

Department of Electrical and Computer Engineering

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Graduate Programs

The Department of Electrical and Computer Engineering offers the degree of Master of Engineering (ME) in Electrical and Computer Engineering, and the degree of Doctor of Philosophy (PhD) in Electrical and Computer Engineering.

Master of Engineering in Electrical and Computer Engineering

The department offers the following graduate programs, all leading to the Master of Engineering in Electrical and Computer Engineering (ME in ECE) degree:

- ECE Thesis Program
- ECE Non-thesis Program
- Information and Communications Technology Program (EICT)

All programs must satisfy either the thesis program requirements or the non-thesis program requirements. The program is indicated on the student's transcript.

Requirements

All relevant requirements and regulations of the University and the Faculty of Engineering and Architecture for the master's degree apply to the ME in ECE programs.

- In order to be eligible for admission, a student must have a bachelor's degree from an accredited university.
- Students, whose undergraduate degree is in an area other than engineering and students whose undergraduate degree is a three-year degree, are considered prospective graduate students.
- Applicants to the graduate programs must sit for the GRE general test.
- Students applying to the thesis programs are normally interviewed by members of the ECE Graduate Committee, and are asked to provide a statement of research describing their experience and research interests.

ECE Thesis Program Requirements

Thirty (30) credit hours: 24 course credit hours and 6 thesis credit hours:

- a minimum of 21 credits in graduate courses
- a minimum of 18 credits in ECE courses
- a minimum of 9 graduate credits in the major area
- a minimum of 6 graduate credits in the minor area
- 6 credits for master's thesis
- the seminar course

ECE Non-Thesis Program Requirements

Thirty-three (33) credit hours in graduate courses:

- a minimum of 12 graduate credits in the major area
- a minimum of 6 graduate credits in the minor area
- a minimum of 24 credits in ECE courses
- the seminar course

Information and Communications Technology Program

The Information and Communications Technology (EICT) Program is consistent with the requirements for the ME in ECE thesis program, and consists of 30 credits distributed as follows:

- 15 credits in core courses
- 9 credits in elective courses
- an internship (no credits) with a minimum duration of 10 weeks and a maximum duration of six months
- 6 credits for the master's thesis
- the seminar course

The courses are divided into three areas: software systems, telecommunications, and business/management. The 15-credit core courses should satisfy the following conditions:

- 6 credits in software systems selected from a set of core courses
- 6 credits in telecommunications selected from a set of core courses
- 3 credits in business/management selected from a set of core courses

The 9-credits in elective courses should satisfy the following conditions:

- one regular 3-credit course from either the software systems elective pool or the telecommunications elective pool
- one regular 3-credit course from the business/management elective pool
- the remaining 3 credits consist of one graduate level lab course and two technical special courses

All elective courses should be taken from the three defined pools of elective courses (software systems pool, telecommunications pool, and business/management pool).

Core Courses

- **Software Systems:** EECE 625, EECE 630, EECE 635, EECE 654
- **Telecommunications:** EECE 640, EECE 643, EECE 651, EECE 653, EECE 655
- **Business/Management:** DCSN 330, INFO 300, INFO 310

Elective Courses

- **Software Systems:** EECE 625, EECE 630, EECE 631, EECE 632, EECE 634, EECE 635, EECE 652, EECE 654
- **Telecommunications:** EECE 640, EECE 641, EECE 642, EECE 643, EECE 644, EECE 645, EECE 646, EECE 647, EECE 651, EECE 653, EECE 655, EECE 656, EECE 680, EECE 681
- **Business/Management:** DCSN 330, INFO 300, INFO 310, INFO 315, INFO 320, MKTG 306, ENMG 654, ENMG 656, ENMG 657
- **Lab courses:** EECE 640L, EECE 651L, EECE 691L

Master's Degree—Major and Minor Areas

The major and minor areas for the ME in ECE programs are shown below, with their corresponding courses.

Applied Electromagnetics and RF Systems

Core Graduate Courses

- EECE 613: RF and Microwave Circuits for Communications
- EECE 643: RF System Engineering for Wireless Communications
- EECE 680: Antenna Theory and Design
- EECE 682: Time-Harmonic Electromagnetic Fields

Elective Graduate Courses

- EECE 681: Advanced Antenna Design
- EECE 683: Numerical Methods in Electromagnetics

Biomedical Engineering

Core Graduate Courses

- EECE 601: Biomedical Engineering I
- EECE 603: Biomedical Signal and Image Processing

Elective Graduate Courses

- EECE 401: Biomedical Engineering Seminar
- EECE 602: Biomedical Engineering II
- EECE 605: Neuroengineering I
- EECE 661: Robotics
- MECH 633: Biomechanics
- MECH 634: Biomaterial and Medical Devices

Communications

Core Graduate Courses

- EECE 640: Wireless Communications
- EECE 640L: Wireless Communications Laboratory
- EECE 641: Information Theory
- EECE 646: Advanced Digital and Data Communications

Elective Graduate Courses

- EECE 604: Communications Engineering for Genetics and Bioinformatics
- EECE 642: Introduction to Coding Theory
- EECE 643: RF System Engineering for Wireless Communications
- EECE 644: Stochastic Processes, Detection, and Estimation
- EECE 645: The UMTS Cellular System

Relevant Graduate Courses

- EECE 622: VLSI for Communications and Signal Processing
- EECE 647: Queuing Theory
- EECE 654: Pervasive Computing Systems and Applications
- EECE 656: Mobile Ad hoc and Sensors Networks
- EECE 680: Antenna Theory and Design
- EECE 695: Adaptive Filtering

Computer Architecture and VLSI Circuits

Core Graduate Courses

- EECE 611: Introduction to Analog VLSI Systems
- EECE 616: Advanced Digital Integrated Circuits
- EECE 621: Advanced Computer Architecture

Elective Graduate Courses

- EECE 613: RF and Microwave Circuits for Communications
- EECE 615: Computer Methods for Circuit and System Analysis
- EECE 622: VLSI for Communications and Signal Processing
- EECE 623: Reconfigurable Computing
- EECE 624: Digital Systems Testing
- EECE 625: Embedded Systems Design

