concepts in EE/CP and allied subjects. Some problems will be constructed to test the ability of the student to simultaneously apply the concepts learnt in separate courses. Some choice of questions will be given.

The examination will be held twice a year, in the beginning of each semester. The exact dates will be announced on the website and in the ECE office.

A doctoral student must take this examination no later than the first year of study at UML as an EE/CP doctoral student. So, if a student is accepted into the Doctoral Program in the Fall, the student must take the exam in the following Spring semester. If a student is accepted into the Doctoral Program in the Spring, the student must take the exam in the following Fall semester. The doctoral committee reserves the right to drop from the program those students who do not comply with the requirements of this clause.

A doctoral student who fails at the first attempt will be allowed one more opportunity to retake this examination and this must be done the next time it is held. So, if the student fails the exam in the Fall, he/she must retake the exam in the Spring OR if the student fails the exam in the Spring, then he/she must retake the exam in the Fall.

2. Taking the qualifying examination before admission.

Students who are interested in entering the doctoral program and meet one or more of the following requirements may submit a petition for taking Doctoral Qualifying Examination before applying for admission to the doctoral program.

(1) Enrollment in one of the ECE Master programs with a minimum of 700 (Quantitative) and 400 (verbal) in GRE.

(2) BS or MS in EE/CP and a GPA of 3.5 or better.

(3) Enrollment in one of the ECE Master program with the Thesis option and recommendation from the Thesis Advisor.

An applicant for the doctoral program must still satisfy all the admission requirements. The performance in this examination may be used as one of the inputs in processing the applications for admission. Students who pass the examination, admitted and start the program within 2 years are not required to take the examination again.

3. Registration Procedures

Any student accepted into the doctoral program, must take the qualifying examination within a year of study as a doctoral student.

Any person who is interested in entering the doctoral program may submit a petition for taking the qualifying exam before applying for admission. To do this, it is necessary that one or more of the requirements prescribed in the previous section "Taking Qualifying Examination before admission" are satisfied.

It is not necessary that an application for admission to the doctoral program be made at the same time. The petition should specify those clauses given in the "Taking Qualifying Examination before Admission" section applicable to the petitioner.

The form for the registration can also be found on : <http://www.uml.edu/engineering/electrical-computer/Documents/Registr%20form%20DocQualifying%20Exam.pdf>

4. Qualifying Examination CP Option

The NEW format of the Qualifier Exam for the CP option is comprised of 5 main groups. The student MUST answer one question out of each group.

CP QUALIFIER EXAM (Must Answer 1 out of each group)

	<u>UML Courses</u>
<u>Group 1: Circuits and Devices</u>	
i. Circuit Theory	16.201/16.202
ii. Electronic Devices	16.365
iii. Electronic Circuits	16.366
iv. Signals and Systems	16.362
 <u>Group 2: Computer Hardware</u>	
i. Logic Design	16.265
ii. Digital System Design	16.450
 <u>Group 3: Computer Software</u>	
i. Data Structures and Algorithms	16.322
ii. Application Programming	16.216
 <u>Group 4: Computer Systems</u>	
i. Network Design	16.483
ii. Operating Systems	16.481
iii. Computer Architecture	16.482
iv. Assembly Language and Microprocessors	16.317
v. Microprocessors 2 and Embedded Systems	16.480
 <u>Group 5: Mathematics:</u>	
i. Vector Calculus and Differential Equations	92.231 & 92.236
ii. Complex Variables	16.364
iii. Discrete Mathematics and Structures	92.360
iv. Probability and Random Processes	16.363

5. Qualifying Examination EE Option

The NEW format of the Qualifier Exam for the EE option is comprised of 5 main groups. The student MUST answer one question out of each group.

EE QUALIFIER EXAM (Must Answer 1 out of each group)

UML Courses

Group 1: Circuits and Devices

- | | | |
|------|----------------------------------|---------------|
| i. | Circuit Theory | 16.201/16.202 |
| ii. | Electronic Devices and Materials | 16.365&16.333 |
| iii. | Electronic Circuits | 16.366 |

Group 2: Systems Analysis

- | | | |
|------|----------------------------------|--------|
| i. | Signals and Systems | 16.362 |
| ii. | Probability and Random Processes | 16.363 |
| iii. | Linear Feedback Systems | 16.413 |

Group 3: Computer Logic and Programming

- | | | |
|------|---------------------------------------|--------|
| i. | Logic Design | 16.265 |
| ii. | Application Programming | 16.216 |
| iii. | Assembly Language and Microprocessors | 16.317 |

Group 4: Electromagnetics & Power

- | | | |
|------|------------------------|--------|
| i. | Electromagnetic Fields | 16.360 |
| ii. | Electromagnetic Waves | 16.461 |
| iii. | Electromechanics | 16.355 |

Group 5: Mathematics:

- | | | |
|-----|--|-----------------|
| i. | Vector Calculus and Differential Equations | 92.231 & 92.236 |
| ii. | Complex Variables | 16.364 |

IV. POLICIES GOVERNING DISSERTATION REQUIREMENTS

1. **Dissertation Topic and Dissertation Advisor/s**

A full-time student must establish a Graduate Advisory Committee before the completion of the second semester following admission. Students who are employed full-time, and enrolled on a part-time basis, may add two semesters to the time required to form a committee. A written statement from the employer may be required. The formation of a Graduate Advisory Committee is a critical step in the progression toward completion of the degree. No progress toward a degree can be assured until after the committee has been formed. Students should begin to explore faculty for membership on their committee early in their program. Students are advised that faculty serve on advisory committees at the individual faculty member's discretion. Students failing to establish a committee within the prescribed time limits may not be permitted to register for classes, may be asked to withdraw from the program, or may have their admission revoked.

Informal discussion between a student and a professor is a good route for arriving at the Dissertation topic and Dissertation advisor/s. The process is formalized when the student files an application (form included in the Appendix) for the appointment of his (her) Dissertation advisor. The form will have a column to indicate the consent of the professor to be the Dissertation advisor of the student. The Dissertation advisor must be a member of the Faculty from the ECE Department. The Dissertation advisor bears the major responsibility in supervising the student regarding the Dissertation requirement.

A student from industry will have an advisor from the full-time faculty of the department and may request for a co-advisor from industry when s/he expects to do a significant part of her/his Dissertation research in industry. The resume of the co-advisor will be attached to the form.

2. **Advisory Committee**

The Dissertation advisor shall initiate a recommendation for the appointment of the Advisory Committee, consisting of a minimum of three members of the faculty. At least two of the members of the Advisory Committee must be from the Department of Electrical & Computer–Engineering. The Doctoral Committee then shall appoint the Advisory Committee.

The Doctoral Committee may appoint additional members to the Advisory Committee, at the request of the advisor, for the purpose of performing one or more of the duties of the Advisory Committee. The additional members may be from the adjunct faculty and/or from the faculties of other universities and/or from Industry.

The Advisory Committee will conduct (a) 'Defense of Dissertation Proposal' examination and, (b) 'Defense of Dissertation' examination.

3. **Registration for Dissertation Credits**

Registration for Dissertation credits is permitted only after the Dissertation advisor has been appointed.

A student cannot register for more than a total of 9 credits of Dissertation before s/he passes the qualifying examination.

A student cannot register for more than a total of 15 credits of Dissertation before s/he passes the oral examination or defense of the Dissertation proposal.

4. Dissertation Proposal and Oral Exam

"Dissertation Proposal and Oral Examination" shall be an oral examination, conducted by the Student's Advisory Committee." The purpose of the examination is to determine (i) whether the proposed dissertation topic is acceptable, (ii) whether the student is sufficiently prepared to undertake the required research.

The student shall submit a written document of the proposal that gives a tentative (i) title of the Dissertation (ii) literature survey (iii) a short account of the proposed or ongoing research work by the student on the Dissertation topic.

The members of the Committee will receive a copy of the Dissertation proposal at least one week before the examination date.

At the conclusion of the examination, the Committee will decide first whether the proposed Dissertation topic is acceptable. If it is not, then the committee will decide, in conference with the student and his advisor, as to what actions are necessary to make the proposed research topic and its approach acceptable. When the proposed Dissertation topic is considered acceptable, then the Committee will decide whether the student is sufficiently prepared to undertake the required research. Three decisions are possible.

(a) The student is fully qualified to undertake the proposed research topic.

(b) The student is considered only conditionally qualified and the Committee will recommend specific activities to remedy any deficiencies. These recommendations will be supervised by the student's Dissertation advisor and s/he will decide when the student can then proceed to undertake the proposed research topic.

(c) The student is deemed to be unprepared for the proposed research and, in addition to accomplishing the specific recommendations of the Committee, must reappear again before the Committee and undergo an additional review to determine his/her degree of preparedness. The time for this additional review will be determined by both the student and his/her Advisory Committee and will occur within one year of the first review.

5. Defense of Dissertation

"Defense of Dissertation" examination is the final oral examination, conducted by the Advisory Committee. The membership of the committee may be augmented by non-voting faculty.

The candidate has to submit a written Dissertation based on the research conducted (of publishable standard) during the registration of 21 Dissertation credits.

After receiving the approval of the advisor and the Advisory Committee, the final oral examination shall be conducted.

In order to pass, the candidate may not receive more than one dissenting vote from the membership of the examination committee.

V. New Graduate Seminar course

Course Number: 16.601 (Fall) and 16.602 (Spring)

Title: Graduate Seminar

Credit: 0.0

Grading: S/U

For whom:

- Doctoral students (PhD. And D.Eng.) must take Graduate Seminar for a total of TWO semesters during their doctoral studies. This course is mandatory for doctoral students.
- MS students with thesis-option must enroll in the seminar for ONE semester only.
 - MS students with thesis-option must take it the first time they register for 16.743/16.746
- Recommended for all MS students with non-thesis option.
 - MS students plan/expect to select the thesis-option are recommended to take it as early as possible

Description: There will be a series of seminars by distinguished researchers from academia and industry, in addition to UML faculty. Moreover, there will be seminars dedicated to instructional sessions in library services, introduction to Department and Faculty research, and information on thesis requirements and professional ethics. Attendance is mandatory for doctoral and MS students with thesis option. The students are required to write short reports after each seminar.

Frequency of offering: Fall and Spring semesters.

Suggested semester to start offering Graduate Seminar: Spring 2013

Suggested semester to start implementing requirement:

- This requirement will be applied to PhD and DEng students who have been admitted Fall 2012 or later.
- This requirement will be applied to MS with thesis students who have been admitted Fall 2013 or later.

VI. Faculty Research Interests and Areas of Expertise

Akyurtlu, Alkim: Theoretical and computational electromagnetics with applications to electromagnetic wave interactions with complex materials, antenna theory and design, and microwaves. Design, modeling, characterization, and applications of novel metamaterials in microwave to visible regimes. Printed electronics for RF applications, novel material (inks and substrates) development for printed electronics.

Armiento, Craig: Fiber optic communication systems; photonic device design, Dense Wavelength Division Multiplexing (DWDM) technologies, optical network design, semiconductor device physics, process development for III-V semiconductors, optical subsystem development using hybrid integration, access network architectures.

Chandra, Kavitha: Analysis, characterization and modeling of voice, video and data traffic for Internet and asynchronous transfer mode networks; development of traffic descriptors for network performance analysis, admission control, policing and resource allocation; design of rate adaptive feedback control schemes for video encoders; ultrasonic imaging and computational models for acoustic scattering; echo cancellation in room acoustics.

Cheney, George: Digital and analog design, automated test systems, software engineering.

Chigan, Chunxiao (Tricia): Vehicular Ad Hoc Networking (VANET); Wireless ad hoc networks and sensor networks; Cognitive radio networking and its security; Wireless network security; Dependable computing and communication systems; Network resource allocation and management.

Dutta, Joyita: Biomedical image reconstruction and analysis

Hu, Tingshu: Nonlinear systems theory; Control systems with saturation; Optimal control and optimization techniques; Robust control; Control applications to mechanical systems and biomechanical systems.

Ibe, Oliver: Mobile and fixed wireless communications, voice over IP networks, communications systems performance analysis, stochastic systems modeling, and statistical signal processing.

Lu, Xuejun: Silicon based nanophotonics, uncooled QDIP sensors, Nonlinear thresholding optical gates, guided wave optical interconnects, Ultra high-speed transceiver interface, Optical CDMA transceivers.

Luo, Yan: Network processors, low power processors, internet router and web server architecture, parallel and distributed system, simulation and performance evaluation, embedded systems, computer architecture.

Mah'd, Mufeed: Digital signal and medical image processing; nuclear medicine; Positron Emission Tomography (PET), Single Positron Emission Tomography (SPECT); Computerized Tomography (CT); Magnetic Resonance Imaging (MRI). Image reconstruction and restoration; image registration and fusion; real time signal/image code development and hardware implantation. Reliability analysis; fault tolerant control systems; system modeling; estimation and identification; computational methods and numerical analysis.

Margala, Martin: Low-Power Memories, Adaptable Circuits and Architectures, SIMD and MIMD Processing, Analog-to-Converter Design, Design for Reliability, Multi-Gigahertz Testing, Embedded Testing, Design for Testing Room Temperature Terahertz Circuits and Systems, Ballistic Operation.

