Historical Developments

ICS312

Machine-Level and Systems Programming

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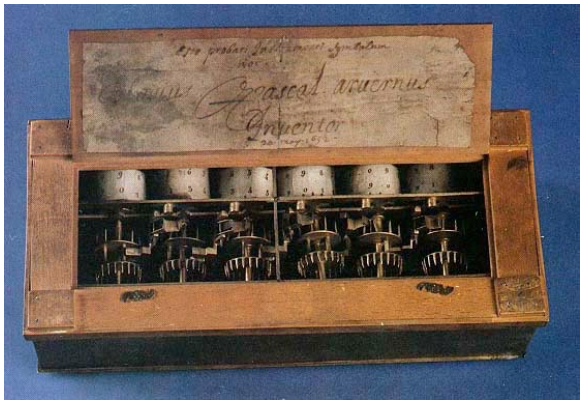
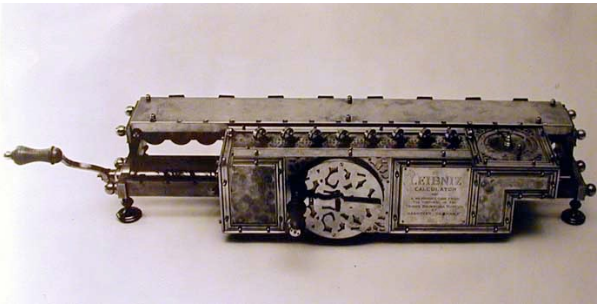
Historical Developments

- The history of “computers” is long and fascinating
- Some of it should be part of your culture
  - Many books exist that detail the history of computers in many more details that what we can do in this course
  - And of course you can always go to a computer museum
- 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 which one was the “first computer” as well

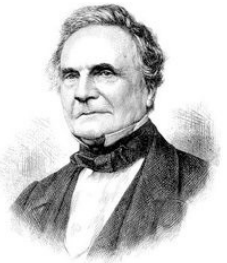
Generation 0: Mechanical Calculators

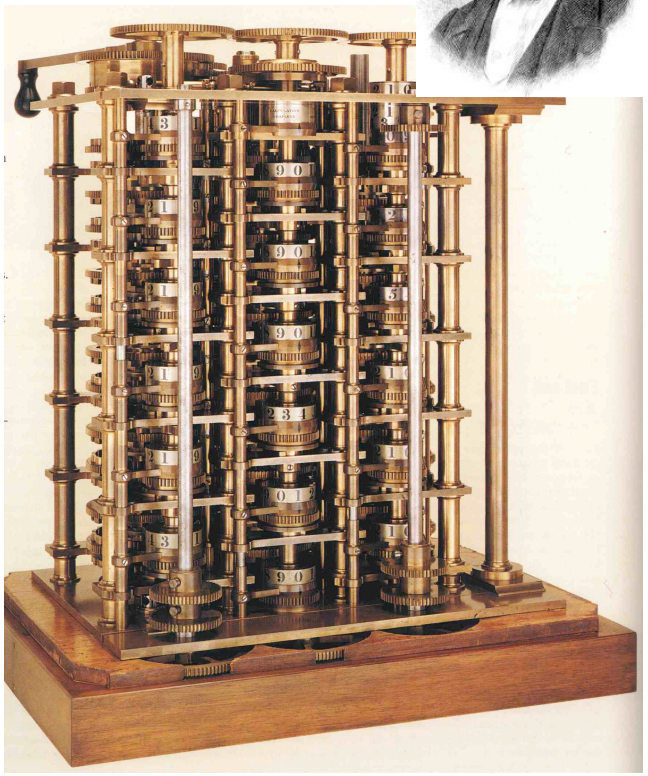
- Before the 1500s, in Europe, calculations were made with an abacus
  - Invented around 500BC, available in many cultures (China, Mesopotamia, Japan, Greece, Rome, etc.)
- In 1642, Blaise Pascal (French mathematician, physicist, philosopher) invented a mechanical calculator called the Pascaline
  - 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





