A Proposal for a

MASTER OF SCIENCE DEGREE IN COMPUTER ENGINEERING

Marlan and Rosemary Bourns College of Engineering University of California – Riverside
Riverside, CA 92521

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M.S. CEN Approvals

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<th>Approvals</th>
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<tr>
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<td>Divisional Approval</td>
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SECTION I: INTRODUCTION

1. Introduction to Computer Engineering

This document is a proposal for a Master of Science (M.S.) degree in Computer Engineering. Computer Engineering at UCR is an interdepartmental program jointly managed by the Electrical Engineering and Computer Science and Engineering departments within the Bourns College of Engineering. Degree requirements as well as the administration of this program are described herein.

The specific focus of Computer Engineering (CEN) is on the design and construction of computing structures, both software and hardware.

CEN has been a distinct discipline for over 30 years. In most universities it is managed within the Computer Science or Electrical Engineering departments or jointly, as is the case at UCR. Some universities, such as UC Santa Cruz, have a separate Department of Computer Engineering within the College of Engineering.

At UCR, the B.S. degree in Computer Engineering is a popular degree in the Bourns College of Engineering. Undergraduate CEN enrollment for 2009 is 210, which accounts for ~16% of the total enrollment in BCOE. Recently, BCOE has established several five-year BS/MS programs and desires to offer one in CEN as well. Currently, there are nine faculty members in the Departments of Electrical Engineering and Computer Science and Engineering whose areas of research fit squarely within Computer Engineering.

The proposed degree will rely on the faculty members and resources already available in the EE and CSE departments. It will primarily admit students with undergraduate degrees in CEN, CS or EE, as well as students with other undergraduate majors who have the necessary pre-requisite courses.

2. Definitions and Program Objectives

Computer Engineering (CEN) is concerned with the design, programming and use of computing structures, large and small.

Computer engineering is a discipline that embodies the science and technology of design, construction, implementation, and maintenance of software and hardware components of modern computing systems and computer-controlled equipment. Computer engineering has traditionally been viewed as a combination of both computer science (CS) and electrical engineering (EE). [IEEE/ACM Curriculum Guidelines for Undergraduate Degree Programs in Computer Engineering, 2004]

Computer engineers have training in electronic engineering, software design and hardware-software integration. They are involved in many aspects of computing, from the design of individual microprocessors, personal computers, and supercomputers, to circuit design. This field of engineering not only focuses on how computer systems themselves work, but also how they integrate into the larger picture of the specific application.

This major has seen and continues to see a very healthy growth in employment. The Bureau of Labor Statistics (BLS) ranks this profession as one of the fastest growing employment opportunities. The objective of the M.S. CEN is to offer more opportunities and access for students to this training at the graduate level.
3. Facilities and Resources

The proposed degree program will leverage the facilities existing in the Departments of Electrical Engineering and Computer Science and Engineering. The faculty affiliated with this program will be primarily these departments. The course program relies on courses already being offered in these two departments. Future course offerings will be made through these two departments.

4. Justification of the M.S. CEN Program

Computers have and continue to penetrate every aspect of life. As an example: 10 years ago, having a few microcomputers in a luxury car was a novelty. Now, low-end cars have dozens of microcomputers.


"Significant Points:
- Computer software engineers are one of the occupations projected to grow the fastest and add the most new jobs over the 2006-16 decade.
- Excellent job prospects are expected for applicants with at least bachelor’s degree in computer engineering or computer science and with practical work experience.
- Computer software engineers must continually strive to acquire new skills in conjunction with the rapid changes that occur in computer technology".

In its summary, the BLS document stresses the need for advanced degrees and for continuous education in this area.

The master’s degree has been increasing in popularity. The number of degrees awarded in the U.S. has increased by 43% from 1996 to 2006. One of the reasons stated for the increased popularity of the master’s degree is:

“Professional master’s degree programs combine advanced discipline-specific course work with workplace skills such as communications, critical thinking, time management, and analytical ability that are highly valued by employers in business, government, and non-profit organizations. All these skills are highly transferable as job changes and career moves occur.”

Furthermore, data from the National Research Council indicates that there is a strong financial motivation for pursuing a master’s degree in science and engineering (S&E):2

“...data from the National Science Foundation (NSF) reveal that median salaries of master’s degree recipients one to five years after the degree was conferred tend to be higher than those of doctorates. More importantly, salaries of master’s degree holders in science and engineering have grown faster over the past 10 years than salaries of baccalaureate or doctorate holders.”

According to the National Science Foundation there is substantial room for growth of the master’s degree in S&E disciplines. The table below shows the percentage of degrees awarded in 2006 in S&E. The data show a potential pool of M.S. students 10 times larger than the current pool of doctoral students most of whom are US nationals or permanent residents.