Megherbi, Dalila: Distributed Systems and High Performance computing; HighSpeed Networks/Networking; Parallel Computers/Computing; Artificial and Machine Intelligence; Computer vision and Image processing including Applications to Homeland Security and Bio-Engineering; Optical and Digital Signal Processing; Remote Sensing and large Image Data Compression; Knowledge and Data Engineering and Applications; Design Methodologies and Tools for Architecture Design, and Fault Tolerance systems; Embedded Real-Time Systems and Architectures; MEMS and Computational Modeling for Nanotechnology Applications including DNA Computational Processing and Analysis.

Mil'Shtein, Samson: Current research is focused on: 1) GaAs and Si Field Effect Transistors (FET's) with tailored fields. Properly tailored electrical fields allows the suppression of intervalley transfer for high frequency amplifiers, or to enhance intervalley scattering for high power, high frequency oscillators. (2) Vacuum microtubes with controlled emitters for telecommunication and flat panels. Microtubes created on Si and GaAs wafers with spacing between the electrodes of about 2000 Angstroms and picosecond transit time. (3) Microwave systems for anticrime applications. (4) Quantum Well Lasers (QWL's). Study and improvement of parameters of QWL's for various applications. (5) Efficient Solar Cells. Study of front emitter, back contact, and defects with the goal to improve performance of solar cells. (6) Reliability of Transistors. Study of defects in channels produced by epitaxy, suppression of hot electron phenomena in transistors. (7) Quality Control and Characterization Techniques (SEM-DVC, LEBEAMS, DLTS, and SEM without high vacuum in the chamber).

Pakdelian, Siavash: Electric machines and drives, Power electronics

Prasad, Kanti: Reliability analysis and enhancement for GaAs and silicon devices through novel techniques; Design of protocol controllers for wireless communication systems; ASIC chip design for graphical interfaces; Collision avoidance chip design for intelligent transportation systems.

Rao, Tenneti C.: Novel transmission line and waveguide structures for millimeter wave propagation; Development of new analytical tools to analyze monostatic and bistatic scattering cross-sections from a terrain covered with snow or vegetation; Chiral materials and their possible uses for mm wave applications; Determination of the material parameters by nearfield measurements; Cavity backed aperture antennas. (Work is analytical, numerical and also experimental).

Salameh, Ziyad: (1) Hybrid Wind/Photovoltaic (PV) for stand alone as well as utility interactive systems which includes PV sizing, battery sizing, steady state performance, mathematic modeling of the system and dynamic behavior under wind gust and passing clouds. This research is done in the NEL. (2) Mathematic modeling, performance evaluation of all kinds of batteries (capacity, efficiency, state of charge, impedance, charge/discharge rates) such as lead acid, Nicad, NMH (Nickel Metal Hydrite). This research is done in the BEL. (3) Static Var Compensator SVC, operation, design using new technologies (MCTs), Harmonic generation, cascade connection of MCTs, the use of artificial neural network in the design of SVC. This research is done in the PEL. (4) Electric Vehicle: electric vehicle battery charger performance evaluation (efficiency, power factor, EMI, harmonics, reliability, charging algorithm, compatibility to different car batteries) for different sizes and manufacturers. Electric vehicle battery evaluation, capacity and efficiency. Electric vehicle range as a function of the battery capacity and battery type. This research is done in the EVL.

Son, Seung Woo: high performance computing, parallel I/O, data-intensive computing, computer architecture, compiler optimizations.

Therrien, Joel: Nanoscale sensors, nanoelectromechanical devise, chemical-biological sensors, optoelectronics. Device design and fabrication. Scanning Probe Microscopy for nanomanufacturing.

Thompson, Charles: Physical acoustics, computational modeling, nonlinear systems, telecommunications, hydrodynamic stability.

Vokkarane, Vinod: The design, analysis, and modeling of architectures, protocols, and algorithms for ultra-high speed networks, such as Optical networks, Grid/Cloud networks, and Big-data networks.

Wang, Xingwei: Optical biosensing and biomedical devices; nanoprobe design and fabrication; self-assembled nanostructures; electromagnetic wave propagation; temperature, pressure, acoustic, strain, and chemical sensors.

Weitzen, Jay: Wireless communication, digital communication systems, navigation systems.

Yu Hengyong: Computed Tomograhpy, Medical Image Processing;

VII. APPENDIX A

FORMS

ELECTRICAL AND COMPUTER ENGINEERING DEPARTMENT

DOCTORAL DISSERTATION AGREEMENT

Name of Professor (printed): _____

I agree to supervise the E.C.E. Doctoral Dissertation of the

Student (printed): _____

Circle the appropriate options:

_____ Electrical Engineering

_____ Computer Engineering

_____ Ph.D

_____ D.Eng

The tentative topic is (5 words or less):

Professor's Signature: _____ Date: _____

Student's Signature: _____ Date: _____

The original of this form is to be returned to the ECE office. Copies are to be retained by the professor and the student.

ELECTRICAL ENGINEERING CORE REQUIREMENTS

*In all of these pages, each course is to be assumed to be of 3 credits (semester hours) unless specifically mentioned otherwise.

(Student must select three of the following nine courses)

Course No.	Course Title	Semester	Grade
16.507	Electromag Waves & Mat'l	_____	
16.508	Quantum Electronics for Eng	_____	
16.509	Linear Systems Analysis	_____	
16.513	Control Systems	_____	
16.515	Power Electronics	_____	
16.520	Comp Aided Eng Analysis	_____	
16.543	Comm Theory	_____	
16.584	Prob and Random Proc	_____	
16.595	Solid State Electronics	_____	

Notes:

Total Credits

Grade Points

COMPUTER ENGINEERING CORE REQUIREMENTS

*In all these pages, each course is to be assumed to be of 3 credits (semester hours) unless specifically mentioned otherwise.

(Student must take three of the following four courses)

Course No.	Course Title	Semester	Grade
16.561	Computer Arch & Design	_____	
16.573	Operating Systems and Kernel Design	_____	
16.562	VHDL/Verilog Synthesis and Design	_____	
16.553	Software Engineering	_____	
16.574	Advanced Logic Design	_____	

Notes:	Total Credits
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Grade Points

DISSERTATION REQUIREMENTS

1. DISSERTATION CREDITS REGISTRATION:

Semester	Credits	Semester	Credits
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

TOTAL DISSERTATION CREDITS: (Exactly 21 credits required.)

2. DISSERTATION PROPOSAL AND ORAL EXAMINATION:

Defense of the Dissertation proposal before the Advisory Committee:

Date of Passing: _____

3. ORAL DEFENSE OF THE DISSERTATION:

Date of Examination

Result

Notes:

VIII. APPENDIX B

GENERAL

DEPARTMENTAL

INFORMATION

AND

COURSE DESCRIPTIONS

B.1. Department Faculty and Staff

Administrative Faculty

Department Head

Martin Margala: Professor; Ph.D., University of Alberta, Canada.

Associate Department Head and Undergraduate Transfer Advisor

Jay Weitzen, Professor; Ph.D., University of Wisconsin Madison.

Associate Department Head (Grad) and Doctoral Program Coordinator

Alkim Akyurtlu: Professor; Ph.D., Penn State.

Graduate Program Coordinator

Yan Luo, Associate Professor; Ph.D., University of California, Riverside.

Co-Op Program Coordinator

Ziyad M. Salameh, Professor; Ph.D., University of Michigan.

Industry Coordinator

Jay A. Weitzen, Professor; Ph.D., University of Wisconsin, Madison.

Non-Administrative Faculty

Armiento, Craig: Professor; Ph.D., Massachusetts Institute of Technology.

Chandra, Kavitha: Professor; DEng., University of Massachusetts Lowell.

Chigan, Chunxiao (Tricia): Associate Professor; Ph.D., State University of New York.

Darish, Michael: Lecturer; Ph.D. UMass Lowell.

Dutta, Joyita: Assistant Professor; Ph.D.; University of Southern California

Geiger, Michael: Lecturer; Ph.D., University of Michigan.

Hu, Tingshu: Professor; Ph.D., University of Virginia.

Ibe, Oliver: Associate Professor; ScD, Massachusetts Institute of Technology.

Luo, Yan: Associate Professor; Ph.D., University of California Riverside.

Lu, Xuejun: Professor; Ph.D., University of Texas at Austin.

Mah'd, Mufeed: Associate Professor; Ph.D. University of Western Ontario, London, Ontario, Canada.

Megherbi, Dalila B.: Associate Professor; Ph.D. (ECE), Brown University.

Mil'shtein, Samson: Professor; Ph.D., University of Jerusalem, Israel.

Pakdelian, Siavash: Assistant Professor; Ph.D., Texas A&M University

Palma, John: Lecturer; Ph.D. UMass Lowell.

Prasad, Kanti: Professor; Ph.D., University of South Carolina.

Rao, Tenneti C.: Professor; Ph.D., Indian Institute of Science, Bangalore.

Son, Seung Woo: Assistant Professor; Ph.D., Pennsylvania State University.

Therrien, Joel: Associate Professor; Ph.D., University of Illinois at Urbana-Champaign.

Thompson, Charles: Professor; Ph.D., Massachusetts Institute of Technology.

Tredeau, Frank: Lecturer; Ph.D., University of Massachusetts Lowell.

Vokkarane, Vinod: Associate Professor, University of Texas Dallas.

Wang, Xingwei: Associate Professor; Ph.D., Virginia Tech.

Yu, Hengyong: Associate Professor; Ph.D. Xi'an Jiaotong University

Technical Support Staff

Senait Haileselassie, Adaptive Technologist; BSEE, University of Massachusetts Lowell.

Ruth E. Dubey-Leduc, Department-Administrative Assistant

B.2. Faculty Directory

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CHANDRA, Kavitha	978-934-3356	kavitha_chandra@uml.edu	703
CHENEY, George P	978-934-3331	george_cheney@uml.edu	705
CHIGAN, Chunxiao	978-934-3342	tricia_chigan@uml.edu	711
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B.3. Department Centers and Laboratories

Centers

Advanced Electronics Technology Center	Prof. S. Mil'shtein
Center for Advanced Computation and Telecommunications	Prof. K. Chandra
	Prof. C. Thompson
Center for Atmospheric Research	Prof. B. Reinisch (Dept. of Earth Sciences)
	Prof. G. Sales (Emeritus)
	Prof. G. Cheney
Center for Computer Man/Machine Intelligence, Networking and Distributed Systems	Prof. D. B. Megherbi,
Center for Electric Cars and Energy Conversion	Prof. Z. Salameh
Center for Photonics, Electromagnetics and Nanoelectronics	Prof. C. Armiento
	Prof. A. Akyurtlu
	Prof. X. Lu
	Prof. M. Margala
	Prof. J. Therrien
	Prof. X. Wang

Laboratories

Advanced Computation and Telecommunications Laboratory	Prof. K. Chandra
	Prof. C. Thompson
Advanced Digital Systems Design Laboratory	Prof. D. B. Megherbi
Analog Devices Laboratory	Prof. G. Cheney
Assistive Technology Laboratory	Prof. D. Clark,
	Mr. A. Rux
Battery Evaluation Laboratory	Prof. Z. Salameh
Computer Architecture and Network Systems Laboratory	Prof. Y. Luo
Distributed Integrated Semiconductor Processing Laboratory	Prof. K. Prasad

Electric Vehicles Laboratory	Prof. Z. Salameh
Electromagnetic and Complex Media Laboratory	Prof. A. Akyurtlu
Electro-Optics Laboratory	Prof. C. Armiento, Prof. X. Lu
Medical Image Processing and Real time Signal Processing Laboratory	Prof. M. Mah'd
Microwave Laboratory	Prof. T. Rao
Networking, Artificial and Machine Intelligence and Computer Vision Laboratory	Prof. D. B. Megherbi
Power Electronics Laboratory	Prof. Z. Salameh
Renewable Energy Laboratory	Prof. Z. Salameh
Solid State Electronics Laboratory	Prof. S. Mil'shtein
Sun Microsystems/Cadence Laboratory	Prof. K. Prasad
UPS Industrial Technology Laboratory	Mr. A. Rux

B.4. Electrical and Computer Engineering Courses

Courses (Prefix: 16)

Undergraduate Courses

16.100 Introduction to Electrical and Computer Engineering

This introductory course is designed to expose students to many of the new developments in Electrical Engineering, especially those on-going in the Department. It will also provide information about co-op opportunities and career planning, while also allowing faculty in the Department to describe their courses and answer questions. Prerequisite: none.

16.201 Circuit Theory I

Terminal characteristics of ideal elements, active and passive. Ohm's law and Kirchhoff's Laws. Introduction to network topology, independent variables, loop and nodal analysis with matrix methods. Definition and consequences of linearity. Superposition theorem. Concept of excitation and response. Passive equivalent circuits; active equivalent circuits. Thevenin's and Norton's theorems. Ideal inductance and capacitance, volt-ampere characteristics, energy relations, First-order transients: initial conditions, natural response, and natural frequencies. Network response to unit step function and unit impulse. Second-order transients: RLC circuits, natural frequencies and the complex frequency s -plane. Introduction to matrices and their use in circuit analysis. Prerequisite: GPA at least 2.000, 92.132 Grade "C" or better, Co-requisite: [16.207](#).

