

Chapter 2

Computer Engineering as a Discipline

This chapter presents some of the characteristics that distinguish computer engineering from other computing disciplines. It provides some background of the field and shows how it evolved over time. It also highlights some of the characteristics expected from its graduates, preparation for entering the curriculum, and student outcomes and assessment. The chapter also highlights the importance of graduates to have a proper sense of professionalism to ensure a proper perspective in the practice of computer engineering.

2.1 Background

Computer engineering 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). It has evolved over the past three decades as a separate, although intimately related, discipline. Computer engineering is solidly grounded in the theories and principles of computing, mathematics, science, and engineering and it applies these theories and principles to solve technical problems through the design of computing hardware, software, networks, and processes.

Historically, the field of computer engineering has been widely viewed as “designing computers.” In reality, the design of computers themselves has been the province of relatively few highly skilled engineers whose goal was to push forward the limits of computer and microelectronics technology. The successful miniaturization of silicon devices and their increased reliability as system building blocks has created an environment in which computers have replaced the more conventional electronic devices. These applications manifest themselves in the proliferation of mobile telephones, personal digital assistants, location-aware devices, digital cameras, and similar products. It also reveals itself in the myriad of applications involving embedded systems, namely those computing systems that appear in applications such as automobiles, large-scale electronic devices, and major appliances.

Increasingly, computer engineers are involved in the design of computer-based systems to address highly specialized and specific application needs. Computer engineers work in most industries, including the computer, aerospace, telecommunications, power production, manufacturing, defense, and electronics industries. They design high-tech devices ranging from tiny microelectronic integrated-circuit chips, to powerful systems that utilize those chips and efficient telecommunication systems that interconnect those systems. Applications include consumer electronics (CD and DVD players, televisions, stereos, microwaves, gaming devices) and advanced microprocessors, peripheral equipment, systems for portable, desktop and client/server computing, and communications devices (cellular phones, pagers, personal digital assistants). It also includes distributed computing environments (local and wide area networks, wireless networks, internets, intranets), and embedded computer systems (such as aircraft, spacecraft, and automobile control systems in which computers are embedded to perform various functions). A wide array of complex technological systems, such as power generation and distribution systems and modern processing and manufacturing plants, rely on computer systems developed and designed by computer engineers.

Technological advances and innovation continue to drive computer engineering. There is now a convergence of several established technologies (such as television, computer, and networking technologies) resulting in widespread and ready access to information on an enormous scale. This has created many opportunities and challenges for computer engineers. This convergence of technologies and the associated innovation lie at the heart of economic development and the future of many organizations. The situation bodes well for a successful career in computer engineering.

2.3 Characteristics of Computer Engineering Graduates

With the ubiquity of computers and computer-based systems in the world today, computer engineers must be versatile in the knowledge drawn from standard topics in computer science and electrical engineering as well as the foundations in mathematics and sciences. Because of the rapid pace of change in the computing field, computer engineers must be life-long learners to maintain their knowledge and skills within their chosen discipline.

2.3.1 Distinctions

An important distinction should be made between computer engineers, electrical engineers, other computer professionals, and engineering technologists. While such distinctions are sometimes ambiguous, computer engineers generally should satisfy the following three characteristics.

1. Possess the ability to design computer systems that include both hardware and software to solve novel engineering problems, subject to trade-offs involving a set of competing goals and constraints. In this context, “design” refers to a level of ability beyond “assembling” or “configuring” systems.
2. Have a breadth of knowledge in mathematics and engineering sciences, associated with the broader scope of engineering and beyond that narrowly required for the field.
3. Acquire and maintain a preparation for professional practice in engineering.

In contrast, electrical engineers concern themselves mostly with the physical aspects of electronics including circuits, signal analysis, and microelectronic devices. Computer scientists concern themselves primarily with the theoretical and algorithmic aspects of computing with a focus on the theoretical underpinnings of computing. Software engineers have a focus on the principles underlying the development and maintenance of correct (large-scale) software throughout its lifecycle. Information systems specialists encompass the acquisition, deployment, and management of information resources for use in organizational processes. Information technology specialists would focus on meeting the needs of users within an organizational and societal context through the selection, creation, application, integration, and administration of computing technologies. Computer engineering technologists concern themselves with making computer-based products work properly and in the maintenance of those products.