Control and Intelligent Systems**Core Graduate Courses**

- EECE 461: Instrumentation
- EECE 660: System Analysis and Design

Elective Graduate Courses

- EECE 661: Robotics
- EECE 662: Optimal Control
- EECE 663: System Identification
- EECE 665: Adaptive Control

Energy and Power Systems**Elective Graduate Courses**

- EECE 670: Power System Planning
- EECE 671: Environmental Aspects of Energy Systems
- EECE 672: Energy Planning and Policy
- EECE 673: Power Electronics Systems and Applications
- EECE 675: Renewable Energy Systems
- EECE 677: Electric Power System Operation and Control
- EECE 678: Advanced Power System Analysis

Relevant Graduate Courses

- EECE 660: System Analysis and Design
- EECE 662: Optimal Control
- EECE 664: Fuzzy Sets, Logic and Applications
- EECE 665: Adaptive Control
- EECE 667: Pattern Recognition

Networks**Core Graduate Courses**

- EECE 651: Internet Engineering
- EECE 653: Multimedia and Networking
- EECE 656: Mobile Ad hoc and Sensor Networks

Elective Graduate Courses

- EECE 647: Queuing Theory
- EECE 655: Internet Security
- EECE 657: Wireless Security
- EECE 632: Cryptography and Computer Security

Relevant Graduate Courses

- EECE 630: Distributed and Object Database Systems
- EECE 640: Wireless Communications
- EECE 652: Web Server Design and Programming
- EECE 654: Pervasive Computing Systems and Applications

Signal and Image Processing**Core Graduate Courses**

- EECE 603: Biomedical Signal and Image Processing
- EECE 691: Digital Signal Processing
- EECE 694: Digital Image Processing
- EECE 695: Adaptive Filtering

Elective Graduate Courses

- EECE 667: Pattern Recognition
- EECE 693: Neural Networks

Relevant Graduate Courses

- EECE 644: Stochastic Processes, Detection, and Estimation
- EECE 663: System Identification

Software Systems**Software Engineering**

- EECE 631: Advanced Topics in Algorithms
- EECE 635: Advanced Software Engineering
- EECE 637: Advanced Programming Practice
- EECE 638: Software Testing

Intelligent Systems

- EECE 630: Distributed and Object Database Systems
- EECE 633: Data Mining
- EECE 639: Advanced Techniques and Applications in Data Mining

Computational Systems

- EECE 632: Cryptography and Computer Security
- EECE 634: Optimizing Compilers
- EECE 652: Web Server Design and Programming

Mobile Computing

- EECE 625: Embedded Systems Design
- EECE 654: Pervasive Computing Systems and Applications
- EECE 656: Mobile Ad hoc and Sensor Networks
- EECE 657: Wireless Security

PhD in Electrical and Computer Engineering

Mission

The mission of the doctoral program is to provide high quality education in electrical and computer engineering which prepares students for employment and leadership roles in academic, industrial, or research positions.

Objectives

The objectives of the program are to

- provide the student with the research opportunities to acquire a depth of knowledge in one specialization area of electrical and computer engineering, and familiarity with allied areas;
- provide opportunities for the doctoral student to develop competence in performing independent research, communicating effectively, and learning independently;
- advance the state of electrical and computer engineering research at AUB, in Lebanon, and the region;
- and advance the state of the art in electrical and computer engineering.

Program Outcomes

Graduates of the program are expected to have

- a breadth of knowledge in electrical and computer engineering, and a depth of knowledge in their specific area of research
- an ability to identify and define research problems
- experience in performing research and communicating the results effectively
- experience in doing independent academic work
- a published contribution to the existing knowledge in electrical and computer engineering

Admission Requirements

Applicants to the PhD program must hold a master's degree in electrical and computer engineering or in a related discipline from AUB or another recognized institution of higher education, with a minimum cumulative average of 85.0 over 100 or its equivalent. Admission is determined by evaluating the following:

- Transcripts of academic record from the institution(s) of higher education attended by the applicant
- Graduate Record Examination (GRE) general test scores

- A written statement of purpose
- Three letters of recommendations
- A portfolio that includes a resume and samples of work
- An interview, conducted either in person, by phone, or over the Internet

All applicants must also satisfy the University requirements for admission to PhD programs.

Program Requirements

The completion of at least forty-eight (48) credits of graduate study consisting of combined course work and research beyond the master's degree is required for the PhD degree in Electrical and Computer Engineering. A minimum of eighteen (18) credits of course work and a minimum of eighteen credits (18) of research and thesis work are required.

The basic program of study for the PhD degree is built around one major area and a minimum of one minor area. Students take courses to satisfy the major and minor area requirements and to acquire the knowledge needed for the required written and oral examinations. Students should take at least six graduate courses, including courses prior to admission to the PhD program, in their PhD major area, which corresponds to one of the fields shown on page 256. Students should also take at least three graduate courses in their PhD minor area, including courses taken prior to admission to the PhD program. The minor courses may be taken in one of the ECE areas, or an area outside the ECE department, or a combination of courses taken in the department and outside the department that defines a minor area.

Each student must maintain an 85.0/100 cumulative average in order to remain in good standing. The cumulative average is calculated for courses taken beyond the master's degree. A student will be placed on probation if s/he fails a course (below 70), or her/his cumulative average falls below 85.0. A student has one semester to raise his/her cumulative average to 85.0 or better and has to repeat failed courses as soon as they are offered. Failure to do so will result in academic dismissal. A student cannot earn the PhD with a cumulative average below 85.0. The PhD Comprehensive Examination

After taking at least twelve credits of course work and mastering the knowledge defined in the PhD major area, students take a comprehensive written examination. The exam is given twice a year, at the end of the fall and spring semesters. Students are informed beforehand of the subjects that will be covered in the examination. Students who do not pass may repeat the exam only once, during the following semester. If the student does not pass the exam after his/her second attempt, the student will be asked to discontinue his/her PhD studies.

