Chapter 2: Computer Hardware and Software Evolution, and Computer Architecture

- Generations of Computers
- Milestones in Computer HW & SW Development
- Characteristics and Types of Computers *
- Software Generations and Evolution
- Components of the Computer System
- Microcomputer Architecture

Learning Objectives

- Define a computer
- Appreciate the evolution of computer (HW & SW) through five generations
- Identify the characteristics of computers
- Classification of computers*
- Understand functionality of various parts of a computer through Block diagrams

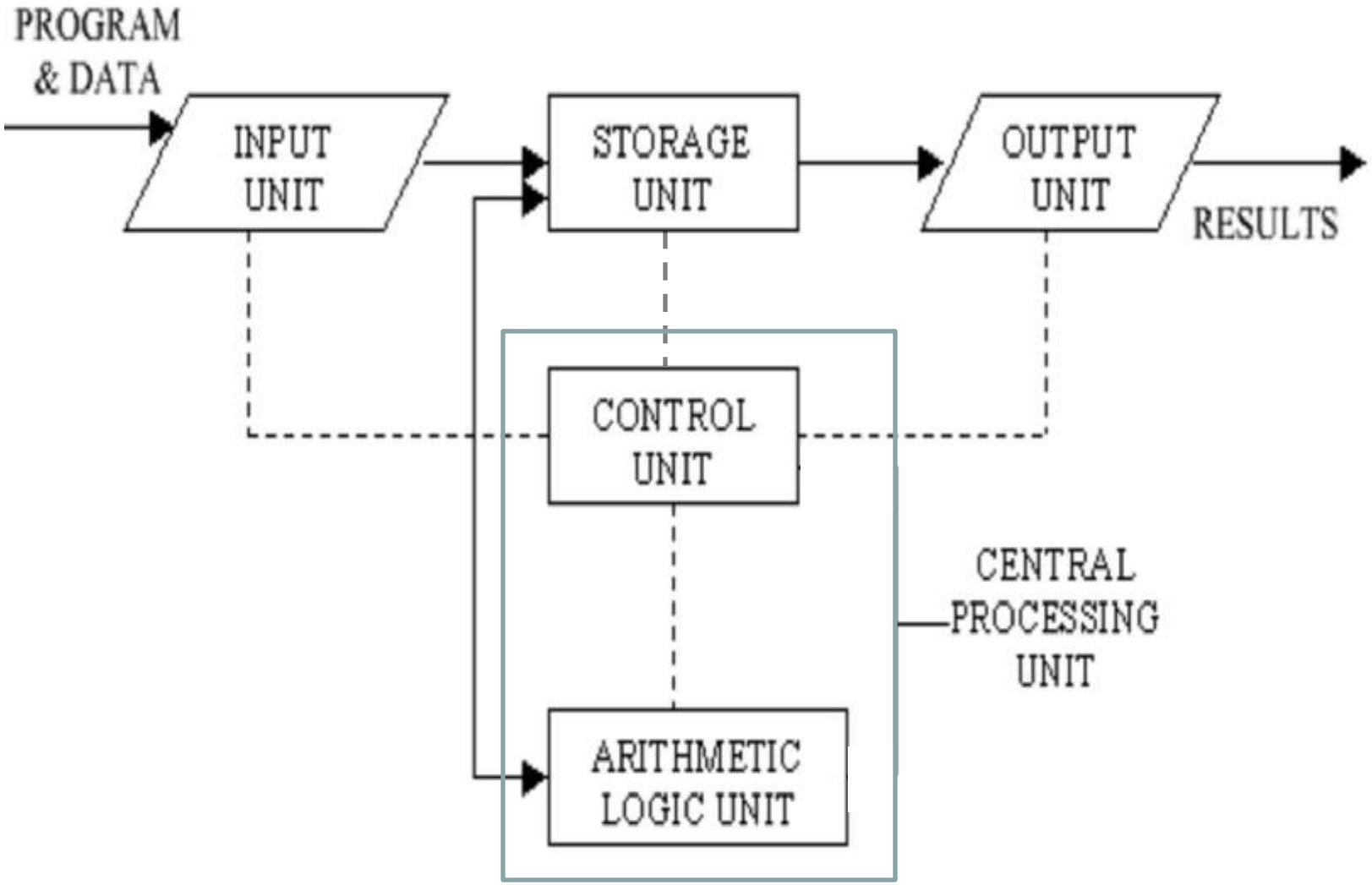
Definition of a Computer

- a general purpose,
- programmable,
- information processor
- with input and output

- Fixed Program Computer (embedded)
- Stored Program Computer

Definition of Computer --- Continued

- Computer is a programmable machine.
- Computer is a machine that manipulates data according to a set of instructions.
- Computer is any device which assists humans in performing various kinds of computations or calculations.