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1 Council of Graduate Schools, “Why Should I Get a Master’s Degree?”. This brochure is available at http://www.cgsnet.org/portals/0/pdf/Why_Should_I_Get_A_Masters_BW.pdf.
5. Enrollment Projections for the M.S. CEN at UCR

We project an enrollment that will progressively grow to reach levels comparable to those of M.S. students in Computer Science and Electrical Engineering respectively.

<table>
<thead>
<tr>
<th>Year</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enrollment</td>
<td>6</td>
<td>12</td>
<td>25</td>
<td>40</td>
<td>40</td>
</tr>
</tbody>
</table>

6. Administration of the M.S. CEN

The Computer Engineering Program (CEN) and its associated faculty in BCOE will administer the MS CEN.

- CEN Program administration already exists for the CEN B.S. program. Administration for the CEN program is carried out by a Director and an Associate Director, nominated by the Dean from the CEN Faculty. This same administrative structure will oversee the CEN M.S. degree program.
- A CEN Program Committee will assist the Program Director and Associate Director in overseeing the B.S. and M.S. degree programs.
- The Computer Engineering Program Committee consists of the Program Director, Associate Director and two additional members selected by the Dean from the Computer Engineering Faculty.
- The Program Director nominates a Graduate Advisor and an Undergraduate Advisor for the CEN Program from among the CEN Faculty.
- The CEN Faculty is comprised of senatorial faculty members from both the Electrical Engineering and Computer Science and Engineering Departments whose research expertise is in Computer Engineering.
- New CEN faculty members are proposed by the CEN Committee and approved by majority vote by the CEN Faculty.

The current and founding Computer Engineering Faculty members are:

- Laxmi Bhuyan (CSE)
- Philip Brisk (CSE)
- Rajiv Gupta (CSE)
- Roger Lake (EE)
- Walid Najjar (CSE)
- Sheldon Tan (EE)
- Frank Vahid (CSE)
- Albert Wang (EE)

The current CEN Committee consists of:

- Walid Najjar - Director
- Sheldon Tan – Associate Director
- Frank Vahid - Member
The biographies of the CEN Faculty members are included in Appendix A.

7. Plan for Evaluation of the M.S. CEN

As is the norm for all graduate programs at the UCR campus, an outside team of experts will evaluate the program once every six or seven years. Beginning with the second year the CEN Program Committee will initiate an internal review of the M.S. CEN Program.
8. Relationship to Other Programs in the UC System

The only UC campus that offers an M.S. in Computer Engineering is UC Santa Cruz, in the Department of Computer Engineering. Many other campuses offer an M.S. in Computer Science and Engineering or in Electrical and Computer Engineering.
SECTION II: PROGRAM

1. Admission Requirements and Undergraduate Preparation

A. Admission

All applicants to this program must have completed a Bachelor’s degree or its approved equivalent from an accredited institution and to have attained undergraduate record that satisfies the standards established by the Graduate Division and University Graduate Council. Applicants should have at least an undergraduate major in Computer Engineering, Computer Science, Electrical Engineering or a closely related field. Applicants who fail to meet this criterion may sometimes be admitted with course deficiencies. However, no more than three deficiencies will be allowed.

A student who is deficient in a competency area may be asked to complete the corresponding UCR course with a letter grade of at least B+, or to pass a challenge examination based on that course’s final exam with a grade of at least B+. All such remedial work should be completed within the first year of graduate study, and in all cases the deficiency(s) must be corrected BEFORE a student can enroll in any graduate course from the same specialty area.

All applicants must submit scores from the Graduate Record Exam, General Test (GRE). The GRE subject test in Computer Science or Electrical Engineering is recommended but not required. Applicants whose first language is not English are required to submit acceptable scores from the TEST of English as a Foreign Language (TOEFL) or the International English Language Testing System (IELTS) unless they have a degree from an institution where English is the exclusive language of instruction. Additionally each applicant must submit three letters of recommendation, at least two of which must be academic references. All other application requirements are specified in the graduate application.

B. Prerequisite Material

Competence in the areas defined by the following UCR courses is essential to graduate study in computer engineering:

EE 100A, EE 100B, EE 110A, EE 110B, CS 153, CS 161, CS 161L, CS/EE 120A and CS/EE 120B.

The complete catalogue description of these courses is presented in Section V.

A student who is deficient in any of these competency areas may be asked to complete the corresponding UCR course with a letter grade of at least B+, or to pass a challenge examination based on that course’s final exam with a grade of at least B+. All such remedial work should be completed within the first year of graduate study, and in all cases the deficiency must be corrected BEFORE a student can enroll in any graduate course from the same specialty area.