Table A-1 The Computer Engineering Body of Knowledge

<i>Computer Engineering Knowledge Areas and Units</i>	
<p>CE-ALG Algorithms and Complexity [30 core hours] CE-ALG0 History and overview [1] CE-ALG1 Basic algorithmic analysis [4] CE-ALG2 Algorithmic strategies [8] CE-ALG3 Computing algorithms [12] CE-ALG4 Distributed algorithms [3] CE-ALG5 Algorithmic complexity [2] CE-ALG6 Basic computability theory</p>	<p>CE-CAO Computer Architecture and Organization [63 core hours] CE-CAO0 History and overview [1] CE-CAO1 Fundamentals of computer architecture [10] CE-CAO2 Computer arithmetic [3] CE-CAO3 Memory system organization and architecture [8] CE-CAO4 Interfacing and communication [10] CE-CAO5 Device subsystems [5] CE-CAO6 Processor systems design [10] CE-CAO7 Organization of the CPU [10] CE-CAO8 Performance [3] CE-CAO9 Distributed system models [3] CE-CAO10 Performance enhancements</p>
<p>CE-CSE Computer Systems Engineering [18 core hours] CE-CSE0 History and overview [1] CE-CSE1 Life cycle [2] CE-CSE2 Requirements analysis and elicitation [2] CE-CSE3 Specification [2] CE-CSE4 Architectural design [3] CE-CSE5 Testing [2] CE-CSE6 Maintenance [2] CE-CSE7 Project management [2] CE-CSE8 Concurrent (hardware/software) design [2] CE-CSE9 Implementation CE-CSE10 Specialized systems CE-CSE11 Reliability and fault tolerance</p>	<p>CE-CSG Circuits and Signals [43 core hours] CE-CSG0 History and overview [1] CE-CSG1 Electrical Quantities [3] CE-CSG2 Resistive Circuits and Networks [9] CE-CSG3 Reactive Circuits and Networks [12] CE-CSG4 Frequency Response [9] CE-CSG5 Sinusoidal Analysis [6] CE-CSG6 Convolution [3] CE-CSG7 Fourier Analysis CE-CSG8 Filters CE-CSG9 Laplace Transforms</p>
<p>CE-DBS Database Systems [5 core hours] CE-DBS0 History and overview [1] CE-DBS1 Database systems [2] CE-DBS2 Data modeling [2] CE-DBS3 Relational databases CE-DBS4 Database query languages CE-DBS5 Relational database design CE-DBS6 Transaction processing CE-DBS7 Distributed databases CE-DBS8 Physical database design</p>	<p>CE-DIG Digital Logic [57 core hours] CE-DIG0 History and overview [1] CE-DIG1 Switching theory [6] CE-DIG2 Combinational logic circuits [4] CE-DIG3 Modular design of combinational circuits [6] CE-DIG4 Memory elements [3] CE-DIG5 Sequential logic circuits [10] CE-DIG6 Digital systems design [12] CE-DIG7 Modeling and simulation [5] CE-DIG8 Formal verification [5] CE-DIG9 Fault models and testing [5] CE-DIG10 Design for testability</p>
<p>CE-DSP Digital Signal Processing [17 core hours] CE-DSP0 History and overview [1] CE-DSP1 Theories and concepts [3] CE-DSP2 Digital spectra analysis [1] CE-DSP3 Discrete Fourier transform [7] CE-DSP4 Sampling [2] CE-DSP5 Transforms [2] CE-DSP6 Digital filters [1] CE-DSP7 Discrete time signals CE-DSP8 Window functions CE-DSP9 Convolution CE-DSP10 Audio processing CE-DSP11 Image processing</p>	<p>CE-ELE Electronics [40 core hours] CE-ELE0 History and overview [1] CE-ELE1 Electronic properties of materials [3] CE-ELE2 Diodes and diode circuits [5] CE-ELE3 MOS transistors and biasing [3] CE-ELE4 MOS logic families [7] CE-ELE5 Bipolar transistors and logic families [4] CE-ELE6 Design parameters and issues [4] CE-ELE7 Storage elements [3] CE-ELE8 Interfacing logic families and standard buses [3] CE-ELE9 Operational amplifiers [4] CE-ELE10 Circuit modeling and simulation [3] CE-ELE11 Data conversion circuits CE-ELE12 Electronic voltage and current sources CE-ELE13 Amplifier design CE-ELE14 Integrated circuit building blocks</p>
<p>CE-ESY Embedded Systems [20 core hours] CE-ESY0 History and overview [1] CE-ESY1 Embedded microcontrollers [6] CE-ESY2 Embedded programs [3] CE-ESY3 Real-time operating systems [3] CE-ESY4 Low-power computing [2] CE-ESY5 Reliable system design [2] CE-ESY6 Design methodologies [3] CE-ESY7 Tool support CE-ESY8 Embedded multiprocessors CE-ESY9 Networked embedded systems CE-ESY10 Interfacing and mixed-signal systems</p>	<p>CE-HCI Human-Computer Interaction [8 core hours] CE-HCI0 History and overview [1] CE-HCI1 Foundations of human-computer interaction [2] CE-HCI2 Graphical user interface [2] CE-HCI3 I/O technologies [1] CE-HCI4 Intelligent systems [2] CE-HCI5 Human-centered software evaluation CE-HCI6 Human-centered software development CE-HCI7 Interactive graphical user-interface design CE-HCI8 Graphical user-interface programming CE-HCI9 Graphics and visualization CE-HCI10 Multimedia systems</p>