Dotted lines indicate flow of instructions
Solid lines indicate flow of data

Basic computer Organization

Anatomy of a Computer

- Every computer has four basic parts, or units:
  - an input unit such as the keyboard, that feeds information into the computer
  - a central processing unit (CPU) that performs the various tasks of the computer
  - an output unit , such as a monitor , that displays the results;
  - a memory that stores information and instructions.

Computer vs Human

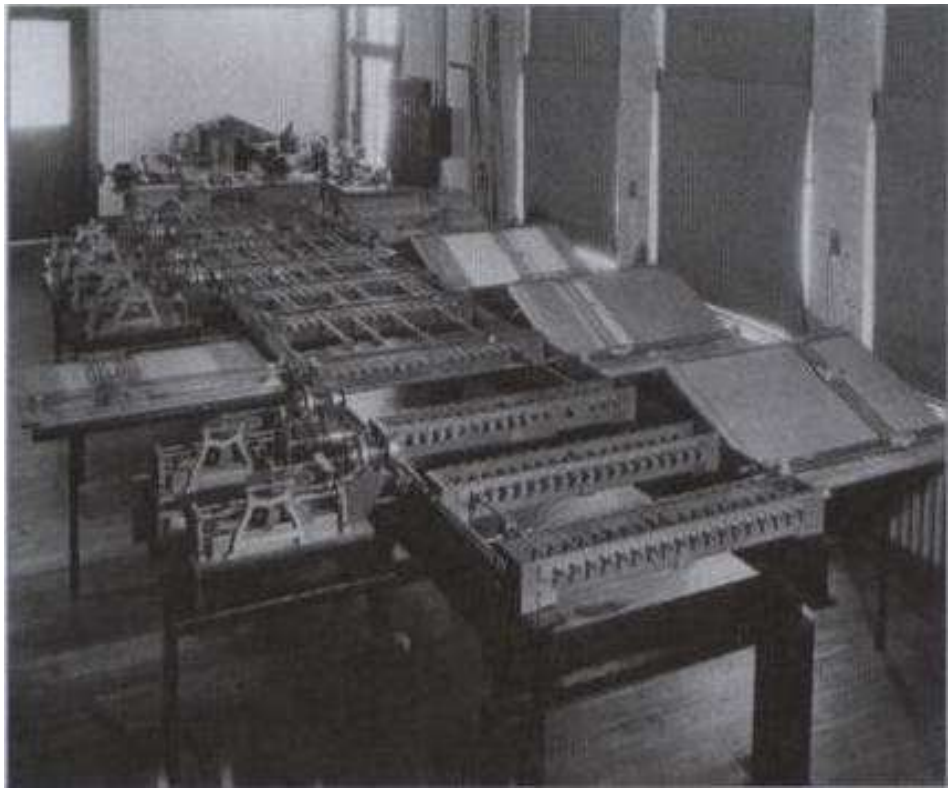
- Input - Five senses
- Central Processing Unit (CPU) - brain
- Output - Body Parts
- Memory - Human memory

- Hardware
  - Physical components
- Software
  - Programs for operations and problem solving

History of Computers

- Older computers were analog
  - represent data as variable points along a continuous spectrum of values.
  - More flexible but not necessarily more precise and reliable

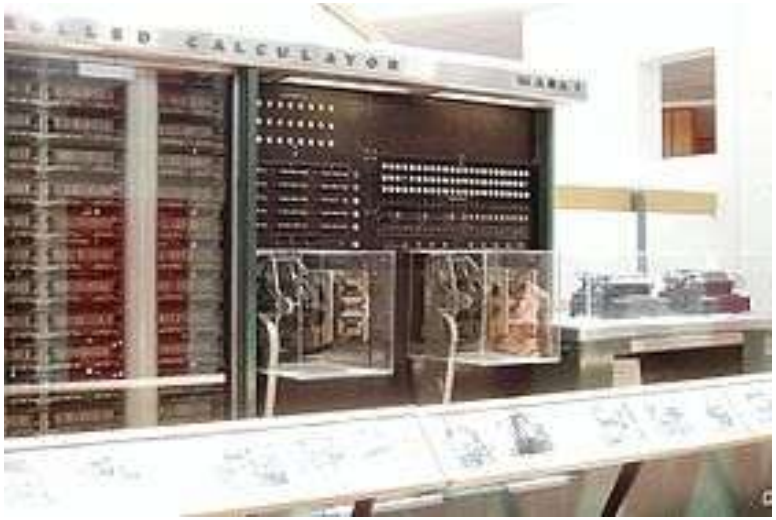
An early analog computer in the late 1920s



Harvard Mark I (1944)

- Built from Switches, Relays, rotating shafts and clutches
- 765,000 components
- Hundreds of meters of wires
- Volume
  - Length (51ft) x Height (8 ft) x Depth (2 ft)
- Weight 4500 kg
- Used decimal number systems
- Called Automatic Sequence Controlled Calculator (ASCC)