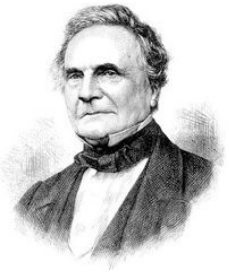
Generation 0: Babbage



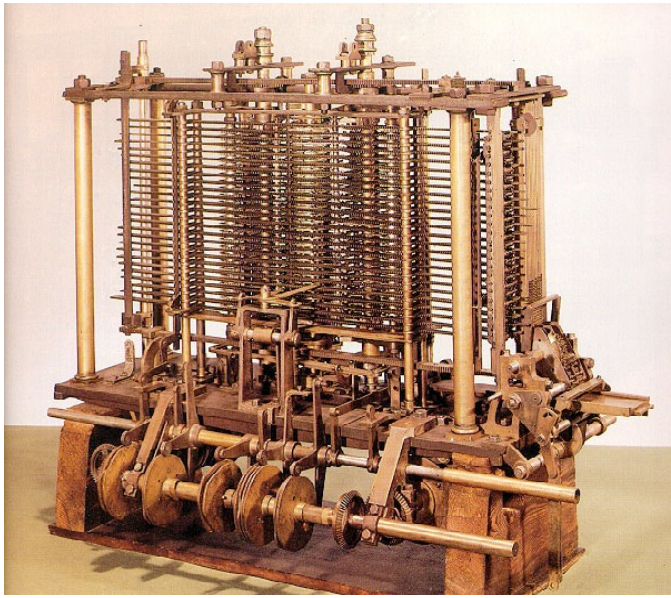


- In 1822 Charles Babbage (English mathematician, philosopher), sometimes called the “father of computing” built the Difference Engine
- Machine designed to automate the computation of polynomial functions (which are known to be good approximations of many useful functions)
  - Based on the “method of 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
  - You can check out this video...

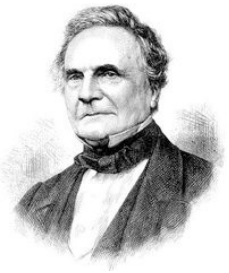
Generation 0: Babbage



- 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!



Generation 0: Babbage



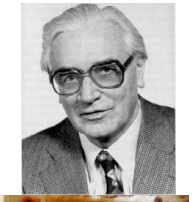
- In 1843, Ada Lovelace (English mathematician, daughter of Lord Byron) wrote instructions for the Analytical Engine to compute the Bernoulli numbers: the first computer program!
  - A programming language was named after her

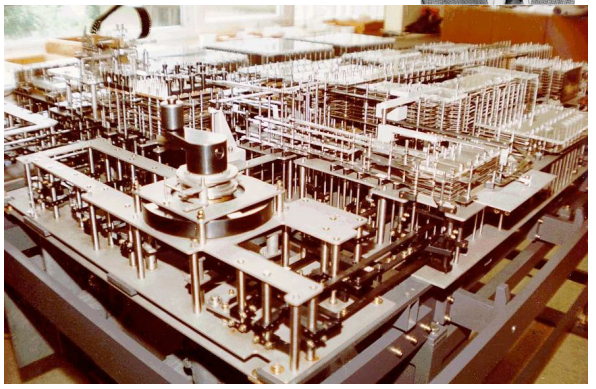
Excerpt from the “The Thrilling Adventures of Lovelace and Babbage (the mostly true story of the first computer)” comic book by Sidney Padua.

http://sydneypadua.com/2dgoggles/

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
  - 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

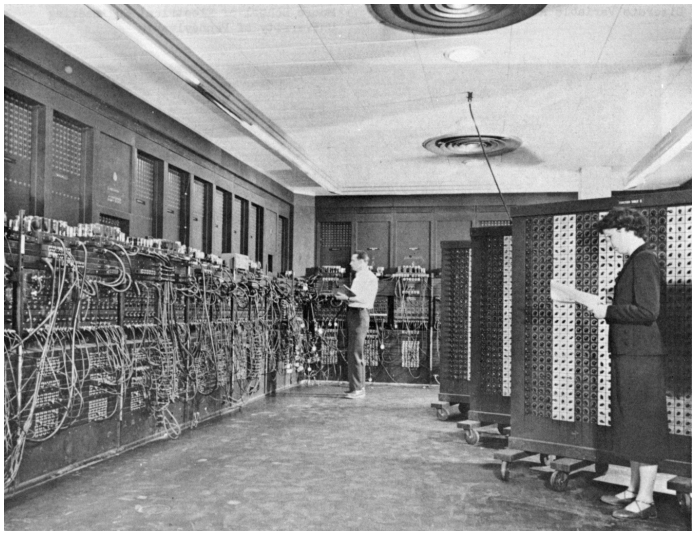




Generation 1: ENIAC

- 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
  - Programmed during WW2 by a team of 6 women
- Specs
  - 17,468 vacuum tubes
  - 1,800 sqft
  - 30 tons
  - 174 kilowatt of power
  - 1,000-bit memory

Generation 1: ENIAC



HOW MUCH IS $\sqrt[3]{2589}^{16}$?

