

## Electrical and Computer Engineering

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**Kang Yen**, Professor, and Director of the International

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## Master of Science in Electrical Engineering

The Department of Electrical and Computer Engineering offers both thesis and non-thesis options for the Master's Degree. The program provides a broad and multidisciplinary education, followed by in-depth studies of areas of interest.

All work counted for the Master's degree must be completed during the 5 years immediately following the date of admission.

### Admission Requirements

The following are in addition to the University's graduate admission requirements:

1. A student seeking admission into the program must have a bachelor's degree in engineering, physical sciences, computer science or mathematics from an accredited institution, or, in the case of foreign students, from an institution comparable or equivalent to US degree for further study at the graduate-level, or, a bachelor's degree in a related and a minimum of one year of work experience in the broad areas of electrical engineering and/or technology.
2. An applicant must have a GPA score of 3.0 or higher in upper-level undergraduate work.
3. Applicants who have not satisfied the above score may be evaluated for conditional admission.
4. International applicants whose native language is not English are required to demonstrate English language proficiency through one of the following:
  - 80 on the iBT TOEFL (equivalent to 550 on the paper-based version of the Test of English as a Foreign Language);
  - 6.5 overall on the International English Language Testing System (IELTS);
  - 53 Pearson Test of English - Academic;
  - Cambridge English – Advanced;
  - An undergraduate or graduate degree from an accredited institution where the language of instruction is English.

In lieu of the above requirement a student may opt for (a) or (b) below along with an additional method of direct assessment of English language acquisition of an interview or proctored video-taped session

- a) Successful completion of University level English courses from an accredited institution (e.g. ENC 1101, ENC 1102 or other equivalent courses with a letter grade of "B" or higher) that prepare applicants to be proficient in English.

OR

- b) English Language Institute Level Six: successful completion with passing grades for all content areas;

Plus, one of the following additional methods of assessment:

- i) Interview (in person when possible or via videoconference) with admissions committee.
  - ii) Proctored video-taped responses to questions from the admissions committee.
5. Applicants from science areas other than electrical or computer engineering will be expected to complete sufficient background material at the undergraduate level prior to unconditional acceptance into the graduate program.

6. Applicants from science areas other than electrical or computer engineering will be expected to complete sufficient background material at the undergraduate level prior to unconditional acceptance into the graduate program.

### Graduation Requirements

The degree will be conferred when the following conditions have been met:

1. Recommendation of the advisor and faculty of the Department.
2. Certification by the Dean of the College that all requirements of the degree being sought have been completed.
3. A GPA of at least 3.0 has been earned for certain courses required by the program.
4. Met the undergraduate deficiencies, if any existed in the student's graduate program, as additional courses toward the degree.
5. Completed the required semester hours of graduate-level credit (not more than 6 graduate semester hours with a grade of "B" or higher can be transferred from other accredited institutions).
6. Students must maintain an overall GPA of 3.0. No grade below "C" will be accepted in a graduate program. In the event that a student is placed on probationary status, he or she must obtain a directed program from his or her advisor and approved by the Dean prior to continuing further course work toward the degree. The student must satisfy the directed course of action within the prescribed time limit; otherwise he or she will be academically dismissed.
7. Complied with all University policies and regulations.

### Thesis Option

A student must complete 24 semester credit hours of technical course work plus 6 semester credit hours of EEL 6971 - Master's Thesis. The candidate's Thesis committee shall approve an appropriate thesis topic.

The course requirements include a minimum of 12 hours of 6000 level course credit and a minimum of 9 hours at the 5000-6000 level in Electrical Engineering.

Upon the successful completion of all course work, including thesis work, and after the determination by the student's advisor that he or she has completed the objectives of the thesis research, the student must pass a final oral examination which is primarily a defense of the thesis research.

The courses are chosen by mutual agreement between the student and the thesis advisor.

### Non-Thesis Option

Students may choose the non-thesis option for their master's degree. The degree requirements differ from the thesis option in one aspect. The student must either:

1. Complete 27 credits of coursework approved by his advisor and successfully finish EEL 6916 Graduate Project with at least a 'B'.

**OR**

2. Complete 30 credits of coursework approved by the Graduate Program Director.

Students choosing the non-thesis option must take:

1. Two sets of graduate-level Electrical Engineering approved sequence courses from the catalog. Each set includes a minimum of 6 semester credit hours.

2. Six semester credit hours at the 5000-6000 level in mathematics.

### Math Electives in ECE

EEL 5171	Advanced System Theory	3
EEE 5543	Random Signal Principles	3
EEL 6020	Numerical Analysis of Electrical Devices	3

The above list may be changed or expanded by the Graduate Advisory Committee.

The remaining elective courses can be chosen from Science, Technology Engineering, and Mathematics (STEM) disciplines based upon student approved plan of study and will be selected by the student and his or her advisor based on the student's career objectives.

Any course taken without the proper prerequisites and corequisites will be dropped automatically before the end of the term, resulting in a grade of "DR" or "DF".

Students, who are dismissed from the University due to low grades, may appeal to the Dean for reinstatement. A second dismissal results in no possibility of reinstatement. Any exception to the program requires the department's approval.

### Master of Science in Electrical Engineering- Energy Cybersecurity

Common Core (6 credits)

EEL 5171	Advanced Systems Theory	3
EEL 5543	Random Signal Principles	3
EEL 6805	Advanced Malware Reverse Engineering	3
EEL 5718	Computer Communication Network	3
EEL 6803	Advanced Digital Forensics	3
EEL 6787	Network Security	3
EEL 5285	Sustainable and Renewable Energy Sources and their Utilization	3
EEL 6267	Application of Intelligent Systems to Power System Operations	3
EEL 5717	Advanced Security of Internet of Things and Cyber-Physical Systems	3
EEL 5278	Smart Grid Cyber Security and Intelligent Electronic Devices	3

### Master of Science in Electrical Engineering- RF and Microwave

Common Core (6 credits)

EEL 5171	Advanced Systems Theory	3
EEL 5543	Random Signal Principles	3
EEL 5426	RF Circuit Design	3
EEL 5437	Microwave Engineering	3
EEL 5467	Antennas for Wireless Communication	3
EEL 5482	Fields and Waves Engineering	3
EEL 5500	Digital Communication System I	3
EEL 5501	Digital Communication System II	3
EEL 5563	Introduction to Optical Fibers	3
EEL 6463	Antenna Theory and Design	3

### Combined BS/MS in Electrical Engineering Degree Pathway

This five-year pathway seamlessly combines a baccalaureate degree in Electrical Engineering with the

Master's in Electrical Engineering. To be considered for admission to the combined bachelor's/master's degree pathway, students must have completed at least 75 credits required for the bachelor's degree program at FIU, have earned at least a 3.2 GPA on both overall and upper-division courses, and meet the admissions criteria for the graduate degree program to which they are applying. Students need only apply once to the combined degree pathway; the application is submitted to Graduate Admissions typically before the student starts the last 30 credits of the bachelor's degree program. A student admitted to the combined degree pathway will be considered to have undergraduate status until the student applies for graduation from their bachelor's degree program. Upon conferral of the bachelor's degree, the student will be granted graduate status and be eligible for graduate assistantships. Students enrolled in the pathway may count up to 9 hours of graduate-level courses (i.e., 5000 level or higher) as credits for both the undergraduate and graduate degree programs. Only graduate courses with formal lectures can be counted for both degrees. For each of the courses counted as credits for both BS and MS degree, a minimum grade of 'B' is required. Upon completion of the combined BS/MS pathway, students must have accumulated a minimum of 24 hours of credits at the graduate (5000+) level. Students enrolled in the pathway are encouraged to seek employment with a department faculty member to work as a student assistant on a sponsored research project.