C. Course Requirements

Students must be in residence for one year and complete a minimum of 36 quarters units of graduate and upper division undergraduate courses in or related to the major subject area. Students who have completed similar courses elsewhere may petition for waiver of a required course or for substitution of an alternative course. For students interested in interdisciplinary research, individual study programs can be approved.
1. **Core Requirement (12 units)**. Three courses from the list of core courses below, with no grade lower than B-.

2. **Technical Electives (12 units)**. Three courses from the list of technical elective courses below.

3. **Colloquium (3 units)**. Satisfactory completion of three quarters of CS 287 (Colloquium in Computer Science) or EE 259 (Colloquium in Electrical Engineering) in three distinct quarters.

4. **Capstone Experience** - All students must complete a capstone experience that synthesizes and integrates the knowledge and skills obtained throughout the master’s program, according to one of the following options. It is the responsibility of the student to find a faculty member willing to supervise the master’s project or thesis, to form the faculty examining committee, and to schedule the oral examination.
   
a. **Thesis Option (Plan I)**. A minimum of 36 quarter units of graduate and upper division undergraduate courses in or related to the major subject area are required. At least 24 of the 36 units must be in graduate courses taken at this University; of these 6 to 12 must be graduate research units (CS 290, CS 297, CS 299, EE 290, EE 297, EE 299). Students must submit a master’s thesis in accordance with the general requirements of the university. The thesis is original research work, and it should demonstrate the student’s ability to study a research area, identify an open problem and make a research contribution. The thesis must be presented to and approved by a committee of at least three faculty members.

b. **Project Option (Plan II)**. A minimum of 36 quarter units of graduate and upper division undergraduate courses in or related to the major subject area are required; of these at least 18 units must be in graduate courses taken at this University, of which none may be in graduate research (CS 299 or EE 299) for the thesis or dissertation. In addition, a student pursuing this option must include 4 to 8 units of graduate research (CS 290, CS 297, CS 299, EE 290, EE 297, EE 299). Students must complete a research project under the guidance of a faculty member. This project will require a written report and will be presented to a committee of at least two faculty members.

**D. Core Courses**

- CS 203A - Advanced Computer Architecture
- CS 220 - Synthesis of Digital Systems
- CS 201 - Compiler Construction **OR** CS 202 - Advanced Operating Systems
- EE 213 - Computer-Aided Electronic Circuit Simulation
- EE 221 - Radio-Frequency Integrated Circuit Design

**E. Technical Elective Courses**

Any core course not used to fulfill the core requirement can be used as a technical elective. Additional technical elective courses are:

- CS 203B. Advanced Computer Architecture
- CS 213. Parallel Processing Architectures
- CS 218. Design and Analysis of Algorithms
- CS 223. Reconfigurable Computing
- CS 255. Computer Security
- CS 204. Advanced Computer Networks
- CS 257. Wireless Networks and Mobile Computing
- CS 246. Advanced Verification Techniques in Software Engineering
- CS 240. Network Routing
- CS 239. Performance Evaluation of Computer Networks
- EE 202. Fundamentals of Semiconductors and Nanostructures
- EE 203. Solid-State Devices
- EE 210. Advanced Digital Signal Processing
- EE 211. Adaptive Signal Processing
- EE 222. Advanced Radio-Frequency Integrated Circuit Design
- EE 226. Wireless Communications
- EE 229. Video Processing and Communication
- EE 241. Advanced Digital Image Processing
- EE 243. Advanced Computer Vision
- EE 215. Stochastic Processes
- EE 235. Linear System Theory

The Computer Engineering Program Committee will, from time to time, update the list of Technical Elective Courses and propose the changes to the Computer Engineering Faculty for their approval by simple majority vote.
2. Sample Program for M.S. CEN Student

The following is a sample program for an M.S. CEN degree with the Thesis Option.

<table>
<thead>
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<th>Year in Program</th>
<th>Fall</th>
<th>Winter</th>
<th>Spring</th>
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<tbody>
<tr>
<td></td>
<td>(4) CS 201 - Compiler Construction</td>
<td>(4) CS 223 - Reconfigurable Computing</td>
<td>(4) EE 203 - Solid-State Devices</td>
</tr>
<tr>
<td></td>
<td>(1) CS 287 – Colloquium in Computer Science</td>
<td>(1) CS 287 – Colloquium in Computer Science</td>
<td>(1) CS 287 – Colloquium in Computer Science</td>
</tr>
<tr>
<td>Year 2</td>
<td>(2) CS 297 – Directed Research</td>
<td>(4) CS 297 – Directed Research</td>
<td>(4) CS 297 – Directed Research</td>
</tr>
<tr>
<td></td>
<td>(4) EE 202- Fundamentals of Semiconductors and Nanostructures</td>
<td>(4) CS 246 - Advanced Verification Techniques in Software Engineering</td>
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SECTION III: PROJECTED NEEDS

1. Student Demand for the Program

Student demand for the M.S. CEN degree program at UCR is evidenced by the large and growing enrollment in the Computer Engineering B.S. degree program.