The Army's ENIAC can give you the answer in a fraction of a second!

Think that's a stumper? You should see some of the ENIAC's problems! Brain twisters that if put to paper would run off this page and feet beyond . . . addition, subtraction, multiplication, division—square root, cube root, any root. Solved by an incredibly complex system of circuits operating 18,000 electronic tubes and tipping the scales at 30 tons!

The ENIAC is symbolic of many amazing Army devices with a brilliant future for you! The new Regular Army needs men with aptitude for scientific work, and as one of the first trained in the post-war era, you stand to get in on the ground floor of important jobs which have never before existed. You'll find that an Army career pays off.

The most attractive fields are filling quickly. Get into the swim while the getting's good! 1½, 2 and 3 year enlistments are open in the Regular Army to ambitious young men 18 to 34 (17 with parents' consent) who are otherwise qualified. If you enlist for 3 years, you may choose your own branch of the service, of those still open. Get full details at your nearest Army Recruiting Station.

YOUR REGULAR ARMY SERVES THE NATION AND MANKIND IN WAR AND PEACE

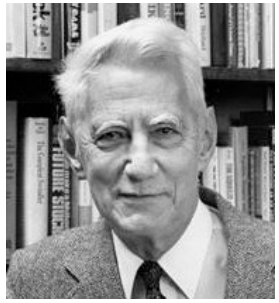
A GOOD JOB FOR YOU

U. S. Army

CHOOSE THIS FINE PROFESSION NOW!

OCTOBER 1946

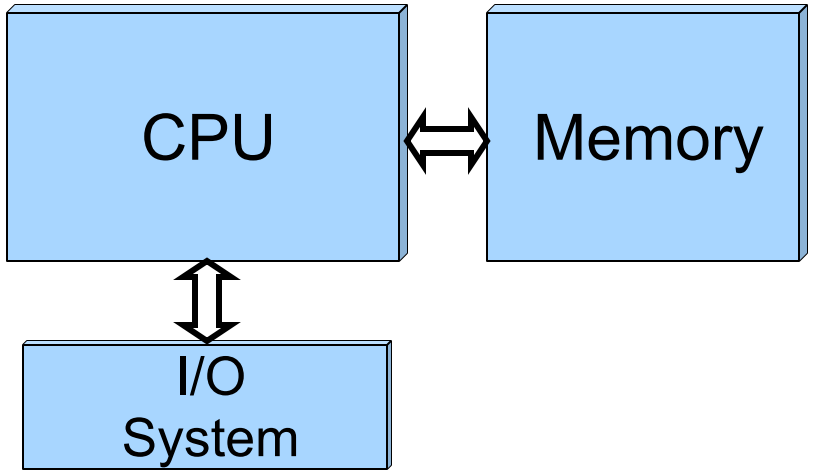
Generation 1: New Concepts



- The use of binary
  - In the 30s Claude Shannon (the father of "information theory") had proposed that 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)

