Historical Developments

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Machine-Level and Systems Programming

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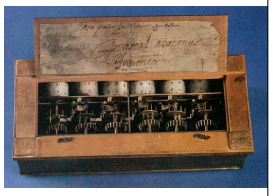
Historical Developments

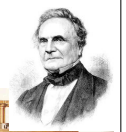
- The history of "computers" is long and fascinating
- It should be part of your culture as computer scientists
  - Many books exist that detail the history of computers in many more details that what we can do in this course
- We're going to proceed in "generations"
  - Nobody is in perfect agreement about these generations
  - But they are a convenient way to organize the history of computers
  - People disagree about the "first computer" as well

Generation 0: Mechanical Calculators

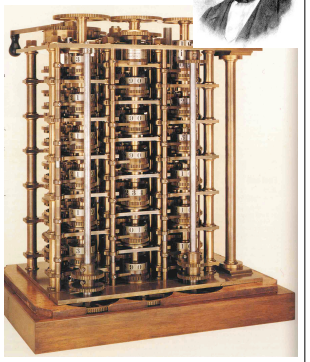
- Before the 1500s, in Europe, calculations were made with an abacus
  - Invented around 500BC, available in many cultures (China, Mesopotamia, Japan, Greece, Rome, etc.)
- In 1642, Blaise Pascal (French mathematician, physicist, philosopher) invented a mechanical calculator called the Pascaline
  - Additions, subtractions, carries
  - Initially used to help Pascal's father with Tax computations!
  - Survived in some shape or form until the early 20th century
- In 1671, Gottfried von Leibniz (German mathematician, philosopher) extended the Pascaline to do multiplications, divisions, square roots: the Stepped Reckoner
- None of these machines had memory, and they required human intervention at each step



Generation 0: Babbage

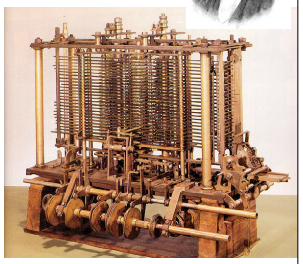


- In 1822 Charles Babbage (English mathematician, philosopher), sometimes called the "father of computing" built the Difference Engine
- Machine designed to automate the computation of polynomial functions (which are known to be good approximations of many useful functions)
  - Based on the "method of finite difference" by which polynomial values can be computing without ever having to do a multiplication
  - Implements some storage
    - All internal and temporary, the user doesn't store anything
  - Let's check out the video...



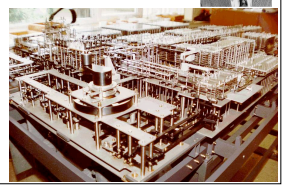
Generation 0: Babbage

- In 1833 Babbage designed the Analytical Engine, but he died before he could build it
  - It was built after his death, powered by steam!
- It was much more general than the difference engine, and could in theory perform "any" mathematical operation
- This is really the first machine that somewhat resembles our computers
  - An arithmetic processing unit (the mill)
  - A memory (the store)
  - Input/output devices (punched metal cards)
    - Inspired by Jacquard automatic weaving loom!
    - Convenient for "wheeled" machines
  - A conditional branching instruction!
- In 1842, Ada Lovelace (English mathematician, daughter of Lord Byron) wrote instructions for the Analytical Engine to compute the Bernoulli numbers: the first computer program!
  - A programming language is named after her



Generation 1: Vacuum Tubes

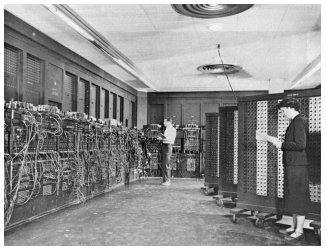
- The vacuum tube is the first known device to amplify, switch, or modify a signal (by controlling the movements of electrons)
  - The basis from a whole generation of computers
    - But high energy consumption, high heat, large, flaky
  - Still used today in high-end audio amplifiers and other applications
- In the 1930s, Konrad Zuse (German) designed a machine akin to the Analytical Engine of Babbage that was *supposed to* use vacuum tubes
  - But it didn't, due to lack of funds (Zuse was building it in his parents' living room in Berlin)
  - He used electromechanical relays instead
  - He never managed to convince the Nazis to buy/ fund his invention!
  - His machines were called the Z1, Z2, and Z3, and destroyed during the WWII bombing of Berlin



