COMPUTER ENGINEERING

The following emphasis areas are offered at the bachelor of science level: computational intelligence, computer architecture and embedded systems, integrated circuits and logic design, and networking, security and dependability.

The computer engineering program is designed to prepare an engineer to work with software and hardware of computers. In the software world, high level languages and complex programs are often the solution to a problem. In the hardware world, designs also include many aspects of the physical world, like temperature or noise, and often must include compromises between many opposing factors. The ability of a computer engineer to work in both worlds is what distinguishes them from a computer scientist or from an electrical engineer who specializes in computers. Computer scientists typically have little training with hardware. Electrical engineers typically have little training with software. Our students are trained to work with both, since many computer systems cannot be built well without a clear understanding of both.

Computer engineers can be found just about anywhere there are computers. Computer engineers might build the integrated circuits (ICs) that go into your home video game or your cell phone. They might develop the microprocessor that goes into your home computer, deciding what instructions it executes and how it interfaces with memory. Computer engineers also build computer systems that use these integrated circuits – for example, they might put together the ICs to build the motherboard for your home computer or the video card that goes into that computer. Computer engineers also help computers work together, for example developing computer networks or working with parallel processing. Computer engineers also help build embedded computer systems. These are devices with a computer inside them that work directly with their environment. They could be as complicated as a satellite or as everyday as your car, your phone, or even your microwave oven. Computer engineers also build software. They might be found at companies like Microsoft, working strictly with software or helping complex software systems interface better with hardware. They might make computers "smarter" using concepts of computational intelligence. Since computers are such an important part of our lives, the options for computer engineers are wide open.

Our ABET-accredited computer engineering program emphasizes both hands-on experience and training in fundamental concepts and theory. Students participate in many laboratories that include both hardware and software. Many lecture courses include one or more projects that require the student to build something "real" and make it work. All students take a 1-year design course for this reason in their final year in the program. While these projects are challenging, they are also fun and prepare a student to perform immediately on the job when they get out of school. Coursework also concentrates strongly on theory and fundamentals because this background is essential for our students to fully understand the systems they will work on to quickly learn new concepts as their job function changes and to adapt to the rapidly changing world of computers in the future.

Students complete the foundational engineering and computing program, thus obtaining basic science skills and an overview of the various degree programs at Missouri S&T, before entering the main program. This allows students time to consider different career options before they commit to a given degree program.The computer engineering program includes several courses in both electrical engineering and computer science. The program follows the electrical engineering program into the sophomore year, including courses like circuits and electronics, and then branches into computer science courses such as data structures and operating systems.

Students work closely with their advisors to carefully plan each semester class schedule in order to have the correct prerequisites for courses in the following semesters. Working with their advisor, they should also select electives in the program to provide the background in areas they wish to emphasize for their career path.

Double majors – particularly with electrical engineering and computer science – are a possibility. Students working with their advisor should be able to plan a program that allows them to quickly graduate with more than one degree by sharing some electives and carefully planning additional course work. Students considering taking several more classes should also consider the alternative of working towards an M.S. or Ph.D. degree in graduate school.

Educational Mission

The electrical and computer engineering department strives to contribute to the state, nation, and world through the education of outstanding professionals and leaders in engineering. Our educational focus is on a broad, rigorous education in all areas of electrical and computer engineering with significant hands-on experiences. The program will provide students with an understanding of engineering problem solving at all levels and an appreciation for engineering as a profession.

Objectives

The electrical and computer engineering degree programs seek to prepare its graduates to attain the following accomplishments a few years after graduation:

- Succeed in professional career placement and practice as ethical engineers, scholars and entrepreneurs;
- Grow their career through technical and professional activities and leadership roles;
- Contribute to society and the economy through technical products, services, communication and knowledge; and
- Adapt to an ever-changing world through continued education, through graduate study, professional development activities, independent learning, or pursuit of follow-on degrees

In order to attain these objectives, students graduating from the electrical and computer engineering degree programs should have the following attributes:

- **Technical Competency.** Graduates will have a sound knowledge of the fundamentals in electrical or computer engineering that allows them to analyze and solve technical problems, to apply hardware and software tools, to create and evaluate technical products, to learn independently, and to succeed in the workplace and in graduate school.
- **An Engineering Perspective.** Graduates will be capable of understanding complex projects and the creative process required to find innovative problem solutions, including project evolution and abstraction and the optimization of associated decisions and risk, both locally and globally.