## Master of Science in Computer Engineering

The Department of Electrical and Computer Engineering offers both thesis and non-thesis options for the Master's Degree.

All work counted for the Master's degree must be completed during the 5 years immediately following the date of admission.

The program provides a broad and multidisciplinary education, followed by in-depth studies of areas of interest.

### Admission Requirements

The following is in addition to the University Graduate School admission requirements:

1. A student seeking admission into the program must have a bachelor's degree in engineering, physical sciences, computer science or mathematics from an accredited institution, or, in the case of foreign students, from an institution comparable or equivalent to US degree for further study at the graduate-level, or, a bachelor's degree in a related and a minimum of one year of work experience in the broad areas of computer engineering and/or technology.
2. An applicant must have a GPA score of 3.0 or higher in upper-level undergraduate work.
3. Applicants who have not satisfied the above score may be evaluated for conditional admission.
4. International applicants whose native language is not English are required to demonstrate English language proficiency through one of the following:
  - 80 on the iBT TOEFL (equivalent to 550 on the paper-based version of the Test of English as a Foreign Language);'

- 6.5 overall on the International English Language Testing System (IELTS);
- 53 Pearson Test of English - Academic;
- Cambridge English – Advanced;
- An undergraduate or graduate degree from an accredited institution where the language of instruction is English.

In lieu of the above requirement a student may opt for (a) or (b) below along with an additional method of direct assessment of English language acquisition of an interview or proctored video-taped session

a) Successful completion of University level English courses from an accredited institution (e.g. ENC 1101, ENC 1102 or other equivalent courses with a letter grade of "B" or higher) that prepare applicants to be proficient in English.

OR

b) English Language Institute Level Six: successful completion with passing grades for all content areas;

Plus, one of the following additional methods of assessment:

- i) Interview (in person when possible or via videoconference) with admissions committee.
  - ii) Proctored video-taped responses to questions from the admissions committee.
5. Applicants from science areas other than electrical or computer engineering will be expected to complete sufficient background material at the undergraduate level prior to unconditional acceptance into the graduate program.

### Graduation Requirements

The degree will be conferred when the following conditions have been met:

1. Recommendation of the advisor and faculty of the Department.
2. Certification by the Dean of the College that all requirements of the degree being sought have been completed.
3. A GPA of at least 3.0 has been earned for certain courses required by the program.
4. Met the undergraduate deficiencies, if any existed in the student's graduate program, as additional courses toward the degree.
5. Completed the required semester hours of graduate-level credit (not more than 6 graduate semester hours with a grade of "B" or higher can be transferred from other accredited institutions).
6. Students must maintain an overall GPA of 3.0. No grade below "C" will be accepted in a graduate program. In the event that a student is placed on a probationary status, he or she must obtain a directed program from his or her advisor and approved by the Dean prior to continuing further course work toward the degree. The student must satisfy the directed course of action within the prescribed time limit, otherwise he or she will be academically dismissed.
7. Complied with all University policies and regulations.

### Thesis Option

A student must complete 24 semester credit hours of technical course work plus 6 semester credit hours of EEL 6971 - Master's Thesis. The candidate's Thesis committee shall approve an appropriate thesis topic.

The course requirements include a minimum of 12 hours of 6000 level course credit and a minimum of 9 hours at the 5000-6000 level in Computer Engineering.

Upon the successful completion of all course work, including thesis work, and after the determination by the student's advisor that he or she has completed the objectives of the thesis research, the student must pass a final oral examination which is primarily a defense of the thesis research.

The courses are chosen by mutual agreement between the student and the thesis advisor.

### Non-Thesis Option

Students may choose the non-thesis option for their master's degree. The degree requirements differ from the thesis option in one aspect. The student must either:

3. Complete 27 credits of coursework approved by his advisor and successfully finish EEL 6916 Graduate Project with at least a 'B'.

OR

4. Complete 30 credits of coursework approved by the Graduate Program Director.

Students choosing the non-thesis option must take:

1. Two sets of graduate-level Computer Engineering approved sequence courses from the catalog. Each set includes a minimum of 6 semester credit hours.
2. Six semester credit hours at the 5000-6000 level in mathematics.

### Math Electives in ECE

EEL 5171	Advanced Systems Theory	3
EEE 5543	Random Signal Principles	3
EEL 6020	Numerical Analysis of Electrical Devices	3

The above lists may be changed or expanded by the Graduate Advisory Committee.

The remaining elective courses can be chosen from Science, Technology Engineering, and Mathematics (STEM) disciplines based upon student approved plan of study.

Any exception to the program requires the department's approval.

## Master of Science in Computer Engineering- Machine Learning

Common Core (6 credits)

EEL 5171	Advanced Systems Theory	3
EEL 5543	Random Signal Principles	3

Track- Specific Courses

EEL 6825	Pattern Recognition	3
EEL 5813	Neural Networks- Algorithms and Applications	3
EEL 6812	Advanced in Neural Networks	3
EEL 6681	Fuzzy Systems Design	3

The Machine Learning track will require 6 credits as common core, 12 credits of track-specific core courses and 12 credits of elective 5000- or 6000- level graduate courses from the ECE department, for a total of 30 credits.

## Combined BS/MS in Computer Engineering Degree Pathway

This five-year pathway seamlessly combines a baccalaureate degree in Computer Engineering with the

Master's in Computer Engineering. To be considered for admission to the combined bachelor's/master's degree pathway, students must have completed at least 75 credits required for the bachelor's degree program at FIU, have earned at least a 3.2 GPA on both overall and upper-division courses, and meet the admissions criteria for the graduate degree program to which they are applying. Students need only apply once to the combined degree pathway; the application is submitted to Graduate Admissions typically before the student starts the last 30 credits of the bachelor's degree program. A student admitted to the combined degree pathway will be considered to have undergraduate status until the student applies for graduation from their bachelor's degree program. Upon conferral of the bachelor's degree, the student will be granted graduate status and be eligible for graduate assistantships. Students enrolled in the pathway may count up to 9 hours of graduate-level courses (i.e., 5000 level or higher) as credits for both the undergraduate and graduate degree programs. Only graduate courses with formal lectures can be counted for both degrees. For each of the courses counted as credits for both BS and MS degree, a minimum grade of 'B' is required. Upon completion of the combined BS/MS pathway, students must have accumulated a minimum of 24 hours of credits at the graduate (5000+) level. Students enrolled in the pathway are encouraged to seek employment with a department faculty member to work as a student assistant on a sponsored research project.

## Master of Science in Computer Engineering – Network and Security Online

The Master of Science in Computer Engineering – Network Security Online program is similar to the existing/approved face-to-face program in terms of curriculum and admissions requirements.

