Electrical Engineering

Degrees Offered

- Masters of Science, Electrical Engineering (M.S.E.E.)
- Doctor of Philosophy, Electrical Engineering (Ph.D.)

Nature of the Program

The Masters of Science in Electrical Engineering (M.S.E.E.) degree program is intended for students who have an undergraduate degree in Electrical Engineering, Computer Engineering, or a closely related discipline, and wish to broaden their depth of understanding in one or more areas of the field. Program graduates will be qualified to pursue careers in industry, government, or further academic study. The Doctor of Philosophy program should be considered by those with superior academic achievement and who desire to pursue a career of research or teaching.

Masters Program Educational Objectives & Outcomes

The objective of the Master of Science in Electrical Engineering (M.S.E.E.) degree program is to produce graduates who have the knowledge, skills, and attitudes that will ensure success in professional positions in business, industry, research, government service, or in further graduate or professional study.

Specific outcomes that will be achieved by graduates of the program are:

1. Achieve a depth of proficiency in a specific field of Electrical Engineering by completing major courses in one of four areas: electronics and photonics; systems and signals; computer systems; or software and knowledge engineering.
2. Achieve a breadth of understanding of Electrical Engineering by completing minor coursework requirements in another area, and by participation in graduate seminar requirements.
3. Demonstrate professionalism and communication skills through completion of coursework, project or thesis defense.

Doctoral Program Educational Objectives & Outcomes

The objective of the Ph.D. Program in Electrical Engineering degree program is to produce graduates who have the knowledge, skills, and attitudes that will ensure success in professional positions in business, industry, research, government service, or in further graduate or professional study.

Specific outcomes that will be achieved by graduates of the program are:

1. Achieve a depth of understanding in Electrical Engineering, as demonstrated by completion of core Ph.D. courses and examination on that material through the Qualifying Examination process.
2. Achieve a breadth of understanding of the Electrical Engineering discipline, as demonstrated by completion of remaining doctoral coursework and participation in graduate seminar.
3. Demonstrate the ability to conduct independent research by completion and defense of a dissertation.

Admissions

All Masters and Ph.D. programs require applicants to provide the items below to be considered for admission. Specific programs may have additional requirements. Exception: These requirements do not apply to nontraditional students in the Certificate of Software Engineering program and M.S.S.E. program (see certificate program and M.S.S.E. program for more information):

- A minimum cumulative grade point average of 3.0 or equivalent, based on a 4.0 system.
- Three letters of reference.
- International students must demonstrate proficiency in communicating in English (a minimum TOEFL Score of 550, or iBT Score of 79, or IELTS Score of 6.5). (Students who have completed a recent four-year bachelor’s degree in the USA need not submit these scores.)
- All graduate degree programs require the GRE general test, with a suggested score of either the 80th percentile on the quantitative part or 80th percentile total (verbal + quantitative + analytical).
- All graduate degree programs require an appropriate bachelors or master’s degree for entry. Students lacking some foundation courses appropriate to a particular degree program may be assigned some remedial coursework as a condition of admission.
- See: Certificate in Software Engineering; Master of Science in Software Engineering for alternative admission requirements to those programs for working professionals.

Regular, Provisional, and Non-Degree Admission

Students admitted into a program are designated as regular status or provisional. The department also admits students to non-degree status in the College of Engineering and Mineral Resources, but these students are not admitted to any specific program. Regular status is given to students who are
qualified for unconditional admission to a specific program. Provisional status is given to students who have deficiencies to make up such as incomplete credentials or other reasons as identified by the graduate coordinator. In all cases, the student’s letter of admission will state what must be done to attain regular status.

Provisional students must complete the requirements for transfer to regular status by the end of the semester in which they complete eighteen credit hours. Usually provisional students are not considered for graduate assistantships or tuition waivers.

Non-degree status is granted upon request to students meeting the minimum admission requirements. A non-degree student is one who wishes to take courses without seeking a formal degree. Non-degree students require permission of the instructor to take courses that are restricted to specific majors. There is no guarantee of eventual acceptance into a degree program, and in no case may more than twelve hours be transferred to a degree program.