Harvard Mark I

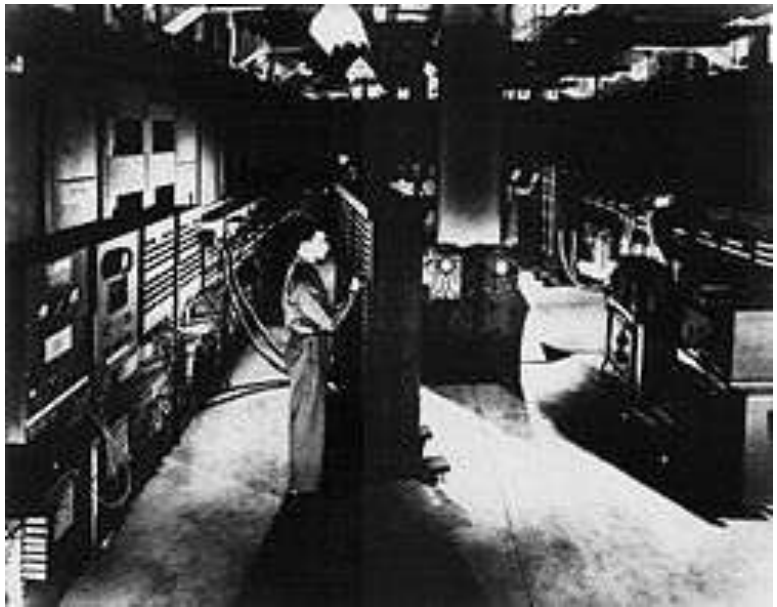


ENIAC

- 1946 First general purpose electronic computer
- Electronic Numerical Integrator And Computer (ENIAC)
- Technology used
  - Vacuum tubes 17,468
  - Crystal Diodes 7,200
  - Relays 1,500
  - Transistors 70,000
  - Capacitors 10,000
  - Hand soldered joints 1 million

ENIAC

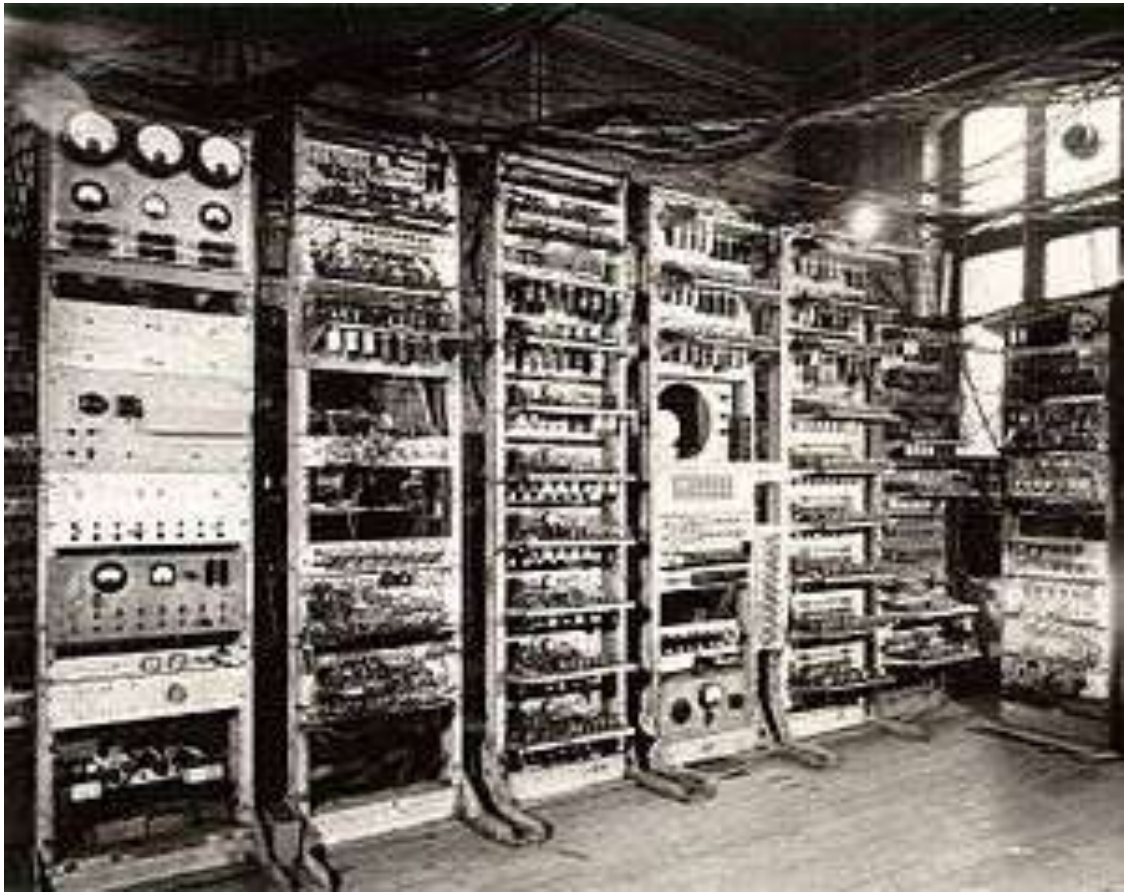
- Weight 30 tons
- Volume 100 ft (L) X 8 ft (H) X 3 ft (D)
- Covers 1800 sq. feet
- Power consumption 150 kW
- Uses punch cards