Students sit for two exams that together constitute the comprehensive examination: one in the major area, and one in the minor area. These two exams are taken separately at different times, but during the same examination period. The major area exam consists of six questions, out of which four questions should be answered in three hours. The minor area exam consists of six questions, out of which two questions should be answered in two hours. The area exams are prepared by the corresponding area faculty committee, and are designed to evaluate the student's understanding of the fundamentals in the area. Passing the comprehensive exam requires an average of no less than 80/100 with no less than 80/100 in the major area and no less than 70/100 in the minor area.

Dissertation Committee

The PhD dissertation committee is composed of at least four faculty members from the student's major area, recommended by the dissertation advisor and approved by the ECE Graduate Committee (EGC), FEA Graduate Studies Committee (GSC), and the Board of Graduate Studies (BGS). Changes in the committee, including the dissertation advisor, are possible with the approval of the EGC, FEA GSC, and BGS. It is advisable that the dissertation committee include one member from outside AUB. All committee members should hold professorial rank. The dissertation committee approves the dissertation topic and research agenda and conducts the oral qualifying examination, and the dissertation defense examination. The proposal of the dissertation topic and the selection of the members of the dissertation committee should be approved at least two semesters before the student defends the dissertation.

The PhD Dissertation Proposal and Oral Qualifying Examination

Within two semesters after passing the comprehensive examination, the student must take an oral qualifying examination, conducted by his/her dissertation committee. The defense of the PhD dissertation proposal is considered a part of the oral qualifying examination. In addition to reviewing the prospectus of the dissertation, the nature and the content of the examination are related to the student's field of research.

Admission to Candidacy

Students must be admitted to candidacy at least two semesters before obtaining the PhD degree. For admission to candidacy, students are expected to have:

- submitted a program approved by the dissertation committee, the EGC, the FEA GSC, and the BGS
- passed the oral qualifying examination
- completed at least 12 credits of graduate courses beyond the master's degree
- attained a cumulative average of at least 85.0 in all courses taken beyond the master's degree
- maintained good academic standing.

PhD Dissertation

The student must submit a dissertation based on the results of original, independent research. The PhD dissertation is expected to make a significant contribution in electrical and computer engineering. Upon completion of the dissertation and after its approval by the dissertation advisor, the dissertation must be defended orally.

Dissertation Defense

The dissertation defense is open to the public and must be scheduled no later than October 30, March 1, and June 10, for students who wish to graduate at the end of the fall, the spring semester, or the summer session respectively. "Pass" or "Fail" is reported for the combined dissertation and defense. If "Fail" is reported, the student may resubmit the dissertation and defend it after a period of at least three months. Failure on the second attempt results in the discontinuation of graduate work.

A student must be registered for the dissertation or at least one course in the session in which they expect to graduate.

Residence Requirements

A student must register for at least four semesters beyond the completion of the master's degree. Requirements for the PhD degree must be completed within a period of five years after starting graduate work beyond the master's degree. Extension beyond the five-year limit requires the approval of the EGC, the FEA GSC, and the BGS.

Seminar Requirement

A student must register for EECE 797: Seminar, as long as s/he is in the program.

Program Completion Requirements

To earn the PhD degree in electrical and computer engineering, the student must complete the following requirements:

- Have at least one journal paper, based on the PhD dissertation, accepted in a leading international journal in his or her field of specialty that requires at least two reviews. Additionally at least two refereed conference papers, based on the dissertation, must have appeared in conference proceedings.
- Have a cumulative average, beyond the master's degree, of 85.0 or above, and be in good academic standing.
- Satisfy the course and research credit requirements.
- Pass the comprehensive and oral qualifying examinations.
- Complete and successfully defend a PhD dissertation.
- Satisfy the residence requirement and all other pertinent AUB regulations.

PhD Major and Minor Areas

The PhD major and minor areas with their corresponding courses are the following:

- **Computer and Software Systems:** EECE 611, EECE 612, EECE 614, EECE 615, EECE 616, EECE 620, EECE 621, EECE 622, EECE 623, EECE 624, EECE 625, EECE 626, EECE 630, EECE 631, EECE 632, EECE 633, EECE 634, EECE 635, EECE 636, EECE 651, EECE 652, EECE 653, EECE 654, EECE 655, EECE 656, EECE 657.
- **Communications and Signal Processing:** EECE 603, EECE 604, EECE 622, EECE 640, EECE 641, EECE 642, EECE 643, EECE 644, EECE 645, EECE646, EECE 647, EECE 651, EECE 663, EECE 691, EECE 691L, EECE 693, EECE 694, EECE 695.
- **Control, Biomedical, and Intelligent Systems:** EECE 601, EECE 602, EECE 603, EECE 604, EECE 605, EECE 660, EECE 661, EECE 662, EECE 663, EECE 664, EECE 665, EECE 667, EECE 693
- **Electrical Energy Systems:** EECE 670, EECE 671, EECE 672, EECE 673, EECE 675, EECE 676, EECE 677, EECE 678.
- **Electromagnetics and RF Circuits and Systems:** EECE 611, EECE 613, EECE 643, EECE 680, EECE 681, EECE 682, EECE 683.