### Admission Requirements

The following is in addition to the University Graduate School admission requirements:

1. A student seeking admission into the program must have a bachelor's degree in engineering, physical sciences, computer science or mathematics from an accredited institution, or, in the case of foreign students, from an institution comparable or equivalent to US degree for further study at the graduate-level, or, a bachelor's degree in a related and a minimum of one year of work experience in the broad areas of computer engineering and/or technology, or a bachelor's degree in any field plus 3 years of relevant work experience will be considered. The student must take and pass two deficient courses required by the program.
2. An applicant must have a GPA score of 3.0 or higher in upper-level undergraduate work.
3. Applicants who have not satisfied the above score may be evaluated for conditional admission.
4. International students whose native language is not English, must take the Test of English as a Foreign Language (TOEFL) or the International English Language Testing System Test (IELTS). Minimum required score is: 550 on the paper-based test (PBT)

- TOEFL), or 80 on the iBT TOEFL, or 6.5 overall on the IELTS test.
5. Applicants from science areas other than electrical or computer engineering will be expected to complete sufficient background material at the undergraduate level prior to unconditional acceptance into the graduate program.

The Master of Science in Computer Engineering – Network Security Online program requires 30 semester hours beyond the bachelor's degree. This is a lock-step program that consists of a specific sequence of courses. The Master of Science in Computer Engineering – Network Security Online program includes two required components:

#### Computer Engineering Courses (24 credits)

CIS 5208	Social, Economic and Policy Aspects of Cybersecurity	3
CNT 5415	Practical Applied Security	3
EEL 6803	Advanced Digital Forensics	3
EEL 6805	Advanced Malware Reverse Engineering	3
EEL 5718	Computer-Communication Network Engineering	3
EEL 5807	Advanced Ethical Hacking	3
EEL 6787	Network Security	3
TCN 5271	Advanced IoT Communications and Networking	3

#### Math Electives (6 credits)

EEL 5171	Advanced Systems Theory	3
EEE 5543	Random Signal Principles	3
EEL 6020	Numerical Analysis of Electrical Devices	3

The Math Electives may be changed or expanded by the Graduate Advisory Committee.

Any exception to the program requires the department's approval.

### Master of Science in Internet of Things

#### Core Courses 21 credits:

TCN 5271	Ubiquitous and Embedded Sensor Network Centric Telecommunications	3
EEE 5718	Advanced Security of Internet of Things and Cyber-Physical Systems	3
EEE 6525	Advanced Sensor Signal Processing	3
TCN 6276	Antennas for Wireless and Body-Centric Communications	3
EEL 6795	Power Aware Computing	3
EEL 6787	Network Security	3
CNT 6148	Advanced IoT and Sensor Big Data Analytics	3

#### Elective Courses 9 credits:

EEL 6463	Antenna Theory and Design	3
EEL 6894	Real-Time Computing and Applications	3
EEL 5757	Real-Time Digital Signal Processing Implementations	3
EEL 5741	Advanced Microprocessor Systems	3
EEL 6020	Numerical Analysis of Electrical Devices	3
EEL 5718	Computer-Communication Network Engineering	3
EEL 5591C	Wireless Digital Communications with USRP Applications	3

EEL 5467	Antennas for Wireless Communication Systems	3
EEL 5437	Microwave Engineering	3
EEL 5145	Advanced Filter Design	3
EEE 6311	Advanced Electronic Systems I	3
CNT 6311	Advanced IoT and Sensor Data Visualization	3
CNT 6156	Advanced IoT and Sensor Programming with Python	3
CNT 6144	Advanced IoT Analytics with Cloud Services	3
CNT 6154	Advanced IoT Applied Machine Learning	3
CNT 6150	Sensor and IoT Data Analytics with Deep Learning	3

### Doctor of Philosophy in Electrical and Computer Engineering

#### Admission Requirements

The requirements for admission to the doctoral program in Electrical and Computer Engineering are:

- Applicants having a bachelor's degree in engineering, physical sciences, computer science or mathematics from an accredited institution must provide the followings for admission to the doctoral program:
  - An applicant must have a GPA score of 3.0 or higher.
  - Applicants who have not satisfied the above score may be evaluated for conditional admission.
  - Applicants must submit GRE scores although no minimum scores are required to be considered for admission.
  - Three letters of recommendation in the forms provided by the department
  - International graduate student applicants whose native language is not English are required to submit a score for the Test of English as a Foreign Language (TOEFL) or for the International English Language Testing System (IELTS). A total score of 80 on the iBT TOEFL or 6.5 overall on the IELTS is required.
- Applicants having a Master's degree in Electrical or Computer Engineering from an accredited institution must provide the followings for admission to the doctoral program:
  - GPA of at least 3.3/4.0 in the master's program
  - Applicants must submit GRE scores although no minimum scores are required to be considered for admission.
  - Three letters of recommendation in the forms provided by the department
  - International graduate student applicants whose native language is not English are required to submit a score for the Test of English as a Foreign Language (TOEFL) or for the International English Language Testing System (IELTS). A total score of 80 on the iBT TOEFL or 6.5 overall on the IELTS is required.

- Credentials of all other applicants will be examined by the Graduate Admission Committee on a case by case basis. In addition to the departmental requirements, all students must satisfy the University's Graduate Policies and Procedures.

### Identification of Research Area

Within 12 months upon acceptance into the Ph.D. program, the student has to identify an area of research of his or her interest by contacting and being accepted by a professor willing to guide the dissertation research. If no such professor can be found, the student will be dismissed from the Ph.D. program. Contact the Department for a list of the faculty members with Dissertation Advisor status and their research interests.

### Course Requirements

The Ph.D. in Electrical and Computer Engineering requires at least 75 credit hours beyond the bachelor's degree. A maximum of 30 credit hours of course work earned in a Master's degree in Electrical or Computer Engineering, from FIU or another accredited institution, may be counted toward the Ph.D. provided that a minimum grade of "B" is earned in each course.

### Degree Requirements

- Students must complete at least 9 credits of coursework in their major area (EEL 6905, 6916, 6932 and 6971 will not be counted as coursework) and at least 6 credits in two different breadth areas (a grade of "B" or better in each course). The appropriate areas of study and specific courses are determined by the dissertation advisor. Students majoring in Electrical Engineering should have one minor in computer engineering, and those majoring in Computer Engineering should have one minor in Electrical Engineering.
- The student must have completed a minimum of 45 credits of graduate course work toward the Ph.D. before the student is eligible for the candidacy. This includes up to 30 transfer credits.
- At least 15 credits of EEL 7980 are required. Registration for EEL 7980 Ph.D. Dissertation is allowed only after passing the qualifying examination.
- Fifty percent of the total hours counted toward the doctoral degree have to be at the 6000 and 7000 level (including EEL 7980).

### Residency Requirements

The Ph.D. student must spend at least one academic year in full-time residency. Usually, this will be after being admitted to candidacy. To satisfy the residency requirement for a Ph.D. degree in Electrical and Computer Engineering, the candidate must complete a minimum of 18 credit hours within a period of 12 months in residency at the University.

### Graduate Supervisory and Research Committee

The student's Ph.D. Graduate Supervisory and Research Committee should be appointed as soon as possible and not later than 15 months after being admitted to the Ph.D. program. Consult the Graduate Handbook in the Department for more details on how to select the committee members.

### Ph.D. Course Breadth Requirements

The student must submit information about how the breadth requirement has been satisfied to the Graduate Program Director at the time he/she signs up for the Ph.D. Qualifying Examination.