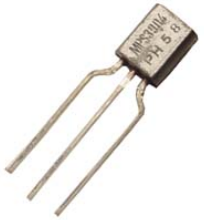
The Von-Neumann Architecture

- 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

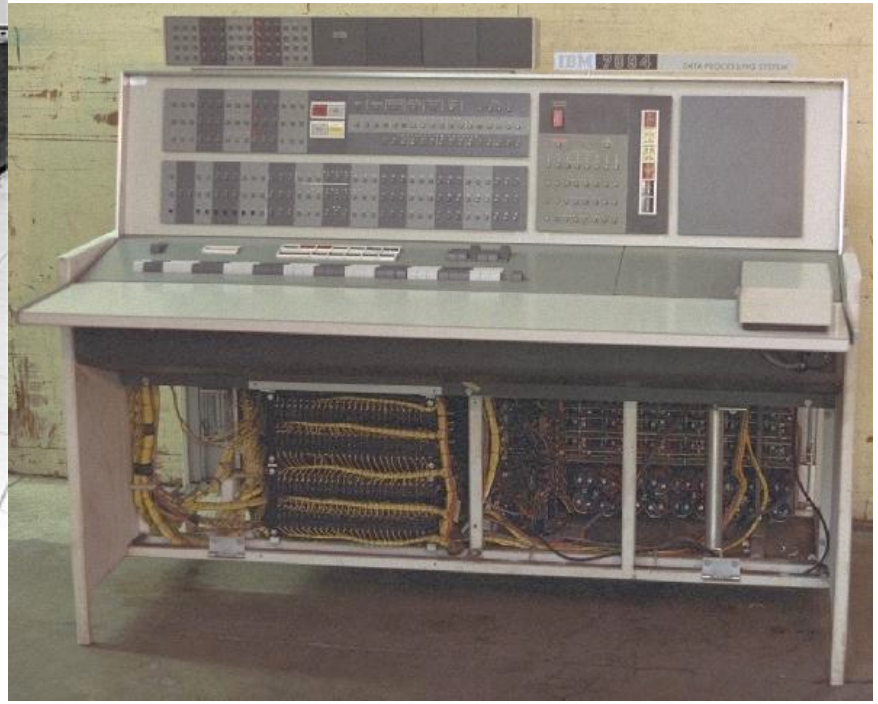
- Vacuum tubes have many shortcomings, as we've seen, but on top of it they are were not reliable
  - ENIAC often had more downtime than uptime
- In 1948, Bardeen, Brattain, and Shockley invented the transistor at Bell Labs
  - A solid-state version of the vacuum tube that uses silicon, a semi-conductor
  - 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



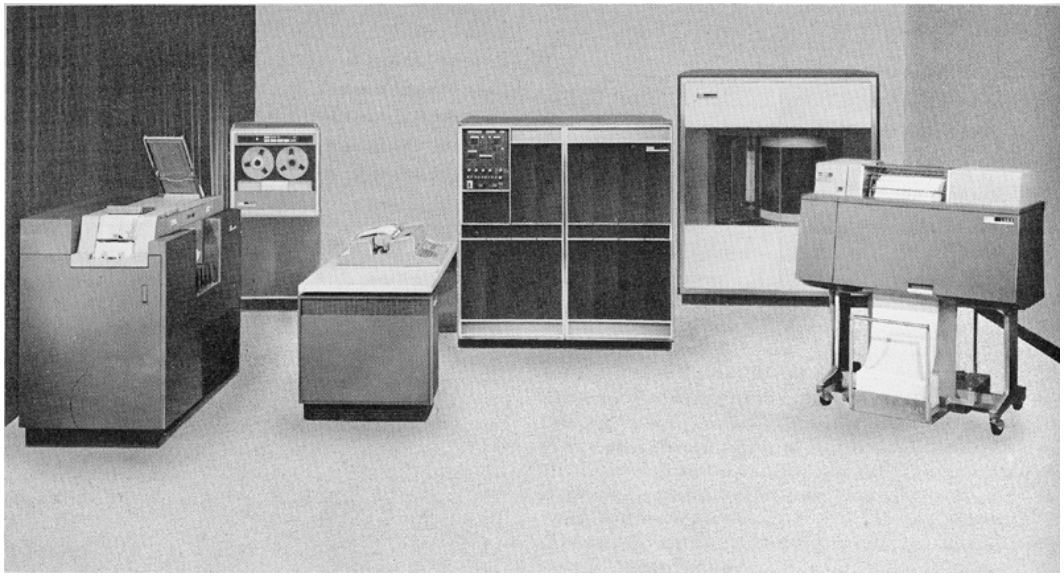
Generation 2: Transistors

- 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 computers enabled space travel and many other advances