- **Professional Skills and Knowledge.** Graduates will have the ability to communicate well in both oral and written form, to interact in teams, to manage and lead technical projects, to manage their career, and to conduct themselves with an understanding of ethics, economics, and intellectual property.

Objectives approved by the ECE faculty in October 2017 with update in November 2020.

Student Outcomes

Students graduating from the computer engineering program should have:

1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
3. an ability to communicate effectively with a range of audiences
4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
6. an ability to develop and conduct appropriate experimentation. analyze and interpret data, and use engineering judgment to draw conclusions
7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies

Bachelor of Science Computer Engineering [1]

For the Bachelor of Science degree in Computer Engineering, a minimum of 128 credit hours is required. These requirements are in addition to credit received for algebra, trigonometry, and basic ROTC courses. An average of at least two grade points per credit hour must be attained. At least two grade points per credit hour must also be attained in all courses taken in Computer Engineering.

Electrical and Computer Engineering degree programs will require a minimum of 21 credit hours of humanities/social-sciences as specified below:

- ENGLISH 1120
- HISTORY 1200 **or** HISTORY 1300 **or** HISTORY 1310 **or** POL SCI 1200
- ECON 1100 **or** ECON 1200
- Technical Communication Elective: ENGLISH 1160 **or** ENGLISH 3560
- SP&M S 1185
- The remaining minimum of 6 additional credit hours must be three-credit hour lecture courses offered in disciplines in the humanities and social sciences. Humanities courses are defined as those in: Art, English and Technical Communication, Etymology, Foreign Languages, Music, Philosophy, Speech and Media Studies, and Theatre. Social Sciences courses are defined as those in: Economics, History, Political Science, and Psychology. Study abroad courses may count as H/SS courses. H/SS courses numbered 2001, 3001, and 4001 (experimental courses) may also be used to complete these elective requirements.

Courses in business, education, information science and technology, or any other discipline not listed above will **not** satisfy the humanities/social sciences elective requirement, although such courses may count toward general education requirements. Transfer credits from other universities in sociology and general humanities may count as humanities or social science electives.

The Computer Engineering program at Missouri S&T is characterized by its focus on the scientific basics of engineering and its innovative application; indeed, the underlying theme of this educational program is the application of the scientific basics to engineering practice through attention to problems and needs of the public. The necessary interrelations among the various topics, the engineering disciplines, and the other professions as they naturally come together in the solution of real world problems are emphasized as research, analysis, synthesis, and design. These interrelations are presented and discussed through classroom and laboratory instruction.

Free Electives Footnote:

Each student is required to take three hours of free electives in consultation with his/her academic advisor. Credits which do not count towards this requirement are deficiency courses (such as algebra and trigonometry), and extra credits in required courses. Any courses outside of engineering and science must be at least three credit hours.

Freshman Year

First Semester	Credits	Second Semester	Credits
FR ENG 1100[2]	1	COMP SCI 1500	3
MATH 1214 or 1211[3,21]	4	MATH 1215[3]	4
CHEM 1310	4	PHYSICS 1135[3,4]	4
CHEM 1319	1	ECON 1100 or 1200	3
HISTORY 1200, or 1300, or 1310, or POL SCI 1200	3	Elective-Hum or Soc (any level)[5]	3
ENGLISH 1120	3		
	16		**17**

Sophomore Year

First Semester	Credits	Second Semester	Credits
ELEC ENG 2100[3,6,7]	3	COMP ENG 2210[3,6,8]	3
ELEC ENG 2101[3,6]	1	COMP ENG 2211[3,6]	1
MATH 3304	3	ELEC ENG 2120[3,7,9]	3
COMP SCI 1570[3]	3	MATH 2222	4
COMP SCI 1580[3]	1	COMP SCI 1200[3]	3
PHYSICS 2135[3,4]	4	COMP SCI 1575	3
	15		**17**