Manchester Mark I

- 1948
- First stored program computer,
- Based on Von Neumann architecture
- Manchester Mark 1 , built in UK. Using valves
- it can perform about 500 operations per second and has the first RAM .
- It fills a room the size of a small office.

Manchester Mark I



Computer Generations

Generation 0: Mechanical Calculators (relays)

Generation 1: Vacuum Tube Computers

Generation 2: Transistor Computers

Generation 3: Integrated Circuits

Generation 4: Microprocessors

Generation 5: Artificial Intelligence

Generation of Computers

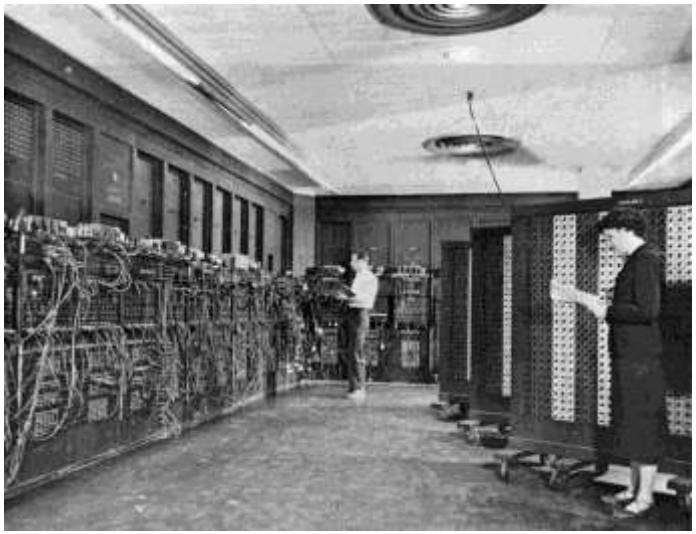
Generation	Dates	Characteristic
1st	1944-59	Use Valves (Vacuum tubes)
2nd	1959-64	Use transistors
3rd	1965-70	Integrated & Large Scale Integrated Circuits
4th	1970 - 90	Very Large Scale Integrated Circuits
5th	1990 - Under development	“Artificial Intelligence” based computers

Computer Generations

	First Generation	**Second Gen.**	**Third Gen.**	**Fourth Gen.**
Technology	Vacuum Tubes	Transistors	Integrated Circuits (multiple transistors)	Microchips (millions of transistors)
Size	Filled Whole Buildings	Filled half a room	Smaller	Tiny - Palm Pilot is as powerful as old building sized computer

Generation 1 : ENIAC

The ENIAC (Electronic Numerical Integrator and Computer) was unveiled in 1946: the first all-electronic, general-purpose digital computer