### Qualifying Examination

To be eligible for the written qualifying examination, the student must have satisfied the Ph.D. course breadth requirements in his or her area of specialization and in two other areas. The students can take the qualifying examination no later than the semester in which all the required coursework for the degree is completed. Failure to do this is causation for dismissal from the Ph.D. program.

One of the following two options will be selected by the student's major advisor for the qualifying exam: (1) Written exam and (2) Research paper preparation and presentation. Failing any part of the exam implies the failure of the entire examination. The exam must be retaken the next time it is offered. Failing a second time is cause for dismissal from the Ph.D. program.

Consult the Graduate Handbook available in the Department for details on examination procedures, dates, duration, application and grading criteria.

### Proposal Defense

Proposal defense must be taken within one semester after the satisfactory completion of the qualifying examination.

### Admission to Candidacy

Candidacy status indicates that a doctoral student is ready for the completion of the dissertation. A student is admitted to candidacy upon successfully completing all required course work and passing the qualifying examination.

### Oral Defense and Submission of Doctoral Dissertation

A dissertation is required of all candidates for the doctoral degree. A proposal must be submitted to the student's Dissertation Committee for approval, following the general guidelines in the "Regulations for Thesis and Dissertation Preparation". A student must enroll for dissertation credits in the semester in which he or she expects to be admitted to candidacy, and must maintain continuous enrollment for not less than 3 credits of EEL 7980 every semester, including Summers, until the semester in which the doctoral degree is awarded. Upon completion of the dissertation, the degree candidate will submit to the Dean of the Graduate School an application for dissertation defense signed by the student's Dissertation Committee with sufficient time to allow for publishing a notice in the monthly calendar of dissertation and theses defenses to invite members of the university community to observe the defense.

Following the successful defense of the dissertation, as determined by a majority vote of the student's research committee, the dissertation must be forwarded to the Dean of the College of Engineering and Computing and the Dean of the Graduate School for their approval.

All dissertations submitted in fulfillment of requirements for graduate degrees must conform to University guidelines (see "Regulations for Thesis and Dissertation

Preparation"). One final, approved copy of the dissertation must be delivered to the Chairperson of the Department of Electrical and Computer Engineering. Library copies must conform to University guidelines, also published in "Regulations for Thesis and Dissertation Preparation". Any exception to the program requires the department's approval.

### Financial Aid

Consult the Department for information on research and teaching assistantships available for doctoral students.

### MS en-route to PhD

Students in the ECE PhD program may obtain an MS degree in Electrical Engineering or Computer Engineering provided that the following conditions are satisfied.

- Completed 30 credits of graduate course work at FIU. Only the letter-graded (i.e. not P/F) courses are counted towards this requirement.
- The courses have not been used for a previously earned master's degree.
- In good academic standing and all courses are within the time limits to degree completion.
- All courses are B or better.
- No pending Incomplete grades.
- Have approved D1, D2 and D3 on file with UGS.

This is subject to approval by the GPD and UGS.

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## Course Descriptions

### Definition of Prefixes

CNT-Computer Networks; EEE-Engineering: Electrical and Electronic; EEL-Engineering: Electrical; OSE-Optical Science and Engineering; TCN-Telecommunications/Networking

**CNT 5415 Practical Applied Security (3).** Hands-on training in practical installation and maintenance of secure systems, including such topics as security configuration, DMZs, firewalls, anti-virus software, and hardware security modules. Prerequisite: Graduate standing.

**CNT 6144 Advanced IoT Analytics with Cloud Services (3).** This course will focus on the theoretical concepts, principles, tools, techniques and deployment models and analytics for cloud services.

**CNT 6148 Advanced IoT & Sensor Big Data Analytics (3).** This course focuses on Big Data processing associated with IoT/sensor devices in extracting actionable intelligence. The fundamental algorithms and techniques of Big Data for IoT data are explored.

**CNT 6150 Advanced Sensor & IoT Data Analysis with Deep Learning (3).** This course will focus on the use of deep learning techniques and algorithms on structured and unstructured data received from sensors and IoT devices.

**CNT 6154 Advanced IoT Applied Machine Learning (3).** The course focuses on the theoretical and principles of applying machine learning algorithms to sensor/IoT data

sets, engaging in the techniques of feature extraction and evaluation in model building.

**CNT 6156 Advanced IoT & Sensor Programming with Python (3).** This course will focus on implementing control system applications with the Python programming language for IoT and sensor systems.

**EEE 5261 Bioelectrical Models (3).** Engineering models for electrical behavior of nerve and muscle cells, electrode-tissue junctions, volume conductions in tissue and the nervous system as an electrical network. Prerequisites: EEE 4202C or permission of the instructor. (F)

**EEE 5275 Bioradiation Engineering: Detection and Measurement (3).** Spectrum of radiation sources, types of fields, properties of living tissue, mechanisms of field propagation in tissue. Application in imaging and therapy, hazards and safety. Prerequisites: EEL 4410 or permission of the instructor. (S)

**EEE 5348 Digital Electronics (3).** Analysis and design of logic gates using saturated and non-saturating elements, transmission gates, interfacing of logic families, bistable circuits, A/D and D/A converters. Prerequisites: EEE 4304 or permission of the instructor.

**EEE 5352 Bipolar Junction Transistors (3).** Bipolar junction transistor physics. Semiconductor bulk properties at equilibrium and nonequilibrium. PN junction theory. Theory of the bipolar junction transistor. Prerequisites: EEE 3396 or permission of the instructor. (S)

**EEE 5353 Field Effect Transistors (3).** Field effect device physics and technology. MOS capacitor. DC and AC characteristics of the MOS transistor. The MOS transistor in dynamic operation. Prerequisites: EEE 3396 or permission of the instructor. (F)

**EEE 5366 Industrial Electronics (3).** A study of solid-state devices for the control of power, their applications and limitations in power-switching circuits and in the control of physical transducer. Prerequisites: EEL 4213, EEE 4304 or permission of the instructor. (F, every third year)

**EEE 5371 High-Frequency Amplifiers (3).** Analysis and design of high-frequency amplifiers and oscillators: stability, scattering parameters, use of the Smith chart and other practical design tools, noise. Prerequisites: EEE 4304, EEL 4410 or permission of the instructor. (F, every third year)

**EEE 5425 Introduction to Nanotechnology (3).** Nanoscale electrical, optical and magnetic device operation. Overview of new devices enabled by nanotechnology, methods for fabrication and characterization of nanoscale and devices. Prerequisite: EEE 3396.

**EEE 5427C Advanced Nanofabrication of Electronic Devices (3).** This course covers the advanced theory and technology for the fabrication of micro/nano-scale electronic devices. Includes lectures and laboratory sessions on techniques such as lithography and etching. Prerequisites: EEE 5425 or permission of the instructor.

**EEE 5515 Signal Detection Theory (3).** This course thoroughly investigates the fundamentals of modern signal detection theory. The topics to be covered include:

Deterministic signals, Random signals, Statistical decision theory. Prerequisites: EEE 5543 or permission of the instructor.

**EEE 5543 Random Signal Principles (3).** Noise, random processes, correlation, spectral analysis in the analysis and design of communication systems. Optimization techniques; minimum mean square error. Prerequisite: EEL 3514. (SS, alternating years)

**EEE 5718 Advanced Security of Internet of Things and Cyber-Physical Systems (3).** In this project-based class, the students will gain advanced hands-on training in the security of Internet-of-Things (IoT) and Cyber-Physical Systems (CPS) areas. Prerequisites: Programming coursework or any CS oriented courses (e.g. COPXXXX) or any embedded coursework or permission of the instructor.