2. Opportunities for Placement of Graduates

This topic has been extensively discussed in Section I.4 (page 6).

3. Relationship of the Program to Research and Professional Interests of Faculty

A number of faculty members in CSE and EE have research interests in Computer Engineering. However, the only graduate curricula currently available are the EE or CSE programs. The CEN program will provide a much better fit for the preparation of the students that they supervise.
SECTION IV: FACULTY AND STAFF

Nine faculty members in BCOE have research activities that fit within the scope of Computer Engineering. This number is likely to grow somehow as the CSE and EE Departments hire more faculty members in this area.

**Dr. Laxmi Bhuyan**  
Professor, Department of Computer Science and Engineering  
Ph.D. Computer Engineering, Wayne State University, 1982  
Research Interests: Multiprocessor architecture; network processors; internet routers; web servers; parallel and distributed computing; performance evaluation.

**Dr. Philip Brisk**  
Assistant Professor, Department of Computer Science and Engineering  
Ph.D. Computer Science, University of California Los Angeles, 2006  
Research Interests: Reconfigurable computing; application-specific and customizable processors; computer architecture; compilers

**Dr. Rajiv Gupta**  
Professor, Department of Computer Science and Engineering  
Ph.D. Computer Science, University of Pittsburgh, 1987  
Research Interests: Compilers and architectures for embedded systems; software tools for profiling, slicing, and debugging; program analysis: static, dynamic, and profile-based.

**Dr. Roger Lake**  
Professor, Department of Electrical Engineering  
Ph.D. Electrical Engineering, Purdue University, 1992  
Research Interests: Theory of electron transport through nanostructured, disordered and amorphous materials; modeling semiconductor devices from the atomistic, to the device, through the circuit level; theoretical and computational electronics and opto-electronics; ultra-scaled devices and device physics; high frequency and transient quantum device simulation; and novel materials, devices and architectures.

**Dr. Walid Najjar**  
Professor, Department of Computer Science and Engineering  
Ph.D. Computer Engineering, University of Southern California, 1988  
Research Interests: Computer architecture and parallel computing; compilation and code optimizations for reconfigurable computing systems; novel platforms and programming paradigms for sensor networks; low power computer architectures.

**Dr. Sheldon Tan**  
Associate Professor, Department of Electrical Engineering  
Ph.D. Electrical & Computer Engineering, University of Iowa, 1999  
Research Interests: Design automation for VLSI integrated circuits – high performance power/ground distribution network design and optimization, simulation and synthesis of mixed-signal/RF/analog circuits, embedded system design based on FPGA platforms and signal integrity issues in VLSI physical design (crosstalk analysis, substrate noise analysis and optimization).

**Dr. Frank Vahid**  
Professor, Department of Computer Science and Engineering  
Ph.D. Information and Computer Science, University of California Irvine, 1994  
Research Interests: Embedded systems, FPGA-based computing
Dr. Albert Wang
Professor, Department of Electrical Engineering
Ph.D. Electrical and Computer Engineering, State University of New York, Buffalo, 1996
Research Interests: RF/Analog/Mixed-Signal Integrated Circuits (IC), Reliability & ESD
(Electrostatic Discharge) Protection design for ICs, SoC (System-on-a-Chip), IC CAD and
Modeling, Emerging Semiconductor and Nano Devices.
SECTION V: COURSES

1. Prerequisite Courses

EE 100A. *Electronic Circuits* (4) Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): EE 001B. Electronic systems, linear circuits, operational amplifiers, diodes, nonlinear circuit applications, junction and metal-oxide-semiconductor field-effect transistors, bipolar junction transistors, MOS and bipolar digital circuits. Laboratory experiments are performed in the subject areas and SPICE simulation is used.

EE 100B. *Electronic Circuits* (4) Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): EE 100A. Differential and multistage amplifiers, output stages and power amplifiers, frequency response, feedback, analog integrated circuits, filters, tuned amplifiers, and oscillators. Laboratory experiments are performed in the subject areas and SPICE simulation is used.

EE 110A. *Signals and Systems* (4) Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): CS 010; EE 001B (may be taken concurrently); MATH 046. Basic signals and types of systems, linear time-invariant (LTI) systems, Fourier analysis, frequency response, and Laplace transforms for LTI systems. Laboratory experiments with signals, transforms, harmonic generation, linear digital filtering, and sampling/aliasing.