16.202 Circuit Theory II

Sinusoidal forcing function, complex numbers, phasors, sinusoidal steady-state conditions. Impedance, average real power, reactive power and rms values. Exponential forcing function, poles and zeros in the s -plane, concept of the system function and its use in determining the forced response and natural behavior of circuits. Frequency response and resonance, reactance cancellation and concept of s -plane vectors. Thevenin's and Norton's theorems, superposition, reciprocity, and maximum power in the frequency domain. Impedance and admittance and hybrid parameters for a two-port network. Magnetic coupling, mutual inductance, ideal transformer. Prerequisite: [16.201](#). Co-requisite: [16.208](#).

16.207 Basic EE I Laboratory

Experimental work designed to verify theory and to acquaint students with electrical measurement techniques: experiments on meters, bridges, and oscilloscopes. Experiments are correlated with course 16.201 and concern: resistive measurements, Kirchhoff's laws, network theorems, conservation of power and maximum power transfer, inductance and capacitance, and first and second-order transients, operational amplifiers. Co-requisite: [16.201](#).

16.208 Basic EE II Laboratory

Experimental work, designed to emphasize electrical measurement techniques of linear systems with time-varying signals. Waveform measurements with ac meters as well as advanced use of the digital oscilloscope. Experiments

are integrated with course 16.202. Experiments cover: Kirchhoff's laws for phasors, magnitude and phase measurements of impedance, network theorems, frequency response, pole and zero location, resonance, inductance, statistical variation of components, modeling with MATLAB. : [16.207](#). Co-requisite: [16.202](#).

16.211/213 Fundamentals of Electricity

An introduction to direct current and alternating current analysis of electric circuits, with emphasis on energy and power. Design and use of multirange voltmeters, ammeters, and ohmmeters. Use of bridges and oscilloscopes. Phasor analysis of AC circuits, Trigonometric Fourier series, and BODE plots. Transformers, relays, and solenoids. DC and AC motors and generators. Semiconductor devices: p-n junctions, diodes, Zener diodes, bipolar transistors, JFETs, MOSFETs. Amplifiers. Operational amplifiers and their applications. Introduction to digital logic including minimization techniques. Not for ECE majors. Prerequisite: 92.132.

16.212 Fundamentals of Electricity Laboratory

Laboratory for 16.211/213. Experiments designed to correlate with the topics covered in the course 16.211. Reinforcement of various concepts through measurement techniques. Experiments cover: measurement of current and voltage, series and parallel DC circuits; superposition theorem, Thevenin's theorem, use of oscilloscope, impedance measurements of RLC, frequency response of RL, RC networks, diode operations, clipper actions, rectifiers and operational amplifiers. Co-requisite: [16.211](#).

16.216 ECE Application Programming

Introduces C programming for engineers. Covers fundamentals of procedural programming with applications in Electrical and Computer Engineering and embedded systems. Topics include variables, expressions and statements, console input/output, modularization and functions, arrays, pointers and strings, algorithms, structures, and file input/output. Introduces working with C at the bit manipulation level. Laboratories include designing and programming engineering applications. Prerequisite: [25.108](#).

16.265 Logic Design I

Number systems and computer codes. Switching algebra. Canonical and fundamental forms of switching functions. Minimization of switching functions. Two-level and multilevel digital circuits. Decoder, encoders, multiplexers, and demultiplexers. Design of combinational circuits using SSI, MSI and programmable logic devices. Latches and flipflops. Registers and counters. Analysis and synthesis of synchronous sequential circuits. Design of more complex circuits: datapath and control. Prerequisite: [25.108](#) or 91.101.

16.311 Electronics I Laboratory

Laboratory experiments coordinated with the subject matter of 16.365. Characteristics and use of electronic instrumentation for making measurements on electronic circuits. Methods of designing and characterizing diode and transistor circuits. Analysis of performance characteristics of digital and linear semiconductor circuits, including logic elements and amplifiers. Design and construction of circuits using monolithic op amps. Co-requisite: [16.365](#).

16.312 Electronics II Laboratory

Laboratory experiments coordinated with the subject matter of 16.366. High-frequency characteristics of transistors and transistor amplifiers. Feedback in electronic circuits. Electronic oscillators. Differential amplifiers.

Properties of linear IC operational amplifiers and their application in amplifier circuits and waveform generation circuits. Linear circuit design and analysis. Prerequisite: [16.311](#). Co-requisite: [16.366](#).

16.317 Microprocessor Systems Design I

This three credit course provides an introduction to microprocessors. It uses assembly language to develop a foundation on the hardware, which executes a program. Memory and I/O interface design and programming. Study of microprocessor and its basic support components, including CPU architecture, memory interfaces and management, coprocessor interfaces, bus concepts, serial I/O devices, and interrupt control devices. Laboratories directly related to microprocessor functions and its interfaces. Prerequisites: 16.265 and 16.365.

16.322 Data Structures and Algorithms

Introduction to object-oriented programming using C++, including: C++ input/output operators, default arguments, function overloading, strings, classes, dynamic memory allocation, and templates, Covers algorithms and their performance analysis, data structures, abstraction, and encapsulation. Introduces structures and their physical storage representation. Studies vectors, stacks, queues, linked lists, trees, graphs, heaps, priority queues, and hashing. Discusses efficient sorting (quicksort and heapsort) and introduces experimental analysis of algorithms as applied to engineering applications. Examines several design issues, including selection of data structures based on what operations need to be optimized (insertion, deletion, traversal, searching, sorting, evaluation), encapsulation of algorithms using class and template techniques, and how and when to use recursion (versus explicit stack-based techniques). Laboratories include programming of data structures in C++ applied to Engineering. Prerequisite: [16.216](#).

16.333 Chemistry and Engineering of Electronic Materials

The production and processing of materials into finished products constitutes a large part of the present economy. To prepare students for to use of a variety of traditional and new materials, this course will cover: atomic structure and chemical bonding, crystal geometry and defects, mechanical properties and phase diagrams of metals and alloys, electrical and optical properties of semiconductors, ceramics and polymers; brief description of electronic, quantum electronic and photonic devices; benefits and difficulties of materials design with decreasing dimensions from millimeters to micrometers and to nanometers. Prerequisites: 92.132 and 95.144.

16.339 Principles of Communication Systems

An introduction to communication systems. Introduces modulations and demodulations; noise and signal-to-noise ratio analysis; the measure of information, channel capacity. Topics include bit error rates, coding and signal orthogonality, modulation, transmission, detection techniques for data systems, multiplexing (in space, time and frequency), access techniques, spread spectrum and data encryption and their uses in modern data communications systems. Prerequisite: [16.362](#).

16.355 Electromechanics

Alternating current circuits, three phase circuits, basics of electromagnetic field theory, magnetic circuits, inductance, electromechanical energy conversion. Ideal transformer, iron-core transformer, voltage regulation, efficiency equivalent circuit, and three phase transformers. Induction machine construction, equivalent circuit, torque speed characteristics, and single phase motors. Synchronous machine construction, equivalent circuit, power relationships phasor diagrams, and synchronous motors. Direct current machines construction, types, efficiency, power flow diagram, and external characteristics. Prerequisites: [16.202](#) and 95.144.

16.360 Engineering Electromagnetics I

Waves and Phasors, Transmission lines as Distributed Circuits, Smith Chart Calculations, Impedance Matching, Transients on Transmission Lines, Vector Analysis, Electrostatics and Capacitance, Steady current flow in conductors and Resistance, Magnetostatics and Inductance. Prerequisite: [16.202](#).

16.362 Signals & Systems I

A study of various continuous voltage/current time functions and their applications to linear time-invariant electrical systems. Review of pertinent topics from 16.202 such as system functions, S-plane concepts and complete responses. Step, ramp and impulse responses of linear circuits. Sifting integrals. Types of analog filter responses. Designs for Butterworth and Chebyshev filters. Fourier Analysis, Fourier Transforms, Convolution, Laplace Transforms, Parseval's Theorem. Prerequisites: [16.202](#) and 92.236.

16.363 Introduction to Probability and Random Processes

This course employing probabilistic methods of signal and system analysis (an extension of 16.362) considers the random nature of the world faced by electrical engineers. The course addresses the issues of the nature and characterization of random events, especially noise and its effect on systems. The course is divided into three parts, 1) Introduction to discrete and continuous probability 2) Introduction to statistical methods and 3) random signals and noise and the response of linear systems to random signals. There will be frequent use of Monte-Carlo simulation techniques on the computer to allow students to verify theory and to learn the important technique of simulation. Applications of theory to manufacturing and reliability, noise analysis, spectral analysis, data communication, data collection, and system design will be presented. Prerequisite: [16.362](#).

16.364 Engineering Mathematics

The course covers the main topics in complex variables and applications including: Complex numbers, Argand plane, derivatives of complex numbers, limits and continuity, derivative and Cauchy Riemann conditions, analytic functions, integration in the complex plane, Cauchy's integral formula, infinite series for complex variables, Taylor series, Laurent series, residue theory, evaluation of integrals around indented contours. Additionally, the following topics in linear algebra will be covered: Linear vector spaces, matrices and determinants, eigenvalues and eigenvectors. Prerequisites: [16.201](#) and 92.236.

16.365 Electronics I

A brief introduction to solid-state physics, leading to discussion of physical characteristics of p-n junction diodes, bipolar junction transistors, and field-effect transistors: active, saturated, and cut-off models of bipolar transistors and triode, constant current, and cut-off models of MOSFETs. Circuit models for diodes, and diode applications. Circuit models for transistors, and transistor applications in bipolar and MOS digital circuits and low-frequency amplifier circuits. Analysis of digital circuits and linear circuits based on application of circuit models of devices and circuit theory. Prerequisites: [16.202](#), 95.144 and either Calculus III or Differential equations. Corequisite: [16.311](#).

16.366 Electronics II

A continuation of 16.365 with discussion of differential amplifiers, operational amplifiers and op amp applications, transistor amplifiers at very high frequencies; direct-coupled and band pass amplifiers; small and large signal amplifiers; feedback amplifiers and oscillators. Active filters, wave form generation circuits including Schmitt trigger, multiplexers, and A/D and D/A converters. Circuit design employing integrated circuit operational

amplifiers and discrete devices. Circuit analysis using SPICE. An electronic design project constitutes a major part of the course. Prerequisite: [16.365](#). Co-requisite: [16.312](#).

16.399 Capstone Proposal

This course discusses and presents the non-technical tools and procedures for bringing a potential product from the idea or basic concept stage through final design and to market. Fundamentals of market research, product safety and liability concerns, necessary technical communication skills. Economic concerns, patent, application procedures, design procedures and people skills necessary to be part of an engineering team. Prerequisites: [16.312](#), [16.317](#), [16.363](#), [16.366](#), and less than 30 credits remaining at the time of registration to complete major. Co-requisite: 16.400.

16.400 Engineering Topics

This course introduces to the seniors developing the capstone proposal important concepts such as economics, environmental, sustainability, manufacturability, ethical, health, safety, social and political constraints and how these are related to the overall engineering processes. These will be used as an integral part of their capstone projects. Co-requisite: [16.399](#).

16.403 Microwave Design Theory

An introductory course in the analysis and design of passive microwave circuits beginning with a review of time-varying electromagnetic field concepts and transmission lines. Smith Chart problems; single and double stub matching; impedance transformer design; maximally flat and Chebyshev transformers; microstrip transmission lines, slot lines, coplanar lines; rectangular and circular waveguides; waveguide windows and their use in impedance matching; design of directional couplers; features of weak and strong couplings; microwave filter design; characteristics of low-pass, high-pass, band-pass, band-stop filter designs; two-port network representation of junctions; Z and Y parameters, ABCD parameters, scattering matrix; microwave measurements; measurement of VSWR, complex impedance, dielectric constant, attenuation, and power. A design project constitutes a major part of the course. Prerequisite: [16.461](#).

16.409/16.410/16.412 Project Laboratory

The purpose of this course is to provide an opportunity for qualified Electrical Engineering students to investigate specific areas of interest. The actual project undertaken may be software or hardware oriented. The most important characteristics of the projects are that the end results represent independent study and that they are research and development oriented, and that they are accomplished in an engineering environment. Design reviews and progress reports are expected for each project. A final formal report to be permanently filed in the ECE Department is required for each project. Prerequisites: at least three courses from [16.355](#), [16.360](#), [16.362](#), [16.365](#), and [16.366](#).

16.411/16.511 Medical Diagnostic Imaging

This course covers the physics and electrical engineering aspects of how signals are acquired from which images will be formed, and the principal methods by which the signals are processed to form useful medical diagnostic images. Modalities studied include: x-rays, ultra-sound, computed tomography, and magnetic resonance imaging. The principles of signal processing via Fourier transform will be reviewed. Noise and other artifacts that degrade the medical diagnostic of images are considered. MATLAB is heavily used in simulation and verification. . Prerequisite: [16.362](#).

16.413 Linear Feedback Systems

Concepts of feedback; open loop and closed loop systems. Feedback in electrical and mechanical systems. Mathematical models of systems and linear approximations. Transfer functions of linear systems, block diagrams and signal flow graphs. Sensitivity, control of transient response, disturbance signals. Time domain performance: steady state errors, performance indices. Stability related to s-plane location of the roots of the characteristic equation. Routh-Hurwitz criterion. Graphical analysis techniques: root locus, frequency response as polar plot and Bode diagrams. Closed loop frequency response. A control system design project is included in the course. Prerequisites: [16.362](#) and [16.364](#).

