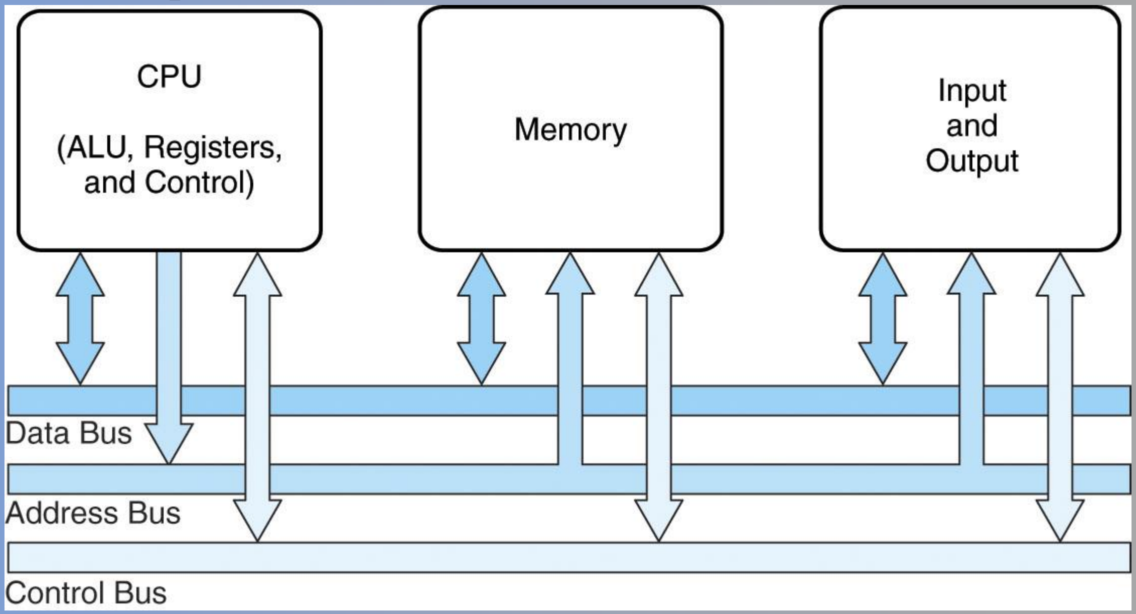
Computer Evolution

- We begin with a brief, introductory look at the components in a computer system
- We will then consider the evolution of computer hardware
- We end this chapter by considering the structure of the typical computer, known as a Von Neumann computer
- Its noteworthy that anything that can be done in software can also be done in hardware and vice versa
  - This is known as the principle of *equivalence of Hardware and Software*
    - general-purpose computers allow the instructions to be stored in memory and executed through a decoding process
    - we could take any program and “hard-wire” it to be executed directly without the decoding – this is faster, but not flexible

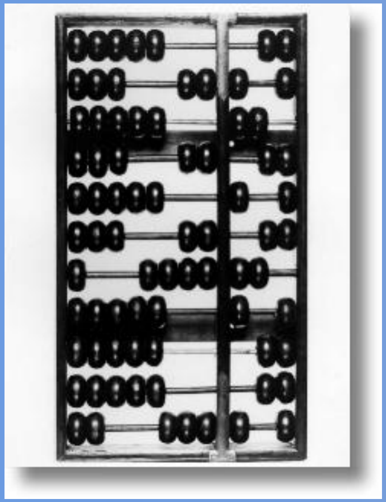
The Main Components

- CPU
  - does all processing and controls the other elements of the computer
    - it contains circuits to perform the execution of all arithmetic and logic operations (ALU), temporary storage (Registers) and the circuits to control the entire computer
- Memory
  - stores data and program instructions
    - includes cache, RAM memory, ROM memory
- Input and Output (I/O)
  - to communicate between the computer and the world
- The Bus
  - to move information from one component to another
  - divided into three sub-buses, one each for data, addresses and control signals