EE 110B. *Signals and Systems* (4) Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): EE 110A. Fourier analysis for discrete-time signals and systems, filtering, modulation, sampling and interpolation, z-transforms. Laboratory experiments with signals, transforms, harmonic generation, linear digital filtering, and sampling/aliasing.

CS 153. *Design of Operating Systems* (4) Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): CS 061, CS 100, CS 111, C++ programming proficiency. Covers the principles and practice of operating system design. Includes concurrency, memory management, file systems, protection, security, command languages, scheduling, and system performance.

CS 120A. *Logic Design* (5) Lecture, 3 hours; laboratory, 6 hours. Prerequisite(s): CS 061 with a grade of "C-" or better. Covers the design of digital systems. Topics include Boolean algebra; combinational and sequential logic design; design and use of arithmetic-logic units, carry-lookahead adders, multiplexors, decoders, comparators, multipliers, flip-flops, registers, and simple memories; state-machine design; and basic register-transfer level design. Interdisciplinary laboratories involve use of hardware description languages, synthesis tools, programmable logic, and significant hardware prototyping. Cross-listed with EE 120A.

CS 120B. *Introduction to Embedded Systems* (5) Lecture, 3 hours; laboratory, 6 hours. Prerequisite(s): CS 120A/EE 120A. Introduction to hardware and software design of digital computing systems embedded in electronic devices (such as digital cameras or portable video games). Topics include embedded processor programming, custom processor design, standard peripherals, memories, interfacing, and hardware/software tradeoffs. Interdisciplinary laboratory involves use of synthesis tools, programmable logic, and microcontrollers and development of working embedded systems. Cross-listed with EE 120B.

CS 161. *Design and Architecture of Computer Systems* (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): CS 120B/EE 120B; concurrent enrollment in CS 161L. A study of the fundamentals of computer design. Topics include the performance evaluation of microprocessors, instruction set design and measurements of use, microprocessor
implementation techniques including multicycle and pipelined implementations, computer arithmetic, memory hierarchy, and input/output (I/O) systems.

CS 161L. Laboratory in Design and Architecture of Computer Systems (2) Lecture, 1 hour; laboratory, 3 hours. Prerequisite(s): CS 120B/EE 120B; concurrent enrollment in CS 161. Students design and simulate a complete computer system, using hardware description language and simulator. Topics include instruction set architecture design, assemblers, data-path and control unit design, arithmetic and logic unit, memory and input/output (I/O) systems, and integration of all parts into a working computer system.

2. Core Courses

- CS 203A - Advanced Computer Architecture
- CS 220 - Synthesis of Digital Systems
- CS 201 - Compiler Construction OR CS 202 - Advanced Operating Systems
- EE 213 - Computer-Aided Electronic Circuit Simulation
- EE 221 - Radio-Frequency Integrated Circuit Design

CS 201. Compiler Construction (4) Lecture, 3 hours; outside research, 3 hours. Prerequisite(s): CS 152. Covers theory of parsing and translation. Also addresses compiler construction, including lexical analysis, syntax analysis, code generation, and optimization. May be taken Satisfactory (S) or No Credit (NC) by students advanced to candidacy for the Ph.D.

CS 202. Advanced Operating Systems (4) Lecture, 3 hours; outside research, 3 hours. Prerequisite(s): CS 153. Examines recent developments in operating systems. Also covers multiprogramming, parallel programming, time sharing, scheduling and resource allocation, and selected topics. May be taken Satisfactory (S) or No Credit (NC) by students advanced to candidacy for the Ph.D.

CS 203A. Advanced Computer Architecture (4) Lecture, 3 hours; research, 3 hours. Prerequisite(s): CS 161. Covers contemporary computer systems architecture, including stack computers, parallel computers, pipeline processing, database machines, and multiprocessor architecture. Includes evaluation of computer performance. May be taken Satisfactory (S) or No Credit (NC) by students advanced to candidacy for the Ph.D.

CS 220. Synthesis of Digital Systems (4) Lecture, 3 hours; outside research, 3 hours. Prerequisite(s): CS 141, CS 161. Covers the synthesis and simulation of digital systems. Topics include synthesis at the system, behavioral, register-transfer, and logic levels; application-specific processors; simulation; and emerging system-on-a-chip design methodologies. May be taken Satisfactory (S) or No Credit (NC) by students advanced to candidacy for the Ph.D.

EE 213. Computer-Aided Electronic Circuit Simulation (4) Lecture, 3 hours; outside research, 3 hours. Prerequisite(s): EE 001A, EE 001B, EE 133. Introduction to numerical algorithms and computer-aided techniques for the simulation of electronic circuits. Covers theoretical and practical aspects of important analyses. Topics include circuit formulation methods; large-signal nonlinear direct current, small-signal alternating current, and moment-matching transient; sensitivity; and noise. Also discusses recent advances in timing analysis, symbolic analysis, and radio frequency circuit analysis.