16.418/16.582 Wireless Communications

Cellular systems and design principles, co-channel and adjacent channel interference, mobile radio propagation and determination of large scale path loss, propagation mechanisms like reflection, diffraction and scattering, outdoor propagation models, Okumura and Hata models, small scale fading and multipath, Doppler shift and effects, statistical models for multipath, digital modulation techniques QPSK, DPSK, GMSK, multiple access techniques, TDMA, FDMA, CDMA, spread spectrum techniques, frequency hopped systems, wireless systems and worldwide standards. Prerequisite: [16.360](#).

16.420/16.520 Computers in Engineering Analysis and Design

An advanced programming course, which considers the digital computer as a tool for solving significant engineering problems. The course is based on a specific area in engineering which will be selected from such topics as digital and image processing, spectral estimation, optimization techniques, etc. Typical algorithms related to the specific topic will be studied. User oriented programs or subroutine packages will be developed in a project. Prerequisite: senior standing in ECE.

16.421/16.521 Real-Time Digital Signal Processing

This course provides an introduction to real-time digital signal processing techniques using ADSP-21161, 21262, BF561, TS201S floating/fixed point processors. This is a practical course with 'hands on' training using the latest software development tools. First the core elements of the processor (computational units, data address generators, program sequencer) are examined in detail along with the relevant assembly code instructions. Internal and external memory configuration is also discussed. Advanced instructions are presented with a follow on lab on code optimization. The I/O peripherals (SPORTS, link ports, external port) are discussed in detail along with DMA operation between these peripherals and internal memory. Throughout the course, the various aspects of the software development process using the latest tools are discussed including setting up and building projects, assembly language programming, code debugging, simulation, tool support for code overlays and shared memory, and 'C' programming support. Hardware development tools, such as evaluation boards and ICE's are introduced with a follow on hardware/software lab where the student develops a simple interrupt driven application for a hardware target. Prerequisites: [16.362](#) and C or Assembly programming knowledge.

16.423/16.523 Introduction to Solid-State Electronics

A design of semiconductor device and manufacturing technology is linked to the solid state physics principles in this course. Topics covered: The electronic structure of the atom, wave-particle duality of moving electrons. Schrodinger equation for periodic crystalline structure. Band theory of semiconductors. Brillouin zones. Statistics of electrons and holes. Kinetic effects: electrical conductivity, Hall effect, magnetoresistance. Optical properties:

photoconductivity, light absorption and emission. Thermal properties including thermal conductivity, thermo EMF, recombination processes and role of defects. Prerequisite: [16.365](#) or Permission of Instructor.

16.428/16.528 Alternate Energy Sources Photovoltaics

PV conversion, cell efficiency, cell response, systems and applications. Wind Energy conversion systems: Wind and its characteristics; aerodynamic theory of windmills; wind turbines and generators; wind farms; siting of windmills. Other alternative energy sources: Tidal energy, wave energy, ocean thermal energy conversion, geothermal energy, solar thermal power, satellite power, biofuels. Energy storage: Batteries, fuel cells, hydro pump storage, flywheels, compressed air. Prerequisite: Permission of Instructor.

16.429/16.529 Electric Vehicle Technology

Electric vehicle VS internal combustion engine vehicle. Electric vehicle (EV) saves the environment. EV design, EV motors, EV batteries, EV battery chargers and charging algorithms, EV instrumentation and EV wiring diagram. Hybrid electric vehicles. Fuel cells. Fuel cell electric vehicles. The course includes independent work. Prerequisite: Permission of Instructor.

16.431/16.531 RF Design

Two-port network parameters, Smith chart applications for impedance matching, transmission line structures like stripline, microstrip line and coaxial line, filter designs for low-pass, high-pass and band-pass characteristics, amplifier design based on sparameters, bias network designs, one port and two port oscillator circuits, noise in RF systems. Prerequisite: [16.360](#).

16.434 Active Network Theory

A study of active inductorless networks with emphasis on design and implementation. The course will cover the following subjects: approximation theory, the operational amplifier, the gyrator, the negative impedance converter, analysis of basic second-order active building blocks, the biquad building block, the state-variable filter, and the design of filters. The course includes a detailed design project. Prerequisite: [16.366](#).

16.435 Computational Electromagnetics

Formulation of electromagnetic problems for computer solution. Variational principles in electromagnetics. Method of moments. Applications in electrostatics, wire antennas, waveguides and cavities. Simple scattering problems. Finite difference methods. Finite element method. Prerequisite: [16.461](#).

16.439 Theory of Communication

An introduction to the study of time and frequency domain characteristics of signals arising in communications systems. Fourier analysis, discrete transform, correlation functions, power and energy density spectra. Time and frequency characteristics of thermal noise and random signals in data and noise communications. Spread spectrum concepts. Signal to noise ratio. Amplitude modulation, frequency modulation. Digital modulation, PAM, PCM, bandwidth control, time division multiplexing, transmission of binary data in noise. Prerequisite: [16.362](#).

16.440 Communication Systems

Analysis of the performance and operating characteristics of communication systems from the viewpoint of probability theory. Concentration on digital systems. Fundamentals of probability, expectation operator, Gaussian

random variable. Markov processes, fundamentals of random processes. Discretization of analog signals. Fundamentals of information theory and coding. PN coding. Transmission of binary data in noise (matched filters). Optimal filters, tradeoffs of bandwidth power, and coding complexity in digital transmission. Applications. Hardware and/or simulation projects. Prerequisite: [16.362](#).

16.443/16.514 Power Systems Analysis

An intermediate course in analysis and operation of electrical power systems using mathematical techniques including applied calculus and matrix algebra. Topics include network reductions and representation of lines, generators, and transformers, network topology and transform methods. An introduction to protection and relaying is included. Symmetrical components will be introduced with application to polyphase systems. A design project is a major portion of the course. Prerequisite: [16.355](#).

16.444/16.525 Power Systems Distribution

An intermediate course in analysis and operation of electrical power distribution systems using applied calculus and matrix algebra. Topics include electrical loads characteristics, modeling, metering, customer billing, voltage regulation, voltage levels, and power factor correction. The design and operation of the power distribution system components will be introduced: distribution transformers, distribution substation, distribution networks, and distribution equipment. Prerequisite: [16.355](#).

16.445/16.565 Analog Devices & Techniques

A survey of analog devices and techniques, concentrating on operational amplifier design and applications. Monolithic operational amplifier design is studied both from the point of view of the op-amp designer whose goal is to optimize performance, as well as the application engineer who needs to understand the limitations of real op-amps, and to be able to interpret their specifications. Representative applications may include: simple amplifiers, differential and instrumentation amplifiers, summers, integrators, active filters, nonlinear circuits, and waveform generation circuits. A design project is required. Prerequisite: [16.366](#).

16.453/553 Software Engineering

Introduces software life cycle models, and engineering methods for software design and development. Design and implementation, testing, and maintenance of large software packages in a dynamic environment, and systematic approach to software design with emphasis on portability and ease of modification. Laboratories include a project where some of the software engineering methods (from modeling to testing) are applied in an engineering example. Prerequisites: [16.216](#) and [16.322](#).

16.450/16.550 Advanced Digital Systems Hardware Design

Design of logic machines, finite state machines, gate array designs, ALU and 4 bit CPU unit designs, microprogrammed systems. Hardware design of advanced digital circuits using XILINX. Application of probability and statistics for hardware performance and upgrading hardware systems. Laboratories incorporate specification, top down design, modeling, implementation and testing of actual advanced digital design systems hardware. Laboratories also include simulation of circuits using VHDL before actual hardware implementation and PLDs programming. Prerequisite: [16.265](#).

16.460/16.560 Medical Instrumentation

Analysis and design of Biomedical Instrumentation systems that acquire and process biophysical signals. properties of biopotential signals and electrodes; biopotential amplifiers and signal processing; basic sensors and principles; medical imaging systems; electrical safety. Prerequisites: 92.132 and 95.144.

16.461 Engineering Electromagnetics II

Continuation of Magnetostatics, Maxwell's Equations for Time-varying Fields, plane waves: time-harmonic fields, polarization, current flow in good conductors and skin effect, power density and Poynting vector, wave reflection and transmission; Snell's Law, fiber optics, Brewster angle, radiation and simple antennas, electromagnetic concepts involved in a topical technology in development. Prerequisites: [16.360](#).

16.462/16.506 Antenna Theory and Design

An introduction to properties of individual antennas and arrays of antennas. Retarded potentials, dipoles of arbitrary length, radiation pattern, gain, directivity, radiation resistance, will be covered. The loop antenna. Effects of the earth. Reciprocity, receiving antennas, effective length and area. Moment methods. Arrays: collinear, broadside, endfire. Array synthesis. Mutual coupling. Log-periodic and Yagi arrays. Radiation from apertures, including the waveguide horn antenna. Numerical software packages will be used throughout the course. A design project is required in the course. Prerequisite: [16.461](#).

16.465 Logic Design II

Error detection and correction codes. Map-entered variables. Minimization by Quine- McCluskey method. Multiple-output circuits. Timing hazards and hazard-free design. Analysis and Synthesis of synchronous and asynchronous sequential circuits. Races and essential hazards. Primitive flow tables. Flow table reductions and state assignments. Design using MSIs. Programmable logic devices: ROMs, PLAs, PALs, and PLSs. Design projects are included in the course. Prerequisite: [16.265](#).

16.466/16.566 Guided Wave Photonic Devices

Topics for the course will include guide-wave optics in 2D and 3D optical waveguides, and optical fiber together with concepts such as mode dispersion, and group velocity dispersion. Additional subjects include: Mode-coupling theory, directional coupler, and electro-optic effect and devices. The course will also cover optical amplifiers and DWDM technologies. Prerequisites: 16.360 and 16.461.

16.468/568 Electro Optic and Integrated Systems

Introduction to physical optics, wave propagation, interference, diffraction, and polarization, guide-wave optics: 2D and 3D optical waveguide, mode dispersion, group velocity and group velocity dispersion, mode-coupling theory, Mach-Zehnder interferometer, directional coupler, taps and WDM coupler, passive and active optical waveguide devices, electro-optics, index tensor, electro-optic effect in crystal, electro optic coefficient, Electro-optical modulators, Photonic switches and all optical switches, light emission, absorption and photon density of states, fiber optical amplifiers. Pre-requisite: 16.360.

16.469/16.502 VLSI Design

Introduction to CMOS circuits including transmission gate, inverter, NAND, NOR gates, MUXes, latches and registers. MOS transistor theory including threshold voltage and design equations. CMOS inverter's DC and AC

characteristics along with noise margins. Circuit characterization and performance estimation including resistance, capacitance, routing capacitance, multiple conductor capacitance, distributed RC capacitance, multiple conductor capacitance, distributed RC capacitance, switching characteristics incorporating analytic delay models, transistor sizing and power dissipation. CMOS circuit and logic design including fan-in, fan-out, gate delays, logic gate layout incorporating standard cell design, gate array layout, and single as well as two-phase clocking. CMOS test methodologies including stuck-at-0, stuck-at-1, fault models, fault coverage, ATPG, fault grading and simulation including scan-based and self test techniques with signature analysis. A project of modest complexity would be designed to be fabricated at MOSIS. Prerequisites: [16.265](#) and [16.365](#).

16.470/16.504 VLSI Fabrication

Fabrication of resistors, capacitors, p-n junction and Schottky Barrier diodes, BJT's and MOS devices and Integrated circuits. Topics include: silicon structure, wafer preparation, sequential techniques in micro-electronic processing, testing and packaging, yield and clean room environments. MOS structures, crystal defects, Fick's laws of diffusion; oxidation of silicon, photolithography including photoresist, development and stripping. Metallization for conductors, Ion implantation for depletion mode and CMOS transistors for better yield speed, low power dissipation and reliability. Students will fabricate circuits using the DSIPL Laboratory. Prerequisite: [16.365](#).

16.472/16.572 Embedded Real-Time Systems

Design of embedded real-time computer systems. Polled vs. interrupt-driven input/output. Writing interrupt handlers. Types of real-time systems, including foreground/background, non-preemptive multitasking, and priority-based pre-emptive multitasking systems. Soft vs. hard real time systems. Task scheduling algorithms and deterministic behavior. Task synchronization and inter-task communication including: semaphores, mutexes, mailboxes and message queues. Deterministic memory management schemes. Application and design of a real-time kernel. A project is required. Prerequisites: [16.216](#), [16.317](#), and [16.322](#) or Permission of Instructor.

16.473/16.515 Power Electronics

A one-semester course with emphasis on the engineering design and performance analysis of power electronics converters. Topics include: power electronics devices (power MOSFETs, power transistors, diodes, silicon controlled rectifiers SCRs, TRIACs, DIACs and Power Darlington Transistors), rectifiers, inverters, ac voltage controllers, dc choppers, cycloconverters, and power supplies. The course includes a project, which requires that the student design and build one of the power electronics converters. A demonstrative laboratory to expose the students to all kinds of projects is part of the course. Prerequisites: [16.355](#) and [16.366](#).