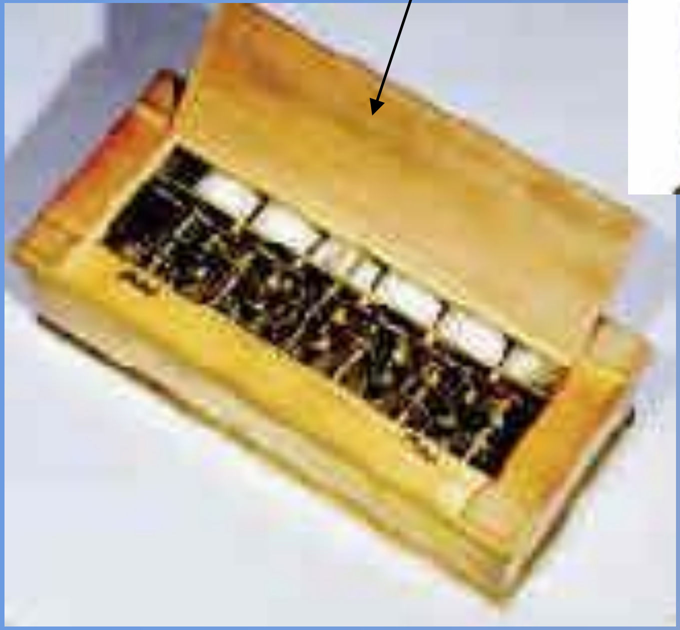
A History Lesson

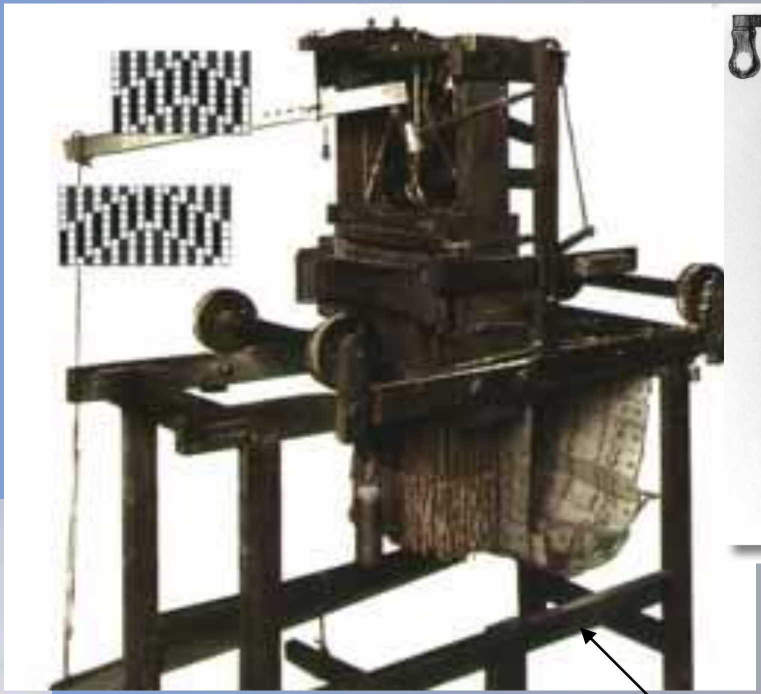
Early mechanical computational devices

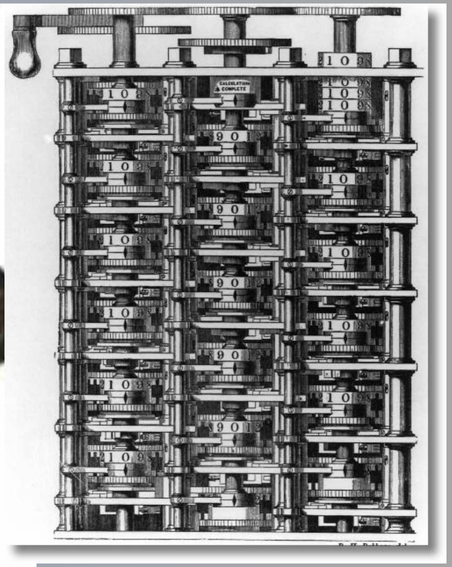


Abacus

Pascal's Calculator (1600s)