Non-degree students may not be offered graduate assistantships or tuition waivers.

**Curriculum in Master of Science in Electrical Engineering Masters**

A candidate for the M.S. degree in electrical engineering must comply with the rules and regulations as outlined in the WVU Graduate Catalog and the specific requirements of the Statler College and the Lane Department of Computer Science and Electrical Engineering.

**Program Requirements**

All M.S. degree candidates are required to perform research and follow a planned program of study. The student’s research advisor, in conjunction with the student’s Advising and Examining Committee (AEC) will be responsible for determining the plan of study appropriate to the student’s needs. The underlying principle of the planned program is to provide the students with the necessary support to complete their degree and prepare them for their career.

**Curriculum Requirements**

A minimum cumulative GPA of 3.0 is required

<table>
<thead>
<tr>
<th>Course Requirements *</th>
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<tbody>
<tr>
<td>No more than 9 credit hours may be at the 400 level.</td>
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| EE 796 | Graduate Seminar | 1 |

<table>
<thead>
<tr>
<th>Area of Concentration</th>
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<tbody>
<tr>
<td>Complete one Area of Concentration:</td>
<td>9</td>
</tr>
<tr>
<td>One Core course</td>
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<tr>
<td>Two Elective courses</td>
<td>3</td>
</tr>
<tr>
<td>Complete one additional core course from a second area of concentration.</td>
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</tr>
<tr>
<td>Choose 12 additional credit hours from the courses listed in any EE area of concentration</td>
<td>12</td>
</tr>
</tbody>
</table>

| Complete 1 of the following options: | 7-9 |

<table>
<thead>
<tr>
<th>Thesis Option - 7 hours</th>
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<tbody>
<tr>
<td>EE 796</td>
<td>Graduate Seminar (1 hour)</td>
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<tr>
<td>EE 697</td>
<td>Research (6 hours)</td>
</tr>
<tr>
<td>Thesis</td>
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<tr>
<td>Final Oral or Written Examination</td>
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</table>

<table>
<thead>
<tr>
<th>Problem Report Option - 9 hours</th>
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<tbody>
<tr>
<td>Complete a minimum 6 additional hours of coursework, at least 3 hours of which must be from the completed area of concentration.</td>
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</tr>
<tr>
<td>EE 697</td>
<td>Research (3 hours)</td>
</tr>
<tr>
<td>Formal written report or professional report/paper</td>
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<tr>
<td>Final Oral or Written Examination</td>
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</table>

<table>
<thead>
<tr>
<th>Coursework Option - 9 hours</th>
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<tbody>
<tr>
<td>Complete a minimum of 9 additional hours of coursework, at least 6 hours of which must be from the completed area of concentration.</td>
<td></td>
</tr>
<tr>
<td>Final Oral or Written Examination</td>
<td></td>
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</tbody>
</table>

**Total Hours** 32-34

* Students who do not hold a baccalaureate degree in electrical engineering are required to take a set of undergraduate electrical engineering courses above and beyond the minimum coursework requirements.
# Areas of Concentration

## ELECTRONIC AND PHOTONICS

### Core Courses
- **EE 550**: Advanced Semiconductor Electronics (3 credits)
- **EE 551**: Linear Integrated Circuits (3 credits)

### Elective Courses
- **EE 435**: Introduction to Power Electronics (3 credits)
- **EE 437**: Fiber Optics Communications (3 credits)
- **EE 455**: Introduction to Microfabrication (3 credits)
- **EE 457**: Fundamentals of Photonics (3 credits)
- **EE 528**: Biomedical Microdevices (3 credits)
- **EE 650**: Optoelectronics (3 credits)
- **PHYS 771**: Introduction to Solid State Physics (3 credits)
- **PHYS 772**: Semiconductor Physics (3 credits)
- **PHYS 773**: Collective Phenomena in Solids (3 credits)
- **CHE 466**: Electronic Materials Processing (3 credits)