16.474/576 Principles of Solid-State Devices

Principles of Solid State Devices: Crystal properties and growth of semi-conductors, atoms and electrons, Bohr's model, quantum mechanics, bonding forces and energy bands in solids, charge carriers in semiconductors, drift of carriers in electric and magnetic fields, carrier lifetime and photoconductivity, junctions, forward and reverse bias, reverse bias breakdown (Zener effect), tunnel diodes, photodiodes, LED, bipolar junction transistors, field effect transistors. A design project is included in the course. Prerequisite: [16.365](#).

16.475 Automated Test Systems

A design-oriented introduction to the techniques of modern automatic test systems, covering both hardware and software. Topics include: automated testing in engineering and manufacturing; the IEEE-488 instrument bus; programmable test equipment; the device under test interface; modular software development; and human

engineering and ethical considerations. The course includes a project in which students develop a complete automated test system for some real device. Student designs are implemented in the ECE Department's Automated Test System Laboratory. During the project students maintain project schedules and conduct design reviews to critique each other's designs. Completed projects are demonstrated and thoroughly documented. Prerequisite: [16.366](#).

16.476 Photovoltaics

An introductory course in photovoltaics concentrating on solar cells for energy conversion. Solar radiation and conversion efficiency. Photovoltaic materials, energy bands and carrier transport, semiconductors and conductors. P-n junctions, depletion region, current voltage characteristics, efficiency. Heterojunctions and thin film solar cells. Balance of system components for a photovoltaic system including electrical storage. Barrier to extensive use of photovoltaic systems. Prerequisite: 92.132 or Permission of Instructor.

16.480/16.552 Microprocessors II and Embedded Systems

This course provides a continuation of the study of microprocessors begun in 16.317. Topics include CPU architecture, memory interfaces and management, coprocessor interfaces, bus concepts, bus arbitration techniques, serial I/O devices, DMA, interrupt control devices. Focus will be placed on the design, construction, and testing of dedicated microprocessor systems (static and real-time). Hardware limitations of the single-chip system will be investigated along with microcontrollers, programming for small systems, interfacing, communications, validating hardware and software, microprogramming of controller chips, and design methods and testing of embedded systems. Laboratories directly related to microprocessor functions and its interfaces. Prerequisites: [16.311](#), [16.317](#), and [16.365](#).

16.481/16.573 Operating Systems and Kernel Design

Covers the components, design, implementation, and internal operations of computer operating systems. Topics include basic structure of operating systems, Kernel, user interface, I/O device management, device drivers, process environment, concurrent processes and synchronization, inter-process communication, process scheduling, memory management, deadlock management and resolution, and file system structures. Laboratories include examples of components design of a real operating systems. Prerequisite: [16.216](#) or Programming Skills.

16.482/16.561 Computer Architecture and Design

Structure of computers, past and present, including: first, second, third and fourth generation. Combinational and sequential circuits. Programmable logic arrays. Processor design including: information formats, instruction set architecture, integer and real arithmetic, design of the CPU data path, hardwired and micro-programmed control, pipelined and superscalar architectures, Memory hierarchy including cache and virtual memory. Input-output systems, communication and bus control. Multiple CPU systems. Prerequisites: [16.265](#) and [16.317](#).

16.483/16.583 Network Design: Principles, Protocols and Applications

Covers design and implementation of network software that transforms raw hardware into a richly functional communication system. Real networks (such as the Internet, ATM, Ethernet, Token Ring) will be used as examples. Presents the different harmonizing functions needed for the interconnection of many heterogeneous computer networks. Internet protocols, such as UDP, TCP, IP, ARP, BGP and IGMP, are used as examples to demonstrate how internetworking is realized. Applications such as electronic mail and the WWW are studied. Topics include: inter-network architectures, high speed network service protocol implementation, addressing and address mapping,

intra- and inter-domain routing, multicasting, mobility, auto-configuration, resource allocation, transport protocols, naming, client-server model, network programming interfaces (e.g., sockets, RMI, RPC, CORBA), secure transport protocols for high-speed networks and applications. Prerequisite: [16.216](#) or Programming Skills.

16.484/16.581 Computer Vision and Digital Image Processing

Introduces the principles and the fundamental techniques for Image Processing and Computer Vision. Topics include programming aspects of vision, image formation and representation, multi-scale analysis, boundary detection, texture analysis, shape from shading, object modeling, stereo-vision, motion and optical flow, shape description and objects recognition (classification), and hardware design of video cards. AI techniques for Computer Vision are also covered. Laboratories include real applications from industry and the latest research areas. Prerequisites: [16.216](#) or [16.322](#), [16.362](#) or Permission of Instructor.

16.490/16.590 Fiber Optic Communications

Optical fiber; waveguide modes, multimode vs. single mode; bandwidth and data rates; fiber losses; splices, couplers, connectors, taps and gratings; optical transmitters; optical receivers; high speed optoelectronic devices; optical link design; broadband switching; single wavelength systems; wavelength division multiplexing; fiber amplifiers. Prerequisites: [16.360](#) and [16.362](#) or Permission of Instructor.

16.491 Industrial Experiences I, II, and III

This three credit course is for co-op or industrial experience. It may be taken three times and the co-op internship should be for at least 500 hours in order to be eligible for credit. Only 3 credits may be used toward the BS Eng in CpE or EE degree. Registration for this course is conditional on the approval of the Department Co-op coordinator. A grade of Satisfactory or Unsatisfactory is given. Prerequisite: Permission of Instructor.

16.499 Capstone Project

The purpose of the CAPSTONE Project is to provide the student with a design experience which resembles entry level engineering assignments. It is expected that the project encompass a minimum of three technical areas within the CpE or EE discipline, and include some aspects of each step in the development of a marketable product i.e. Research, Design and Development, Manufacture, Marketing and Service. A formal technical report must be submitted prior to the submission of a course grade. Prerequisites: [16.399](#) and [16.400](#).

Graduate Courses

16.501 Discrete Algebra

A comprehensive course addressing the diversity of discrete algebraic systems needed in digital system synthesis and analysis. Logic Sets and Functions. Introduction to algorithms including recursive algorithms, integers, elementary matrix theory. Mathematical reasoning and proofs, proof by induction. Basics of counting, combinatorics, generalized permutations and combinations, elements of discrete probability. Recurrence relations and solution of recurrence relations, generating functions. Relations and their properties, equivalence relations, partial and total orderings. Graph theory, Euler and Hamilton graphs and paths, shortest path algorithm, planar graphs. Trees, spanning trees and minimum spanning trees, binary trees. Prerequisite: [16.362](#) or equivalent.

16.502 VLSI Design

Introduction to CMOS circuits including transmission gate, inverter, NAND, NOR gates, MUXes, latches and registers. MOS transistor theory including threshold voltage and design equations. CMOS inverter's DC and AC characteristics along with noise margins. Circuit characterization and performance estimation including resistance, capacitance, routing capacitance, multiple conductor capacitance, distributed RC capacitance, multiple conductor capacitance, distributed RC capacitance, switching characteristics incorporating analytic delay models, transistor sizing and power dissipation. CMOS circuit and logic design including fan-in, fan-out, gate delays, logic gate layout incorporating standard cell design, gate array layout, and single as well as two-phase clocking. CMOS test methodologies including stuck-at-0, stuck-at-1, fault models, fault coverage, ATPG, fault grading and simulation including scan-based and self test techniques with signature analysis. A project of modest complexity would be designed to be fabricated at MOSIS. Prerequisites: [16.265](#) and [16.365](#).

16.504 VLSI Fabrication

Fabrication of resistors, capacitors, p-n junction and Schottky Barrier diodes, BJT's and MOS devices and Integrated circuits. Topics include: silicon structure, wafer preparation, sequential techniques in micro-electronic processing, testing and packaging, yield and clean room environments. MOS structures, crystal defects, Fick's laws of diffusion; oxidation of silicon, photolithography including photoresist, development and stripping. Metallization for conductors, Ion implantation for depletion mode and CMOS transistors for better yield speed, low power dissipation and reliability. Students will fabricate circuits using the DSIPL Laboratory. Prerequisite: [16.365](#).

16.505 Microwave Electronics

Review of p-n junction theory, depletion layer width and junction capacitance, Schottky barrier diodes, pin diodes and applications in switches and phase shifters, varactors and step recovery diodes, tunnel diodes and circuits, Gunn devices and circuits, avalanche diodes, IMPATT, TRAPATT and BARRITT diodes, microwave bipolar junction transistors (BJT) and field effect transistors (FET), small signal amplifier design, new devices like HEMT and Si-Ge devices, traveling wave tubes and klystrons. Prerequisite: [16.365](#).

16.506 Antenna Theory and Design

An introduction to properties of individual antennas and arrays of antennas. Retarded potentials, dipoles of arbitrary length, radiation pattern, gain, directivity, radiation resistance. The loop antenna. Effects of the earth. Reciprocity, receiving antennas, effective length and area. Moment methods. Arrays: collinear, broadside, endfire.

Array synthesis. Mutual coupling. Log-periodic and Yagi arrays. Radiation from apertures: the waveguide horn antenna, parabolic dish. Antenna noise temperature. Numerical software packages. Prerequisite: [16.461](#).

16.507 Electromagnetic Waves and Materials

This is a graduate core course, which serves the needs of students who study electromagnetics as a basis for a number of electromagnetic technologies including photonic technologies. Study of Electromagnetic Wave Interactions with Bounded Simple Media: transmission lines, Green's function, fibers, conducting waveguides and cavity resonators, Plane waves in Complex Electromagnetic Materials: plasmas, dispersive dielectrics, mixing formulas, optical waves in metals, super conductors, chiral media, crystals, magnetized plasma and time-varying media, layered and periodic media. Prerequisite: [16.461](#).

16.508 Quantum Electronics for Engineers

Introduction to the fundamental postulates of quantum theory: Planck's quantization hypothesis; wave-particle duality; time-dependent and time-independent Schrodinger's Equation; simple quantum mechanical systems. Radiation and quanta; quantization of the radiation field and cavity modes; absorption and emission of radiation; coherence functions; coherent states; importance of quantum fluctuations and quantum nature of light; laser amplifiers and amplifier nonlinearity; electromagnetics and quantum theory of laser oscillators; photons in semiconductors; semiconductor photon sources and detectors. Prerequisites: [16.363](#) and [16.461](#).

16.509 Linear Systems Analysis

Correlation and Circular convolutions. Concepts of orthogonality and Gramm-Schmidt orthogonalization procedure. Fourier series and Fourier transforms (FT): convergence properties; applications to linear systems including modulation, sampling and filtering. Hilbert transforms (HT) and analytic signals. Bilateral Laplace transforms (LT): convergence properties. Contour integration methods applied to FT, HT and LT. Discrete-time Fourier series and Fourier transforms including complex convolution: applications to linear systems. Discrete Fourier transforms and Fast Fourier algorithm. Z-transforms: convergence properties, solution of difference equations, application to linear systems. Correlation. Prerequisite: [16.362](#).

16.510 Digital Signal Processing

Review of Z-Transforms and solutions of linear difference equations. Digital filter structures, parameter quantization effects and design techniques. FFT and Chirp ZTransform methods. Discrete Hilbert Transforms, minimum-phase sequences and their application to Homomorphic Signal Processing and calculation of Complex Cepstrum. Prerequisite: [16.362](#), [16.363](#) preferred.

16.511 Medical Diagnostic Imaging

This course covers the physics and electrical engineering aspects of how signals are acquired from which images will be formed, and the principal methods by which the signals are processed to form useful medical diagnostic images. Modalities studied include: x-rays, ultra-sound, computed tomography, and magnetic resonance imaging. The principles of signal processing via Fourier transform will be reviewed. Noise and other artifacts that degrade the medical diagnostic of images are considered. MATLAB is heavily used in simulation and verification. Prerequisite: [16.362](#).

16.512 Mixed Signals VLSI Design

This course covers a wide spectrum of topics related to challenges in modern VLSI design. Students will learn the skills of overcoming these problems when two opposing signal domains are integrated onto a single chip. Understanding physical layout representation and the effects of alternative layout solutions on circuit and systems specifications is critical to modern designs. Students will learn to use the CAS tools widely used by the semiconductor industry for layout, schematic capture, advanced simulations, parasitic extractions, floor planning and place and route, specifically, the course provides a review of fundamentals of semiconductor components. In the next step, basic building blocks of digital and analog design are described. The course concludes with challenges of large integration under varying operation conditions. An individual project involving a layout design from specification to implementation is included. Prerequisite: 16.502

16.513 Control Systems

System representations, state variables, transfer functions, controllability and observability, phase variables, canonical variables, representation of nonlinear systems, Lagrange's equations, generalized co-ordinates, time response of linear systems, state transition matrix, Sylvester's expansion theorem, stability and state function of Liapunov, transient behavior estimation, optimal control, state function of Pontryagin, variational calculus, Hamilton Jacobi method, matrix Riccati equation, linear system synthesis. Prerequisite: [16.413](#).

16.514 Power Systems Analysis

An intermediate course in analysis and operation of electrical power systems using mathematical techniques including applied calculus and matrix algebra. Topics include network reductions and representation of lines, generators, and transformers, network topology and transform methods. An introduction to protection and relaying is included. Symmetrical components will be introduced with application to polyphase systems. Prerequisite: [16.355](#).

