# Computer engineering

**Computer engineering** (CE) is a branch of engineering that integrates several fields of computer science and electronic engineering required to develop computer hardware and software.[1] Computer engineers usually have training in electronic engineering (or electrical engineering), software design, and hardware-software integration instead of only software engineering or electronic engineering. Computer engineers are involved in many hardware and software aspects of computing, from the design of individual microcontrollers, 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.[2]

Usual tasks involving computer engineers include writing software and firmware for embedded microcontrollers, designing VLSI chips, designing analog sensors, designing mixed signal circuit boards, and designing operating systems. Computer engineers are also suited for robotics research, which relies heavily on using digital systems to control and monitor electrical systems like motors, communications, and sensors.

This motherboard used in a HD DVD player is the result of computer engineering efforts.

In many institutions of higher learning, computer engineering students are allowed to choose areas of in-depth study in their junior and senior year because the full breadth of knowledge used in the design and application of computers is beyond the scope of an undergraduate degree. Other institutions may require engineering students to complete one or two years of general engineering before declaring computer engineering as their primary focus.[3][4][5][6]

## Contents

# History

Computer engineering began in 1939 when John Vincent Atanasoff and Clifford Berry began developing the world's first electronic digital computer through physics, mathematics, and electrical engineering. John Vincent Atanasoff was once a physics and mathematics teacher for Iowa State University and Clifford Berry a former graduate under electrical engineering and physics. Together, they created the Atanasoff-Berry computer, also known as the ABC which took 5 years to complete.[7] While the original ABC was dismantled and discarded in the 1940s a tribute was made to the late inventors, a replica of the ABC was made in 1997 where it took a team of researchers and engineers four years and $350,000 to build.[8]

The modern personal computer emerged in the 1970s, after several breakthroughs in semiconductor technology. These include the first working transistor by William Shockley, John Bardeen and Walter Brattain at Bell Labs in 1947,[9] the silicon surface passivation process (via thermal oxidation) by Mohamed Atalla at Bell Labs in 1957,[10][11][12] the monolithic integrated circuit chip by Robert Noyce at Fairchild Semiconductor in 1959,[13] the metal-oxide-semiconductor field-effect transistor (MOSFET, or MOS transistor) by Mohamed Atalla and Dawon Kahng at Bell Labs in 1959,[14][15][16] and the single-chip microprocessor (Intel 4004) by Federico Faggin, Marcian Hoff, Masatoshi Shima and Stanley Mazor at Intel in 1971.[17]

## History of computer engineering education

The first computer engineering degree program in the United States was established in 1971 at Case Western Reserve University in Cleveland, Ohio.[18] As of 2015, there were 250 ABET-accredited computer engineering programs in the U.S.[19] In Europe, accreditation of computer engineering schools is done by a variety of agencies part of the EQANIE network. Due to increasing job requirements for engineers who can concurrently design hardware, software, firmware, and manage all forms of computer systems used in industry, some tertiary institutions around the world offer a bachelor's degree generally called computer engineering. Both computer engineering and electronic engineering programs include analog and digital circuit design in their curriculum. As with most engineering disciplines, having a sound knowledge of mathematics and science is necessary for computer engineers.

# Education

Computer engineering is referred to as computer science and engineering at some universities. Most entry-level computer engineering jobs require at least a bachelor's degree in computer engineering (or computer science and engineering). Typically one must learn an array of mathematics such as calculus, algebra and trigonometry and some computer science classes. Sometimes a degree in electronic engineering is accepted, due to the similarity of the two fields. Because hardware engineers commonly work with computer software systems, a strong background in computer programming is necessary. According to BLS, "a computer engineering major is similar to electrical engineering but with some computer science courses added to the curriculum".[20] Some large firms or specialized jobs require a master's degree.

It is also important for computer engineers to keep up with rapid advances in technology. Therefore, many continue learning throughout their careers. This can be helpful, especially when it comes to learning new skills or improving existing ones. For example, as the relative cost of fixing a bug increases the further along it is in the software development cycle, there can be greater cost savings attributed to developing and testing for quality code as soon as possible in the process, and particularly before release.[21]

# Applications and practice

There are two major specialties in computer engineering: hardware and software.