## SIGNALS AND SYSTEMS

### Core Courses
- **EE 513**: Stochastic Systems Theory (3 credits)
- **EE 515**: Linear Control Systems (3 credits)

### Elective Courses
- **EE 461**: Introduction to Communications Systems (3 credits)
- **EE 465**: Introduction to Digital Image Processing (3 credits)
- **EE 517**: Optimal Control (3 credits)
- **EE 531**: Advanced Electrical Machinery (3 credits)
- **EE 533**: Computer Applications in Power System Analysis (3 credits)
- **EE 535**: Power System Control and Stability (3 credits)
- **EE 561**: Communication Theory (3 credits)
- **EE 562**: Wireless Communication System (3 credits)
- **EE 565**: Advanced Image Processing (3 credits)
- **EE 567**: Coding Theory (3 credits)
- **EE 568**: Information Theory (3 credits)
- **EE 569**: Digital Video Processing (3 credits)
- **EE 613**: Detection and Estimation Theory (3 credits)
- **EE 713**: Large-Scale System Modeling (3 credits)
- **EE 731**: Real Time Control of Power System (3 credits)
- **EE 733**: Protection of Power Systems (3 credits)
- **EE 735**: HVDC Transmission (3 credits)

## COMPUTER SYSTEMS

### Core Courses
- **CPE 553**: Advanced Networking Concepts (3 credits)
- **CPE 670**: Switching Circuit Theory 1 (3 credits)

### Elective Courses
- **CPE 435**: Computer Incident Response (3 credits)
- **CPE 520**: Application of Neural Networks (3 credits)
- **CPE 521**: Applied Fuzzy Logic (3 credits)
- **CPE 536**: Computer Data Forensics (3 credits)
- **CPE 538**: Intro Computer Security Management (3 credits)
- **CPE 664**: Sensor Actuator Networks (3 credits)
SOFTWARE/KNOWLEDGE ENGINEERING

Core Courses
CPE 684 Advanced Real-Time Systems 3
CS 573 Advanced Data Mining 3
CS 630 Empirical Methods in Software Engineering and Computer Science 3
CS 677 Pattern Recognition 3

Elective Courses
BIOM 693 Special Topics (Advanced Biometrics) 3
CS 533 Developing Portable Software 3
CS 558 Multimedia Systems 3
CS 572 Advanced Artificial Intelligence Techniques 3
CS 665 Computer System Security 3
CS 674 Computational Photography 3
CS 676 Machine Learning 3
CS 757 Distributed Systems and Algorithms 3
EE 565 Advanced Image Processing 3
SENG 550 Object Oriented Design 3

Final Examination

M.S. students following the thesis or problem report option must prepare a written research proposal. The proposal must be approved by the student’s AEC at least one semester prior to the final oral examination.

All students, regardless of option, are required to pass a final oral or written examination, administered by their AEC, covering the thesis or problem report and/or related course material.

All master’s students must defend their thesis or problem report at an oral exam, attended by all members of the committee.

A student who fails the research defense may repeat the defense at most once, at a time determined by the AEC but not necessarily during the same semester.

Suggested Plan of Study

The plan below illustrates the Thesis Option. It is important for students to take courses in the order specified as much as possible; all prerequisites and concurrent requirements must be observed. A typical M.S.E.E degree program that completes degree requirements in one and half years is as follows. Those students who lack course prerequisites may require more than three semesters of full-time study to complete the degree. Students with research assistantships may also require more than three semesters to complete the degree.

First Year

<table>
<thead>
<tr>
<th>Fall</th>
<th>Hours</th>
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</thead>
<tbody>
<tr>
<td>Field of Study 1 Core Course</td>
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</tr>
<tr>
<td>Field of Study 1 Elective Course</td>
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</tr>
<tr>
<td>Elective Course</td>
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</table>

<table>
<thead>
<tr>
<th>Spring</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field of Study 1 Elective Course</td>
<td>3</td>
</tr>
<tr>
<td>Field of Study 2 Core Course</td>
<td>3</td>
</tr>
<tr>
<td>Elective Course</td>
<td>3</td>
</tr>
</tbody>
</table>
Second Year

<table>
<thead>
<tr>
<th>Field of Study 3 Core Course</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elective Course</td>
<td>3</td>
</tr>
<tr>
<td>EE 697</td>
<td>6</td>
</tr>
<tr>
<td><strong>Total Hours</strong></td>
<td><strong>12</strong></td>
</tr>
</tbody>
</table>

Total credit hours: 32

**AREA OF EMPHASIS IN CYBERSECURITY**

A 3.0 GPA is required in AOE coursework.