Early programmable devices:

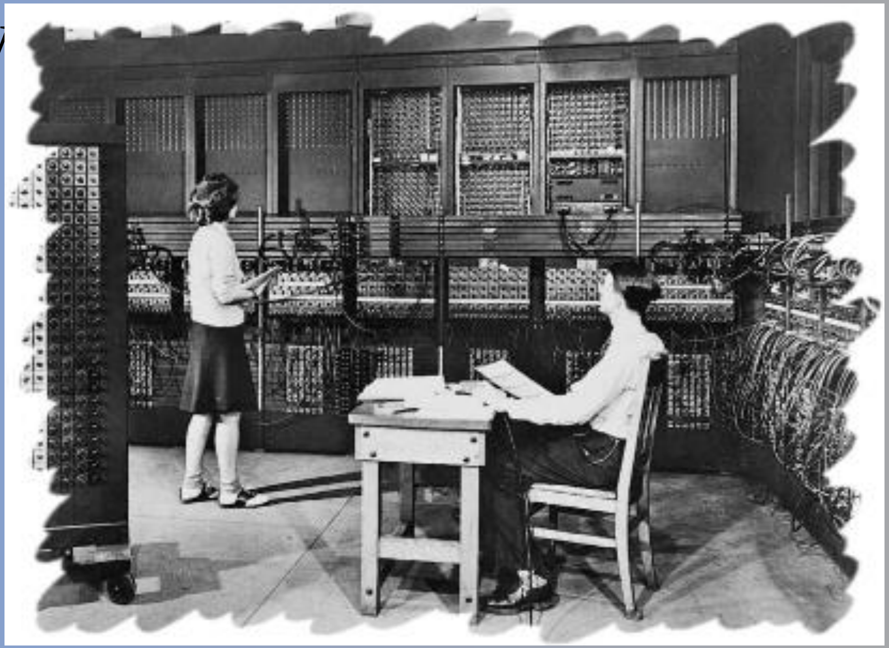
Jacquard's Loom (1800)

Babbage's Analytical Engine (1832)

Tabulating machine for 1890 census

1st Generation Computers

- One of a kind laboratory machines
  - Used vacuum tubes for logic and storage (very little storage available)
  - Programmed in machine language
  - Often programmed by physical connection (hardwiring)
  - Slow, unreliable, expensive
    - Noteworthy computers
      - Z1
      - ABC
      - ENIAC



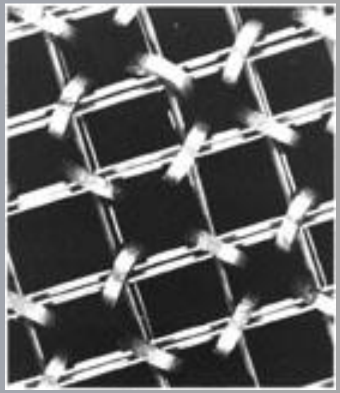
The ENIAC – often thought of as the first programmable electronic computer – 1946

17468 vacuum tubes, 1800 square feet, 30 tons

A vacuum-tube circuit storing 1 byte

2^{nd} Generation Computers

- Transistors replaced vacuum tubes
- Magnetic core memory introduced
  - These changes in technology brought about cheaper and more reliable computers (vacuum tubes were very unreliable)
  - Because these units were smaller, they were closer together providing a speedup over vacuum tubes
  - Various programming languages introduced (assembly, high-level)
  - Rudimentary OS developed
    - The first supercomputer was introduced, CDC 6600 ($10 million)
    - Other noteworthy computers were the IBM 7094 and DEC PDP-1 mainframes



An array of magnetic core memory – very expensive – $1 million for 1 Mbyte!