EE 221. Radio-Frequency Integrated Circuit Design (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): EE 100B; senior or graduate standing. Covers the essentials of contemporary radio frequency (RF) complimentary metal oxide semiconductor (CMOS) integrated circuit (IC) analysis and design. Addresses typical RF building blocks in CMOS and bipolar/CMOS (BiCMOS) technologies, including passive IC components, transistors, distributed networks, voltage reference and biasing circuits, power amplifiers, and feedback networks. Also covers RF device modeling, bandwidth estimation, and stability
3. Technical Elective Courses

- CS 203B. Advanced Computer Architecture
- CS 213. Parallel Processing Architectures
- CS 218. Design and Analysis of Algorithms
- CS 223. Reconfigurable Computing
- CS 255. Computer Security
- CS 204. Advanced Computer Networks
- CS 257. Wireless Networks and Mobile Computing
- CS 246. Advanced Verification Techniques in Software Engineering
- CS 240. Network Routing
- CS 239. Performance Evaluation of Computer Networks
- EE 202. Fundamentals of Semiconductors and Nanostructures
- EE 203. Solid-State Devices
- EE 210. Advanced Digital Signal Processing
- EE 211. Adaptive Signal Processing
- EE 222. Advanced Radio-Frequency Integrated Circuit Design
- EE 226. Wireless Communications
- EE 229. Video Processing and Communication
- EE 241. Advanced Digital Image Processing
- EE 243. Advanced Computer Vision
- EE 215. Stochastic Processes
- EE 235. Linear System Theory

CS 203B. Advanced Computer Architecture (4) Lecture, 3 hours; research, 3 hours. Prerequisite(s): CS 203A with a grade of "B" or better. Covers advanced topics in general-purpose computer architecture including instruction-level parallel architectures, as well as very-long-instruction-word, explicitly parallel instruction computing, and multithreaded architectures. Also covers dataflow machines and vector and single instruction multiple data architectures, including multimedia extensions. Also discusses network processors, multimedia processors, and advanced embedded processors. May be taken Satisfactory (S) or No Credit (NC) by students advanced to candidacy for the Ph.D.

CS 204. Advanced Computer Networks (4) Lecture, 3 hours; consultation, 1 hour. Prerequisite(s): CS 014, CS 164. Covers advanced topics in computer networks, layering, Integrated Services Digital Networks (ISDN), and high-speed networks. Also covers performance models and analysis, distributed systems and databases, and case studies. May be taken Satisfactory (S) or No Credit (NC) by students advanced to candidacy for the Ph.D.

CS 213. Parallel Processing Architectures (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): CS 161 or CS 203A. A study of parallel processing. Covers static and dynamic interconnection networks; shared memory multiprocessors; and cache coherence and synchronization. Also examines pre-fetching; memory management; message-passing architectures; work-station clusters; scheduling and mapping algorithms; and load balancing in Web servers. May be taken Satisfactory (S) or No Credit (NC) by students advanced to candidacy for the Ph.D.

CS 218. Design and Analysis of Algorithms (4) Lecture, 3 hours; outside research, 3 hours. Prerequisite(s): CS 141. A study of efficient data structures and algorithms for solving problems from a variety of areas such as sorting, searching, selection, linear algebra, graph theory, and computational geometry. Also covers worst-case and average-case analysis using recurrence relations, generating functions, upper and lower bounds, and other methods. May be taken Satisfactory (S) or No Credit (NC) by students advanced to candidacy for the Ph.D.
CS 223. *Reconfigurable Computing* (4) Lecture, 3 hours; written work, 3 hours. Prerequisite(s): CS 202 or CS 203A; consent of instructor. Covers reconfigurable computing, a novel computational model that is fast becoming part of the mainstream in high-performance computing. Addresses architectures, software tools and compilers, programming models, and applications. May be taken Satisfactory (S) or No Credit (NC) with consent of instructor and graduate advisor.

CS 239. *Performance Evaluation of Computer Networks* (4) Lecture, 3 hours; outside research, 3 hours. Prerequisite(s): CS 164. Offers models and analytical techniques for evaluating the performance of computer networks. Covers basic and intermediate queuing theory and queuing networks and their application to practical systems. May be taken Satisfactory (S) or No Credit (NC) by students advanced to candidacy for the Ph.D.

CS 240. *Network Routing* (4) Lecture, 3 hours; outside research, 3 hours. Prerequisite(s): CS 141 or CS 204; CS 164. An in-depth study of routing in computer networks. Examines general principles and specific routing protocols and technologies. Topics include Internet, Asynchronous Transfer Mode (ATM), optical, wireless, and ad hoc networks. May be taken Satisfactory (S) or No Credit (NC) by students advanced to candidacy for the Ph.D.