## Computer hardware engineering

According to the BLS, Job Outlook employment for computer hardware engineers, the expected ten-year growth from 2014 to 2024 for computer hardware engineering was an estimated 3% and there was a total of 77,700 jobs that same year. ("Slower than average" in their own words when compared to other occupations)"[22] and is down from 7% for the 2012 to 2022 BLS estimate[22] and is further down from 9% in the BLS 2010 to 2020 estimate." Today, computer hardware is somehow equal to electronic and computer engineering (ECE) and has been divided into many subcategories; the most significant is embedded system design.[20]

## Computer software engineering

According to the U.S. Bureau of Labor Statistics (BLS), "computer applications software engineers and computer systems software engineers are projected to be among the faster than average growing occupations" The expected ten-year growth as of 2014 for computer software engineering was an estimated seventeen percent and there was a total of 1,114,000 jobs that same year.[23] This is down from the 2012 to 2022 BLS estimate of 22% for software developers.[24][23] And, further down from the 30% 2010 to 2020 BLS estimate.[25] In addition, growing concerns over cybersecurity add up to put computer software engineering high above the average rate of increase for all fields. However, some of the work will be outsourced in foreign countries. Due to this, job growth will not be as fast as during the last decade, as jobs that would have gone to computer software engineers in the United States would instead go to computer software engineers in countries such as India.[26] In addition, the BLS Job Outlook for Computer Programmers, 2014–24 has an −8% (a decline, in their words)[26] for those who program computers (i.e. embedded systems) who are not computer application developers.[27][28]

## Computer Engineering licensing and practice

Computer Engineering is generally practiced within larger product development firms, and such practice may not be subject to licensing.[29][30] However, independent consultants who advertise Computer Engineering, just like any form of Engineering, may be subject to state laws which restrict professional

engineer practice to only those who have received the appropriate License.[31][32] National Council of Examiners for Engineering and Surveying (NCEES) first offered a Principles and Practice of Engineering Examination for Computer Engineering[33] in 2003.

# Specialty areas

There are many specialty areas in the field of computer engineering.

## Coding, cryptography, and information protection

Computer engineers work in coding, cryptography, and information protection to develop new methods for protecting various information, such as digital images and music, fragmentation, copyright infringement and other forms of tampering. Examples include work on wireless communications, multi-antenna systems, optical transmission, and digital watermarking.[34]

## Communications and wireless networks

Those focusing on communications and wireless networks, work advancements in telecommunications systems and networks (especially wireless networks), modulation and error-control coding, and information theory. High-speed network design, interference suppression and modulation, design, and analysis of fault-tolerant system, and storage and transmission schemes are all a part of this specialty.[34]

## Compilers and operating systems

This specialty focuses on compilers and operating systems design and development. Engineers in this field develop new operating system architecture, program analysis techniques, and new techniques to assure quality. Examples of work in this field include post-link-time code transformation algorithm development and new operating system development.[34]

## Computational science and engineering

Computational Science and Engineering is a relatively new discipline. According to the Sloan Career Cornerstone Center, individuals working in this area, "computational methods are applied to formulate and solve complex mathematical problems in engineering and the physical and the social sciences. Examples include aircraft design, the plasma processing of nanometer features on semiconductor wafers, VLSI circuit design, radar detection systems, ion transport through biological channels, and much more".[34]

## Computer networks, mobile computing, and distributed systems

In this specialty, engineers build integrated environments for computing, communications, and information access. Examples include shared-channel wireless networks, adaptive resource management in various systems, and improving the quality of service in mobile and ATM environments. Some other examples include work on wireless network systems and fast Ethernet cluster wired systems.[34]

## Computer systems: architecture, parallel processing, and dependability

Engineers working in computer systems work on research projects that allow for reliable, secure, and high-performance computer systems. Projects such as designing processors for multi-threading and parallel processing are included in this field. Other examples of work in this field include development of new theories, algorithms, and other tools that add performance to computer systems.[34]

Computer architecture includes CPU design, cache hierarchy layout, memory organization and load balancing.

### Computer vision and robotics

In this specialty, computer engineers focus on developing visual sensing technology to sense an environment, representation of an environment, and manipulation of the environment. The gathered three-dimensional information is then implemented to perform a variety of tasks. These include improved human modeling, image communication, and human-computer interfaces, as well as devices such as special-purpose cameras with versatile vision sensors.[34]

### Embedded systems

Individuals working in this area design technology for enhancing the speed, reliability, and performance of systems. Embedded systems are found in many devices from a small FM radio to the space shuttle. According to the Sloan Cornerstone Career Center, ongoing developments in embedded systems include "automated vehicles and equipment to conduct search and rescue, automated transportation systems, and human-robot coordination to repair equipment in space."[34] As of 2018, computer embedded computer engineering specializations include system-on-chip design, architecture of edge computing and the Internet of things.