Courses

- EECE 401 Biomedical Engineering Seminar 1 cr.**
Biweekly seminars given by members of the Faculty of Engineering and Architecture or by guest speakers. The seminars cover a range of biomedical engineering topics of theoretical and professional interest. Students are required to submit an assignment based on each seminar, which will be graded. The seminar is required of all students taking the Biomedical Engineering Minor. *Prerequisite: EECE 601, or EECE 603, or MECH 633.*
- EECE 461 Instrumentation 3 cr.**
A design course for complete instrumentation systems, including measurements, sensors, data acquisition, and component integration. Application areas and course projects include industrial control, laboratory measurements, automation systems, and the like. This course is completed with a set of laboratory experiments. *Prerequisite: EECE 460.*
- EECE 601 Biomedical Engineering I 3 cr.**
This course includes an introduction to: general instrumentation configuration, performance of instrumentation systems; types and characteristics of transducers; sources and characteristics of bioelectric signals; types and characteristics of electrodes; temperature regulation and measurement; cardiovascular system, measurements, and diagnostic equipment; blood instruments; patient care and monitoring; and electrical safety of medical equipment. *Prerequisites: EECE 210 and BIOL 210.*
- EECE 602 Biomedical Engineering II 3 cr.**
This course covers the respiratory system and measurements; nervous system and measurements; sensory and behavior measurements; biotelemetry; instrumentation for the clinical laboratory; x-rays and radioisotope instrumentation; magnetic resonance; and special surgical techniques. *Prerequisite: EECE 601.*
- EECE 603 Biomedical Signal and Image Processing 3 cr.**
A course that introduces the fundamentals of digital signal processing as implemented in biomedical applications. It provides a concise treatment of the tools utilized to describe deterministic and random signals as the basis of analyzing biological signals: data acquisition; imaging; denoising and filtering; feature extraction; modeling. The course is tightly coupled with a practical component as it looks at and assigns several laboratory projects. Examples include the auditory system, speech generation, electrocardiogram, neuronal circuits, and medical imaging. Students should have reasonable software skills in Matlab. *Prerequisites: BIOL 210 and STAT 230, or equivalent.*
- EECE 604 Communications Engineering 3 cr.**
for Genetics and Bioinformatics
This course presents current research efforts in the emerging interdisciplinary field of communications engineering for genetics and bioinformatics. It shows how concepts and techniques from the field of communications engineering can be applied to central problems from the fields of genetics and bioinformatics. As a basic analogy, voice information is digitized, transmitted, and processed in communications, and DNA information is replicated, transmitted, and processed in genetics. The main topics covered include DNA compression, mutual information for functional genomics, channel coding for gene expression, genomic signal processing, and biological computation.
- EECE 605 Neuroengineering I 3 cr.**
A course that focuses on the importance of biological systems from the engineering viewpoint; living cells and mechanisms; introduction to the nervous system; the resting membrane potential; generation and propagation of the action potential; motor systems; synaptic transmission; control of movement. *Prerequisite: BIOL 210 or consent of instructor.*

EECE 611 Introduction to Analog VLSI Systems 3 cr.

This course covers an introduction to digital electronic circuits; models, current equations and parasitic of CMOS transistors for digital design; study of CMOS inverter and logic gates, including analysis, design, simulation, layout and verification; advanced circuit styles; sequential circuits; advanced topics: semiconductor memories, power grid, clocking strategies, datapath building blocks, deep-submicron design issues, and interconnect. *Prerequisites: EECE 310 and EECE 320.*

EECE 612 Digital Integrated Circuits 3 cr.

A course on digital electronic circuits; models, current equations, and parasitics of CMOS transistors for digital design; study of CMOS inverter and logic gates, including analysis, design, simulation, layout, and verification; advanced circuit styles; sequential circuits; advanced topics: semiconductor memories, power grid, clocking strategies, datapath building blocks, deep-submicron design issues, interconnect. *Prerequisites: EECE 311 and EECE 320.*

EECE 613 RF and Microwave Circuits for Communications 3 cr.

The course focuses on the analysis and design of high-frequency electronic circuits, with emphasis on RF and microwave circuits and components for communication systems. The course covers the basic principles of radio-frequency (RF) and microwave circuits design, as applied to the design of micro strip and coplanar lines, impedance transformers, low-pass and band-pass filters, directional couplers, power dividers, amplifiers, mixers, and diode detectors. It provides understanding of S-parameters and signal-flow graph analysis techniques. The course enables the student to get hands-on experience in RF and microwave circuit design through the use of computer-aided design tools to simulate and analyze high frequency circuits, build them as part of a course project, and perform measurements in the lab using network and spectrum analyzers. *Prerequisites: EECE 311, EECE 340, and EECE 380.*

EECE 614 Computer-Aided Analysis and Design of VLSI Circuits and Systems 3 cr.

A course on circuit and logic simulation; timing analysis and verification; testing and fault simulation; logic and high-level synthesis; physical design automation. *Prerequisite: EECE 311.*

EECE 615 Computer Methods for Circuit and System Analysis 3 cr.

This course covers numerical methods and techniques for computer simulation of linear and nonlinear circuits and systems. This includes formulation methods, solution of linear equations and systems (DC analysis or static analysis), time-domain solution (transient analysis), solution of large systems, and sensitivity analysis. Application areas include simulation of electronic integrated circuits, power systems, electro-mechanical systems, mechatronics, and systems that can be modeled by sets of algebraic-differential equations. *Prerequisites: EECE 210, MATH 202 and MATH 218 or 219.*

EECE 616 Advanced Digital Integrated Circuits 3 cr.

A graduate level course on advanced digital integrated circuits. The following topics are covered: impact of physical technology on architecture; technology issues: CMOS scaling and issues in deep submicron regimes, process variations; device and interconnect modeling; optimization for speed; high-speed logic families; low-power design: leakage reduction techniques, voltage scaling; power distribution; clocking strategies; timing concepts; memory design: clocked storage elements, SRAM, DRAM, flash memory; and high-speed arithmetic circuits. *Prerequisite: EECE 412 or EECE 612.*

EECE 620 Computer Graphics 3 cr.

A course on interactive graphics; graphics hardware; graphical input devices; windowing; clipping; viewports; zooming, geometrical transformations (2D and 3D); data structures; advanced raster display architectures; raster algorithms; special graphics techniques; applications.

EECE 621 Advanced Computer Architecture 3 cr.

This course focuses on modern advancements in parallel computer architecture, with emphasis on advanced instruction level parallelism (ILP) and multiprocessor architectures. Topics include: advanced branch prediction, data speculation, computation reuse, memory dependence prediction, trace caches, dynamic optimizations, checkpoint architectures, latency-tolerant processors, simultaneous multithreading, speculative multithreading, virtual machines, message passing multiprocessors, UMA, NUMA and COMA shared-memory multiprocessors, single-chip multiprocessors, wormhole routing techniques, cache coherence, memory consistency models, high performance synchronization methods, speculative lock elision and transactional memory. A key component of the course is a research project in which students use architecture performance simulator to investigate novel architecture techniques. *Prerequisite: EECE 421.*

EECE 622 VLSI for Communications and Signal Processing 3 cr.