CS 246. *Advanced Verification Techniques in Software Engineering* (4) Lecture, 3 hours; outside research, 3 hours. Prerequisite(s): CS 111/MATH 111, CS 141, CS 150, or equivalents or consent of instructor. A study of advanced techniques to specify and examine the correctness of complex systems and software. Focuses on concurrent and distributed behavior, formal description languages, temporal logics, model checking and symbolic model checking, partial order reduction, and the use of verification tools. May be taken Satisfactory (S) or No Credit (NC) by students advanced to candidacy for the Ph.D.

CS 257. *Wireless Networks and Mobile Computing* (4) Lecture, 3 hours; outside research, 3 hours. Prerequisite(s): CS 141; CS 164 or CS 204. Introduces basic and advanced concepts of wireless networks and mobile computing. Covers both wireless cellular and ad hoc networks. Includes protocols for medium access control, resource allocation, and routing, as well as transport layer optimizations for the wireless environment. Also covers standards, Bluetooth, and the IEEE 802.11 for wireless local area networks. May be taken Satisfactory (S) or No Credit (NC) by students advanced to candidacy for the Ph.D.

EE 202. *Fundamentals of Semiconductors and Nanostructures* (4) Lecture, 3 hours; outside research, 3 hours. Prerequisite(s): EE 133, EE 201; or consent of instructor. Examines principles of semiconductor materials and nanostructures. Topics include periodic structures, electron and phonon transport, defects, optical properties, and radiative recombination. Also covers absorption and emission of radiation in nanostructures, and nonlinear optics effects. Emphasizes properties of semiconductor superlattices, quantum wells, wires, and dots.

EE 203. *Solid-State Devices* (4) Lecture, 3 hours; outside research, 3 hours. Prerequisite(s): EE 133 or consent of instructor. Covers electronic devices including p-n junctions, field-effect transistors, hetero-junction bipolar transistors, and nanostructure devices. Explores electrical and optical properties of semiconductor heterostructures, superlattices, quantum wires and dots, as well as devices based on these structures.

EE 210. *Advanced Digital Signal Processing* (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): EE 110B, EE 141. Provides in-depth coverage of advanced techniques for digital filter and power spectral estimation. Topics include digital filter design, discrete random signals, finite-wordlength effects, nonparametric and parametric power spectrum estimation, multirate digital signal processing, least square methods of digital filter design, and digital filter applications.

EE 211. *Adaptive Signal Processing* (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): EE 210, EE 215, EE 236. Provides an in-depth understanding of adaptive signal processing techniques. Covers Wold decomposition, Yule-Walker equations, spectrum estimation, Weiner filters, linear prediction, Kalman filtering, time-varying system tracking, nonlinear adaptive filtering,
and performance analysis of adaptive algorithms and their variations including stochastic
gradient, least mean square, least squares, and recursive least squares.

EE 215. *Stochastic Processes* (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): graduate
standing or consent of instructor. A study of probability theory and stochastic processes, with a
focus on the most fundamental aspect of modern communication, control, and signal processing
systems driven by random signal inputs. Topics include random variables and stochastic
processes; spectral analysis; Wiener optimum filter, matched filter, and Karhunen-Loeve
expansion; mean square estimation theory including smoothing, filtering, and linear prediction;
Levinson's algorithm, lattice filters, and Kalman filters; and the Markov process.

EE 222. *Advanced Radio-Frequency (RF) Integrated Circuit Design* (4) Lecture, 3 hours;
discussion, 1 hour. Prerequisite(s): EE 100B; senior or graduate standing. Covers analysis
techniques for nonlinear effects and noise in RF integrated circuit design. Addresses nonlinear,
and distortion behavior, including inter-modulation, cross-modulation, harmonics, gain
compression, and desensitization. Also explores noise effects, including thermal, short, flicker,
and burst noises. Includes single-stage and multiple-stage networks.

EE 226. *Wireless Communications* (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): EE
215, EE 224. Presentation of fundamental cellular concepts and new techniques in wireless
communications. Topics include cellular systems and standards, frequency reuse, system
capacity, channel allocation, cellular radio propagation, fading channel modeling and
equalization, spread spectrum communications and other multiple access techniques, and
wireless networking.

EE 228. *Fundamentals of Data Compression* (4) Lecture, 3 hours; outside research, 3 hours.
Prerequisite(s): EE 215 (may be taken concurrently). Covers the fundamental theory and tools for
designing data and signal compression systems. Topics include lossless coding, scalar
quantization, predictive and transform coding techniques, vector quantization, and the general
trade-off between the reproduction signal quality and the bit-rate of the digital representation.
Provides a foundation for further study and research in speech, audio, image, and video
compression.