3rd Generation Computers

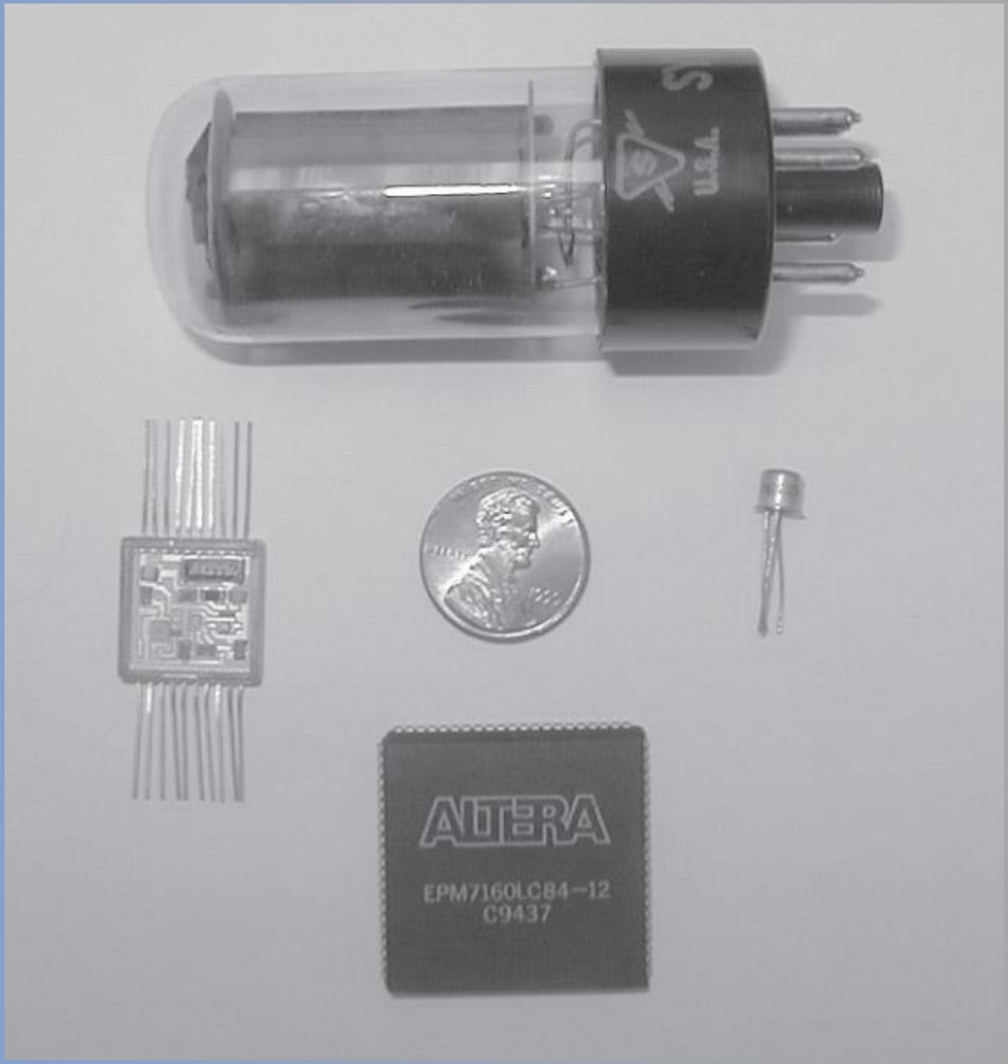
- Integrated circuit (IC) – or the ability to place circuits onto silicon chips
  - Replaced both transistors and magnetic core memory
  - Result was easily mass-produced components reducing the cost of computer manufacturing significantly
  - Also increased speed and memory capacity
  - Computer families introduced
  - Minicomputers introduced
  - More sophisticated programming languages and OS developed
    - Popular computers included PDP-8, PDP-11, IBM 360 and Cray produced their first supercomputer, Cray-1