**EEE 5772 Intelligent Robotics, Vision, and Controls (3).** This course provides the fundamentals of mobile robots, arm robots, camera models, image processing, feature extraction, and multi-view geometry, and visual servo systems. Prerequisite: MATLAB experience or permission from the instructor.

**EEE 6285 Biosignal Processing I (3).** Characterizing biosignals by application of time and frequency domain analytic methods. Comparison of analog and digital processing. Engineering design for VLSI implementations in implantable devices. Prerequisites: EEE 6502 or permission of the instructor. (F)

**EEE 6286 Biosignal Processing II (3).** Engineering design of advanced systems for processing biosignals. Methods for signal compression. Adaptive systems for automatic recognition. Application of artificial intelligence for signal classification. Prerequisites: EEE 6285 or permission of the instructor. (S)

**EEE 6311 Advanced Electronic Systems I (3).** Principles of analog and digital electronics network. Advanced analysis, modeling and computer simulation of op-amps. Analog design techniques and practical examples are covered. Prerequisites: EEE 4314 or permission of the instructor. (F, alternating years)

**EEE 6312 Advanced Electronic Systems II (3).** Study of linear properties of electronic systems and design of fault-tolerant systems using A/D and D/A and control algorithms. Prerequisites: EEE 6311 or permission of the instructor. (S, alternating years)

**EEE 6315 Advanced Solid-State Electronics (3).** IC technologies, properties and fabrication concepts. Bipolar, MOS, I<sup>2</sup>L, CCD, bubble technologies. Ion implantation characteristics. Lithography techniques. Prerequisites: EEE 3396, EEE 4304 or permission of the instructor. (SS, every third year)

**EEE 6332 Thin Film Engineering (3).** Thin films used in microelectronics and optoelectronics; deposition methods; the evolution of film microstructure; film growth modeling; introduction to film analysis. Prerequisite: EEE 3396. (SS, alternating years)

**EEE 6335 Electrical Transport in Semiconductors I (3).** This course focuses on carrier transport fundamentals, beginning at the microscopic level and progressing to the macroscopic effects relevant to semiconductor devices. Prerequisite: EEE 5352. (F, alternating years)

**EEE 6337 Electrical Transport in Semiconductors II (3).** This course focuses on quantum phenomena occurring in carrier transport in modern small-size semiconductor devices. Prerequisite: EEE 6335.

**EEE 6395 Applied Superconductivity (3).** Covers the basic physical properties of superconductors. Superconducting devices: squids, memory & logic elements. Emphasis is placed on applications of superconductors. Prerequisites: EEE 3396 and EEL 4410. Corequisite: Permission of the instructor. (S)

**EEE 6397 Semiconductor Device Theory (3).** Device physics and modeling of GaAs FETS. GaAs analog and digital integrated circuits. Modulation doped field-effect transistors. Heterojunction bipolar transistor theory. Prerequisite: EEE 3396. (S)

**EEE 6399C Electronic Properties of Materials (3).** Properties of materials from which electronic components and structures are fabricated; electrical conduction in metals, semiconductors and insulators; thermal; magnetic; optical. Prerequisite: EEE 3396. (F, alternating years)

**EEE 6429 Advanced Quantum Computers (3).** This course provides advanced principles of quantum computers and quantum information systems with in-depth analysis and state of the art physical implementations.

**EEE 6434 Colloidal and Nanoscale Engineering (3).** In-depth coverage of the fundamentals of colloidal interactions between surfaces, particles, surfactants and biomolecules, and their relevance to self-assembly. Prerequisites: Knowledge of thermodynamics, statistical mechanics and/or physics.

**EEE 6466 Microsystems and MEMS: Chem/Bio Sensors and Microfabrication (3).** This course will give students an introduction with an emphasis on design and analysis of fundamentals of electrochemical sensing and integration into microfluidic systems. Prerequisites: EEL 3396 or permission of the instructor.

**EEE 6502 Digital Signal Processing (3).** Treatment of digital signal and system characteristics: Z transforms and FFT theory. Real-time and correlation functions. Multidimensional signal processing and digital filtering. Prerequisite: Permission of the instructor. (F)

**EEE 6516 Signal Estimation Theory (3).** The course covers both the theoretical and practical aspects of statistical parameter estimation from received signals in noise. Both classical estimation and Bayesian estimation are studied. Prerequisite: EEE 5543 or permission of the instructor.

**EEE 6525 Advanced Sensor Signal Processing (3).** Various sensor systems, sensor signal detection, signal estimations, distributed sensor networks, sensor data fusion approaches, wireless sensor networks, radar networks and optimal sensor allocation and sensor network design. Prerequisite: EEL 3514 or permission of the instructor.

**EEE 6719 Cyberphysical Systems Security (3).** Expose students to fundamental security primitives specific to CPS. The topics will cover the cyber and physical attacks, security of CPS protocols, key management and privacy and control. Prerequisite: A Network Security related course or consent of the instructor



**EEE 6751 Advanced Image and Video Forensics (3).** The course covers the theoretical and advanced practical aspects and principles of forensic image and video analysis and their application to digital forensics.

**EEE 6753 Advanced Network Forensics and Incident Response (3).** The course covers the theoretical and advanced practical aspects of computer network forensics and security.

**EEE 6755 Advanced Mobile Forensics (3).** The course covers the theoretical and advanced practical aspects of digital forensics of mobile devices.

**EEE 6764 Platform Design, Testing, and Validation for IoT Applications (3).** This course will be able to fabricate, assemble, and design driving firmware of the custom-designed IoT system/device and hands-on experience on the IOT hardware platform design, optimization, testing. Prerequisite: Permission from instructor (No hardware design experience is required)

**EEE 6765 Advanced Embedded Systems Design and Implementation for IoT Applications (3).** This course will provide hands-on experience on the hardware design and implementation of a typical IoT system/device using Eagle/Autodesk PCB design software. Prerequisite: EEL 3110 and EEL 3110 or permission from instructor (No hardware design experience is required)

**EEE 6766 Algorithm Design and Firmware Implementation for IoT Sensing, Network Connectivity, and Closed-Loop Control (3).** This course will provide solid firmware programming experience on essential IoT components including wireless communication, sensor interfacing (ADC, USART, I2C and SPI) and digital signal processing. Prerequisite: Permission from instructor (Basic programming experience is required)

**EEE 6767 Advanced Embedded Programming for IoT Sensing, Network, Control, and Applications (3).** This course will provide hands-on experience on the software design and implementation of a typical IoT system/device on a customer-made IoT education platform of CyberSens-EDU. Prerequisite: COP 2210 or permission from instructor (Basic programming experience is required)

**EEL 5009 Concepts in Electrical and Computer Engineering (3).** The course covers a broad range of topics and concepts required for pursuing a Master's Degree in Electrical and Computer Engineering. Prerequisite: Permission of the instructor.

**EEL 5145 Advanced Filter Design (3).** Graduate course in the design and advance analysis of passive and active high order circuits. Use of the computer as a design tool. Prerequisites: EEL 4140 or permission of the instructor. (S, alternating years).