Junior Year

First Semester	Credits	Second Semester	Credits
COMP ENG 3110[3,8]	3	COMP ENG Elective A[3,14]	3
COMP ENG 3150[3,6,8]	3	ELEC ENG 3410[3,6,9]	3
COMP ENG 3151[3,6,8]	1	COMP SCI 3800 or 2500[3]	3
ELEC ENG 2200[3,6,7]	3	STAT 3117[12]	3
ELEC ENG 2201[3,6,7]	1	Communication Elective [13]	3
Mathematics Elective[10]	3		

SP&M S 1185[13]	3		
	17		**15**
Senior Year			
First Semester	**Credits**	**Second Semester**	**Credits**
COMP ENG 5410[3]	3	COMP ENG Elective D[3,15,16]	3
COMP ENG Elective C[3,19]	3	COMP ENG Elective E[3,15,16]	3
COMP ENG 4096[3,17]	1	COMP ENG 4097[3,17]	3
Elective-Hum or Soc (any level)[5]	3	Professional Development Elective[20]	3
Engineering Science Elective [11]	3	Free Elective[18]	3
COMP ENG Elective B[3,14]	3		
	16		**15**

Total Credits: 128

1 The minimum number of hours required for a degree in Computer Engineering is 128.

2 Students that transfer to Missouri S&T after their freshman year are not required to enroll in Foundational Engineering and Computing Seminars.

3 A minimum grade of "C" must be attained in MATH 1214 or MATH 1211, MATH 1215, MATH 2222, and MATH 3304, PHYSICS 1135 and PHYSICS 2135 (or their equivalents), COMP SCI 1570, COMP SCI 1580, COMP SCI 1575, COMP SCI 1200, COMP SCI 2500 or COMP SCI 3800, COMP ENG 2210, COMP ENG 2211, COMP ENG 3150, COMP ENG 3151, COMP ENG 3110,COMP ENG 5410, COMP ENG 4096, and ELEC ENG 2100, ELEC ENG 2101, ELEC ENG 2120, ELEC ENG 2200, ELEC ENG 2201, and ELEC ENG 3410 and the COMP ENG electives A, B, C, D and E. Also, students may not enroll in other courses that use these courses as prerequisites until the minimum grade of "C" is attained.

4 Students may take PHYSICS 1111 and PHYSICS 1119 in place of PHYSICS 1135. Students may take PHYSICS 2111 and PHYSICS 2119 in place of PHYSICS 2135.

5 All electives must be approved by the student's advisor. Students must comply with the general education requirements with respect to selection and depth of study. These requirements are specified in the current catalog.

6 Students who drop a lecture course prior to the deadline to drop a class must also drop the corequisite lab course.

7 Students must earn a passing grade on the ELEC ENG Advancement Exam I (associated with ELEC ENG 2100) before they enroll in ELEC ENG 2120 or ELEC ENG 2200 and ELEC ENG 2201.

8 Students must earn a passing grade on the COMP ENG Advancement Exam (associated with COMP ENG 2210) before they enroll in any course with COMP ENG 2210 and COMP ENG 2211 as prerequisites.

9 Students must earn a passing grade on the ELEC ENG Advancement Exam II (associated with ELEC ENG 2120) before they enroll in ELEC ENG 3410 .

10 Students must take one of the following courses: MATH 3108, MATH 3109, MATH 5302, MATH 5603, MATH 5105, MATH 5106, MATH 5107, MATH 5108, MATH 4209, MATH 4211, MATH 5215, MATH 5222, MATH 5325, MATH 4530, MATH 5737, MATH 5351, MATH 5154, MATH 4096, MATH 5483, MATH 5585, STAT 5644, STAT 5346, STAT 5353.

11 Students must take one of MECH ENG 2340, MECH ENG 2519, MECH ENG 2527, PHYSICS 2311, PHYSICS 2401, CHEM 2210, BIO SCI 2213, BIO SCI 2223, CIV ENG 2200, MECH ENG 2350, PHYSICS 2305, PHYSICS 4311, CER ENG 4240, or NUC ENG 3205.