Used machine languages and magnetic tapes

First Generation Hardware

Vacuum Tubes

Large, not very reliable, generated a lot of heat

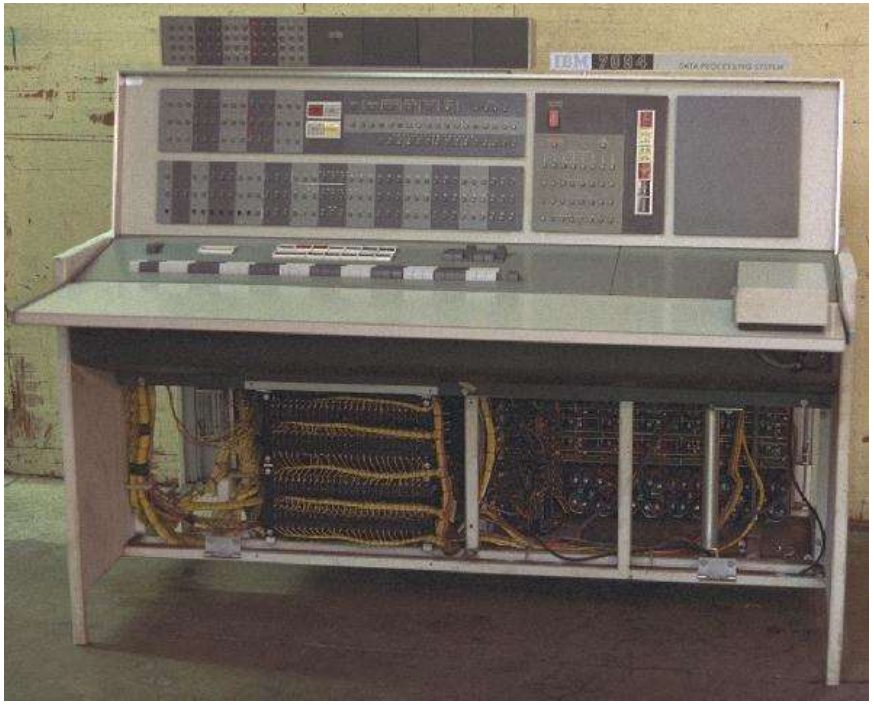
Magnetic Drum

Memory device that rotated under a read/write head

Card Readers → Magnetic Tape Drives

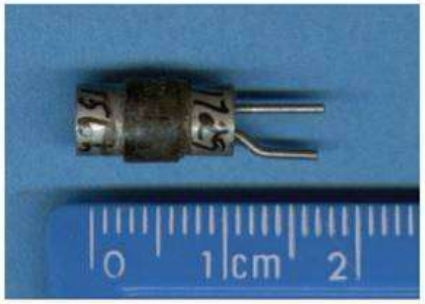
Sequential auxiliary storage devices

Generation 2: IBM7094



These machines used assembly language.

Second Generation Hardware



Transistor

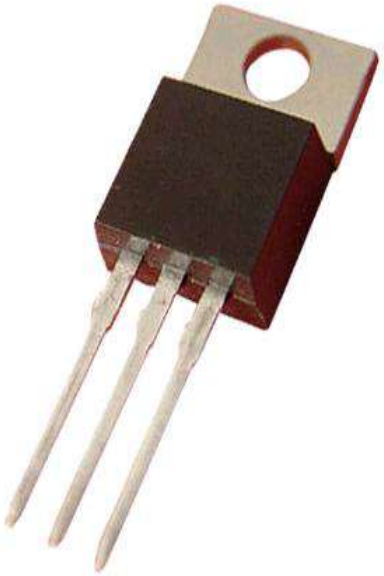
Replaced vacuum tube, fast, small, durable, cheap

Magnetic Cores

Replaced magnetic drums, information available instantly

Magnetic Disks

Replaced magnetic tape, data can be accessed directly



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

Used high level programming languages

Third Generation Hardware

Integrated Circuits

Replaced circuit boards, smaller, cheaper, faster, more reliable

Transistors

Now used for memory construction

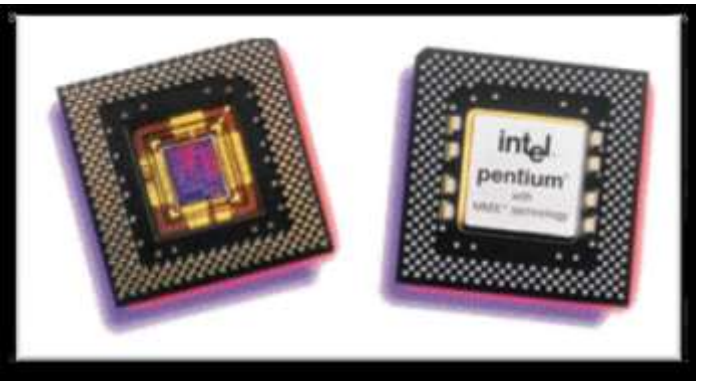
Terminal

An input/output device with a keyboard and screen

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



Microprocessors

Fourth Generation Hardware

Very Large-scale Integration

Great advances in chip technology

PCs, the Commercial Market, Workstations

Personal Computers and Workstations emerge

New companies emerge: Apple, Sun, Dell …

Laptops, Tablet Computers, and Smart Phones

Everyone has his/her own portable computer

The Fifth Generation

- Based on Artificial Intelligence (AI).
- Still in development.
- The use of parallel processing and superconductors is helping to make artificial intelligence a reality.
- The goal is to develop devices that respond to natural language input and are capable of learning and self-organization.
- There are some applications, such as voice recognition, that are being used today.

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
- Parallelism & Networking

Types of computers

- With respect to physical size, speed, storage capacity, purpose, and price

➢ In terms of size
  - ✓ ☐ small
  - ✓ ☐ medium
  - ✓ ☐ large

  – Microcomputers
  – Minicomputers
  – Mainframe Computers
  – Super computers

* The details are left as a Reading Assignment

Computer HW & SW

- Capabilities of Computers
  - Huge Data Storage
  - Input and Output
  - Processing
  - *Hardware stores and transmits data, software processes data.*

Is the CPU only a Hardware?