16.515 Power Electronics

Design and performance analysis of rectifiers, inverters, DC chopper, AC voltage controllers, cycloconverters, and power supplies. The course includes a design project in the laboratory. Prerequisites: [16.355](#) and [16.366](#).

16.516 Advanced Machine Theory

Electromechanical energy conversion. Reference-frame theory. Dynamics of DC, induction, and synchronous machines. Unbalanced operation of induction and synchronous machines. Prerequisite: [16.355](#).

16.517 MMIC Design and Fabrication

The goal of MMIC design and fabrication is to prepare students for designing integrated circuits operating at GHz frequencies. The design is based on scattering parameters of the MESFETs and PHEMTs. The real challenge in this case is to relate S_{11} , S_{12} , S_{21} and S_{22} with the fabrication technology parameters such as channel conductance, transconductance and threshold voltages etc. This course not only covers RF design techniques but also the manufacturability and testability of the circuits at GHz frequencies, including packaging techniques. Prerequisite: [16.360](#) or Permission of Instructor.

16.519 Engineering of Submicron Machines

Recently fabrication of Very Large Scale Integrated circuits has spun-off a new technology of micro-machines (MEMS) and sensors on a semiconductor wafer. These new devices are ideally located next to a microprocessor on the same wafer or a separate chip. The data transfer to and from a miniature machine, sensor or transducer is processed and controlled on site. Topics include design of mechanical, electrical and biological transducers; properties of electronic materials; pattern generation on a semiconductor wafer; interface of a micromachine and processor; applications and markets for submicron machines; their role in nanotechnology. Prerequisite: 16.365 or Permission of Instructor.

16.520 Computer-Aided Engineering Analysis

Taylor series. Number systems and error. Difference and summation calculus. Interpolation. Definite integrals. Differential equation modeling and stability; Predictor- Corrector and Runge-Kutta methods. Orthogonal polynomials. Discrete transforms. Roots of polynomials. Zeros and stationary points of single variable functions. Gradient, quasi-Newton and conjugate gradient methods of optimization. Prerequisites: [16.364](#) and 92.234.

16.521 Real-Time Digital Signal Processing

This course provides an introduction to real-time digital signal processing techniques using ADSP-21161, 21262, BF561, TS201S floating/fixed point processors. This is a practical course with 'hands on' training using the latest software development tools. First the core elements of the processor (computational units, data address generators, program sequencer) are examined in detail along with the relevant assembly code instructions. Internal and external memory configuration is also discussed. Advanced instructions are presented with a follow on lab on code optimization. The I/O peripherals (SPORTS, link ports, external port) are discussed in detail along with DMA operation between these peripherals and internal memory. Throughout the course, the various aspects of the software development process using the latest tools are discussed including setting up and building projects, assembly language programming, code debugging, simulation, tool support for code overlays and shared memory, and 'C' programming support. Hardware development tools, such as evaluation boards and ICE's are introduced with a follow on hardware/software lab where the student develops a simple interrupt driven application for a hardware target. Prerequisites: [16.362](#) and C or Assembly programming knowledge.

16.522 Data Structures

Character strings, character substring searches; lists, their storage structures and uses; trees, tree searches, and storage concepts; compiling, Polish strings, translating from infix to postfix and prefix, conversion to machine code. Prerequisites: [16.216](#) and [16.322](#).

16.523 Introduction to Solid-State Electronics

In this course the design of semiconductor devices and manufacturing technology is linked to the conventional and quantum transport of electrons in semiconductors. Topics covered: The electronic structure of the atom, wave-particle duality of moving electrons. Schrodinger equation for periodic crystalline structure. Band theory of semiconductors. E-k diagrams and Brillouin zones for quantum wires and quantum dots. Statistics of electrons and holes. Kinetic effects: electrical conductivity, Hall effect, magnetoresistance. Optical properties: photoconductivity, light absorption and emission. Thermal properties including thermal conductivity, recombination processes and role of defects. Prerequisite: 16.365 or Permission of Instructor.

16.524 Programming Languages

Syntax and semantics of programming languages. Fundamental concepts of control structures, modularity, scope of identifiers, recursion, and data structures. Examples of real programming languages such as FORTRAN, Pascal, LISP, APL, C++, and ADA. Prerequisite: FORTRAN, Pascal, or C.

16.525 Power Systems Distribution

An intermediate course in analysis and operation of electrical power distribution systems using applied calculus and matrix algebra. Topics include electrical loads characteristics, modeling, metering, customer billing, voltage regulation, voltage levels, and power factor correction. The design and operation of the power distribution system components will be introduced: distribution transformers, distribution substation, distribution networks, and distribution equipment. Prerequisite: [16.355](#).

16.527 Advanced VLSI Design Techniques

This course builds on the previous experience with Cadence design tools and covers advanced VLSI design techniques for low power circuits,. Topics covered include aspects of the design of low voltage and low power circuits including process technology device modeling, CMOS circuit design, memory circuits and subsystem design. This will be a research-oriented course based on team projects. Prerequisite: [16.469](#) or [16.502](#).

16.528 Alternate Energy Sources

Photovoltaics: PV conversion, cell efficiency, cell response, systems and applications. Wind Energy conversion systems: Wind and its characteristics; aerodynamic theory of windmills; wind turbines and generators; wind farms; siting of windmills. Other alternative energy sources: Tidal energy, wave energy, ocean thermal energy conversion, geothermal energy, solar thermal power, satellite power, biofuels. Energy storage: Batteries, fuel cells, hydro pump storage, flywheels, compressed air. Prerequisite: Permission of Instructor.

16.529 Electric Vehicle Technology

Electric vehicle VS internal combustion engine vehicle. Electric vehicle (EV) saves the environment. EV design, EV motors, EV batteries, EV battery chargers and charging algorithms, EV instrumentation and EV wiring diagram. Hybrid electric vehicles. Fuel cells. Fuel cell electric vehicles. The course includes independent work. Prerequisite: Permission of Instructor.

16.531 RF Design

Two-port network parameters, Smith chart applications for impedance matching, transmission line structures like stripline, microstrip line and coaxial line, filter designs for low-pass, high-pass and band-pass characteristics, amplifier design based on sparameters, bias network designs, one port and two port oscillator circuits, noise in RF systems. Prerequisite: [16.360](#).

16.532 Computational Electromagnetics

Formulation of electromagnetic problems for computer solution. Variational principles in electromagnetics. Method of moments. Applications in electrostatics, wire antennas, waveguides and cavities. Simple scattering problems. Finite difference methods. Finite element method. Prerequisite: [16.461](#).

16.533 Microwave Engineering

An introductory course in the analysis and design of passive microwave circuits beginning with a review of time-varying electromagnetic field concepts and transmission lines. Smith Chart problems; single and double stub matching; impedance transformer design; maximally flat and Chebyshev transformers; microstrip transmission lines, slot lines, coplanar lines; rectangular and circular waveguides; waveguide windows and their use in impedance matching; design of directional couplers; features of weak and strong couplings; microwave filter design; characteristics of low-pass, high-pass, band-pass, band-stop filter designs; two-port network representation of junctions; Z and Y parameters, ABCD parameters, scattering matrix; microwave measurements; measurement of VSWR, complex impedance, dielectric constant, attenuation, and power. A design project constitutes a major part of the course. Prerequisite: [16.461](#).

16.541 Introduction to Biosensors

This course introduces the theory and design on biosensors and their applications for pathology, pharmacogenetics, public health, food safety civil defense, and environmental monitoring. Optical, electrochemical, and mechanical sensing techniques will be discussed. Prerequisite: [16.365](#).

16.543 Theory of Communication

This course presents an in-depth [16.363](#) or [16.584](#) or equivalent.

16.546 Communication Networks

This course provides an in-depth study of the elements of the modern computer-based data communication systems. It utilizes elementary concepts from graph theory and queuing theory to study the problems of network protocols, including routing, congestion control and flow control. The topics covered include: Circuit-switched versus Packet-switched Networks; Layered Network Architecture; Framing, Error Detection and Retransmission Strategies; Introduction to Graph Theory; Introduction to Queuing Theory; IP Addressing; Shortest-path Routing Algorithms; Congestion Control Protocols; Transport layer Protocols (TCP, UDP and SCTP); Flow Control Algorithms; Multi-access Communications; Local Area Networks; Network Security; Mobile Ad Hoc Networks; Wireless Sensor Networks; Introduction to Mobile Communication Networks; and Introduction to Converged Communication Networks.

16.548 Coding and Information Theory

Probabilistic measure of information. Introduction to compression algorithms including L-Z, MPEG, JPEG, and Huffman encoding. Determination of the information handling capacity of communication channels and fundamental coding theorems including Shannon's first and second channel coding theorems. Introduction to error correcting codes including block codes and convolutional coding and decoding using the Viterbi algorithm. Applications of information theory and coding to advanced coding modulation such as Trellis code Modulation (TCM) and turbo modulation. Prerequisites: [16.362](#), [16.363](#), [16.543](#), [16.584](#) or equivalent is desirable, programming in C, VB, or Matlab, or Permission of Instructor.

16.550 Advanced Digital Systems Hardware Design

Design of logic machines, finite state machines, gate array designs, ALU and 4 bit CPU unit designs, microprogrammed systems. Hardware design of advanced digital circuits using XILINX. Application of probability and statistics for hardware performance and upgrading hardware systems. Laboratories incorporate specification,

top down design, modeling, implementation and testing of actual advanced digital design systems hardware. Laboratories also include simulation of circuits using VHDL before actual hardware implementation and PLDs programming. Prerequisite: [16.265](#).

16.552 Microprocessors Systems II and Embedded Systems

This course provides a continuation of the study of microprocessors begun in 16.317. Topics include CPU architecture, memory interfaces and management, coprocessor interfaces, bus concepts, bus arbitration techniques, serial I/O devices, DMA, interrupt control devices. Focus will be placed on the design, construction, and testing of dedicated microprocessor systems (static and real-time). Hardware limitations of the single-chip system will be investigated along with microcontrollers, programming for small systems, interfacing, communications, validating hardware and software, microprogramming of controller chips, and design methods and testing of embedded systems. Laboratories directly related to microprocessor functions and its interfaces. Prerequisites: [16.311](#), [16.317](#), and [16.365](#).

16.553 Software Engineering

Introduces software life cycle models, and engineering methods for software design and development. Design and implementation, testing, and maintenance of large software packages in a dynamic environment, and systematic approach to software design with emphasis on portability and ease of modification. Laboratories include a project where some of the software engineering methods (from modeling to testing) are applied in an engineering example. Prerequisites: [16.216](#) and [16.322](#).

16.554 Voice Recognition Processing and Computer Sound Drivers

Introduces voice recognition processing, linear predictive modeling techniques, voice compression methods. Digital voice algorithms and lattice/ladder digital filters in voice models. Topics cover musical instruments using computationally efficient algorithms, microphone arrays for beam-forming, real-time voice processing, 16 bit and higher sound drivers. Laboratories include implementation of voice recognition algorithms, sound drivers and applications. Prerequisite: [16.482](#).

16.556 Robotics

Introduces the basic aspects of mobile robotics programming, starting at low-level PID control and behavioral robot control. Covers the analysis, design, modeling and application of robotic manipulators. Forward and inverse kinematics and dynamics, motion and trajectory control and planning are also covered. Laboratories include design, analysis and simulation of real life industrial robots. Prerequisite: Permission of Instructor.

16.557 Object Oriented Design

Introduces the fundamentals of the object-oriented paradigm, such as classes, objects, the association relationship, the uses relationship, the containment relationship and the inheritance relationship. Studies the relationship between methodologies based on the data driven approach and the behavioral approach. Covers object-oriented design patterns and their relationship to design heuristics. Laboratories includes generic programming, programming by contracts, programming with meta-classes, and the concrete realizations of components in some industrial standards (e.g. Java Swing, Enterprise JavaBeans, JINI, etc.). Prerequisite: [16.322](#).

16.558 World Wide Web Programming

Covers design and development of WWW pages, images, dialogue boxes and tables, using HTML, Java Scripts, image maps and tables, and Java Swing programming principles and techniques. Laboratories include usage of Java Database Connectivity, Servlets, Remote Method Invocation (RMI), Java Networking, and Multimedia, all based on WWW. Prerequisite: [16.322](#).

16.560 Biomedical Instrumentation

Analysis and design of Biomedical Instrumentation systems that acquire and process biophysical signals. properties of biopotential signals and electrodes; biopotential amplifiers and signal processing; basic sensors and principles; medical imaging systems; electrical safety. Prerequisites: 92.132 and 95.144.

16.561 Computer Architecture and Design

Structure of computers, past and present, including: first, second, third and fourth generation. Combinational and sequential circuits. Programmable logic arrays. Processor design including: information formats, instruction set architecture, integer and real arithmetic, design of the CPU data path, hardwired and micro-programmed control, pipelined and superscalar architectures, Memory hierarchy including cache and virtual memory. Input-output systems, communication and bus control. Multiple CPU systems. Prerequisites: [16.265](#) and [16.317](#).