**EEL 5171 Advanced Systems Theory (3).** State-space representations for continuous and discrete-time systems, controllability and observability, pole-zero allocation, Lyapunov stability theorem, state observers. Prerequisites: EEL 3657 or permission of the instructor. (S)

**EEL 5259 Modeling and Analysis of Modern Distribution Grids (3).** This course covers modelling, design, analysis, and operations of low and medium

voltage electric power distribution systems including the increasing penetration of distributed generators.

**EEL 5260 Power System Optimization (3).** This course covers recent advances in optimization techniques and their applications to electric power grid planning and operational problems.

**EEL 5270 Electrical Transients in Power Systems (3).** Traveling waves on transmission and multi-conductor systems, successive reflections, distributed parameter systems, transients on integrated power systems. Prerequisites: EEL 4213 or permission of the instructor.

**EEL 5275 Power Systems Protection (3).** Analysis of power systems under faulted conditions using linear transformation. The study of surge, transient and waves on power lines. Computer-aided analysis and design emphasizing protection of equipment. Prerequisites: EEL 4215 or permission of the instructor. (F)

**EEL 5278 Smart Grid Cyber Security and Intelligent Electronic Devices (3).** Design, simulate and solve smart grid cybersecurity issues. Manmade and natural large scale disturbances. Smart grid cyber networked standards and new Intelligent Electronic Devices (IED). Prerequisite: Graduate standing.

**EEL 5285C Sustainable and Renewable Energy Sources and Their Utilization (3).** Alternative energy techniques, solar power, wind power, biomass, and other sources, electric power grid and integration of renewables, energy storage and smart energy utilization and public policy. Prerequisites: EEL 4213 or equivalent.

**EEL 5426 RF Circuit Design (3).** Transmission lines, guided EM propagation, microwave circuits, resonators, impedance matching, passive components, thin-film circuits, filters, two-port networks, measurements, advanced simulations. Prerequisites: EEL 3135 and EEL 3110.

**EEL 5427C Electromagnetic Modeling of Radio Frequency (RF) Structures (3).** The goal of this course is to teach modeling RF, terahertz and photonics structures using electromagnetic full-wave solvers. The class will use commercial EM solvers to model state-of-the-art problems. Prerequisite: EEL 3135, EEL 4410.

**EEL 5437 Microwave Engineering (3).** Microwave guides. Microwave tubes. Microwave solid-state devices. Microwave integrated circuits, Microwave enclosures. Prerequisites: EEL 4410 or permission of the instructor. (S, every third year)

**EEL 5467 Antennas for Wireless Communication Systems (3).** Antenna principles, wire antennas, printed antennas, antenna arrays, and measurements. Full-wave simulation software is used for the design and analysis of antennas for wireless communication systems. Prerequisite: EEL 4410 or permission of the instructor.

**EEL 5482 Fields and Waves Engineering (3).** Concepts and theorems in fields and waves, analytic techniques for guided waves, radiation and scattering, numerical techniques for analysis of electrical devices. Prerequisites: EEL 4410 or permission of the instructor. (S)

**EEL 5500 Digital Communication Systems I (3).** This course will consider the most important aspects of digital communication systems such as noise-related subjects,

random signals, linear systems, and baseband digital modulation and multiplexing. Prerequisites: EEL 3514 or permission of the instructor. (SS)

**EEL 5501 Digital Communication Systems II (3).** This course will consider more important aspects of digital communication systems such as matched filters, digital base and modulation, multiplexing, carrier digital modulation and error correction coding. Prerequisites: EEL 5500 or permission of the instructor. (F)

**EEL 5563C Introduction to Optical Fibers (3).** Use of fiber optics as a communication medium. Principles of fiber optics; mode theory; transmitters, modulators, sensors, detectors and demodulators; fiber data links. Prerequisites: EEL 3514, EEE 4314 and EEL 4410 or permission of the instructor. (F, alternating years)

**EEL 5587 Long Term Evolution Communication: From Theory to Practice (3).** Introduction to the basic concepts in Long Term Evolution (LTE) technology and beyond. Prerequisite: Permission of the instructor.

**EEL 5591C Wireless Digital Communications with USRP Applications (3).** The course covers the fundamentals of wireless digital communications from a DSP perspective. Hands-on experience with wireless communication principles is achieved through lab experiments and course projects. Prerequisites: EEL 3514, EEE 4510.

**EEL 5653 Digital Control Systems (3).** Analysis and design of digital control systems. Z-transforms, analysis and control of discrete-time systems, digital control of analog systems. Several digital controller design methods. Computer simulation and microprocessor implementation. Prerequisite: EEL 3657. (SS)

**EEL 5669 Autonomous Systems and Controls (3).** This course provides an in-depth discussion to the fundamental components of autonomous systems and controls. In particular, the course will allow the students to master the building blocks. Prerequisite: COP 3337, COP 4338, or permission by instructor.

**EEL 5718 Computer-Communication Network Engineering (3).** System engineering synthesis, analysis, and evaluation of computer-communication networks. Network design, routing and flow control, telecommunication traffic engineering, transmission, switching, etc. Prerequisite: Permission of the instructor. (SS)

**EEL 5719 Digital Filters (3).** Analysis, design and implementation of digital filters. Hardware and software approach to design. Prerequisite: Permission of the instructor. (F)

**EEL 5725 Hardware Description Languages (VHDL or Verilog) (3).** This course involves systematic studies of Fault-Tolerant Digital Systems, VHDL and VERILOG based dynamic digital system designs, and system implementations with CPLDs, FPGAs, ASICs. Prerequisite: EEE 4304, EEL 4746 or Permission of the instructor. (F)

**EEL 5741 Advanced Microprocessor Systems (3).** Interfacing of various microprocessors together. Concepts of master-slave systems, virtual memory and I/O control techniques. Digital system evaluation and optimization.

Prerequisites: EEL 4746 or permission of the instructor. (SS, alternating years)

**EEL 5757 Real-Time Digital Signal Processing Implementations (3).** Techniques for the implementation of Digital Signal Processing (DSP) algorithms in dedicated processors, for assessing the real-time performance of audio, control, and communication systems. Prerequisites: EEE 4510 or permission of the instructor.

**EEL 5799 Advanced Concepts in Computer Engineering (3).** This course covers a range of topics and concepts required for pursuing a Master's Degree in Computer Engineering associated with the integration of hardware and software in devices for cybersecurity. Prerequisite: Instructor's Permission

**EEL 5807 Advanced Ethical Hacking (3).** This will give individuals exposure to the latest hacking tools and techniques to understand the anatomy of computer attacks and teach them the countermeasures to protect their valuable data.

**EEL 5809 Advanced Concepts in Electrical and Computer Engineering (3).** The course covers a range of topics to provide a theoretical foundation of cybersecurity in engineering for students entering into the cybersecurity program. Prerequisite: Instructor's Permission.

**EEL 5813 Neural Networks-Algorithms and Applications (3).** Various artificial neural networks and their training algorithms will be introduced. Their applications to electrical and computer engineering fields will also be covered. Prerequisite: Permission of the instructor. (SS)

**EEL 5820 Digital Image Processing (3).** Image Fundamentals, Image Transforms, Image Enhancement, Edge Detection, Image Segmentation, Texture Analysis, Image Restoration, and Image Compression. Prerequisite: EEL 3135 and knowledge of any programming language (FORTRAN, Pascal, C). (F)

**EEL 5935 Advanced Special Topics (1-3).** A course designed to give groups of students an opportunity to pursue special studies in an advanced topic of Electrical Engineering not otherwise offered. Prerequisite: Consent of instructor.