Silicon chips now contained both logic (CPU) and memory

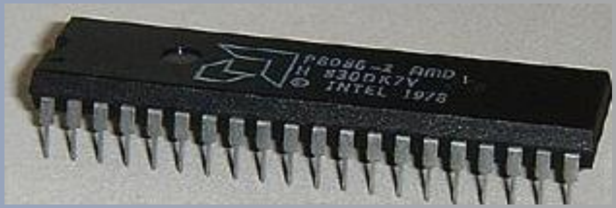
Large-scale computer usage led to time-sharing OS

Size Comparisons

- Here we see the size comparisons of
  - Vacuum tubes (1st generation technology)
  - Transistor (middle right, 2nd generation technology)
  - Integrated circuit (middle left, 3rd and 4th generation technology)
  - Chip (3rd and 4th generation technology)
  - And a penny for scale



4^{th} Generation Computers



- Miniaturization took over
  - From SSI (10-100 components per chip) to
  - MSI (100-1000), LSI (1,000-10,000), VLSI (10,000+)
- Intel developed a CPU on a single chip – the microprocessor
  - This led to the development of microcomputers – PCs and later workstations and laptops
- Most of the 4^{th} generation has revolved around not new technologies, but the ability to better use the available technology
  - with more components per chip, what are we going to use them for? More processing elements? More registers? More cache? Parallel processing? Pipelining? Etc.

The PC Market

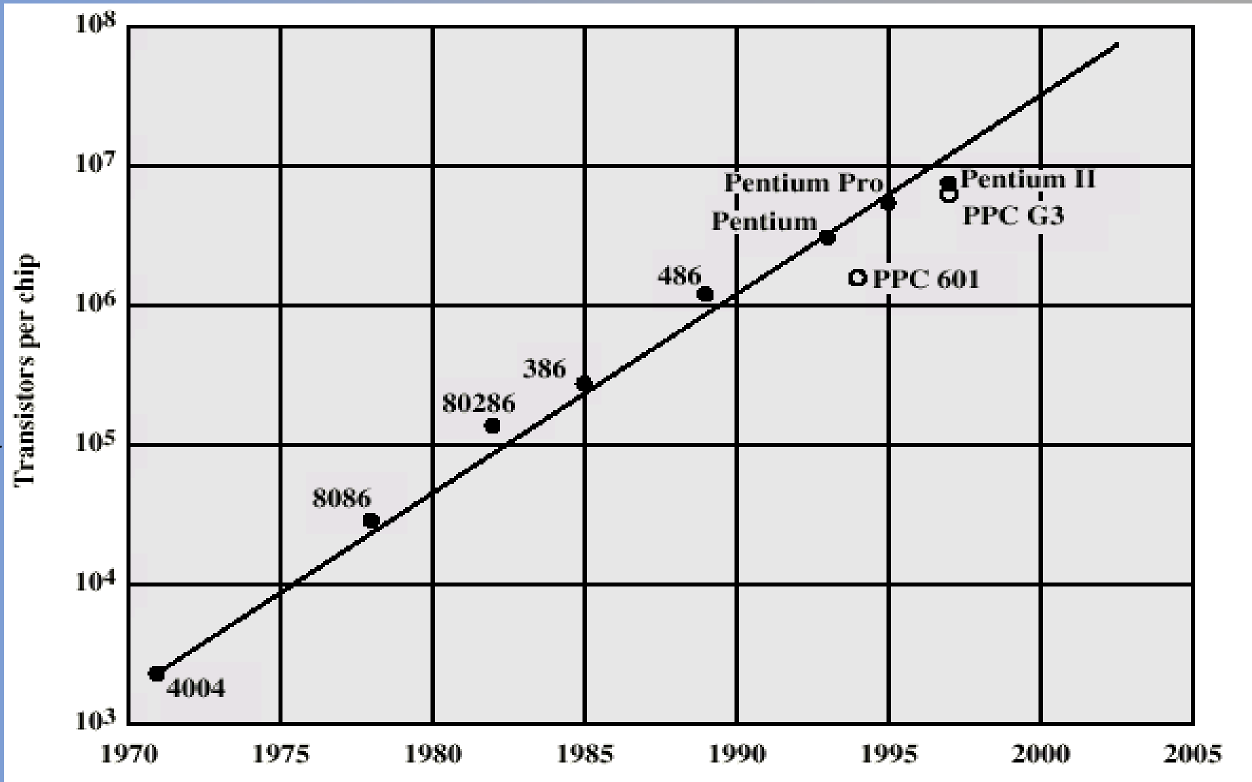
- The impact on miniaturization was not predicted
  - Who would have thought that a personal computer would be of any interest?
  - Early PCs were hobbyist toys and included Radio Shack, Commodore, Apple, Texas Instruments, and Altair
  - In 1981, IBM introduced their first PC
    - they decided to publish their architecture which led to clones or compatible computers
    - Microsoft wrote business software for the IBM platform thus making the machine more appealing
  - These two situations allowed IBM to capture a large part of the PC marketplace
  - Over the years since 1981, PC development has been one of the biggest concerns of the computer industry
    - More memory, faster processors, better I/O devices and interfaces, more sophisticated OS and software