This course introduces concepts in the design and implementation of digital signal processing systems using integrated circuits. The main emphasis is on the architectural exploration, design and optimization of signal processing systems for communications. Algorithm, architecture, and circuit design techniques are introduced that enable joint optimization across the algorithmic, architectural, and circuit domains. A key component of the course is a project in which students investigate problems in the design and implementation of low-power and high-performance communication systems.

EECE 623 Reconfigurable Computing 3 cr.

A course dealing with the design issues pertaining to the implementation of application specific architectures using the reconfigurable computing paradigm allowing the same circuit to be reused in order to run different applications. Emphasis is on the systematic design of reconfigurable computing platforms that exploit a high degree of parallelism. *Prerequisite: EECE 321 or consent of instructor.*

EECE 624 Digital Systems Testing 3 cr.

This course covers an overview of digital systems testing and testable design; test economics, fault modeling, logic and fault simulation, testability measures, test generation for combinational circuits, memory test, delay test, IDDQ test, scan design, and boundary scan. *Prerequisite: EECE 320.*

EECE 625 Embedded Systems Design 3 cr.

A course on embedded hardware and software design; the system design process: requirements analysis, specification, hardware/software co-design, testing; embedded computing platforms: general- and special-purpose processors, hardware accelerators, systems-on-a-chip, intellectual property (IP) core-based design, embedded networks; software design tools and technologies: CAD tools, compilers, and assemblers; hardware design tools and technologies: hardware-description languages, high-level synthesis tools, ASIC and FPGA design flows; real-time operating systems: multiple tasks and processes, context switching, task scheduling, interprocess communication mechanisms; low-power computing: circuit, architecture, and application techniques; system reliability and fault tolerance. *Prerequisites: EECE 321 and EECE 321L.*

EECE 626 Computer System Analysis 3 cr.

A course on the development of analytical models of computer systems and application of such models to performance evaluation. Topics covered include scheduling policies, paging algorithms, multi-programmed resource management, and queuing theory. *Prerequisite: EECE 421.*

EECE 630 Distributed and Object Database Systems 3 cr.

A course that covers design techniques used for distributing databases among multiple sites. The fundamental topics include fragmentation, replication, and allocation. The course also discusses the strategies used in executing distributed queries subject to given criteria and the commit protocols for managing transactions in a distributed environment. Other topics covered include parallel database implementations and the design of object database management systems. The course enables students to get hands-on experience in designing distributed database systems using a design project that requires the implementation of low-level functionality associated with the functions of distributed database system. *Prerequisite: EECE 433.*

EECE 631 Advanced Topics in Algorithms 3 cr.

This is a second course on the general principles of algorithm design and analysis. The course is a continuation of EECE 431. Topics include: computability theory; complexity theory: time complexity, P versus NP, circuit complexity, and space complexity; randomized algorithms; linear programming; approximation algorithms; and selected topics. *Prerequisite: EECE 431.*

EECE 632 Cryptography and Computer Security 3 cr.

This course includes an overview of encryption and computer security; classical encryption techniques, block ciphers and the data encryption standard, finite fields; advanced encryption standard confidentiality using symmetric encryption, public-key cryptography, key management, hash and MAC algorithms, digital signatures, authentication applications, email security, and Web security.

EECE 633 Data Mining 3 cr.

This course is an introduction to data mining. Data mining refers to knowledge discovery from huge amounts of data to find non-trivial conclusions. Topics will range from statistics to machine learning to database, with a focus on analysis of large data sets. The course will target at least one new data mining problem involving real data, for which the students will have to find a solution. *Prerequisites: EECE 230, EECE 330 and EECE 433, or consent of the instructor.*

EECE 634 Optimizing Compilers 3 cr.

Theoretical and practical aspects of building modern optimizing compilers. Topics: intermediate representations, basic blocks and flow graphs, data flow analysis, partial evaluation and redundancy elimination, loop optimizations, register allocation, instruction scheduling, and interprocedural analysis. Students will implement significant optimizations within the framework of a modern research compiler. *Prerequisites: EECE 330 and EECE 421, or consent of the instructor.*

EECE 635 Advanced Software Engineering 3 cr.

This course provides the students with an understanding of current topics in software engineering with an emphasis on software architectural design, software development, and autonomic computing. *Prerequisite: EECE 430.*

EECE 636 Analysis and Verification of Software 3 cr.

This course introduces the basics needed to understand automation techniques for the analysis and verification of computing systems including the logics behind programming languages. We will present tools for automated analysis that improve the reliability and correctness of software that reflect state of the art design and validation techniques that are changing the way software is designed and implemented today. The students will have the chance to practice and possibly advance these techniques in small projects.