**EEL 5941 Graduate Electrical and Computer Engineering Internship (1-3).** Graduate students acquire practical experience through a supervised internship in the industry. The student prepares an internship proposal, and the work performed is documented in a report and presented. Prerequisite: Permission of the student's advisor.

**EEL 5945 Electrical and Computer Engineering Teaching Practicum (1).** Graduate students acquire practical teaching experience through supervised course teaching. The student prepares an internship proposal, and the work performed is documented in a report and presented. Prerequisite: Permission from the student's advisor and department. Corequisite: Teaching at least one full course during that semester.

**EEL 6020 Numerical Analysis of Electrical Devices (3).** Numerical techniques for the analysis of static and diffusion eddy current type field problems and associated phenomena in electrical devices. Emphasis on implementation and applications to practical problems.

Prerequisites: EEL 4213, MAP 3302 or equivalent or permission of the instructor. (SS)

**EEL 6141 Advanced Network Analysis (3).** Modeling and analysis of networks by t-domain and s-domain techniques. Topics include topology, formulation of loop eqs and node pair eqs., state-space networks, computer solutions. Prerequisites: EEL 3112 or permission of the instructor. (S, every third year)

**EEL 6167 VLSI Design (3).** Study of VLSI Design concepts in MOS/CMOS environment, CAD techniques, VLSI array processors and wavefront array processors, and implementation of array processors. Prerequisites: EEL 5741, EEE 4314. (SS, alternating years)

**EEL 6219 Electric Power Quality (3).** Modeling of networks under non-sinusoidal conditions, loads which may cause power quality problems, analysis of harmonics, flickers, impulses, standards, power quality improvement methods. Prerequisites: EEL 4213 or permission of the instructor.

**EEL 6235 Motor Drives Control (3).** Switched, resonant and bidirectional power supplies, DC motors: single, three-phase and chopper drives. AC motors: voltage, current and frequency control. Closed-loop control. Prerequisites: EEL 4213, EEE 3303, EEL 3657. (SS, alternating years)

**EEL 6253 Computer Analysis of Power Systems (3).** Power systems analysis and designs by computer solutions. Interactive solutions, power flow, optimum solutions. Dynamic solutions and stability. Prerequisites: EEL 4215 or permission of the instructor. (F, every third year)

**EEL 6254 Power Systems Reliability (3).** Expansion planning, load forecasting, reliability and availability application to generation planning, bulk power supply systems, generation system operation and production costing analysis. Prerequisites: EEL 4215 or permission of the instructor. (S)

**EEL 6261 Power Systems Engineering (3).** Steady-state analysis, fault studies, load flow, dynamic and transient performance, on-line control, practical applications. Prerequisites: EEL 4215 or permission of the instructor. (SS, every third year)

**EEL 6267 Application of Intelligent Systems to Power System Operations (3).** Power system security assessment using intelligence systems techniques such as pattern recognition, expert systems, and neural networks. Class projects include applying IS to load forecasting, alarm processing. Prerequisites: EEL 4214, EEL 6273. (SS, alternating years)

**EEL 6273 Power System Stability and Control (3).** Direct methods for system stability, computer analysis of large scale models, Lyapunov stability, longer term stability, security analysis, MW-frequency control, isolated and multiple area control. Prerequisites: EEL 4215 or permission of the instructor. (S)

**EEL 6292 Power Systems Economics and Markets (3).** This is a graduate-level course that covers the basic economics principles underpinning the design, operation, and planning of modern power systems in a competitive environment. Prerequisite: EEL 4213 or equivalent.

**EEL 6297 Introduction to Smart Grid and its applications (3).** This course covers the fundamentals of

smart grid. It provides the working definition of the functions, design criteria, tools, techniques, and technology needed for building smart grid. Prerequisite: EEL 4213 or equivalent.

**EEL 6438 RF and Microwave Photonics (3).** This course provides advanced principles of quantum computing and quantum information with in-depth analysis and state of the art implementations.

**EEL 6439 RF System Design for Wireless Communications (3).** The course introduces the basic concepts of wireless transceiver design for digital communications. Topics: RF transmitters and receivers, RF systems blocks, noise and noise figure, non-linearity, and intermodulations, intercepts points, phase noise, IIQ imbalances. Prerequisite: EEL 3514 or permission of the instructor

**EEL 6443 Electro-Optical Devices and Systems (3).** Introduction to optical devices and systems such as solid-state laser systems, their applications in industry. Also holography, linear and non-linear optical modulation and demodulation concepts. Prerequisites: EEL 4410, EEE 4314. Corequisites: EEL 5563 or permission of the instructor. (S, every third year)

**EEL 6444 Optical Fiber Communication Systems (3).** Course focuses on specification, design and application of fiber optic communication systems considering the fiber optic waveguide, optical device sources, photodetector, receiver and transmitter designs. Prerequisites: EEL 5501 or permission of the instructor. (S, every third year)

**EEL 6463 Antenna Theory and Design (3).** Radiation patterns of dipoles and loops, array analysis and synthesis, self-impedance and mutual impedance, frequency-independent antennas and antenna miniaturization, and reflectors and lens antenna. Prerequisite: EEL 4410. (S, alternating years)

**EEL 6468 Adaptive and Smart Antennas (3).** The course introduces an in-depth understanding of modern adaptive and smart antenna concepts. Topics include smart antennas, direction of arrival estimation, beamforming, and space-time processing. Prerequisite: EEL 5467 or permission of the instructor.

**EEL 6479 Electromagnetic Interference and Electromagnetic Compatibility (3).** The goal of this course is to teach concepts of electromagnetic compatibility and electromagnetic interference to the graduate students. Prerequisites: EEL 3135 and EEL 4410

**EEL 6509 Digital Communications by Satellite (3).** This course will consider processing and non-processing transponders, earth terminals, propagation link characteristics, multiple access techniques, and spread spectrum techniques. Prerequisites: EEL 5501 or permission of the instructor. (S)

**EEL 6536 Spectral Analysis (3).** Methods for the analysis and estimation of a signal's spectral content. These include nonparametric, parametric and line spectral estimation, filter bank techniques and array processing. Prerequisites: EEE 5543 or EEE 6502 or permission of the instructor.

**EEL 6572 Pictorial Information Systems Design (3).** Picture input device design, pictorial information systems

hardware, picture processor design, picture storage system design, pictorial database system design, picture communication interface design, and engineering applications. Prerequisites: EEL 4709C or CDA 4400. (SS)

**EEL 6575 Data Communications Engineering (3).** Digital networks for data communications, CCITT, HDLC, SDLC. Real-time switching techniques. Microprocessor-based network topologies. Busing schemes such as VME, MULTIB, RS232. Prerequisites: EEL 4746 and EEE 4314 or permission of the instructor. (F)

**EEL 6614 Modern Control Theory I (3).** Graduate-level treatment of modern control systems. Optimal control of feedback systems. Performance measures, Pontryagin's minimum principle, dynamic programming, numerical techniques. Prerequisites: EEL 5171 or permission of the instructor. (F, alternating years)

**EEL 6615 Modern Control Systems, Theory, and IoT Applications (3).** Course in Internet-of-things (IoT) applications, feedback control, and the hands-on implementation on the CPS systems sensing, and systems testing. Prerequisites: EEL 6614 or permission of the instructor. (S, alternating years)

**EEL 6673 Cyber-Physical Systems Identification and IoT Applications (3).** Course in Cyber-Physical System modeling, diagnostic tests, and systems validation. Hands-on implementation on the design of embedded CPS systems. Prerequisite: EEL 5171. (F, alternating years)

**EEL 6681 Fuzzy Systems Design (3).** Applications of fuzzy theory to develop design methodologies for various engineering systems. Emphasis will be on systems for pattern recognition, model identification, and automatic control. Prerequisite: Permission of the instructor.