16.562VHDL/Verilog Synthesis and Design

Circuit and system representations including behavioral, structural, and physical description using HDL. Modeling of short and narrow MOS transistors for submission applications Overview of CMOS technology including oxidation, epitaxy, deposition, ion implantation, and diffusion essential for multilayer vias. 2-0 and 4-0 memory structures, I/O structures and PADS. System design including structural, hierarchy, regularity, modularity, and programmable gate arrays. RTL synthesis, layout and placement, design capture tools, including schematic Prerequisite: [16.317](#).

16.563 System Programming

System programming structures with emphasis on re-entrant programming and pure procedures. Nested calls, push-down stacks and queues. Re-entrant interrupt programming, activation records and program sharing. Memory allocation by absolute and relocatable loaders. Macro languages, processes and assemblers. Prerequisite: [16.317](#).

16.565 Analog Devices and Techniques

A survey of analog devices and techniques, concentrating on operational amplifier design and applications. Operational amplifier design is studied to reveal the limitations of real op-amps, and to develop a basis for interpreting their specifications. Representative applications are covered, including: simple amplifiers, differential and instrumentation amplifiers, summers, integrators, active filters, nonlinear circuits, and waveform generation circuits. A design project is required. Prerequisite: [16.366](#).

16.568 Electro Optic Systems

Introduction to physical optics, wave propagation, interference, diffraction, and polarization, guide-wave optics: 2D and 3D optical waveguide, mode dispersion, group velocity and group velocity dispersion, mode-coupling theory, Mach-Zehnder interferometer, directional coupler, taps and WDM coupler, passive and active optical

waveguide devices, electro-optics, index tensor, electro-optic effect in crystal, electro optic coefficient, Electro-optical modulators, Photonic switches and all optical switches, light emission, absorption and photon density of states, fiber optical amplifiers. Pre-requisite: 16.360.

16.571 Radar Systems

Introduction to both pulsed and C. W. radar systems. The radar equation and its use in estimating performance of a radar system. Estimation of range, direction and velocity of targets. Detection of radar echoes in noise. Range and Doppler resolution. Basics of Tracking systems. A final project is required in the course. Prerequisites: 16.362, 16.363, and [16.461](#) or Permission of Instructor.

16.572 Embedded Real-Time Systems

Design of embedded real-time computer systems. Polled vs. interrupt-driven input/output. Writing interrupt handlers. Types of real-time systems, including foreground/background, non-preemptive multitasking, and priority-based pre-emptive multitasking systems. Soft vs. hard real-time systems. Task scheduling algorithms and deterministic behavior. Task synchronization and inter-task communication including: semaphores, mutexes, mailboxes, and message queues. Deterministic memory management schemes. Application and design of a real-time kernel. A project is required. Prerequisites: [16.216](#), [16.317](#), and [16.322](#) or Permission of Instructor.

16.573 Operating Systems and Kernel Design for Computer Engineers

Covers the components, design, implementation, and internal operations of computer operating systems. Topics include basic structure of operating systems, Kernel, user interface, I/O device management, device drivers, process environment, concurrent processes and synchronization, inter-process communication, process scheduling, memory management, deadlock management and resolution, and file system structures. laboratories include examples of components design of a real operating systems. Prerequisite: [16.216](#) or Programming Skills.

16.574 Advanced Logic Design

Error detection and correction codes. Minimization of switching functions by Quine- McCluskey (tabular) methods. Minimization of multiple-output circuits. Reed-Muller polynomials and exclusive-OR circuits. Transient analysis of hazards. Hazard-free design. Special properties of switching algebra. Programmable logic devices. Analysis and synthesis of fundamental-mode and pulsed-mode sequential circuits. Test sets and design for testability. Prerequisite: [16.265](#).

16.575 Field Programmable Gate Array Logic Design Techniques

This course presents advanced logic design techniques using FPGAs, PLDs, PALs, and other forms of reconfigurable logic. Architectural descriptions and design flow using Verilog and VHDL will be covered as well as rapid prototyping techniques, ASIC convergence, in-system programmability, and case studies highlighting the tradeoffs involved in designing digital systems with programmable devices. Prerequisite: [16.265](#) or Equivalent.

16.576 Principles of Solid-State Devices

Introduces the principles of Solid State Devices. Crystal properties and growth of semiconductors, atoms and electrons, Bohr's model, quantum mechanics, bonding forces and energy bands in solids, charge carriers in semiconductors, drift of carriers in electric and magnetic fields, carrier lifetime and photoconductivity, junctions,

forward and reverse bias, reverse bias breakdown (Zener effect), tunnel diodes, photodiodes, LED, bipolar junction transistors, field effect transistors. A design project is included in the course. Prerequisite: [16.365](#).

16.577 Verification of Very Large Digital Designs

The increasing complexity of digital designs coupled with the requirement for first pass success creates a need for an engineered approach to verification. This course defines the goals for the verification, presents techniques and applications, and develops a framework for managing the verification process from concept to reality. Prerequisite: [16.574](#) or Equivalent.

16.581 Computer Vision and Digital Image Processing

Introduces the principles and the fundamental techniques for Image Processing and Computer Vision. Topics include programming aspects of vision, image formation and representation, multi-scale analysis, boundary detection, texture analysis, shape from shading, object modeling, stereo-vision, motion and optical flow, shape description and objects recognition (classification), and hardware design of video cards. AI techniques for Computer Vision are also covered. Laboratories include real applications from industry and the latest research areas. Prerequisites: [16.216](#) or [16.322](#), [16.362](#) or Permission of Instructor.

16.582 Wireless Communications

Cellular systems and design principles, co-channel and adjacent channel interference, mobile radio propagation and determination of large scale path loss, propagation mechanisms like reflection, diffraction and scattering, outdoor propagation models, Okumura and Hata models, small scale fading and multipath, Doppler shift and effects, statistical models for multipath, digital modulation techniques QPSK, DPSK, GMSK, multiple access techniques, TDMA, FDMA, CDMA, spread spectrum techniques, frequency hopped systems, wireless systems and worldwide standards. Prerequisite: [16.360](#), [16.363](#).

16.583 Network Design: Principles, Protocols and Applications

Covers design and implementation of network software that transforms raw hardware into a richly functional communication system. Real networks (such as the Internet, ATM, Ethernet, Token Ring) will be used as examples. Presents the different harmonizing functions needed for the interconnection of many heterogeneous computer networks. Internet protocols, such as UDP, TCP, IP, ARP, BGP and IGMP, are used as examples to demonstrate how internetworking is realized. Applications such as electronic mail and the WWW are studied. Topics include: inter-network architectures, high speed network service protocol implementation, addressing and address mapping, intra- and inter-domain routing, multicasting, mobility, auto-configuration, resource allocation, transport protocols, naming, client-server model, network programming interfaces (e.g., sockets, RMI, RPC, CORBA), secure transport protocols for high-speed networks and applications. Prerequisite: [16.216](#) or Programming Skills.

16.584 Probability and Random Processes

Sample space, Field and Probability Measure. Axiomatic definition of Probability. Bayes' theorem. Repeated trials. Continuous and discrete random variables and their probability distribution and density functions. Functions of random variables and their distribution and density functions. Expectation, variance and higher order moments. Characteristic and generating functions. Vector formulation of random variables and their parameters. Mean square estimation and orthogonality principle. Criteria for estimators. Introduction to random processes: distribution and density functions; Ensemble and time averages; correlation functions and spectral densities.

Classification of random processes. Random processes through linear systems. Wiener filters and Kalman filters. Simulation of random variables and hypothesis tests. Prerequisite: [16.362](#).

16.586 Stochastic Modeling in Telecommunications

Discrete and Continuous time Markov Chains; Chapman-Kolmogorov Equation. Kolmogorov Forward and Backward equations; Poisson, Birth, Birth-Death processes. Diffusion processes; Wiener Process; Renewal processes. Fluid approximations; Introduction to rare event analysis and large deviations; AR and ARMA time series models and applications in basic telecommunications systems including traffic forecasting, and queue modeling: Prerequisite: [16.584](#) or equivalent.

16.590 Fiber Optic Communications

Optical fiber; waveguide modes, multimode vs. single mode; bandwidth and data rates; fiber losses; splices, couplers, connectors, taps and gratings; optical transmitters; optical receivers; high speed optoelectronic devices; optical link design; broadband switching; single wavelength systems; wavelength division multiplexing; fiber amplifiers. Prerequisites: [16.360](#) and [16.362](#) or Permission of Instructor.

16.593 Industrial Experience

This no credit course is for co-op or industrial experience.

16.595 Solid-State Electronics

Topics included are physical limits of microminiaturization, metal semiconductor junctions, p-n junction diodes, (rectifiers, varactors, tunnel diodes and photodetectors and solar cells); bipolar junction transistors, field effect transistors (junction FET, MESFET, MOSFET); heterojunction devices and high speed devices; quantum dots, wires and two dimensional quantum well devices, light emitting devices; flat panels, liquid crystals and hot electron emitters. Prerequisite: [16.523](#) or Permission of Instructor.

16.606 High Speed Semiconductor Devices

Materials technologies for high speed devices, ideal semiconductors and fabrication technologies; electric field and current transport, electrons in strong electric field, tunneling, space charge limited current, hot electrons, shape of field in channel; device building blocks, symmetric n-i-n structure, inversion layers, quantum wells. The following devices will be described: submicron MOSFETs, SOI-MOSFETs, short channel MESFETs, the permeable base transistor, heterojunction transistors, single electron transistor and high speed photonic devices. Prerequisite: Permission of Instructor.

16.607 Electromagnetics of Complex Media

Continuation of 16.507 dealing with more current research topics on complex materials. Special emphasis on time-varying media. Prerequisite: [16.507](#) or equivalent.

16.612 Converged Voice and Data Network

Covers the technologies and protocols used to transport voice and data traffic over a common communication network, with emphasis on voice over IP (VoIP). The specific topics covered include voice communication network fundamentals, data networking fundamentals, voice packet processing, voice over packet networking, ITU-T VoIP

architecture, IETF VoIP architecture, VoIP over WLAN, access networks for converged services: xDSL and HFC networks, and IP TV service. Prerequisite: [16.546](#) or Permission of Instructor.

16.613 Nonlinear Systems Analysis

Roots of polynomials. Zeros and stationary points of single variable functions. Gradient, Quasi-Newton and conjugate gradient methods of constrained optimization. Approximation methods for ordinary and partial non-linear differential equations. Stability and the methods of Lyapunov. Prerequisite: [16.520](#).

16.614 Optimal Control Theory

Deterministic optimal control systems. Performance measures for optimal systems. Dynamic programming and related computer techniques. Discrete linear regulator. The Hamilton-Jacobi-Bellman equation. Continuous linear regulator. Calculus of variations and Pontryagin's minimum principle. Minimum time problems. Minimum effort problems. Prerequisites: [16.509](#) and [16.513](#).

16.615 Solid State Drive Systems

Elements of variable speed drive systems. Rectifier and chopper control of DC drives. Control of induction motors by AC voltage controllers. Frequency-controlled induction motor drives. Slip-power controlled wound-rotor induction motor drives. Synchronous motor speed control. Prerequisite: [16.515](#).

16.616 Computational Power System Analysis

Power system matrices, power flow studies, fault studies, state estimation, optimal power dispatch, and stability studies. Prerequisites: [16.443](#) and [16.520](#).

16.617 Modeling and Simulation Techniques for Communication Networks

Overview of general architectures for broadband networks. Performance requirements, traffic management strategies, usage parameter control, connection admission control and congestion control. Stochastic processes models for voice, video and data traffic: Poisson processes, Markov chains and Markov-modulated processes; Queuing analysis: M/M/1, M/M/m, M/G/1 queues, fluid buffer models, effective bandwidth approaches; Simulation and computational modeling: discrete event simulation of transport and multiplexing protocols, statistical techniques for validation and sensitivity analysis. Prerequisite: [16.584](#) and Basic Programming Skills or Permission of Instructor.

16.618 Performance of Wireless Communications Networks

Introduction to fundamental concepts for resource management and performance evaluation of wireless communication networks. Performance of different access and modulation schemes in the presence of channel impairments. Techniques for modeling multipath and fading channels; Simulation and numerical approaches for generating fading signals and wireless link performance analysis; Methods for mitigating the influence of channel induced signal degradations using equalization, forward error control and feed-back control Prerequisites: Background in linear systems ([16.509](#)), stochastic processes ([16.584](#) or equivalent) and some experience in programming or Permission of Instructor.

16.650 Advanced Computing Systems Hardware Architecture

Covers the latest advanced techniques in CPU design, floating point unit design, vector processors, branch prediction, shared memory versus networks, scalable shared memory systems, Asynchronous shared memory algorithms, systems performance issues, advanced prototype hardware structures, and future trends including TeraDash systems. Prerequisite: [16.561](#).

16.652 Parallel and Multiprocessor Architectures

Study of principles of parallel processing and the design of hardware and software parallel computer architectures for a variety of models, including SIMD, MIMD. It also presents the issues related to designing and programming tightly-coupled shared-memory multiprocessor systems at the hardware level. Issues of memory structure, snoopy and directory-based caching, embedded memory consistency, cache controller coherency, processor interconnect strategies, and multiprocessor scalability, synchronization primitives, task scheduling, and memory allocation are covered. Prerequisites: [16.480](#) or [16.552](#) and [16.561](#).