Other Computer Developments

- During the 4th generation, we have seen improvements to other platforms as well
  - Mainframe and minicomputers much faster with substantially larger main memories
  - Workstations introduced to provide multitasking for scientific applications
  - Supercomputers reaching 10s or 100s of trillions of instructions per second speed
  - Massive parallel processing machines
  - Servers for networking
  - Architectural innovations have included
    - Floating point and multimedia hardware, parallel processing, pipelining, superscalar pipelines, speculative hardware, cache, RISC

Moore's Law

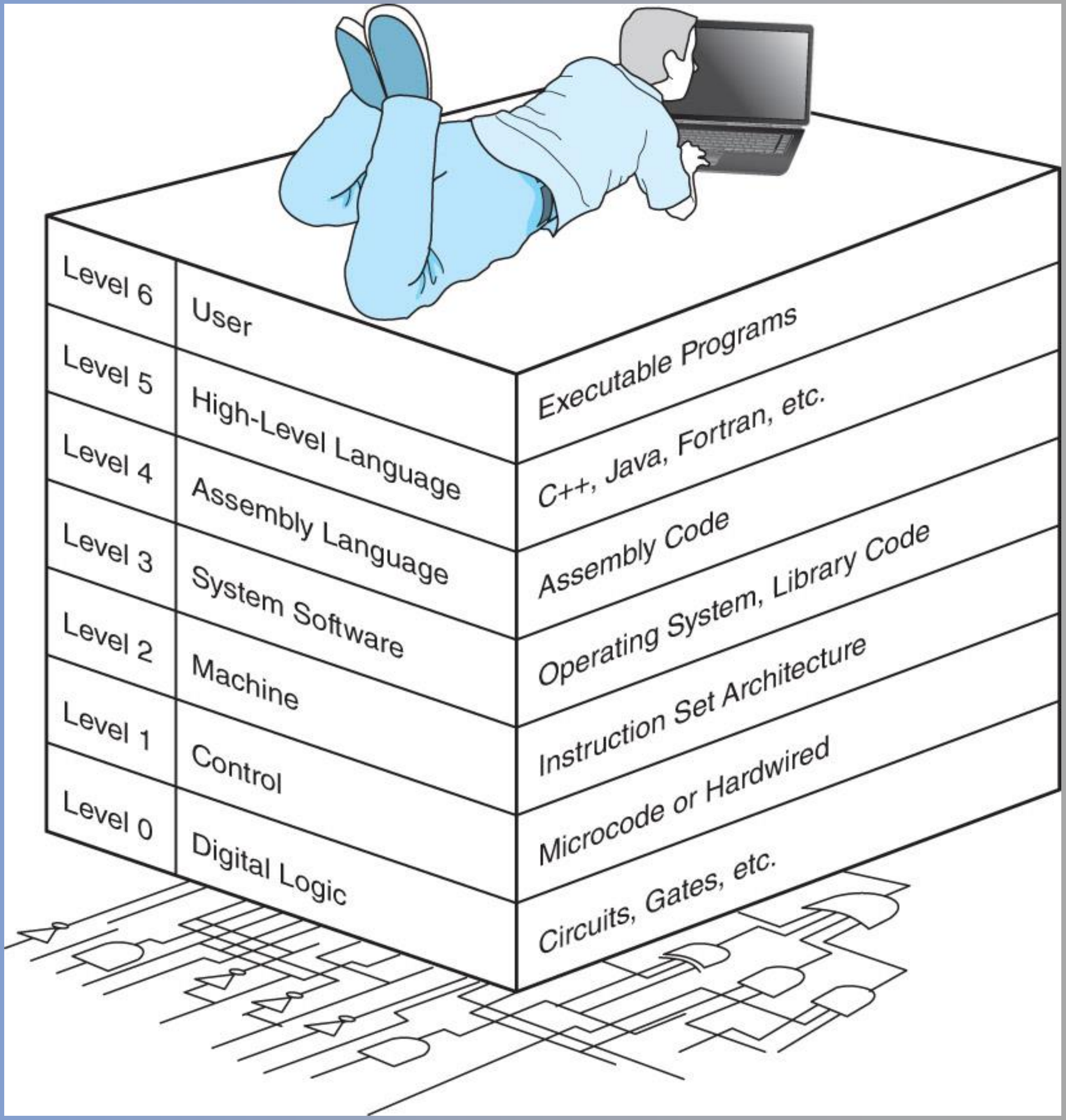
- Gordon Moore (Intel founder) noted that transistor density was increasing by a factor of 2 every 2 years
  - This observation or prediction has held out pretty well since he made it in 1965 (transistor count doubles roughly every 2 years)