**Required Courses**

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Hours</th>
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</thead>
<tbody>
<tr>
<td>CPE 536</td>
<td>Computer Data Forensics</td>
<td>3</td>
</tr>
<tr>
<td>CPE 568</td>
<td>Computer Network Forensics</td>
<td>3</td>
</tr>
<tr>
<td>CS 539</td>
<td>Computer Forensics and the Law</td>
<td>3</td>
</tr>
</tbody>
</table>

Select one of the following:

- CPE 538  Intro Computer Security Management  3
- CS 569   Cybersecurity and Big Data Analytics 3

Total Hours 12

**Curriculum in Doctor of Philosophy – Electrical Engineering Requirements**

A candidate for the Ph.D. degree with a major in electrical engineering must comply with the rules and regulations as outlined in the WVU Graduate Catalog and the specific requirements of the Statler College and the Lane Department of Computer Science and Electrical Engineering.

**Program Requirements**

The doctor of philosophy degree with a major in electrical engineering is administered through the college’s interdisciplinary Ph.D. program. The research work for the doctoral dissertation must show a high degree of originality on the part of the student and must constitute an original contribution to the art and science of electrical engineering.

All Ph.D. degree candidates are required to perform research and follow a planned program of study. The student’s research advisor, in conjunction with the student’s Advising and Examining Committee (AEC) will be responsible for determining the plan of study appropriate to the student’s needs. The underlying principle of the planned program is to provide the students with the necessary support to complete their degree and prepare them for their career.

Research work for the doctoral dissertation must represent a significant contribution to engineering or computer science. It may entail a fundamental investigation into a specialized area. A minimum of twenty-four credit hours of research (EE 797) is required.

**Curriculum Requirements**

A minimum cumulative GPA of 3.0 is required

**Course Requirements**

- A minimum of six credit hours of 600 or higher level courses
- A maximum of six credit hours may be in directed study (EE 795)
- Research 24
- **Total Hours** 42

**Examinations**

- Qualifying Exam
- Candidacy Exam
- Final Exam
Students who do not hold a baccalaureate degree in electrical engineering are required to take a set of undergraduate electrical engineering courses above and beyond the minimum coursework requirements. Doctoral students who do not have an M.S.E.E. degree must either earn this degree, or complete coursework as required for the Master's degree with thesis option. It is not necessary to actually write a thesis. A minimum of twenty-four hours of coursework is required. Up to twelve hours may be transferred from work done at another institution. A minimum of forty-two hours of coursework and thirty hours of independent research beyond a bachelor’s degree, or eighteen hours of coursework and twenty-four hours of independent research beyond an M.S. degree are required.

Examinations

QUALIFYING EXAM

All students must take and pass a written qualifying examination. Normally, the qualifying examination is given no later than one semester after completion of eighteen credit hours toward the doctoral degree. This examination is designed to assess the basic competency of students in the electrical engineering field to determine whether or not they have sufficient knowledge to undertake independent research.

The Lane Department of Computer Science and Electrical Engineering is organized in the following five Areas of Concentration. All Ph.D. degree programs use these Areas to provide organizational structure to the educational process as delineated under specific Ph.D. requirements. The significance of these Areas will be of particular importance in preparation for the Qualifying Exam as each area has designated Ph.D. Qualifier Core Courses as follows:

1. Electronics and Photonics Area
   - EE 550 Advanced Semiconductor Electronics
   - EE 551 Linear Integrated Circuits
   - EE 650 Optoelectronics

2. Signals and Systems Area
   - EE 513 Stochastic Systems Theory
   - EE 515 Linear Control Systems
   - EE 533 Computer Applications in Power System Analysis

3. Computer Systems
   - CPE 670 Switching Circuit Theory 1
   - CS 550 Theory of Operating Systems

4. Software/Knowledge Engineering
   - CPE 684 Advanced Real-Time Systems
   - CS 573 Advanced Data Mining
   - CS 591Q Pattern Recognition

5. Theory of Computing
   - CS 510 Formal Specification of Language
   - CS 520 Advanced Analysis of Algorithms
   - CS 525 Computational Complexity

Ph.D. students must make the first attempt to pass the qualifying exam within fourteen months of their enrollment if they already have a M.S. degree from the Lane Department of CSEE or within twenty-six months otherwise. The Ph.D. qualifying process consists of completion of a research project and oral examination. The project is intended to demonstrate the student's ability to assemble and analyze the relevant literature for a given research problem and to make preliminary steps towards his/her own contribution.