Computer HW & SW

Characteristics of Computers

- High Processing Speed
- Accuracy
- Reliability
- Versatility
- Diligence

DILLIGENCE : A Computer can work for long hours with the same accuracy and speed because it is free from problems of boredom or lack of concentration.

VERSATILITY : The working of computer with different types of data is known as versatility.

Reliability: Produces the same or identical result repeatedly for the same input

History of computing technology

ENIAC (1946):

- 18,000 vacuum tubes, 1,500 relays
- weighed 30 tons, consumed 150 kw

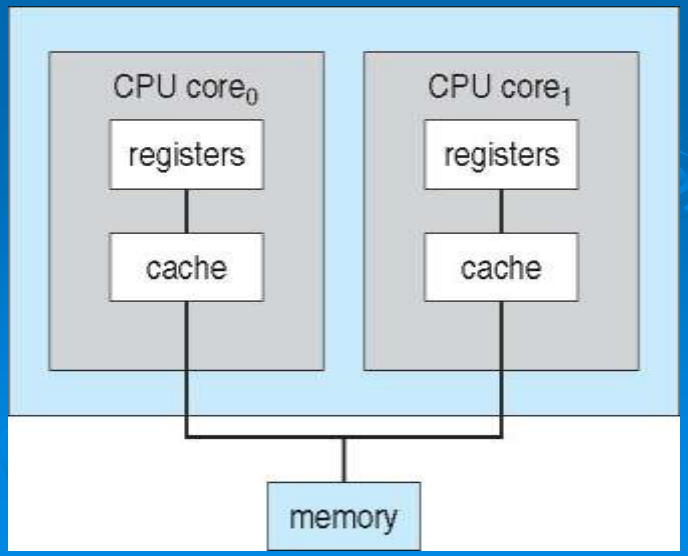
DYK?

When were "modern" computers invented?
When were computers accessible/affordable to individuals?
When was the Internet born?
When was the Web invented?
How did Bill Gates get so rich?

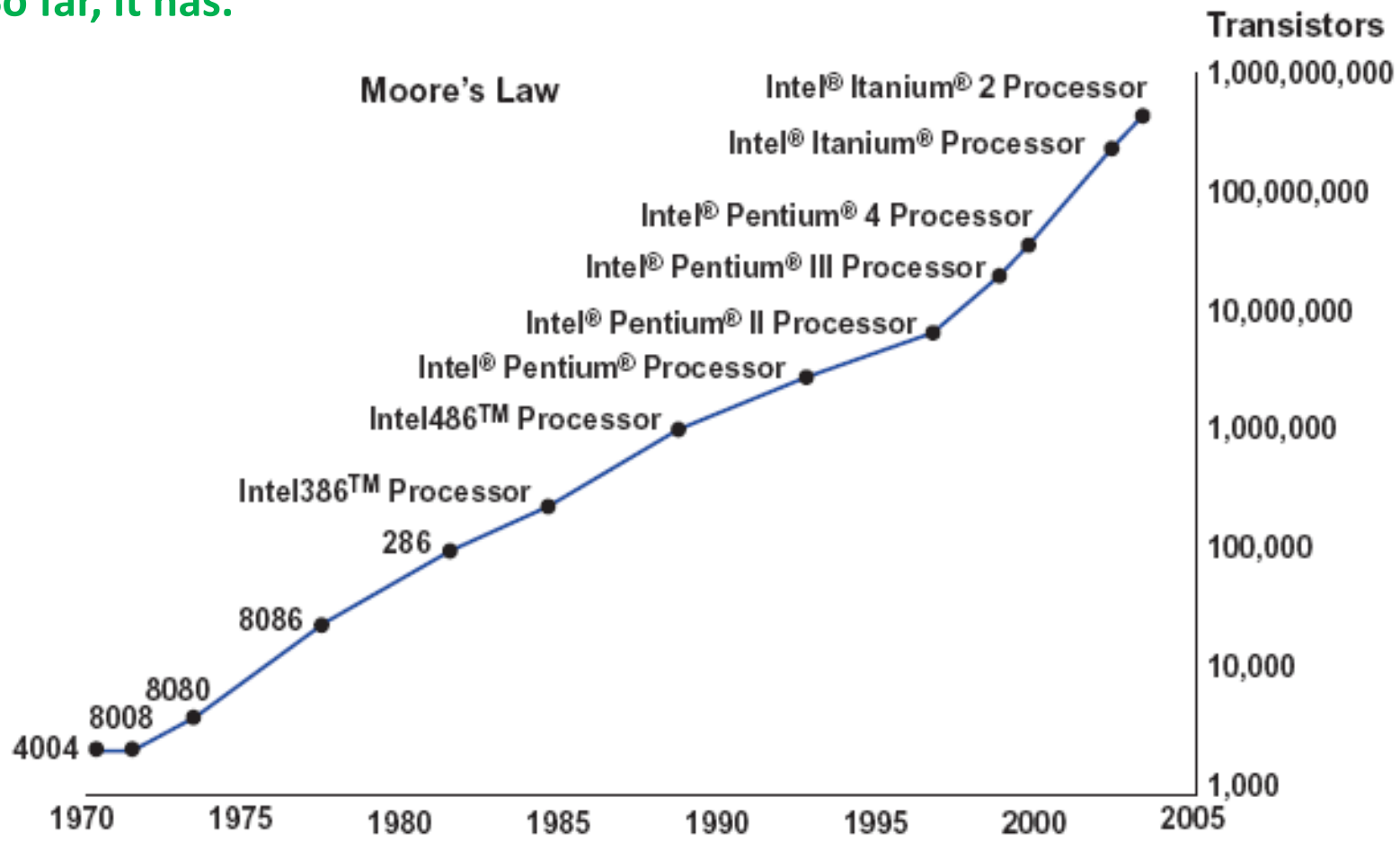
The history of computers can be divided into generations, with each generation defined by a technological breakthrough