EE 235. *Linear System Theory* (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): EE
132, MATH 113. Provides a review of linear algebra. Topics include the mathematical description of
linear systems; the solution of state-space equations; controllability and observability; canonical
and minimal realization; and state feedback, pole placement, observer design, and compensator
design.

EE 241. *Advanced Digital Image Processing* (4) Lecture, 3 hours; outside research, 3 hours.
Prerequisite(s): EE 152 or consent of instructor. Covers advanced topics in digital image
processing. Examines image sampling and quantization, image transforms, stochastic image
models, image filtering and restoration, and image data compression.

EE 242. *Intelligent Systems* (4) Lecture, 3 hours; outside research, 3 hours. Prerequisite(s):
graduate standing or consent of instructor. Introduces fundamental concepts of design of
intelligent systems. Topics include biological versus computational systems, knowledge
representation, computational reasoning, computational learning, language and human- machine
communication, expert systems, computational vision, and examples of intelligent machines.

EE 243. *Advanced Computer Vision* (4) Lecture, 3 hours; outside research, 3 hours.
Prerequisite(s): EE 146 or consent of instructor. A study of three-dimensional computer vision.
Topics include projective geometry, modeling and calibrating cameras, representing geometric
primitives and their uncertainty, stereo vision, motion analysis and tracking, interpolating and
approximating three-dimensional data, and recognition of two-dimensional and three-dimensional
objects.
SECTION VI: RESOURCE REQUIREMENTS

All the technical resources required by the M.S. CEN program are already available in and for the EE and CSE Departments including computing facilities, library resources, teaching laboratories and research facilities.

The only additional resources would be office space and one FTE for administrative support for the graduate and undergraduate programs in CEN.
SECTION VII: GRADUATE STUDENT SUPPORT

MS CEN students are expected to be self-supported. However, GSR and Teaching Assistantships may be available on a case-by-case basis.
SECTION VIII: GOVERNANCE

The governance of the M.S. CEN degree program is described in Section I.6 (page 7).
March 9, 2011

TO: MORRIS MADURO, CHAIR
GRADUATE COUNCIL

FM: MARY W. GAUVAIN, CHAIR
RIVERSIDE DIVISION

RE: M.S. PROPOSAL IN COMPUTER ENGINEERING

The above proposal has been reviewed by the committee on Educational Policy, Planning and Budget, Courses and Library. The three committees approved the creation of this Masters Degree in Computer Engineering.

I am enclosing all three committee responses for your information.

Enclosure
March 2, 2011

TO:    MARY GAUVAIN, CHAIR
       ACADEMIC SENATE

FR:    JOSE WUDKA, CHAIR
       COMMITTEE ON EDUCATIONAL POLICY

RE:    M.S. PROGRAM PROPOSAL IN COMPUTER ENGINEERING

The Committee on Educational Policy voted unanimously (10 Yes, 0 No, 0 Abstentions) to support the proposal for the new M.S. degree in Computer Engineering.
March 7, 2011

TO: M. GAUVAINE, CHAIR
RIVERSIDE DIVISION

FR: J. C. LAURSEN, CHAIR
COMMITTEE ON LIBRARY AND SCHOLARLY INFORMATION

RE: MS IN COMPUTER ENGINEERING

The Committee on Library and Scholarly Information has voted to approve the MS in Computer Engineering. We note that the proposal says that the necessary library resources are presently in the library; we hope that future library cuts will not threaten that availability.
March 8, 2011

TO: MARY GAUVAIN, CHAIR
    RIVERSIDE DIVISION

FM: Y. PETER CHUNG, CHAIR
    PLANNING AND BUDGET

RE: Proposal for an M.S. in Computer Engineering

Planning and Budget met and reviewed the proposal to establish an MS in Computer Engineering. P&B questioned the need for one FTE person as indicated under resource requirements on page 22 of the proposal. P&B recommended that this hiring be postponed until the budget climate improves.

Planning and Budget voted unanimously (6 yes 3 absent 0 no and 0 abstentions) to approve the proposal for an M.S. in Computer Engineering.
March 24, 2011

TO:         WALID A. NAJJAR
            COMPUTER ENGINEERING PROGRAM

FM:         MORRIS MADURO, CHAIR
            GRADUATE COUNCIL

RE:         M.S. PROPOSAL IN COMPUTER ENGINEERING

At its meeting of March 18, 2011, the Graduate Council approved the proposal to establish a Master of Science Degree in Computer Engineering.

From here, the proposal will have to be approved at the next meeting of the Divisional Senate before being sent to the system-wide CCGA.