Examples of devices that use embedded systems

### Integrated circuits, VLSI design, testing and CAD

This specialty of computer engineering requires adequate knowledge of electronics and electrical systems. Engineers working in this area work on enhancing the speed, reliability, and energy efficiency of next-generation very-large-scale integrated (VLSI) circuits and microsystems. An example of this specialty is work done on reducing the power consumption of VLSI algorithms and architecture.[34]

### Signal, image and speech processing

Computer engineers in this area develop improvements in human-computer interaction, including speech recognition and synthesis, medical and scientific imaging, or communications systems. Other work in this area includes computer vision development such as recognition of human facial features.[34]

### Quantum computing

## See also

### Related fields

- Computer programming
- Electrical engineering
- Information engineering
- Software development
- Systems analyst

### Associations

- Association of Computer Engineers and Technicians

## References


1. IEEE Computer Society; ACM (December 12, 2004). *Computer Engineering 2004: Curriculum Guidelines for Undergraduate Degree Programs in Computer Engineering* (http://www.acm.org/education/education/curric_vols/CE-Final-Report.pdf) (PDF). p. iii. Retrieved December 17, 2012. "Computer System engineering has traditionally been viewed as a combination of both electronic engineering (EE) and computer science (CS)."
2. Trinity College Dublin. "What is Computer System Engineering" (http://www.tcd.ie/Engineering/about/what_is_eng/computer_eng_intro.html). Retrieved April 21, 2006., "Computer engineers need not only to understand how computer systems themselves work but also how they integrate into the larger picture. Consider the car. A modern car contains many separate computer systems for controlling such things as the engine timing, the brakes, and the airbags. To be able to design and implement such a car, the computer engineer needs a broad theoretical understanding of all these various subsystems & how they interact.
3. "Changing Majors @ Clemson" (http://www.registrar.clemson.edu/html/changeMjr_Curr.htm). Clemson University. Retrieved September 20, 2011.
4. "Declaring a College of Engineering Major" (https://web.archive.org/web/20141012182736/http://freshmanengineering.uark.edu/2041.php). University of Arkansas. Archived from the original (http://freshmanengineering.uark.edu/2041.php) on October 12, 2014. Retrieved September 20, 2011.
5. "Degree Requirements" (http://www.cmu.edu/me/undergraduate/degree-requirements.html). Carnegie Mellon University. Retrieved September 20, 2011.
6. "Programas de Materias" (http://www.uca.edu.ar/index.php/site/index/es/uca/facultad-de-ciencias-fisicomatematicas-e-ingenieria/alumnos/programas-de-materias/cc1y2/) (in Spanish). Universidad Católica Argentina.
7. "John Vincent Atanasoff - the father of the computer" (http://www.columbia.edu/~td2177/JVAtanasoff/JVAtanasoff.html). *www.columbia.edu*. Retrieved December 5, 2017.
8. "Iowa State replica of first electronic digital computer going to Computer History Museum - News Service - Iowa State University" (https://www.news.iastate.edu/news/2009/dec/abc). *www.news.iastate.edu*. Retrieved December 5, 2017.
9. "1947: Invention of the Point-Contact Transistor" (https://www.computerhistory.org/siliconengine/invention-of-the-point-contact-transistor/). *The Silicon Engine*. Computer History Museum. Retrieved October 9, 2019.
10. Lojek, Bo (2007). *History of Semiconductor Engineering*. Springer Science & Business Media. pp. 120 & 321-323. ISBN 9783540342588.
11. Bassett, Ross Knox (2007). *To the Digital Age: Research Labs, Start-up Companies, and the Rise of MOS Technology* (https://books.google.com/books?id=UUbB3d2UnaAC&pg=PA46). Johns Hopkins University Press. p. 46. ISBN 9780801886393.