- EECE 637 Advanced Programming Practice 3 cr.**
This course is an advanced course on programming practices with a focus on verification. The course introduces programming tools and techniques that make individual engineers more effective and productive and help them develop quality code. Teams will work in Agile and eXtreme programming environments with a focus on design by contract. They will use formal specifications, design patterns and aspect oriented programming. Projects will use tools for code control, building, configuration, language recognition, dynamic documentation, fast prototyping, refinement, coverage, automated and manual debugging, and dynamic and static verification. *Prerequisite: EECE 330.*
- EECE 638 Software Testing 3 cr.**
The course focuses on concepts, techniques and tools for testing software. It provides practical knowledge of a variety of ways to test software and an understanding of some of the tradeoffs between testing techniques. The topics include: software testing at the unit, module, and system levels; functional and structural testing; regression testing; mutation testing; test suite minimization and prioritization; automatic test case generation.
- EECE 639 Advanced Techniques and Applications in Data Mining 3 cr.**
A course that covers advanced topics in data mining and recent progress in this field. Discussions will include which techniques fit best for complex applications in data mining. Mining complex data will include general text mining, Arabic text mining, social network analysis, spatial data mining, mining of the World Wide Web, stream data, time-series data, and sequence data. We will also discuss recent application sectors and trends in data mining such as for the telecommunication, biological, and financial sectors. *Prerequisites: EECE 330; and one of the following EECE 633, EECE 667, or EECE 693.*
- EECE 640 Wireless Communications 3 cr.**
A course that covers the fundamentals of wireless communications with emphasis on wireless channel modeling; digital modulation in wireless channels; diversity techniques; channel coding and interleaving in fading channels; adaptive equalization; multiple access techniques; the cellular concept; overview of current wireless communications systems. *Prerequisite: EECE 442.*
- EECE 640L Wireless Communications Laboratory 1 cr.**
A laboratory course that covers the following topics: basics of radio network planning and optimization, radio network planning for the GSM cellular system, radio network planning for the UMTS cellular system, GSM-UMTS co-existence and co-citing, radio network planning for the WiMAX broadband system, indoor GSM drive testing measurements and analysis, outdoor GSM drive testing measurements and analysis, UMTS drive testing measurements and analysis, and measurement-based wireless channel modeling. *Prerequisite: EECE 640.*
- EECE 641 Information Theory 3 cr.**
In this course students study "data transmission" through introducing the field of information theory. The theory is introduced in a gradual fashion and students study its applications to communications theory, computer science, statistics and probability theory. Covering all the essential topics in information theory, students are introduced to the basic quantities of entropy, relative entropy, and mutual information to show how they arise as natural answers to questions of data compression, channel capacity, rate distortion and large deviation theory. *Prerequisites: STAT 230 and EECE 442.*
- EECE 642 Introduction to Coding Theory 3 cr.**
This course introduces the theory of error-correcting codes with a focus on the asymptotic, algorithmic, and algebraic aspects. Topics include: background material from combinatorics and algebra; Shannon's coding theorem; linear codes; coding bounds; classical algebraic codes: Hamming and Hadamard codes, Reed-Solomon codes and Justesen codes, and decoding algorithms; codes from graphs: low density parity check codes, expander codes, explicit constructions, and decoding algorithms; and an introduction to Turbo codes.

EECE 643 RF System Engineering for Wireless Communications 3 cr.

This course introduces students to system blocks, system parameters, and architectures of RF systems for wireless communications. It focuses on the design of a radio system for transmission and reception of voice and data information: receivers and transmitters system topologies, key system blocks in a wireless system, determination of system block parameters from radio requirements and system analysis, tradeoffs between various blocks in a radio system, and frequency planning. It discusses how modulation and demodulation schemes and multiple-access techniques used in present wireless applications influence RF systems requirements. The last part of the course focuses the link budget analysis of RF radio links. *Prerequisites: EECE 311, EECE 380, and EECE 442.*

EECE 644 Stochastic Processes, Detection, and Estimation 3 cr.

This is a graduate-level introduction to the fundamentals of detection and estimation theory involving signal and system models in which there is some inherent randomness. The concepts that we develop are extraordinarily rich, interesting, and powerful, and form the basis for an enormous range of algorithms used in diverse applications. The material in this course constitutes a common foundation for work in the statistical signal processing, communication, and control areas. *Prerequisites: STAT 230 and EECE 340.*

EECE 645 The UMTS Cellular System 3 cr.

A course on the evolution of cellular technologies; UMTS standardization and services; WCDMA transmitter and receiver link level design; access and core network architectures; physical channels and signaling procedures; power control and soft/softer handover; capacity/coverage tradeoffs and cell breathing; capacity/coverage enhancement techniques; antenna diversity and MIMO techniques; multiuser detection techniques; high speed packet access (HSDPA and HSUPA); and basic principles of LTE. *Prerequisite: EECE 640.*

EECE 646 Advanced Digital and Data Communications 3 cr.

A course that addresses digital communication principles and techniques aimed at achieving improved reliability. The course examines information measures; such as entropy and mutual information for discrete and waveform channels, source coding, channel capacity and coding theorem, linear block and cyclic codes, hard and soft decision decoding, spread spectrum modulation.

EECE 647 Queuing Theory 3 cr.

A course that covers Poisson counting and renewal processes; Markov chains and decision theory, branching processes, birth death processes, and semi-Markov processes; simple Markovian queues, networks of queues, general single and multiple-server queues, bounds and approximations.

EECE 651 Internet Engineering 3 cr.

A course that examines major protocols used in internet engineering: IP, ICMP, TCP, UDP; new technologies introduced on the Internet, such as IP Multicast, Mobile IP, IPv6, VPNs, and quality of service; routing on the internet; network security and firewall design; and an overview of the application protocols such as SMTP, HTTP, RTP, and SNMP. *Prerequisite: EECE 450.*

EECE 651L Internetworking Laboratory 1 cr.

This laboratory course covers the technologies and protocols of the internet. The experiments cover the internet protocol (IP), address resolution protocol (ARP), internet control message protocol (ICMP), user datagram protocol (UDP) and transmission control protocol (TCP), the domain name system (DNS), routing protocols (RIP, OSPF, BGP), network address translation (NAT), dynamic host configuration (DHCP), network management protocols (SNMP), and IP multicast. *Prerequisite: EECE 450.*

EECE 652 Web Server Design and Programming 3 cr.

This course concentrates on major technologies used in building Web servers. Alternate versions are to be given each year: the Windows-based IIS Server and the Linux-based Apache server. For IIS, ASP, NET along with C# are used for programming Web servers. For Apache, PHP is the language of choice. The course starts with a fast track on client programming, the HTTP protocol, SQL database servers, and XML programming. A weekly lab, two application projects, and a research project constitute the major requirements of the course.

EECE 653 Multimedia and Networking 3 cr.

This course covers topics in multimedia such as system requirements, performance requirements, representation and compression. Multimedia networking is emphasized by discussing multicasting, streaming, multimedia networking protocols and quality of service-based traffic management protocols. Other topics covered include synchronization, VoIP, and Internet2. Multimedia networking applications are designed and implemented as student projects. *Prerequisite: EECE 450.*

EECE 654 Pervasive Computing Systems and Applications 3 cr.