0. gears and relays (mechanical)
   - ➔ 1. vacuum tubes (electronic and machine language)
     - ➔ 2. transistors (assembly)
       - ➔ 3. integrated circuits (high level languages)
         - ➔ 4. very large scale integration (OOP)
           - ➔ 5. parallel processing & networking (Natural languages)

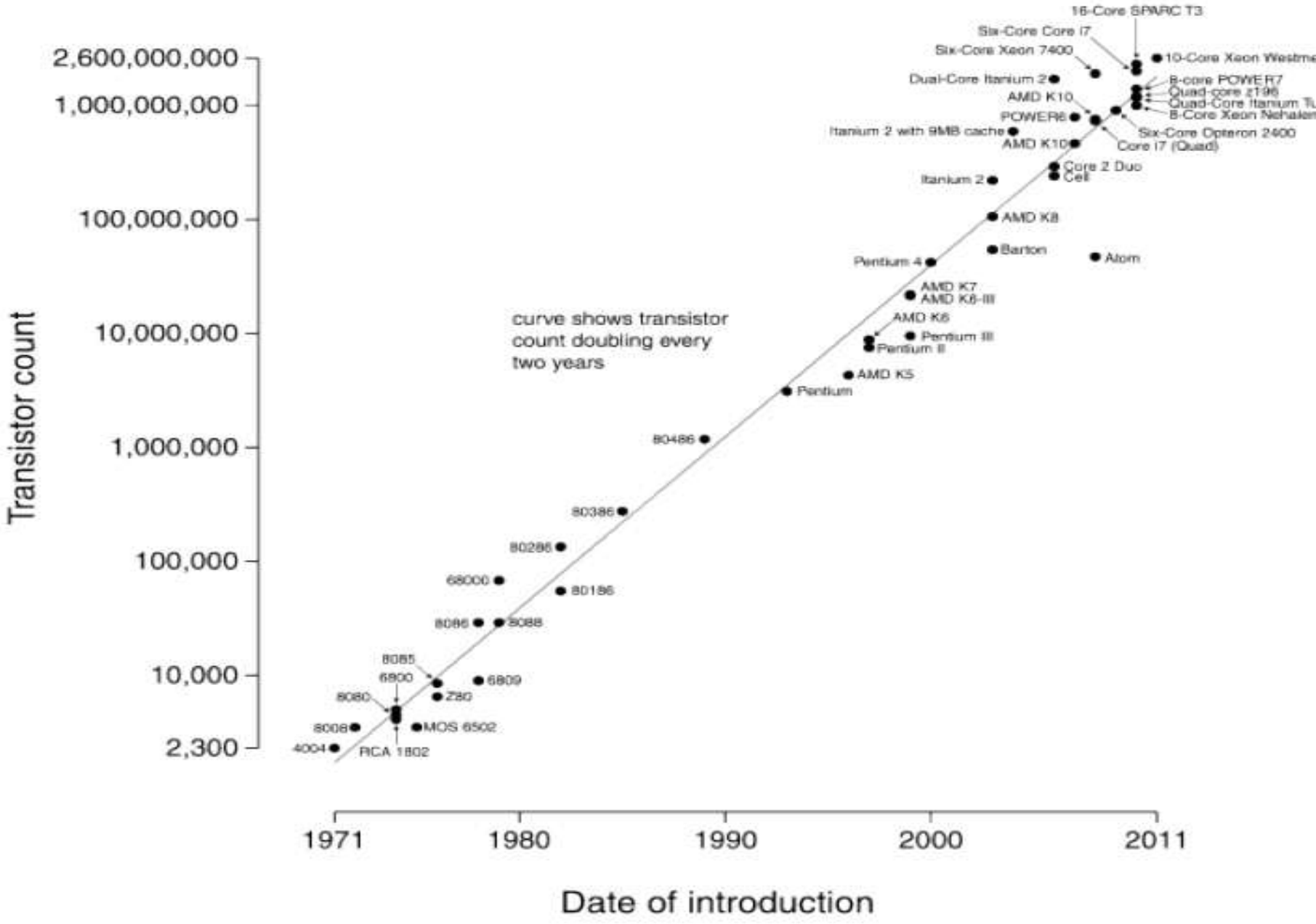
- The three directions of computer development are **miniaturization**, **speed**, and **affordability**
- **Integration (and Mass Production), Core Technology (Multiprocessors), Cost reduction by half every 2 years**