Generation 2: IBM7094



Generation 2: IBM1401



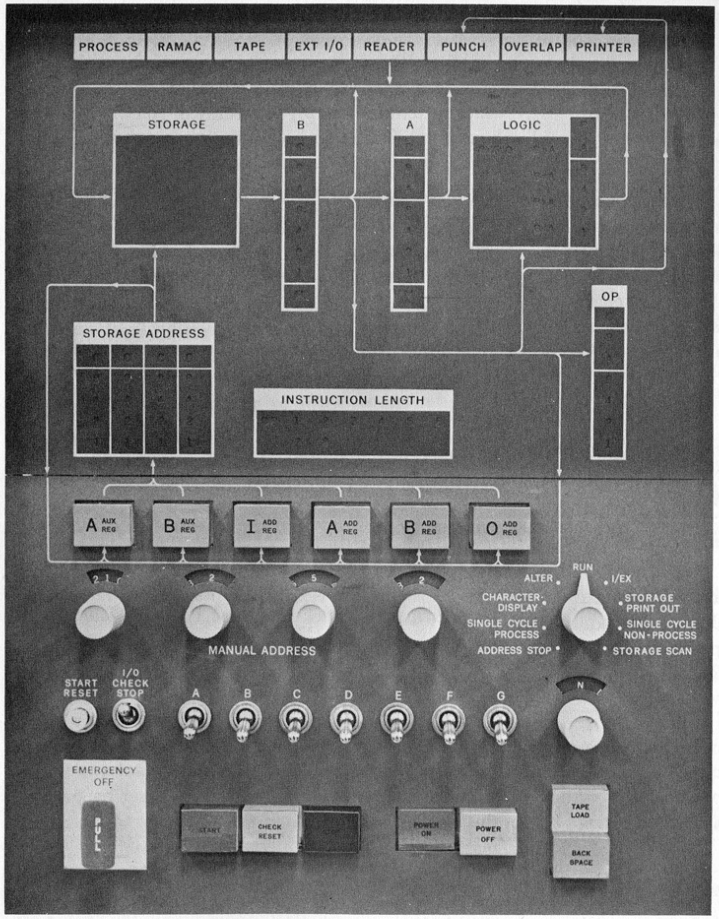


Figure 195. IBM 1401 Console

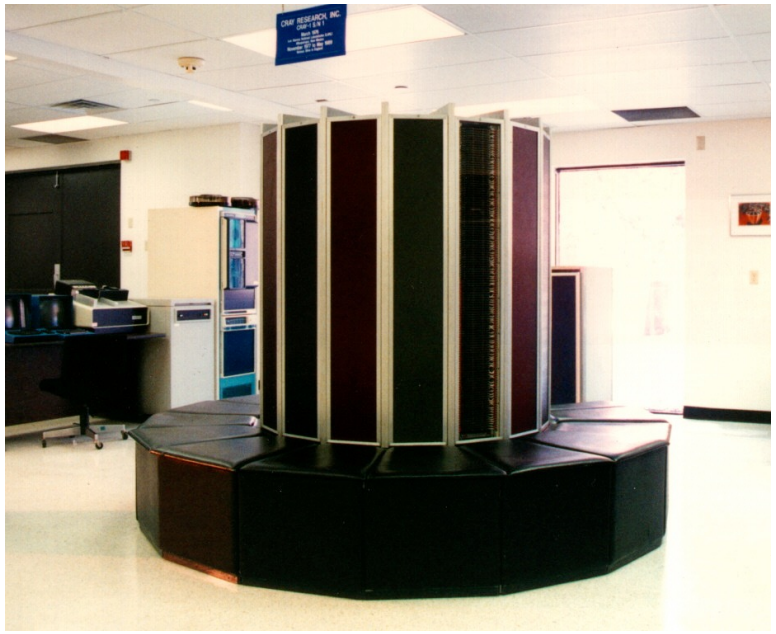
Generation 2: CDC6600

Generation 3: Integrated Circuits

- In the late 50s, Kilby and Noyce independently came up with the 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

My First Computer (I was 11)

Generation 5?

- The term “Generation 5” has been used to refer to all more or less “sci fi” future developments
  - Voice recognition (no longer “sci fi” at all! “ok Google!”)
  - Artificial intelligence (has made huge leaps)
  - Quantum computing (has begun, e.g., commercially available quantum computers!)
  - Bio computing (has begun , e.g., “transcriptor” at MIT)
  - Learning (has made huge leaps)
  - Natural languages (no longer “sci fi”! see Google translate)

Important Takeaways

- **Generation 0:** Mechanical Calculators
  - Pascal and Leibniz
  - Charles Babbage's Difference/Analytical Engine
  - Ada Lovelace: first programmer
- **Generation 1:** Vacuum Tube Computers
  - ENIAC after WW2
  - Von Neumann architecture: CPU, RAM, I/O
- **Generation 2:** Transistor Computers
  - Cheaper, more reliable, less heat, cheaper than vacuum tubes
  - Enables radically new scientific and technological advances
- **Generation 3:** Integrated Circuits
  - IBM, Cray
- **Generation 4:** Microprocessors
  - Intel
  - First personal computers

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 still use in this course