This course covers the technologies involved in integrating front-end mobile devices into local and global networks. An emphasis is placed on the underlying technologies and standards applied when building pervasive solutions. The course has a strong programming component in that it dedicates a significant portion of the time covering the development of mobile applications for three platforms: Windows CE for Pocket PCs, Palm OS for Palm PDAs, and Java 2 Micro Edition (J2ME) for wireless phones that run the Symbian OS. To emphasize this last component, code demonstrations will be held in class, and students will be required to complete three projects targeting the three platforms, designed to cover the different aspects of mobile applications (user interface, local database implementations, and networking). *Prerequisite: EECE 430.*

EECE 655 Internet Security 3 cr.

The course covers topics in internet security. The course discusses security threats, vulnerabilities of protocols and the different types of attacks. Preventive and defensive mechanisms are covered; such as: e-mail security, web security, IP security, network management security, wireless security, intrusion detection techniques, firewalls, VPNs and tracing the source of attacks. Student projects will be composed of implementation, simulation and research components. *Prerequisites: EECE 450 and EECE 632.*

EECE 656 Mobile Ad hoc and Sensor Networks 3 cr.

This course covers all aspects of ad hoc and sensor networking, from design through performance issues to application requirements. The course starts with the design issues and challenges that are associated with implementations of ad hoc and sensor network applications. This includes dealing with mobility, disconnections, and awareness of battery power consumption. The course then provides a detailed treatment of proactive, reactive, and hybrid routing protocols, in addition to the various clustering approaches. Next, it covers the IEEE 802.11 Wireless LAN and Bluetooth standards and discusses their characteristics and operations. The course also discusses research topics that involve collaboration among mobile devices, service discovery, and data caching. Through a project, the course gives students hands-on experience in designing a mobile ad hoc network using available Pocket PCs and simulation tools. *Prerequisite: EECE 450.*

EECE 657 Wireless Security 3 cr.

A course that covers wireless network security; security challenges in wireless networks; security problems facing existing and upcoming wireless networks; security in naming, addressing, neighbor discovery, and routing; and trust and privacy. *Prerequisites: EECE 450 and EECE 632.*

EECE 660 System Analysis and Design 3 cr.

A course that outlines state-space models of discrete and continuous, linear and nonlinear systems; controllability; observability; minimality; Eigenvector and transforms analysis of linear time invariant multi-input multi-output systems; pole shifting; computer control; design of controllers and observers.

EECE 661 Robotics 3 cr.

Robotic manipulators classification and work envelope. Robot kinematics, dynamics and forces. Joints trajectory planning for end effector desired tracking and constrained motion. Control of robots using linear, non-linear, and adaptive controllers. *Prerequisite: EECE 460 or MECH 433.*

EECE 662 Optimal Control 3 cr.

A course on optimization theory and performance measures, calculus of variations, the maximum principle, dynamic programming, numerical techniques, LQR control systems.

EECE 663 System Identification 3 cr.

This course introduces the fundamentals of system identification as the basic mathematical tools to fit models into empirical input-output data. While rooted in control theory, applications extend to general time-series modeling and forecasting, such as stock prices, biological data and others. Topics covered include nonparametric identification methods: time and frequency response analysis; parametric identification methods: prediction error methods, least squares, linear unbiased estimation and maximum likelihood; Convergence, consistency and asymptotic distribution of estimates; properties and practical modeling issues: bias distribution, experiment design and model validation. *Prerequisite: EECE 460.*

EECE 664 Fuzzy Sets, Logic and Applications 3 cr.

A course that outlines fuzzy sets and related concepts; logical connectives; mapping of fuzzy sets; extension principle; fuzzy relations and fuzzy set ordering; fuzzy logic inference; applications: fuzzy control, signal processing, pattern recognition, decision-making, and expert systems.

EECE 665 Adaptive Control 3 cr.

A course that includes the control of partially known systems; analysis and design of adaptive control systems; self-tuning regulators; model reference adaptive control of uncertain dynamic systems; typical applications. *Prerequisite: EECE 460.*

EECE 667 Pattern Recognition 3 cr.

The course provides an overview of the theory, principles and algorithms used in machine learning to construct high performance information processing systems that learn from experience. The course discusses main and modern concepts for model selection and parameter estimation in recognition, decision making and statistical learning problems. Special emphasis will be given to regression, classification, regularization, feature selection and density estimation in supervised mode of learning. Students will be assigned typical machine learning problems to investigate as projects.

EECE 668 Game Theory and Decision making 3 cr.

Game theory provides a set of tools, approaches, and perspectives on decision making to mimic the human elements of decision making that is best described by strategy, coercion and cooperation. This course offers an introduction to fundamentals of game theory and decision making with a special emphasis on the foundations of the mathematical background. Topics covered include: static, evolutionary, supermodular, repeated, cooperative, network, potential and congestion games as well as bargaining and uncertainty in games. Students will be assigned real-world examples of game theory and strategic decision making to investigate as projects.

EECE 670 Power System Planning 3 cr.

A course that investigates energy and peak load forecasts, weather-sensitive forecasts, generation reliability, load duration curves, loss-of-load expectation, capacity reserve evaluation, generation and transmission expansion, power flow analysis, reliability of bulk supply, and cost-benefit analysis. *Prerequisite: EECE 471.*

EECE 671 Environmental Aspects of Energy Systems 3 cr.

A course that examines world energy resources and classifications; sources and effects of air pollution; air quality modeling, Gaussian dispersion models for pollution estimation; motor vehicle emissions and noise pollution; environmental impacts of electricity generation, pollution control systems, electromagnetic radiation, production and impacts in high-voltage applications; environmental impact assessment; basic concepts.

EECE 672 Energy Planning and Policy 3 cr.

A course that focuses on features of modern energy planning and policy. Topics covered include the interaction among the technological, economic, environmental, and sociopolitical aspects of energy supply and use; electricity, oil, and gas industries, and their market structures; elements of energy planning on the sector and national levels; energy decision-making under conditions of uncertainty, risk management in energy planning; liberalization of energy markets; case studies.