The oral exam will include:

1. Presentation by the student of his/her research project
2. Questions about the work, its context, and relevant literature
3. Questions about course work, focusing specifically on the three core courses for which the student has earned credit

The possible outcomes of the first year exam are: “Pass” which means the student is qualified to begin work towards the candidacy exam; “Pass with Recommended Coursework” which means the student is qualified to begin work towards a candidacy exam but certain courses must be taken; or “Fail”. Any student failing the qualifying exam on the initial attempt will have one additional attempt within six months. Failure of the exam on the second attempt will disqualify the student from further doctoral studies in the LCSEE program.
CANDIDACY EXAMINATION

In order to be admitted to candidacy, the student must pass a candidacy exam, which is designed to evaluate the student’s overall ability to engage in high-level research.

When all requirements are completed, the qualifying and candidacy examinations are passed, and the research proposal is successfully defended, the student is formally admitted to candidacy for the Ph.D. degree. For full-time students, admission to candidacy must occur within three years of entering the Ph.D. program.

FINAL EXAMINATION

At the completion of the dissertation research, candidates must prepare a dissertation and pass the final oral examination (defense) administered by their AEC.

In order to complete the Ph.D. requirements, a student must pass a final oral examination on the results embodied in the dissertation. This examination is open to the public and, in order to evaluate critically the student’s competency, may include testing on material in related fields, as deemed necessary by the AEC. All requirements for the degree must be completed within five years after the student has been admitted to candidacy.

Suggested Plan of Study

It is important for students to take courses in the order specified as much as possible; all prerequisites and concurrent requirements must be observed. A typical doctoral degree program that completes degree requirements in three years is as follows. A typical Ph.D. program requires four to five years beyond the baccalaureate degree, although scholarly achievements are more important than length of program.

First Year

<table>
<thead>
<tr>
<th>Fall</th>
<th>Spring</th>
<th>Hours</th>
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<tbody>
<tr>
<td>Course</td>
<td>3 Course</td>
<td>3</td>
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<tr>
<td>Course</td>
<td>3 Course</td>
<td>3</td>
</tr>
<tr>
<td>EE 797</td>
<td>3 EE 797</td>
<td>3</td>
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<tr>
<td></td>
<td></td>
<td>9</td>
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</tbody>
</table>

Second Year

<table>
<thead>
<tr>
<th>Fall</th>
<th>Spring</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>EE 797</td>
<td>9 EE 797</td>
<td>9</td>
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</tbody>
</table>

Third Year

<table>
<thead>
<tr>
<th>Fall</th>
<th>Spring</th>
<th>Hours</th>
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<tbody>
<tr>
<td>Course</td>
<td>3 Course</td>
<td>3</td>
</tr>
<tr>
<td>EE 797</td>
<td>6 EE 797</td>
<td>6</td>
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</tbody>
</table>

Total credit hours: 54

Major Learning Outcomes

ELECTRICAL ENGINEERING

It is our goal that in the first five years after graduation our students will:

2. Be recognized as leaders.
3. Contribute to the well-being of society.

COURSES

EE 513. Stochastic Systems Theory. 3 Hours.

EE 515. Linear Control Systems. 3 Hours.
PR: Consent. Basic concepts in the theory of linear control systems, state variable representation, solution of state equations, controllability, observability, stability, transfer function descriptions, and design of controllers and observers. (3 hr. rec.).
EE 517. Optimal Control. 3 Hours.
PR: Consent. Methods of direct synthesis and optimization of feedback systems; Wiener theory; Pontryagin's maximum principle; dynamic programming; adaptive feedback systems. (3 hr. rec.).