12 Students may replace STAT 3117 with STAT 3115 or STAT 5643.

13 Student must take ENGLISH 3560 or ENGLISH 1160. Students may replace SP&M S 1185 with the ROTC sequence of MIL ARMY 4250 and MIL ARMY 4500 or MIL AIR 4110 and MIL AIR 4120

14 Comp Eng Senior Electives A and B, respectively, must be selected from 4xxx or 5xxx courses in Comp Eng, except Comp Eng 4000, 4099, 4096, 4097, 5000, and 5099. The two courses selected for electives A and B, respectively, should be from two different Comp Eng emphasis areas. The emphasis areas, with course number options, are as follows:

Integrated Circuits and Logic Design: 42xx/52xx

Computational Intelligence 53xx

Computer Architecture and Embedded Systems: 41xx/51xx, 45xx/55xx, 46xx/56xx

Networking, Security, and Reliability: 44xx/54xx, except Comp Eng 5410

15 Comp Eng Senior Electives D and E must be selected from an approved list that contains most 3xxx, 4xxx and 5xxx courses in science, mathematics, and engineering except required courses in Comp Eng, Elec Eng, and Comp Sci and except COMP SCI 3610 and COMP SCI 5600.

16 COMP ENG Electives D and E cannot include more than three hours of Comp Eng/Elec Eng 3002, Comp Eng/Elec Eng/Comp Sci 4000 or 4099.

17 Students pursuing dual degrees in COMP ENG and ELEC ENG may take either COMP ENG 4096 or ELEC ENG 4096 and COMP ENG 4097 or ELEC ENG 4097. Students may not receive credit for both COMP ENG 4096 and ELEC ENG 4096 or COMP ENG 4097 and ELEC ENG 4097 in the same degree program.

18 Students are required to take at least three credit hours. ELEC ENG 2800 level, ELEC ENG 4096, ELEC ENG 4097, COMP ENG 4096 and COMP ENG 4097 may not be used for free electives. No more than one credit hour of COMP ENG 3002 or ELEC ENG 3002 may be applied to the BS degree for free electives.

19 Comp Eng Senior Elective C must be selected from 3xxx, 4xxx or 5xxx courses in Comp Eng, Elec Eng, or Comp Sci, except Comp Eng/Elec Eng/Comp Sci 3000, 4000, 4096, 4097, 4099, 5000, and 5099 and Comp Sci 4010, 3610 and 5600.

20 Students must take one of the following courses: BUS 5980, ECON 4430, ECON 5337, ENG MGT 2310, ENG MGT 3320, ENG MGT 4110, ENG MGT 5514, PHI

21 The course combination MATH 1210 and MATH 1211 may be taken in place of MATH 1214.

Emphasis Areas for Computer Engineering

A declared emphasis area is not required. A student may choose to obtain a Computer Engineering degree without a formal emphasis or may choose to obtain a Computer Engineering degree with a declared emphasis in one or more of the emphasis areas of computer engineering. A major change request is required to add the emphasis area option to the degree program.

Emphasis areas that may be declared, include: **Integrated Circuits and Logic Design, Computer Architecture and Embedded Systems, and Networking, Security, and Dependability**. Note that **Computational Intelligence** is also a Computer Engineering emphasis area but is focused in the graduate program.

For students who seek a Computer Engineering degree without a formal emphasis, these emphasis areas may guide the choice of their COMP ENG Electives A, B, C, D, and E as well as their free electives. Students should consult with their advisors on such course selections.

For students who seek a Computer Engineering degree with a declared emphasis, courses in the declared emphasis area will be applied to COMP ENG Electives A, C, and D in the degree requirements. For students who choose to have multiple emphasis areas, the additional courses will apply to COMP ENG Electives B and E and free elective requirements. Students should seek guidance from their advisors on emphasis areas and on courses that are relevant to more than one emphasis area. Students may have an emphasis area or emphasis areas listed on their transcript by completing **three three-credit-hour courses** in computer engineering from the designated lists. For a single emphasis area, this requirement will be satisfied by completing the relevant 4XXX-level or above course for Elective A and 3XXX-level or above courses for Electives C and D from the designated emphasis area course list. For a second emphasis area, this requirement will be satisfied by completing the relevant 4XXX-level or above course for Elective B, a 3XXX-level or above course for Electives E, and a 3XXX-level or above course for the free elective from the designated second emphasis area course list. Courses not on the emphasis area list, including experimental courses (5001) require departmental approval to apply toward the designated emphasis area.