EECE 673 Power Electronics Systems and Applications 3 cr.

A course that reviews converter topologies for AC/DC, DC/AC, and DC/DC; power supply applications; converter applications to motor drives; utility interface of distributed energy systems; static VAR systems; flexible AC transmission; high voltage DC; power quality control; active and passive harmonics compensation. *Prerequisite: EECE 473 or EECE 471.*

EECE 675 Renewable Energy Systems 3 cr.

A course that covers the principles of renewable energy, solar radiation, solar water heating, building and other thermal applications, photovoltaic generation, wind power, fuel cells and the hydrogen cycle, biomass, and institutional and economic factors.

EECE 676 Computer Analysis of Power Systems 3 cr.

A course on large scale power systems, power system matrices, and programming considerations; advanced power flow studies, voltage, and reactive flow control; fault analysis, transient analysis, and power system stability. *Prerequisite: EECE 471.*

EECE 677 Electric Power System Operation and Control 3 cr.

A course on short-term load forecasting, generation unit commitment, economic load dispatch, loss formula coefficients, nonlinear programming, optimal power flow, security assessment, security dispatch, spinning reserve evaluation, automatic generation control, reactive power and voltage control, and state estimation.

EECE 678 Advanced Power System Analysis 3 cr.

A course on optimal dispatch of generation, symmetrical components and unbalanced faults, transient stability, control of generation, state estimation in power systems, and power system simulation. *Prerequisite: EECE 471*

EECE 680 Antenna Theory and Design 3 cr.

This course provides the students with an understanding of the basic principles of antenna analysis and design; an overview of the fundamental characteristics and parameters of antennas; an overview of analytical and numerical methods used to analyze and design antennas with application to some basic antenna structures such as linear antennas, loop antennas, and antenna arrays. *Prerequisite: EECE 380.*

- EECE 681 Advanced Antenna Design 3 cr.**
This course provides the students with an understanding of advanced antenna structures and presents an overview of analytical and numerical methods used to analyze and design these antenna structures. This course includes broadband antennas, frequency-independent antennas, aperture antennas, horn antennas, microstrip antennas, and reflector antennas. Students will work on a research paper on a selected antenna design topic. *Prerequisite: EECE 680.*
- EECE 682 Time-Harmonic Electromagnetic Fields 3 cr.**
A course on time-varying and time-harmonic EM fields; electrical properties of matter; wave propagation and polarization; construction of solutions; reflection and transmission; electromagnetic theorems and principles in particular equivalence; rectangular waveguides and cavities; dielectric waveguide, circular waveguides, spherical waveguide; radiation from structures; scattering by wedges, cylinders and spheres; radiation from apertures, and perturbational and variational techniques. *Prerequisite: EECE 380.*
- EECE 683 Numerical Methods in Electromagnetics 3 cr.**
This course examines the principles and applications of numerical techniques for solving practical electromagnetics problems. It covers the moment methods, finite difference methods, finite element methods, and hybrid methods. The course also investigates the application of the finite-volume control method in electromagnetics. *Prerequisite: EECE 682.*
- EECE 691 Digital Signal Processing 3 cr.**
Course topics include a review of signals, systems, and transforms; design of digital filters: FIR and IIR; sampling and reconstruction of signals; multi-rate signal processing with applications; effects of finite word length; discrete random signals and spectral estimation; and an introduction to 2D signal and image processing.
- EECE 691L Digital Signal Processing Lab 1 cr.**
This graduate lab is comprised of a set of lab experiments in MATLAB, C and Assembly covering a series of real-time signal processing topics. The developed laboratory material is intended to complement the digital signal processing course (EECE 691). Upon completion of the lab, the student will have acquired the required knowledge and skills to develop real-time DSP systems. *Prerequisite: EECE 691 Digital Signal Processing (may be waived upon approval of course instructor).*
- EECE 693 Neural Networks 3 cr.**
The course provides a comprehensive foundation to artificial neural networks and machine learning with applications to pattern recognition and data mining; learning processes: supervised and unsupervised, deterministic and statistical; clustering; single layer and multilayer perceptrons; least-mean-square, back propagation, and Al-Alaoui algorithms; radial-basis function networks; committee machines; principal component analysis; self-organizing maps; and current topics of interest.
- EECE 694 Digital Image Processing 3 cr.**
A course on two-dimensional signals and systems; image formation and perception; representation, coding, filtering restoration, and enhancements; feature extraction and scene analysis; introduction to computer vision.
- EECE 694L Image Processing Lab 1 cr.**
The EECE 694L graduate lab comprises a set of MATLAB/C++ based lab experiments in different image processing topics covering image pre and post processing techniques, image compression, morphological transformations, image restoration and enhancement techniques, color image processing, computer vision basics, and geographical image processing. In addition, students will be exposed to software optimizations for real time image processing using SIMD instructions. *Prerequisite: EECE 694 or EECE 603 or consent of instructor.*

EECE 695 **Adaptive Filtering** **3 cr.**
 A course that examines the fundamentals of optimal filtering and estimation, Wiener filters, linear prediction, steepest-descent and stochastic gradient algorithms; frequency-domain adaptive filters; method of least squares, recursive least squares, fast fixed order and order-recursive (lattice) filters; misadjustment, convergence and tracking analyses, stability issues, finite precision effects; connections with Kalman filtering; and nonlinear adaptive filters.

Special Courses and Thesis

EECE 796 **Special Project**
 An assigned project of not more than 3-credit hours, supervised by a faculty member

EECE 797 **Seminar**

EECE 798 **Special Topics**

Every semester

EECE 799 **Thesis**

Every semester

EECE 898 **Advanced Topics in Electrical and Computer Engineering**

EECE 990 **PhD Dissertation** **0 cr.**

Every semester

EECE 991 **PhD Dissertation** **3 cr.**

Every semester

EECE 992 **PhD Dissertation** **6 cr.**

Every semester

EECE 993 **PhD Dissertation** **9 cr.**

Every semester