EE 528. Biomedical Microdevices. 3 Hours.
Fundamentals of micro-manufacturing and micro-fluidics, microfluidic platforms and components, biosensors, drug-delivery systems, lab-on-a-chip devices, DNA microarrays, emerging applications in biomedicine and tissue engineering, and photolithography and soft lithography lab demonstration.

EE 531. Advanced Electrical Machinery. 3 Hours.
PR: Consent. Theory and modeling of synchronous, induction, and direct-current machines, and their steady-state and transient analysis. (3 hr. rec.).

EE 533. Computer Applications in Power System Analysis. 3 Hours.
PR: EE 436 or Consent. Steady state analysis by digital computers of large integrated electrical power systems. Bus admittance and impedance matrices, load flow studies, economic dispatch and optimal power flow, steady state security analysis, and fault studies. (3 hr. rec.).

EE 535. Power System Control and Stability. 3 Hours.
PR: EE 515. Review of stability theory, classical transient analysis, dynamical models of synchronous machines, power system stability under small and large perturbations, dynamic, and simulation of power systems. (3 hr. rec.).

EE 550. Advanced Semiconductor Electronics. 3 Hours.

EE 551. Linear Integrated Circuits. 3 Hours.
PR: EE 355 and EE 356 and EE 450 or equivalent. Design and analysis of analog integrated circuits. Both linear and nonlinear transistor models are covered. Applications focus on linear analog circuits including simple amplifiers, operational amplifiers, and reference circuits. This course focuses on CMOS technology.

EE 561. Communication Theory. 3 Hours.
PR: EE 461 or Consent. Detailed study of probability theory and its use in describing random variables and stochastic processes. Emphasis on applications to problems in communication system design. (3 hr. rec.).

EE 562. Wireless Communication System. 3 Hours.
PR: EE 461 and EE 513. Architecture and design of cellular and wireless communication networks, electromagnetic effects of the wireless channel and corresponding statistical models, implementation and performance of diversity reception techniques, and multiple-access.

EE 564. Digital Signal Processing for Radio Astronomy. 3 Hours.
PR: Graduate Standing and/or consent. Digital signal processing as applied to radio astronomy. Filtering, Fourier transforms and correlation firmware are designed for Field Programmable Gate Arrays.

EE 565. Advanced Image Processing. 3 Hours.
PR: EE 465 or equivalent. Covers the theory of statistically modeling image source, algorithms for analysis and processing of image signals, new applications of image processing into computer vision and biomedical imaging, and MATLAB based image processing.

EE 567. Coding Theory. 3 Hours.
PR: MATH 375 or consent. Design, analysis, and implementation of codes for error detection and correction.

EE 568. Information Theory. 3 Hours.
PR: STAT 215 or equivalent, or consent. Information measures and mutual information; noiseless coding theorem, construction of compact codes and universal codes; channel coding theorem and error correcting codes; cryptography and information theory; algorithmic information theory, and rate distortion theory.

EE 569. Digital Video Processing. 3 Hours.
PR: EE 465. Covers basic theory and algorithmic aspects of digital video processing, along with latest video coding standards, multimedia streaming, security video, and biometrics. Hands-on experience in processing video signals under MATLAB in team-based projects.

EE 591L-V. Advanced Topics. 1-6 Hours.
PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

EE 595. Independent Study. 1-6 Hours.
Faculty supervised study of topics not available through regular course offerings.

EE 613. Detection and Estimation Theory. 3 Hours.

EE 650. Optoeletronics. 3 Hours.
PR: EE 450 or PHYS 471 or consent. Semiconductor physics theory of light-emitting diodes, homojunction lasers, single and double heterojunction lasers, separate confinement quantum well lasers, p-i-n and photo detectors and avalanche photo detectors. Optical and electrical analysis of epitaxial and device designs.
EE 689. Graduate Internship. 1-3 Hours.
PR: Completion of a minimum of 18 degree applicable graduate credit hours with a minimum GPA of 3.0 or better. Employment in industry related to degree program. (Graded P/F. May be repeated twice. Cannot be counted toward graduation requirements.).