16.653 Artificial Intelligence and Machine Learning

Study of automated reasoning; representing change and the effects of actions; problem solving and planning. Includes the development of working programs that search, reason, and plan intelligently. Controlling physical mobile robot systems that operate in dynamic, unpredictable environments is covered. Building smart embedded chips for machine learning. Also covers neural networks, Fuzzy logic, genetic Algorithms and other approaches to machine learning. Prerequisites: [16.216](#) or Programming Skills and [16.322](#).

16.656 Fault Tolerant Systems Design

Covers the design and analysis of Fault-Tolerant Systems (hardware and software levels). Redundancy techniques are used for the creation of hardware redundancy, and information redundancy. Topics include: hardware and software architecture of faulttolerant computers, fault tolerance through dynamic or stand-by redundancy, fault detection in multiprocessors, fault detection through duplication and comparison, fault detection using diagnostics and coding techniques, recovery strategies for multiprocessor systems, rollback recovery using hardware checkpoints and control digital logic for processor-cache-based checkpoints. Prerequisite: [16.561](#) or [16.650](#).

16.657 High-Speed Integrated Networks: Design and Evaluation

Covers the design of high-speed multi-service networks, including gigabit networks. Hardware and software fundamentals for high-speed routers, bridges and gateways of emerging network technologies, including multimedia networks are covered. Topics include: High-speed real-time transport protocols, quality-of-service designs, latest hardware embedded systems for efficient routing algorithms, and compression. Wireless communication information networks and personal communications systems including mobile data networks are covered. Laboratories include the usage of high speed CISCO, ATM, and Myrinet switches and Network OOD and OOP and JAVA Network. Prerequisites: [16.216](#) or Programming Skills, [16.546](#), and [16.583](#).

16.658 Computer Network Security

This three credit course covers the fundamentals of data network security. The concepts of data security will be examined through different algorithms. Different concepts on cryptographic systems (software and hardware) are classified. Different attacks on cryptographic systems are classified. Pseudo-random generators are introduced. The concepts of public and private key cryptography are developed. DES, IDEA, and AES are described as important

representatives for private key schemes. The RSA and ElGamal public key schemes and systems based on elliptic curves are then developed. Signature algorithms, hash functions, key distribution, and identification schemes are treated as advanced topics. Some advanced mathematical algorithms for attacking cryptographic schemes are discussed. New methods for efficient hardware implementation of high-speed embedded systems are investigated, e.g. smart cards, cryptographic processors and co-processors, special-purpose hardware for cryptanalysis, DSP chips, etc. Prerequisite: Permission of Instructor.

16.659 Distributed Systems

Covers principles of distributed systems, fundamentals of distributed computing models. The concepts of distributed file and directory services, distributed systems hardware and software design are studied. Topics include implementation of DS issues, reliability and availability, and fault tolerance. System bus structure for distributed systems, and design and implementation of the hardware distributed shared memory are studied. It also addresses logical synchronization and clock synchronization, resource allocation, self-stabilization of network protocols, graph partitions. Laboratories includes implementation of distributed systems (hardware and software) PVM, MPI and JINI. Prerequisites: [16.216](#) or Programming Skills and [16.583](#) or [16.713](#).

16.660 Mobile IP and Networking

Covers the fundamentals of mobile data communications. Introduces state-of-the-art mobile network architectures (Hardware and Software). Addresses an overview of wireless networks. Topics include architecture of existing mobile data networks: ARDIS, Mobitex, TETHRA, Meticom, CDPD and GPRS, wireless LAN technologies: 802.11, HIPERLAN, and wireless ATM. Studies the effects of mobility on different ISO layers, physical layer options, MAC layer in mobile environment, issues in mobile computing, mobile IP and DHCP. It also addresses mobility gateway technologies: MASE and eNetwork, inter-tech roaming and handover for wireless data networks. Laboratories include software tools for simulation of hardware Mobile networks. Prerequisite: [16.583](#).

16.661 Local Area Computer Networking

Characteristics and topology of Local Area Networks(LANs), WANs and MANs. Design of cable plants based on coaxial as well as fiber optic technologies. Data communication including transmission, reception, bandwidth, error correction and detection. LAN architecture with its layers. Applications TCP/IP, FTP, SMTP, TELNET, TFTP, HTML, HTTP and RTP. Addressing, sub-netting and CIDR. Design of ATM networks including addressing and end-to-end services with constant and variable bit rate. Communication links and their characteristics including digital links, frequency and propagation, distortion, dispersion and noise. Security and compression including threats against computers and users. Cryptography including secret and public key algorithms. Security systems with integrity and key management including Kerberos. PGP and Lempel-Ziv compression techniques. Prerequisite: [16.561](#) or [16.563](#) or Permission of Instructor.

16.662 Microprogramming

Horizontal and vertical microprogramming structures including finite state machine controllers. Implementation of digital functions as firmware on microprocessors. Register transfer assemblers. State partitioning and optimization. Micro-instruction set design and design of microprogrammed data paths. Prerequisites: [16.561](#) and [16.574](#).

16.663 Compiler Structures

Translators and interpreters for programming languages. Syntax of programming languages; syntax directed compilation. Parsing techniques: operator precedence, top down, bottom up and reductive strategies. Generation

and optimization of machine code. Error handling: detection and correction. The run time environment, storage allocation. Prerequisite: [16.322](#).

16.666 Storage Area Networks

Introduces the network storage landscape, data flood and fluid data, data storage on open systems servers. SCSI systems servers and their limitations, volume managers and device drivers, software mirroring over LAN and WAN, caches in storage networks are covered. We investigate boosting availability and performance with RAID and disk Subsystems. SAN design, building better backup systems with SANs, fibre channel networking technology for storage networks (point-to-point, loop, fabrics), distributed intelligence data sharing in the SAN, plug and play storage with NAS are also covered. Applications include comparison of SAN and SAN technologies, mapping SCSI-3 (FCP), IP, VIA, HIPPI, IEEE 802.2, 802.3, 803.5, SBCCS, AAL5 of ATM and FICON protocols to fibre channel. Laboratories include the usage of SAN protocols at the hardware and software levels. Prerequisite: [16.583](#).

16.669 Optoelectronic Devices

This course will discuss: Semiconductor energy band diagrams, PN junction principles, LED principles and device structures, Heterojunctions, Semiconductor Lasers, Quantum Wells, VCSELs, PIN photodiode, Avalanche Photodiode, Electro-absorption modulators. Prerequisites: 16.474 or 16.576 or 16.523 and 16.595.

16.684 Time Series Analysis and Forecasting With Applications

Review of Estimation of Stochastic processes: Estimation of mean, variance, autocovariance, autocorrelation and normalized autocovariance of discrete stochastic processes; Generation of White Noise Sequences and tests for white noise; Difference operations. Linear Stationary models: Autoregressive (AR) processes, Yule-Walker equations, partial correlation. Moving Average (MA) processes, invertibility conditions and solution for MA parameters; Relation between AR and MA processes; Autoregressive Moving Average (ARMA) processes, formulation and solution for ARMA parameters. Levinson-Durbin and related algorithms: Deterministic and Probabilistic Methods; Forward-Backward Prediction; Lattice Methods. Gram-Schmidt Orthogonalization method; Burg Algorithm. Linear nonstationary Models: Autoregressive Integrated moving Average processes, differencing to induce stationarity and determination of the order of differencing. Model Identification and Diagnostic Checking: Examples for model identification; Portmanteau test and other tests for residuals to check for white noise. forecasting: Several methods for forecasting; Box- Jenkins forecasting functions, three types; Examples for the three types of forecasting; One-step linear predictors and confidence limits. Seasonal Time Series: Formulation of seasonal time series models and basic ideas of forecasting. Prerequisite: [16.584](#).

16.685 Statistical Communication Theory

Chebyshev and Chernoff bounds. Statistics of random processes (RP) through linear systems. Concepts of entropy, information and channel capacity. Gaussian white noise. Concepts of signal space. Periodic RP. Aperiodic RP and Karhunen-Loeve expansion. Narrow-band Gaussian processes. Continuous-time matched filters. Discrete-time matched filters, discrete Wiener filter. Characterization of signal waveforms. Optimum demodulation of known and random signals in additive Gaussian white noise. Comparison of digital signaling methods. Optimization criteria: maximum a posteriori (MAP), maximum likelihood (ML). Discussion of maximum a posteriori and maximum likelihood receivers Elimination of intersymbol interference without and with Gaussian Noise. Optimization of equalizer coefficients: peak distortion criterion and mean square error criterion, Decision-Feedback equalization. LMS algorithm. Discussion of algorithms for adaptive equalization: recursive least squares, linear prediction and lattice filter. Prerequisites: [16.509](#) and [16.584](#) or Permission of Instructor.

16.687 Applied Stochastic Estimation

Review of random processes and key elements of probability theory. State space description of systems and random processes, relation to frequency domain techniques. Numerical methods of continuous and discrete time random system modeling. Optimal Kalman filtering for discrete and continuous random systems. Sensitivity analysis. Design considerations in the face of model uncertainty, numerical instabilities, bad data. Optimal smoothing. Non linear filtering. Parameter identification. Applications throughout. Prerequisite: [16.584](#).

16.688 Theoretical Acoustics

Fundamental equations: elasticity and fluid equations. Linear Acoustics: equations of fluid at rest, transmission, reflection and propagation of planar waves, radiation of sound, scattering and diffraction of sound, acoustic waveguides and rooms. Acoustics in inhomogeneous media: sheared mean flow, varying sound speed. Nonlinear Acoustics: shock waves, nonlinear viscous effects. Prerequisite: Permission of Instructor.

16.690 Advanced Robotics Automation and Machine Intelligence

Covers advanced foundations and principles of robotic manipulation; includes the study of advanced robot motion planning, task level programming and architectures for building perception and systems for intelligent robots. Autonomous robot navigation and obstacle avoidance are addressed. Topics include computational models of objects and motion, the mechanics of robotic manipulators, the structure of manipulator control systems, planning and programming of robot actions. Components of mobile robots, perception, mechanism, planning, and architecture; detailed case studies of existing systems. Prerequisite: [16.556](#).

16.692 Directed Studies

Provides an opportunity to get a specialized or customized instruction in consultation with a faculty member. This course is not intended as a vehicle for research projects. It may only be taken in the last semester of a student's Masters program. This course is intended only for Masters students and can only be taken once. Documentation is required and must be approved by the ECE Graduate Coordinator (who will provide a permission number). The documentation must include the course syllabus, frequency and time/date of meetings, grading policy, and expectations of the instructor.

16.710 Selected Topics I in Electrical and Computer Engineering

Advanced topics in various areas of electrical engineering and related fields. Prerequisite: specified at time of offering. Prerequisite: Permission of Instructor.

16.711 Selected Topics II in Electrical and Computer Engineering

Advanced topics in various areas of Computer Engineering and related fields. Prerequisite: specified at time of offering. Prerequisite: Permission of Instructor.

16.725 Selected Topics III in Electrical and Computer Engineering

Advanced topics in various areas of Computer Engineering and related fields. Prerequisite: specified at time of offering. Prerequisite: Permission of Instructor.

16.729 Selected Topics IV in Electrical and Computer Engineering

Advanced topics in various areas of Computer Engineering and related fields. Prerequisite: specified at time of offering. Prerequisite: Permission of Instructor.

16.733 Advanced Graduate Project

The Advanced Project is a substantial investigation of a research topic under the supervision of a faculty member. A written proposal must be on file in the Electrical Engineering Graduate Office before enrollment. A written report is required upon completion of the project. However, this course is graded only on a Pass or Fail basis and hence will not factor in the CGPA. It can be taken only once, and may evolve into a master's thesis. Prerequisite: Permission of Instructor and filing of a graduate project agreement signed by the student and the instructor with the ECE Department Office.

16.743 Master's Thesis Research 3 credits

16.746 Master's Thesis Research 6 credits

16.749 Master's Thesis Research 9 credits

Requirements for 16.743, 16.746, and 16.749:

A student cannot register for more than a total of three credits in his/her Masters degree program before completing two 3.0-credit Electrical and Computer Engineering graduate courses. Prerequisite: Permission of Instructor, thesis advisor, and filing of a thesis agreement signed by the student and the instructor thesis advisor with the Electrical and Computer Engineering Department office.

16.753 Doctoral Dissertation Research 3 credits

16.756 Doctoral Dissertation Research 6 credits

16.759 Doctoral Dissertation Research 9 credits

Requirements for 16.753, 16.756, and 16.759:

Prerequisites: Written approval by the dissertation advisor; matriculated status in the doctoral program in ECE. No more than 9 credits of doctoral dissertation research may be taken before passing the doctoral qualifying examination. No more than 15 credits of doctoral dissertation research may be taken before passing the defense of the thesis proposal examination. Prerequisite: Permission of Instructor, dissertation advisor, and filing of a dissertation agreement signed by the student and the instructor dissertation advisor with the Electrical and Computer Engineering Department office.

16.763 Continued Graduate Research 3 credits

16.766 Continued Graduate Research 6 credits

16.769 Continued Graduate Research 9 credits

Requirements for 16.763, 16.766, and 16.769:

Students who do not meet the requirement of 16.743, 16.746, 16.749, 16.753, 16.756, or 16.759 for theses or dissertations may register for 16.763, 16.766, or 16.769. The credits count toward their degree programs. Prerequisite: Permission of thesis/dissertation advisor.