**EEL 6726 Advanced VLSI Design (3).** Advanced design and development of Very Large Scale Integrated Circuit (VLSI) Micro Chip Structures. Micro Chip routing and thermal optimizations will be emphasized for implementing VLSI units. Prerequisite: Permission of the instructor. (S, every third year)

**EEL 6751 Wavelet Theory Applied to Signal Processing (3).** Application of wavelet theory to transient and non-stationary signal processing; compression and noise reduction of signals, singularity and edge detection, and time-frequency analysis. Prerequisites: EEL 3135 or equivalent.

**EEL 6758 Engineering Design of Microprocessor-Based Operating Systems (3).** Hardware microprocessor-based systems, BIOS (basic input and output), Kernel partitions, memory, stack organization and physical design of operating systems. Prerequisites: EEL 4709C and EEL 4746 or permission of the instructor. (S, every third year)

**EEL 6787 Network Security (3).** Network Security Requirements, Number Theory, Steganography, Encryption Design Principles and Algorithms, Message Authentication and Digital Signature Principle and Designs, Network System Security Design. Prerequisite: Permission of Instructor.

**EEL 6795 Power-Aware Computing (3).** The power/thermal challenges in computing system design; source of the power dissipation and power/thermal modeling; power/thermal aware design techniques at

different design abstraction levels. Prerequisites: EEL 4709C or permission of the instructor.

**EEL 6803 Advanced Digital Forensics (3).** This course provides students with the advanced skills to track and counter a wide range of sophisticated threats including espionage, hacktivism, financial crime syndication, and APT groups. Prerequisite: EEL 4802.

**EEL 6805 Advanced Malware Reverse Engineering (3).** This course provides the student with the necessary tools and techniques to perform practical reverse engineering on suspicious files and firmware encountered in a range of devices and understanding the implications associated with malware attacks. Prerequisite: EEL 4802.

**EEL 6812 Advances in Neural Networks (3).** Latest concepts in artificial neural networks research and newly developed applications. Implementation, convergence in learning algorithms, accuracy refinement, and optimal structure of neural networks. Engineering applications. Prerequisite: EEL 5810. (F, alternating years)

**EEL 6816 Electronic Neural Systems (3).** This course bridges electronics to the understanding of neurobiologically inspired models. Biological tasks and neural computations are studied in the context of networks and processing elements. Prerequisite: Permission of Instructor.

**EEL 6821 Computer Vision (3).** Image formation and image properties, Radiance and irradiance, introduction to Brain Topography, Color Vision, visual machinery of the brain, statistical pattern classification and decision functions, the eigensystem and its computational aspects, stereo vision, motion vision, size and orientation independence. Prerequisite: EEL 5820. (S)

**EEL 6825 Pattern Recognition (3).** Pattern recognition techniques via computer: decision functions, optimum decision criteria, training algorithms, unsupervised learning, feature extraction, data reduction, machine intelligence. Prerequisites: EEE 5543 or permission of Instructor.

**EEL 6836 Computer Visualization of Brain Electrical Activity (3).** Computer techniques for the visualization of brain electrical activity. Analysis of the origin of this activity as it relates to its measurement and visualization through computerized systems. Prerequisites: EEE 4510 or permission of instructor.

**EEL 6870 Intelligent Computer Design (3).** The course involves self-testing and correcting type of modular computer system development. Also concepts relating to Artificial Intelligence and Expert systems will be integrated into the computer system design. Prerequisite: EEL 4709C. (F, alternating years)

**EEL 6894 Real-Time Computing and Applications (3).** Introduction to real-time computing; real-time system modeling; classic uniprocessor scheduling; power-aware and thermal-aware real-time scheduling; multiprocessor and distributed real-time computing. Prerequisites: EEL 4709C or permission of the instructor.

**EEL 6905 Individual Work (1-4).** Special problems or projects selected by the students and faculty member. The student conducts the project with a minimum of supervision. Consent of Department Chairperson and Faculty Advisor.

**EEL 6916 Graduate Project (3).** Independent research work culminating in a professional practice-oriented report for the requirements of the non-thesis option of the M.S. degree project. Prerequisites: Fifteen graduate credits and approved project plan.

**EEL 6931 Special Topics in Electrical and Computer Engineering (1-3).** Course covers advanced topics not in existing graduate courses in electrical and computer engineering. Prerequisite: Permission of the instructor.

**EEL 6932 Graduate Seminar (1).** An examination of recent technical findings in selected areas of concern. Emphasis is placed on presentations (oral and written), research activities, readings, and active discussions among participants. Prerequisite: Consent of graduate advisor.

**EEL 6971 Research Master's Thesis (1-6).** The student, following the option of the Master's Degree with thesis, should work for his/her thesis through this course. Prerequisite: Graduate standing.

**EEL 6977 Extended Thesis Research (0).** For Graduate research students who have completed their sequence of thesis credits, but must register for a course to remain on graduate student status.

**EEL 7910 Advanced Research (1-6).** Advanced research credits under the supervision of the dissertation advisor. Prerequisite: Completion of the written comprehensive examination.

**EEL 7980 Ph.D. Dissertation (1-12).** Doctoral research leading to Ph.D. Electrical Engineering Dissertation. Prerequisites: Permission of Major Professor and Doctoral Candidacy.

**OSE 6492 Nanophotonics (3).** This course focuses on nanoscale processes and devices and their applications for manipulating light on the nanoscale. Photonic crystals, plasmonics, metamaterials and Si photonics are covered. Prerequisites: EEE 3396, EEE 5425 or equivalent.

**TCN 5155 Wireless Communications with Multimedia Applications (3).** Overview of wireless communications systems; interference, blocking, spectral efficiency; performance of digital modulation in the presence of fading; diversity techniques; and multimedia applications. Prerequisite: EEL 3514.

**TCN 5271 Advanced IoT Communications and Networking (3).** This course presents advanced paradigms in terms of communication of IoT devices and the underlying networking protocols. Topics covered include IoT platforms, applications and protocol stack. Prerequisites: Graduate standing and permission of the instructor.

**TCN 6276 Antennas for Wireless and Body-Centric Communications (3).** Advanced antenna theory, simulation, and design as applied to wireless communications, advanced state-of-the-art antenna systems, and body-centric wireless communications. Prerequisites: EEL 4410 or permission of the instructor.

**TPA 5213 Performing Arts Technology (2).** Applications of structural, mechanical, electrical and electronic technologies to prepare performing arts students for management and production roles. Includes basic circuits

and NEC codes, control systems. Prerequisite: Permission of graduate advisor.