EE 691. Advanced Topics. 1-6 Hours.
PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

EE 695. Independent Study. 1-6 Hours.
Faculty supervised study of topics not available through regular course offerings.

EE 697. Research. 1-15 Hours.
PR: Consent. Research activities leading to thesis, problem report, research paper or equivalent scholarly project, or a dissertation. (Grading may be S/U.)

EE 699. Graduate Colloquium. 1-6 Hours.
PR: Consent. For graduate students not seeking coursework credit but who wish to meet residency requirements, use the University's facilities, and participate in its academic and cultural programs. Note: Graduate students who are not actively involved in coursework or research are entitled, through enrollment in their department's 699/799 Graduate Colloquium to consult with graduate faculty, participate in both formal and informal academic activities sponsored by their program, and retain all of the rights and privileges of duly enrolled students. Grading is S/U, colloquium credit may not be counted against credit requirements for masters programs. Registration for one credit of 699/799 graduate colloquium satisfies the University requirement of registration in the semester in which graduation occurs.

EE 713. Large-Scale System Modeling. 3 Hours.
PR: EE 515. Characterization of large-scale systems, model simplification through aggregation and perturbation methods, optimal and chained aggregation, balanced realization and cost component procedures, optimal model reduction, simplification effects, decentralized control, and feasibility and design. (3 hr. lec.).

EE 731. Real Time Control of Power System. 3 Hours.
PR: EE 515 and EE 517 and EE 533. Application of computers to modern control theory for reliable and economic real-time operation of integrated power systems. (3 hr. rec.).

EE 733. Protection of Power Systems. 3 Hours.
PR: EE 436 or Consent. Principles of relay protection for faults on transmission lines and other devices. Use of overcurrent, differential distance, and pilot relaying systems. Special relay applications. Determination of short-circuit currents and voltages from system studies. (3 hr. rec.).

EE 735. HVDC Transmission. 3 Hours.
PR: EE 435 and EE 533. Line-commutated converter analysis, operation of two terminal and multiterminal dc systems, harmonics and filters, modeling of ac/dc system, and design of modulation controllers.

EE 790. Teaching Practicum. 1-3 Hours.
PR: Consent. Supervised practice in college teaching of electrical engineering. Note: This course is intended to insure that graduate assistants are adequately prepared and supervised when they are given college teaching responsibility. It will also present a mechanism for students not on assistantships to gain teaching experience. (Grading will be S/U.).

EE 791. Advanced Topics. 1-6 Hours.
PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

EE 792. Directed Study. 1-6 Hours.
Directed study, reading, and/or research.

EE 793. Special Topics. 1-6 Hours.
A study of contemporary topics selected from recent developments in the field.

EE 794. Seminar. 1-6 Hours.
Special seminars arranged for advanced graduate students.

EE 795. Independent Study. 1-9 Hours.
Faculty supervised study of topics not available through regular course offerings.

EE 796. Graduate Seminar. 1 Hour.
PR: Consent. Each graduate student will present at least one seminar to the assembled faculty and graduate student body of his or her program.

EE 797. Research. 1-15 Hours.
PR: Consent. Research activities leading to thesis, problem report, research paper or equivalent scholarly project, or a dissertation. (Grading may be S/U.)

EE 798. Thesis or Dissertation. 1-6 Hours.
PR: Consent. This is an optional course for programs that wish to provide formal supervision during the writing of student reports (698), or dissertations (798). Grading is normal.
EE 799. Graduate Colloquium. 1-6 Hours.
PR: Consent. For graduate students not seeking coursework credit but who wish to meet residency requirements, use the University's facilities, and participate in its academic and cultural programs. Note: Graduate students who are not actively involved in coursework or research are entitled, through enrollment in their department's 699/799 Graduate Colloquium to consult with graduate faculty, participate in both formal and informal academic activities sponsored by their program, and retain all of the rights and privileges of duly enrolled students. Grading is S/U; colloquium credit may not be counted against credit requirements for masters programs. Registration for one credit of 699/799 graduate colloquium satisfies the University requirement of registration in the semester in which graduation occurs.