Computer Engineering Course List Designations:

Integrated Circuits and Logic Design	**9**
COMP ENG 42XX and COMP ENG 52XX Courses	
Computer Architecture and Embedded Systems	**9**
COMP ENG 41XX, COMP ENG 51XX, COMP ENG 45XX, COMP ENG 55XX, COMP ENG 46XX, and COMP ENG 56XX Courses	
Networking, Security, and Dependability	**9**
COMP ENG 44XX and COMP ENG 54XX Courses, Except COMP ENG 5410	
Computational Intelligence	**9**
COMP ENG 53XX Courses	

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Minor Curriculum

A minor in computer engineering will require the following:

Pass the ELEC ENG Advancement Exam I (ELEC ENG 2100 final) with a "C" or better *		
Pass the COMP ENG Advancement Exam (COMP ENG 2210 final) with a "C" or better **		
A "C" or better in the following courses:		
	COMP ENG 3150	Introduction to Microcontrollers and Embedded System Design
	COMP ENG 3110	Computer Organization and Design
	COMP ENG 5410	Introduction to Computer Communication Networks
	or COMP SCI 560	Advanced Computer Networks
Pass 3 hours of additional 4XXX-level or above COMP ENG or ELEC ENG or COMP SCI coursework with a "C" or better, excluding senior design, special problems, and undergraduate research. Transfer courses cannot be used to satisfy this requirement. The course choice for this requirement is subject to the approval of the minor advisor.		

* One opportunity will be given to pass the EL ENG Advancement Exam I if a student has prior course or experience in circuits. Otherwise, the student must pass ELEC ENG 2100.

** One opportunity will be given to pass the COMP ENG Advancement Exam if a student has prior course or experience in digital circuits. Otherwise, the student must pass COMP ENG 2210.

Levent Acar, Associate Professor
PHD Ohio State University

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PHD Iowa State University

Daryl G Beetner, Professor[1]
DSC Washington University

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PHD Missouri Univeristy of Science & Technology

Rohit Dua, Associate Teaching Professor
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Donald C Wunsch II, Professor[1]
PHD University of Washington

Maciej J Zawodniok, Associate Professor
PHD University of Missouri-Rolla

Jiangfan Zhang, Assistant Professor
PHD Lehigh University

COMP ENG 1200 Introduction to Digital Electronics (LEC 3.0)
Introduction to electronics and digital circuit design including combinational logic and sequential circuits using circuit design tools, logic gates, integrated circuits and field programmable gate arrays. This course provides S&T equivalent credit for the Project Lead The Way Digital Electronics course.

COMP ENG 2001 Special Topics (LEC 0.0-6.0)
This course is designed to give the department an opportunity to test a new course. Variable title.

COMP ENG 2210 Introduction to Digital Logic (LEC 3.0)
Examines the core components from which digital systems are designed, constructed, and analyzed. Topics include binary numbers, truth tables, Boolean algebra, Karnaugh maps, combinational logic, digital components, CMOS, programmable logic devices, and sequential circuits. Prerequisites: Accompanied by Comp Eng 2211 for Computer Engineering and Electrical Engineering majors.

COMP ENG 2211 Computer Engineering Laboratory (LAB 1.0)
Introduction to digital design techniques, logic gates, Medium Scale Integration (MSI) parts and flipflops, Timing analysis, Programming and use of Programmable Logic Devices (PLD). Prerequisite: Preceded or accompanied by Comp Eng 2210.

COMP ENG 3000 Special Problems (IND 1.0-6.0)
Problems or readings on specific subjects or projects in the department. Consent of instructor required.

COMP ENG 3001 Special Topics (LEC 1.0-6.0)
This course is designed to give the department an opportunity to test a new course. Variable title.

COMP ENG 3002 Cooperative Engineering Training (IND 1.0)
On-the-job experience gained through cooperative education with industry, with credit arranged through departmental cooperative advisor. Grade received depends on quality of reports submitted and work supervisor's evaluation. Pass-fail grading option only. Prerequisite: Consent of the Electrical and Computer Engineering Department required.