12. Sah, Chih-Tang (October 1988). "Evolution of the MOS transistor-from conception to VLSI" (http://www.dejazzer.com/ece723/resources/Evolution_of_the_MOS_transistor.pdf) (PDF). *Proceedings of the IEEE*. **76** (10): 1280–1326 (1290). Bibcode:1988IEEEP..76.1280S (https://ui.adsabs.harvard.edu/abs/1988IEEEP..76.1280S). doi:10.1109/5.16328 (https://doi.org/10.1109%2F5.16328). ISSN 0018-9219 (https://www.worldcat.org/issn/0018-9219). "Those of us active in silicon material and device research during 1956–1960 considered this successful effort by the Bell Labs group led by Atalla to stabilize the silicon surface the most important and significant technology advance, which blazed the trail that led to silicon integrated circuit technology developments in the second phase and volume production in the third phase."
13. Saxena, Arjun N. (2009). *Invention of Integrated Circuits: Untold Important Facts* (https://books.google.com/books?id=-3lpDQAAQBAJ&pg=PA140). World Scientific. p. 140. ISBN 9789812814456.
14. "1960 - Metal Oxide Semiconductor (MOS) Transistor Demonstrated" (https://www.computerhistory.org/siliconengine/metal-oxide-semiconductor-mos-transistor-demonstrated/). *The Silicon Engine*. Computer History Museum.
15. "Who Invented the Transistor?" (https://www.computerhistory.org/atchm/who-invented-the-transistor/). *Computer History Museum*. December 4, 2013. Retrieved July 20, 2019.
16. "Triumph of the MOS Transistor" (https://www.youtube.com/watch?v=q6fBEjf9WPw). *YouTube*. Computer History Museum. August 6, 2010. Retrieved July 21, 2019.
17. "1971: Microprocessor Integrates CPU Function onto a Single Chip" (https://www.computerhistory.org/siliconengine/microprocessor-integrates-cpu-function-onto-a-single-chip/). *Computer History Museum*. Retrieved July 22, 2019.
18. "History" (https://engineering.case.edu/about/history). *engineering.case.edu*. Case School of Engineering.
19. "Find an ABET-Accredited Program | ABET" (http://main.abet.org/aps/accreditedprogramsearch.aspx). *main.abet.org*. Retrieved November 29, 2015.
20. "Computer Hardware Engineers" (http://www.bls.gov/ooh/architecture-and-engineering/computer-hardware-engineers.htm). Bureau of Labor Statistics. January 8, 2014. Retrieved July 20, 2012.
21. "Feabhas_Infographic_FINAL" (http://www.feabhas.com/sites/default/files/uploads/News/Feabhas_Infographic_FINAL.pdf) (pdf). *feabhas*. Feabhas.
22. "Computer Hardware Engineers: Occupational Outlook Handbook" (http://www.bls.gov/ooh/architecture-and-engineering/computer-hardware-engineers.htm). U.S. Bureau of Labor Statistics.
23. "Software Developers: Occupational Outlook Handbook" (http://www.bls.gov/ooh/computer-and-information-technology/software-developers.htm). U.S. Bureau of Labor Statistics.
24. "Computer Software Engineer" (https://web.archive.org/web/20130726002354/http://www.bls.gov/k12/computers04.htm). Bureau of Labor Statistics. March 19, 2010. Archived from the original (http://www.bls.gov/k12/computers04.htm) on July 26, 2013. Retrieved July 20, 2012.
25. "Software Developers" (http://www.bls.gov/ooh/computer-and-information-technology/software-developers.htm). Bureau of Labor Statistics. January 8, 2014. Retrieved July 21, 2012.
26. "Computer Programmers: Occupational Outlook Handbook" (http://www.bls.gov/ooh/computer-and-information-technology/computer-programmers.htm). U.S. Bureau of Labor Statistics.
27. https://www.bls.gov/opub/regional_reports/200908_silicon_valley_high_tech.htm
28. https://www.designnews.com/design-hardware-software/soon-be-extinct-embedded-software-engineer/39152617858743?ADTRK=UBM&elq_mid=4305&elq_cid=37479
29. "The North Carolina Engineering and Land Surveying Act" (https://www.ncleg.gov/Laws/GeneralStatuteSections/Chapter89C).
30. "Definitions - The North Carolina Engineering and Land Surveying Act" (https://www.ncleg.gov/EnactedLegislation/Statutes/HTML/BySection/Chapter_89C/GS_89C-3.html).

31. "Unlawful to practice engineering or land surveying without licensure - The North Carolina Engineering and Land Surveying Act" (https://www.ncleg.gov/EnactedLegislation/Statutes/HTML/BySection/Chapter_89C/GS_89C-23.html).
32. "Professional Licensure for Computer Engineers and Software Engineers" (https://insight.ieeeusa.org/articles/professional-licensure-for-computer-engineers-and-software-engineers/). *IEEE-USA InSight*. Retrieved January 6, 2020.
33. PE Electrical and Computer exam, [NCEES (https://ncees.org/engineering/pe/electrical-computer/) ]
34. "Computer Engineering Overview" (https://web.archive.org/web/20120916035940/http://www.careercornerstone.org/pdf/compeng/compeng.pdf) (PDF). Sloan Career Cornerstone Center. Archived from the original (http://www.careercornerstone.org/pdf/compeng/compeng.pdf) (PDF) on September 16, 2012. Retrieved July 20, 2012.

17. ^ https://www.ece.iastate.edu/the-department/history/history-of-computing

18. ^ https://collegegrad.com/careers/computer-hardware-engineers

19. ^ https://www.sokanu.com/careers/software-engineer/

# External links

- Media related to Computer engineering at Wikimedia Commons