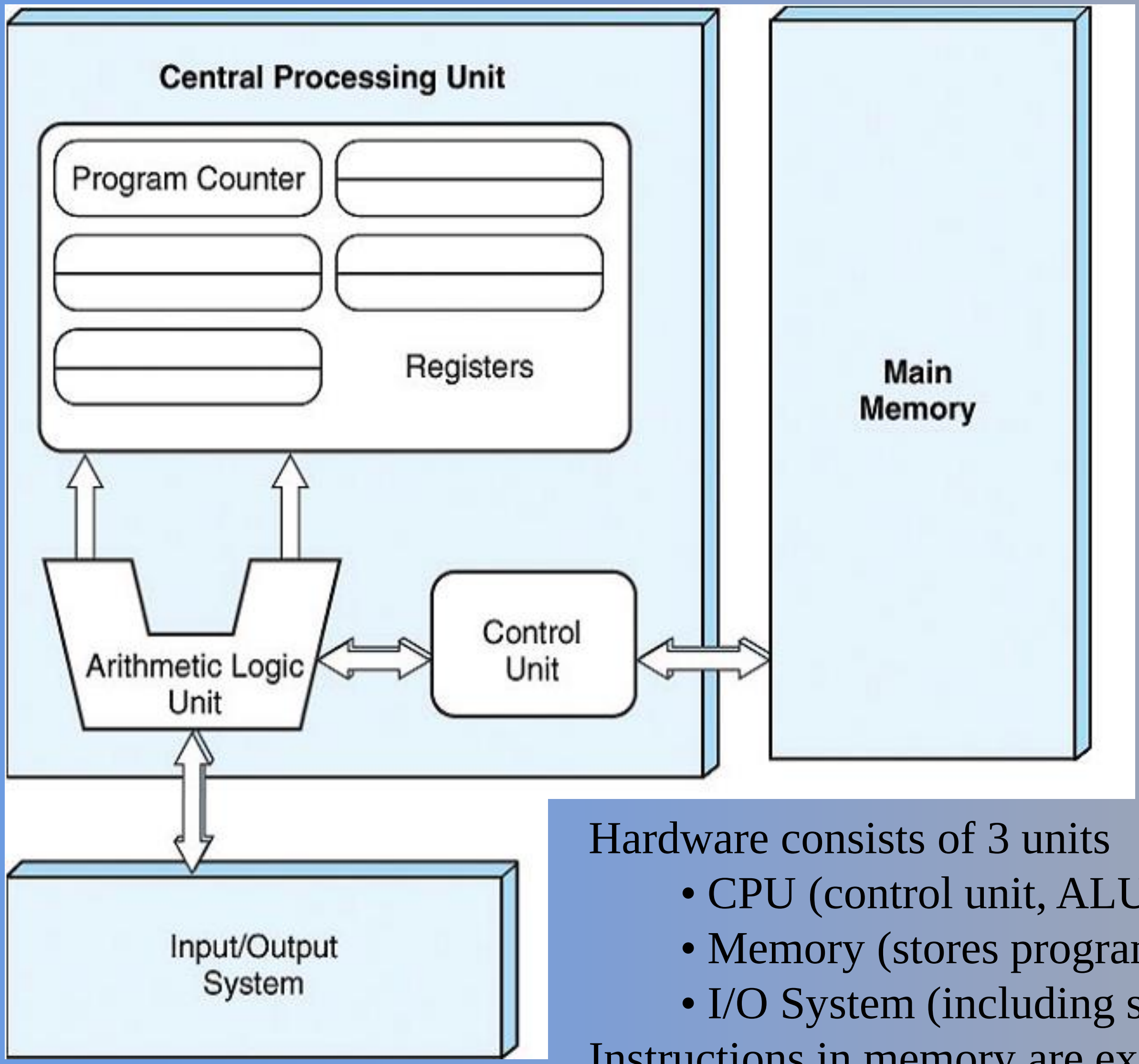
The growth has meant an increase in transistor count (and therefore memory capacity and CPU capability) of about 2^{20} since 1965, or computers 1 million times more capable!

How much longer can Moore's Law continue?

View of Computing Through Abstraction



The Von Neumann Architecture



Named after John von Neumann, Princeton, he designed a computer architecture whereby data and instructions would be retrieved from memory, operated on by an ALU, and moved back to memory (or I/O)

This architecture is the basis for most modern computers (only parallel processors and a few other unique architectures use a different model)

Hardware consists of 3 units
- CPU (control unit, ALU, registers)
- Memory (stores programs and data)
- I/O System (including secondary storage)

Instructions in memory are executed sequentially unless a program instruction explicitly changes the order

More on Von Neumann Architectures

- There is a single pathway used to move both data and instructions between memory, I/O and CPU
  - the pathway is implemented as a bus
  - the single pathway creates a bottleneck
    - known as the *von Neumann bottleneck*
  - A variation of this architecture is the *Harvard architecture* which separates data and instructions into two pathways
  - Another variation, used in most computers, is the system bus version in which there are different buses between CPU and memory and memory and I/O
- The von Neumann architecture operates on the *fetch-execute cycle*
  - Fetch an instruction from memory as indicated by the Program Counter register
  - Decode the instruction in the control unit
  - Data operands needed for the instruction are fetched from memory
  - Execute the instruction in the ALU storing the result in a register
  - Move the result back to memory if needed