<p>CE-NWK Computer Networks [21 core hours] CE-NWK0 History and overview [1] CE-NWK1 Communications network architecture [3] CE-NWK2 Communications network protocols [4] CE-NWK3 Local and wide area networks [4] CE-NWK4 Client-server computing [3] CE-NWK5 Data security and integrity [4] CE-NWK6 Wireless and mobile computing [2] CE-NWK7 Performance evaluation CE-NWK8 Data communications CE-NWK9 Network management CE-NWK10 Compression and decompression</p>	<p>CE-OPS Operating Systems [20 core hours] CE-OPS0 History and overview [1] CE-OPS1 Design principles [5] CE-OPS2 Concurrency [6] CE-OPS3 Scheduling and dispatch [3] CE-OPS4 Memory management [5] CE-OPS5 Device management CE-OPS6 Security and protection CE-OPS7 File systems CE-OPS8 System performance evaluation</p>
<p>CE-PRF Programming Fundamentals [39 core hours] CE-PRF0 History and overview [1] CE-PRF1 Programming Paradigms [5] CE-PRF2 Programming constructs [7] CE-PRF3 Algorithms and problem-solving [8] CE-PRF4 Data structures [13] CE-PRF5 Recursion [5] CE-PRF6 Object-oriented programming CE-PRF7 Event-driven and concurrent programming CE-PRF8 Using APIs</p>	<p>CE-SPR Social and Professional Issues [16 core hours] CE-SPR0 History and overview [1] CE-SPR1 Public policy [2] CE-SPR2 Methods and tools of analysis [2] CE-SPR3 Professional and ethical responsibilities [2] CE-SPR4 Risks and liabilities [2] CE-SPR5 Intellectual property [2] CE-SPR6 Privacy and civil liberties [2] CE-SPR7 Computer crime [1] CE-SPR8 Economic issues in computing [2] CE-SPR9 Philosophical frameworks</p>
<p>CE-SWE Software Engineering [13 core hours] CE-SWE0 History and overview [1] CE-SWE1 Software processes [2] CE-SWE2 Software requirements and specifications [2] CE-SWE3 Software design [2] CE-SWE4 Software testing and validation [2] CE-SWE5 Software evolution [2] CE-SWE6 Software tools and environments [2] CE-SWE7 Language translation CE-SWE8 Software project management CE-SWE9 Software fault tolerance</p>	<p>CE-VLS VLSI Design and Fabrication [10 core hours] CE-VLS0 History and overview [1] CE-VLS1 Electronic properties of materials [2] CE-VLS2 Function of the basic inverter structure [3] CE-VLS3 Combinational logic structures [1] CE-VLS4 Sequential logic structures [1] CE-VLS5 Semiconductor memories and array structures [2] CE-VLS6 Chip input/output circuits CE-VLS7 Processing and layout CE-VLS8 Circuit characterization and performance CE-VLS9 Alternative circuit structures/low power design CE-VLS10 Semi-custom design technologies CE-VLS11 ASIC design methodology</p>

<i>Mathematics</i>		<i>Knowledge Areas and Units</i>	
<p>CE-DSC Discrete Structures [33 core hours] CE-DSC0 History and overview [1] CE-DSC1 Functions, relations, and sets [6] CE-DSC2 Basic logic [10] CE-DSC3 Proof techniques [6] CE-DSC4 Basics of counting [4] CE-DSC5 Graphs and trees [4] CE-DSC6 Recursion [2]</p>	<p>CE-PRS Probability and Statistics [33 core hours] CE-PRS0 History and overview [1] CE-PRS1 Discrete probability [6] CE-PRS2 Continuous probability [6] CE-PRS3 Expectation [4] CE-PRS4 Stochastic Processes [6] CE-PRS5 Sampling distributions [4] CE-PRS6 Estimation [4] CE-PRS7 Hypothesis tests [2] CE-PRS8 Correlation and regression</p>		

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Typical College Curriculum to Prepare for Your Career
Engineering Bachelor's Degree Programs
Computer Engineering

Courses	% time
Math	14
Physics or Chem.	13
Intro. Computing	5
Computer Hardware & Microcomputers	7
Software Engineering	7
Lab & Design Work	9
Electrical engineering electives	9
Other technical electives	9
Oral/Written Communications	5
Social Science/Humanities	13
Other electives*	9

*Electives may include additional technical courses in Semiconductor Device Construction, Advanced Topics in Computer Languages, Computer Architecture, Computer Construction, Communications, Microwaves, etc., depending on the interests and the size of the faculty. Topics in business and arts and sciences may also be included.