Generation 1: ENIAC

- The ENIAC (Electronic Numerical Integrator and Computer) was unveiled in 1946: the first all-electronic, general-purpose digital computer
  - Designed by Mauchly and Eckert
  - Shares many elements with the ABC computer, which was built to solve linear equations
- Specs
  - 17,468 vacuum tubes
  - 1,800 sq ft
  - 30 tons
  - 174 kilowatt of power
  - 1,000-bit memory
  - Punched card

Generation 1: ENIAC



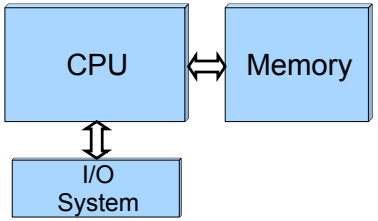
Generation 1: New Concepts

- The use of binary
  - In the 30s Claude Shannon (the father of "information theory") had proposed that the use of binary arithmetic and boolean logic should be used with electronic circuits

- The Von-Neumann architecture
  - In 1944, John von Neumann (Hungarian) learned about ENIAC and joined the group.
  - He wrote a memo about computer architecture, formalizing the ideas that came out of ENIAC and transferring them to a wider audience
  - This became the Von Neumann machine model, which we still use today
    - Note that Eckert and Mauchly have pretty much been forgotten (they were the real inventors)

The Von-Neumann Architecture

- Three hardware systems
  - A Central Processing Unit (CPU)
  - A memory, which stores both program and data
  - An input/output system
- Computers today are still very close to this basic architecture
- We'll come back to it



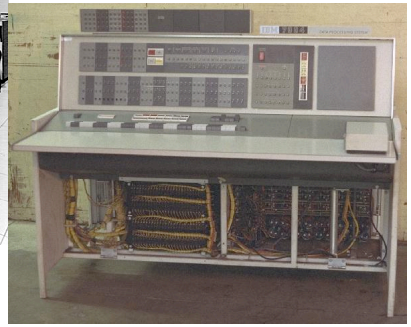
Generation 2: Transistors

- Vacuum tubes have many shortcomings, as we've seen, but on top of it they are were not reliable
  - ENIAC often had more downtime than uptime
- In 1948, Bardeen, Brattain, and Shockley invented the transistor at Bell Labs
  - A solid-state version of the vacuum tube that uses silicon, which is a semi-conductor
  - Lower power consumption, smaller, more reliable, cheaper, much lower heat dissipation
- This was the beginning of a new era for electronics and for the computer market

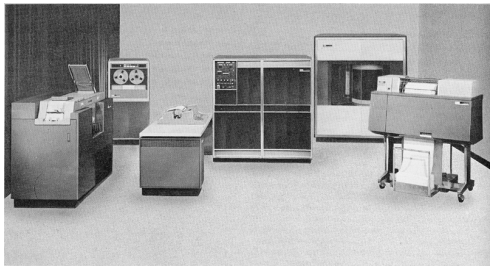
Generation 2: Transistors

- Generation 2 computers were still bulky and expensive, and so there were only in universities, government agencies, and large businesses
- It was the beginning of big computer vendors
- IBM
  - IBM7094: for scientific application (1962)
  - IBM1401: for business applications (1959)
- DEC, Univac
- CDC 6600: first "supercomputer"
  - $10 million
  - 10 million instructions/sec, 60-bit words, 128kword of memory
  - Build by a team led by Seymour Cray
- Transistor-based computer enabled space travel and many other advances