COMP ENG 3110 Computer Organization and Design (LEC 3.0)
Introduction to basic concepts of computer organization and design: metrics for computer performance, computer arithmetic, Von Neumann architecture, instruction implementation, control unit, pipelining, memory systems hierarchy, cache memories and basic I/O controllers. Prerequisites: Comp Eng 2210; preceded or accompanied by Comp Eng 3150. (Co-listed with Comp Sci 3803).

COMP ENG 3150 Introduction to Microcontrollers and Embedded System Design (LEC 3.0)
Microcontroller-based digital system design methodology and techniques. Topics include basic machine organization, interface design, and C and assembly language programming for real-time embedded systems. Prerequisites: Comp Eng 2210 and Comp Sci 1500 (or instructor approved programming course) each with grade of "C" or better.

COMP ENG 3151 Digital Engineering Lab II (LAB 1.0)
Advanced digital design techniques, Microcontroller based design, hardware and software codesign. Prerequisites: Comp Eng 2210, Comp Eng 2211, and Comp Sci 1570 (or programming equivalent) each with grade of "C" or better. Preceded or accompanied by Comp Eng 3150.

COMP ENG 4000 Special Problems (IND 1.0-6.0)
Problems or readings on specific subjects or projects in the department. Consent of instructor required.

COMP ENG 4001 Special Topics (LAB 0.0 and LEC 0.0)
This course is designed to give the department an opportunity to test a new course. Variable title.

COMP ENG 4096 Computer Engineering Senior Project I (LAB 0.50 and RSD 0.50)
A complete design cycle. Working in small teams, students will design, document, analyze, implement, and test a product. Topics include: Iteration in design, prototyping, group dynamics, design reviews, making effective presentations, concurrent design, designing for test, ethics and standards, testing and evaluation. Prerequisites: Comp Eng 3150, Comp Eng 3151, Comp Eng 3110. Preceded or accompanied by either English 3560 or English 1160, Elec Eng 2200, and Comp Sci 1575.

COMP ENG 4097 Computer Engineering Senior Project II (LAB 3.0)
A continuation of Comp Eng 4096. Prerequisites: Comp Eng 4096 with a grade of "C" or better, Stat 3117 or Stat 3115 or Stat 5643, and Sp&M S 1185.

COMP ENG 4099 Undergraduate Research (IND 1.0-6.0)
Designed for the undergraduate student who wishes to engage in research. Not for graduate credit. Not more than six (6) credit hours allowed for graduation credit. Subject and credit to be arranged with the instructor.

COMP ENG 5000 Special Problems (IND 1.0-6.0)
Problems or readings on specific subjects or projects in the department. Consent of instructor required.

COMP ENG 5001 Special Topics (LEC 1.0-6.0)
This course is designed to give the department an opportunity to test a new course. Variable title.

COMP ENG 5040 Oral Examination (IND 0.0)
After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/ comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

COMP ENG 5070 Teaching Engineering (LEC 3.0)
Introduction to teaching objectives and techniques. Topics include: using course objectives to design a course; communication using traditional and cutting-edge media; textbook selection; assessment of student learning; grading; student learning styles; cooperative/active learning; and student discipline. Prerequisite: Graduate standing. (Co-listed with Eng Mgt 5070, Env Eng 5070, Elec Eng 5070, Civ Eng 5070).

COMP ENG 5085 Internship (IND 1.0-15)
Students working toward a master degree may select, with the advice of their committees, an appropriate internship opportunity as an integral part of the degree program. The internship plan must conform to the purpose of providing a high level engineering experience consistent with the intent of the master degree. This course will explore how well the current graduate curriculum prepares students for tackling the practical problems that they will encounter in the workplace. Assessment may be based upon the Satisfactory/Unsatisfactory grading option depending on the quality of reports and/or presentations summarizing the outcomes of internship activity to the student's academic advisor.

COMP ENG 5099 Special Research And Thesis (IND 1.0-15)
Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Prerequisite: Consent of the instructor required.

COMP ENG 5110 Principles of Computer Architecture (LEC 3.0)
Principles of performance measurement and instruction set design; advanced issues in pipelining; instruction level parallelism (dynamic scheduling, branch prediction, multi-issue processors); memory hierarchies for superscalar processors; multiprocessors; multi-threading; storage systems; and interconnection networks. Prerequisite: Comp Eng 3110. (Co-listed with Comp Sci 5803).

COMP ENG 5120 Digital Computer Design (LEC 3.0)
Organization of modern digital computers; design of processors, memory systems and I/O units, hardware-software tradeoffs in different levels of computer system design. Prerequisites: COMP ENG 3150 and COMP ENG 3151.

COMP ENG 5130 Advanced Microcomputer System Design (LEC 3.0)
The design of digital systems based on advanced microprocessors. Introduction to microcomputer logic development systems. I/0 interfaces. Assembly and high level language tradeoffs. Hardware and software laboratory projects required. Prerequisites: COMP ENG 5110.

COMP ENG 5151 Digital Systems Design Laboratory (LAB 1.0 and LEC 2.0)
Design of 32-bit microcontroller based systems. Topics include the instruction set architecture of a 32-bit microcontroller, assembly language and C programming, using microcontroller peripherals for communication, measurement and control. Student designs, programs and tests microcontroller based projects. Prerequisites: Comp Eng 3150 or Comp Eng 5110.

COMP ENG 5160 Embedded Processor System Design (LEC 3.0)
Development of hardware and software for embedded systems, including real-time operating systems, advanced programming, communication schemes, hardware peripherals and sensors, control methodologies, printed-circuit board design, interrupts, microcontrollers, and hardware-software co-design. One or more team design projects. Prerequisites: COMP ENG 3150 or equivalent or 80x51 processor experience.

COMP ENG 5170 Real-Time Systems (LEC 3.0)
Introduction to real-time (R-T) systems and R-T kernels, also known as R-T operating systems, with an emphasis on scheduling algorithms. The course also includes specification, analysis, design and validation techniques for R-T systems. Course includes a team project to design an appropriate R-T operating system. Prerequisites: COMP ENG 3150 or COMP SCI 3800. (Co-listed with Comp Sci 5205).

COMP ENG 5210 Introduction To VLSI Design (LEC 3.0)
An introduction to the design and analysis of digital integrated circuits (ICs). Topics include basic manufacturing techniques, transistor-level design and analysis of logic and memory circuits, logic timing, and parasitics. Computer aided design tools are used to develop circuits in the lab. Prerequisites: Elec Eng 2200 and Comp Eng 2210.

COMP ENG 5220 Digital System Modeling (LEC 3.0)
Digital system modeling for simulation, synthesis, and rapid system prototyping. Structural and behavioral models, concurrent and sequential language elements, resolved signals, generics, configuration, test benches, processes and case studies. Prerequisite: Comp Eng 2210 with a grade of "C" or better.

COMP ENG 5230 Quantum Computing (LEC 3.0)
Introduction to the principles, subsystems, and architectures of quantum computing. Topics include architectural and general considerations of quantum systems which are suitable for parallel computing applications using a rule-based approach. Prerequisite: Comp Eng 2210. (Co-listed with Elec Eng 5250).

COMP ENG 5310 Computational Intelligence (LEC 3.0)
Introduction to Computational Intelligence (CI), Biological and Artificial Neuron, Neural Networks, Evolutionary Computing, Swarm Intelligence, Artificial Immune Systems, Fuzzy Systems, and Hybrid Systems. CI application case studies covered include digital systems, control, power systems, forecasting, and time-series predictions. Prerequisite: Graduate Standing. (Co-listed with Elec Eng 5810 and Sys Eng 5211).

COMP ENG 5320 Game Theory for Computing (LEC 3.0)
This course introduces the mathematical and computational foundations of game theory, and its applications to computer science (e.g., cybersecurity, robotics and networking). Topics include decision rationality, game representations, equilibrium concepts (e.g., Nash equilibrium), Bayesian games, dynamic games, cooperative game theory, and mechanism design. Prerequisites: A grade of "C" or better in both Comp Sci 2500 and Math 3108, and in one of Stat 3113, Stat 3115, Stat 3117, or Stat 5643. (Co-listed with Comp Sci 5408).