Generation 2: IBM7094



Generation 2: IBM1401



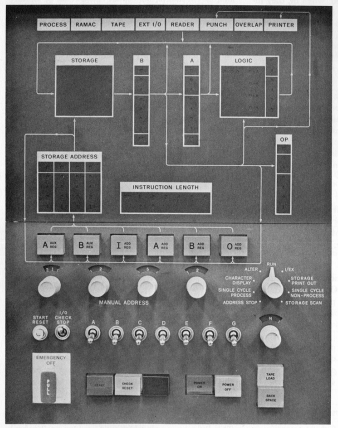
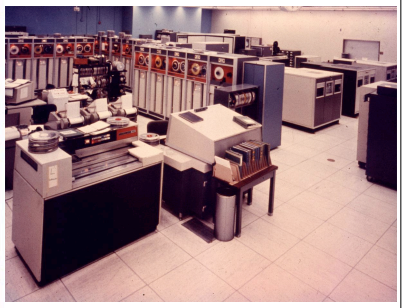


Figure 195. IBM 1401 Console

Generation 2: CDC6600

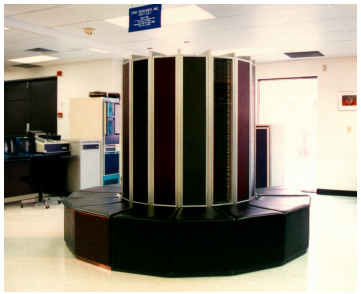


Generation 3: Integrated Circuits

- In the late 50s, Kilby and Noyce independently came up with the idea of an Integrated Circuit (IC)
- The IC allowed dozens of transistors to exist on a single “silicon chip,” which was smaller than the previously available single transistor
- This led computers to become smaller, faster, and cheaper
- The IBM System/360 was the first computer to be built entirely with ICs
  - Other new concept for these computers: (assembly) code was portable across different machines in the family!

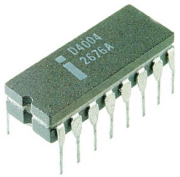
Generation 3: Integrated Circuits

- Seymour Cray created the Cray Research Corporation
- Cray-1: $8.8 million, 160 million instructions per seconds and 8 Mbytes of memory



Generation 4: VLSI

- Improvements to IC technology made it possible to integrate more and more transistors in a single chip
  - SSI (Small Scale Integration): 10-100
  - MSI (Medium Scale Integration): 100-1,000
  - LSI (Large Scale Integration): 1,000-10,000
  - VLSI (Very Large Scale Integration): >10,000
  - This keeps increasing, doubling every 24 months or so (the famous Moore's law)



- Many argue that VLSI marks the beginning of Generation 4
- The important point is that with VLSI it became possible to have a full CPU on a single chip, also called a microprocessor
- The first microprocessor was created by Intel in 1971 (many people start generation 4 then)
  - 4004 microprocessor: 4-bit, 108KHz
  - RAM chip: 4Kbit

Generation 4: ENIAC on a chip

- In 1997, the 50th anniversary of the ENIAC, students at U. Penn built a single chip equivalent to the ENIAC
- ENIAC
  - 1,800 sqft, 30-ton, 174 kilowatts
- On one-tenth of a chip!
  - 174,569 transistors
  - ~10 times less than typically present on a chip in 1997!

Generation 4: Microprocessors

- With the advent of microprocessors it became possible to build "personal computers"
  - 1977: Apple II
  - 1981: IBM PC

Generation 5?

- The term “Generation 5” is used sometimes to refer to all more or less “sci fi” future developments
  - Voice recognition
  - Artificial intelligence
  - Quantum computing
  - Bio computing
  - Nano technology
  - Learning
  - Natural languages

Summary

- Generation 0: Mechanical Calculators
- Generation 1: Vacuum Tube Computers
- Generation 2: Transistor Computers
- Generation 3: Integrated Circuits
- Generation 4: Microprocessors

Conclusion

- Computers have come a long way, but it is somewhat surprising to realize how the general principles are still the same
  - The Von-Neumann architecture
  - Binary encoding
  - Transistors
- These are the age-old computer architecture principles that we will assume in this course