COMP ENG 5410 Introduction to Computer Communication Networks (LEC 3.0)
The objective of this course is to introduce the concepts, terminology, theoretical foundations, and methods used for data communication in computer networks. Emphasis will be on network architecture, services and protocols, interoperability, and performance considerations. Prerequisites: Comp Eng 3150 or computer hardware competency and Stat 3117 or Stat 3115 or Stat 5643 or equivalent.

COMP ENG 5420 Introduction to Network Security (LEC 3.0)
This course examines basic issues in cryptography and network security. Topics include encryption, key management, authentication, data integrity, intrusion detection, malicious attack, and insider threats, among others. Prerequisite: Comp Eng 5410 or Comp Sci 5600.

COMP ENG 5430 Wireless Networks (LAB 1.0 and LEC 2.0)
Introduction to wireless communications and networking. Topics include transmission fundamentals, wireless channel, coding techniques and error control, satellite and cellular networks, cordless systems, mobile IP and management, multiple access techniques and wireless protocols, wireless LAN, IEEE 802.11, and adhoc and sensor networks. Prerequisites: Comp Eng 3150. (Co-listed with Elec Eng 5430 and Sys Eng 5323.).

COMP ENG 5450 Digital Image Processing (LEC 3.0)
Fundamentals of human perception, sampling and quantization, image transforms, enhancement, restoration, channel and source coding. Prerequisites: Elec Eng 3430. (Co-listed with Elec Eng 5450).

COMP ENG 5460 Machine Vision (LEC 3.0)
Image information, image filtering, template matching, histogram transformations, edge detection, boundary detection, region growing and pattern recognition. Complementary laboratory exercises are required. Prerequisites: Elec Eng 3430. (Co-listed with Elec Eng 5460).

COMP ENG 5510 Fault-Tolerant Digital Systems (LEC 3.0)
Design and analysis of fault-tolerant digital systems. Fault models, hardware redundancy, information redundancy, evaluation techniques, system design procedures. Prerequisites: Comp Eng 2210 and Comp Eng 2211.

COMP ENG 5610 Real-Time Digital Signal Processing (LAB 1.0 and LEC 2.0)
Introduction to the use of programmable DSP chips. Includes real-time data acquisition, signal generation, interrupt-driven programs, high-level language, and assembly level routines. Applications to real-time systems are also presented. Prerequisite: Elec Eng 3400 or Elec Eng 3410.

COMP ENG 5620 Signal Integrity in High-Speed Digital & Mixed Signal Design (LEC 3.0)
Signal integrity ensures signals transmitted over a propagation path maintain sufficient fidelity for proper receiver operation. Compromised signal integrity is often associated with parasitics (e.g. unintentional inductance, capacitance). Theory and CAD tools used for signal integrity analysis of functioning designs. Prerequisites: Elec Eng 3600 or Comp Eng 3150, and Senior standing. (Co-listed with Elec Eng 5620).

COMP ENG 5803 Mathematical Logic I (LEC 3.0)
A mathematical introduction to logic with some applications. Functional and relational languages, satisfaction, soundness and completeness theorems, compactness theorems. Examples from Mathematics, Philosophy, Computer Science, and/or Computer Engineering. Prerequisite: Philos 3254 or Math 5105 or Comp Sci 2500 or Comp Eng 2210. (Co-listed with Comp Sci 5203, Philos 4354 and Math 5154).

COMP ENG 5820 Mechatronics (LAB 1.0 and LEC 2.0)
This course will introduce students to the basics of mechatronics (i.e., the integration of mechanical, electrical, computer, and control systems). Students will learn the fundamentals of sensors and actuators for mechanical systems, computer interfacing, microcontrollers, real-time software, and control. Prerequisite: Mech Eng 4479 or equivalent. (Co-listed with Mech Eng 5478, Aero Eng 5478 and Elec Eng 5870).

COMP ENG 5880 Introduction to Robotics (LEC 3.0)
This course provides an introduction to robotics, covering robot hardware, fundamental kinematics, trajectories, differential motion, robotic decision making, and an overview of current topics in robotics. Prerequisite: A grade of "C" or better in both Math 3108 and Comp Sci 1575. (Co-listed with Comp Sci 5403 and Elec Eng 5880).