Moore's law suggests that computer power will double every 18 to 24 months. So far, it has.



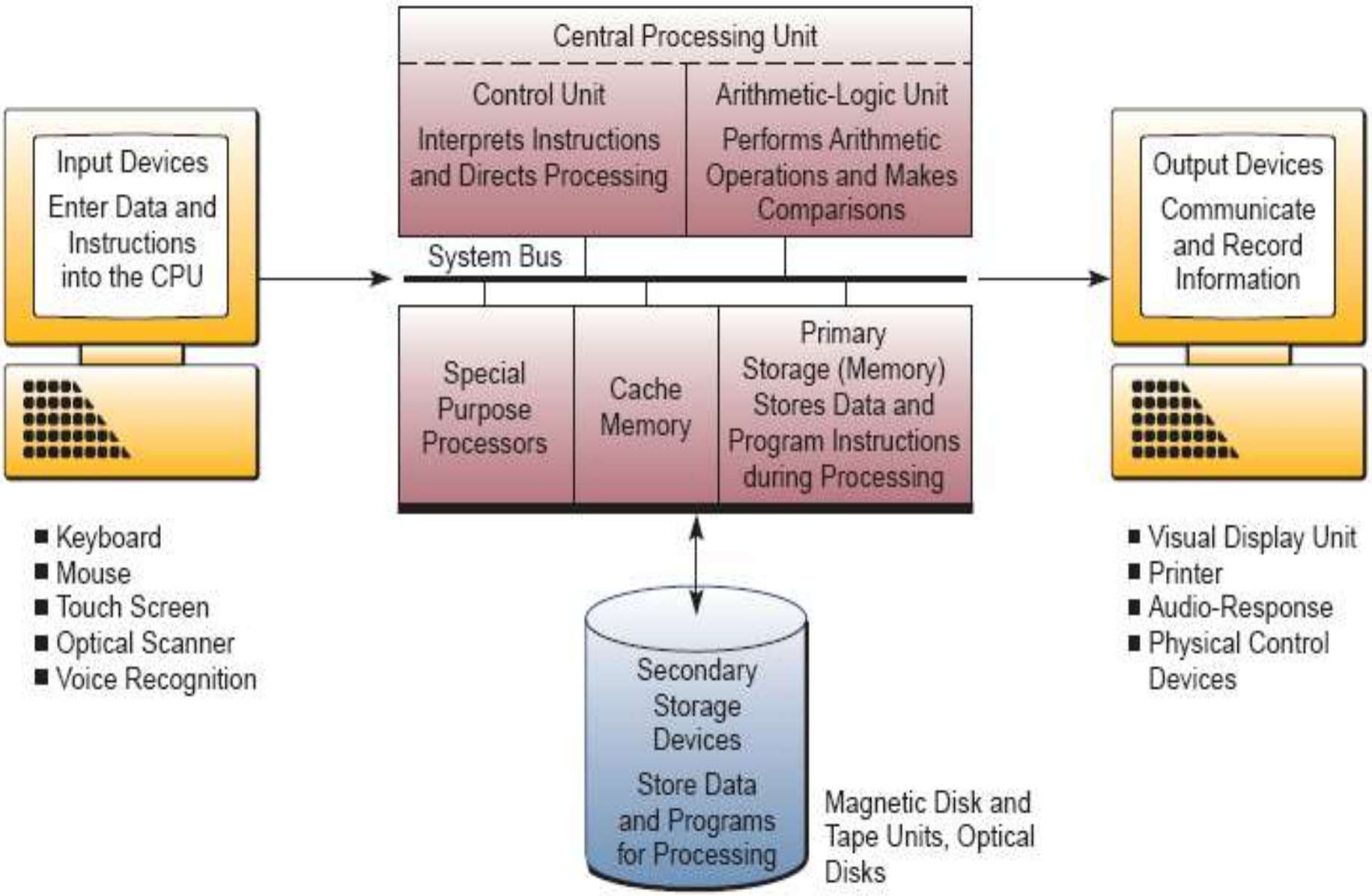
Microprocessor Transistor Counts 1971-2011 & Moor's Law



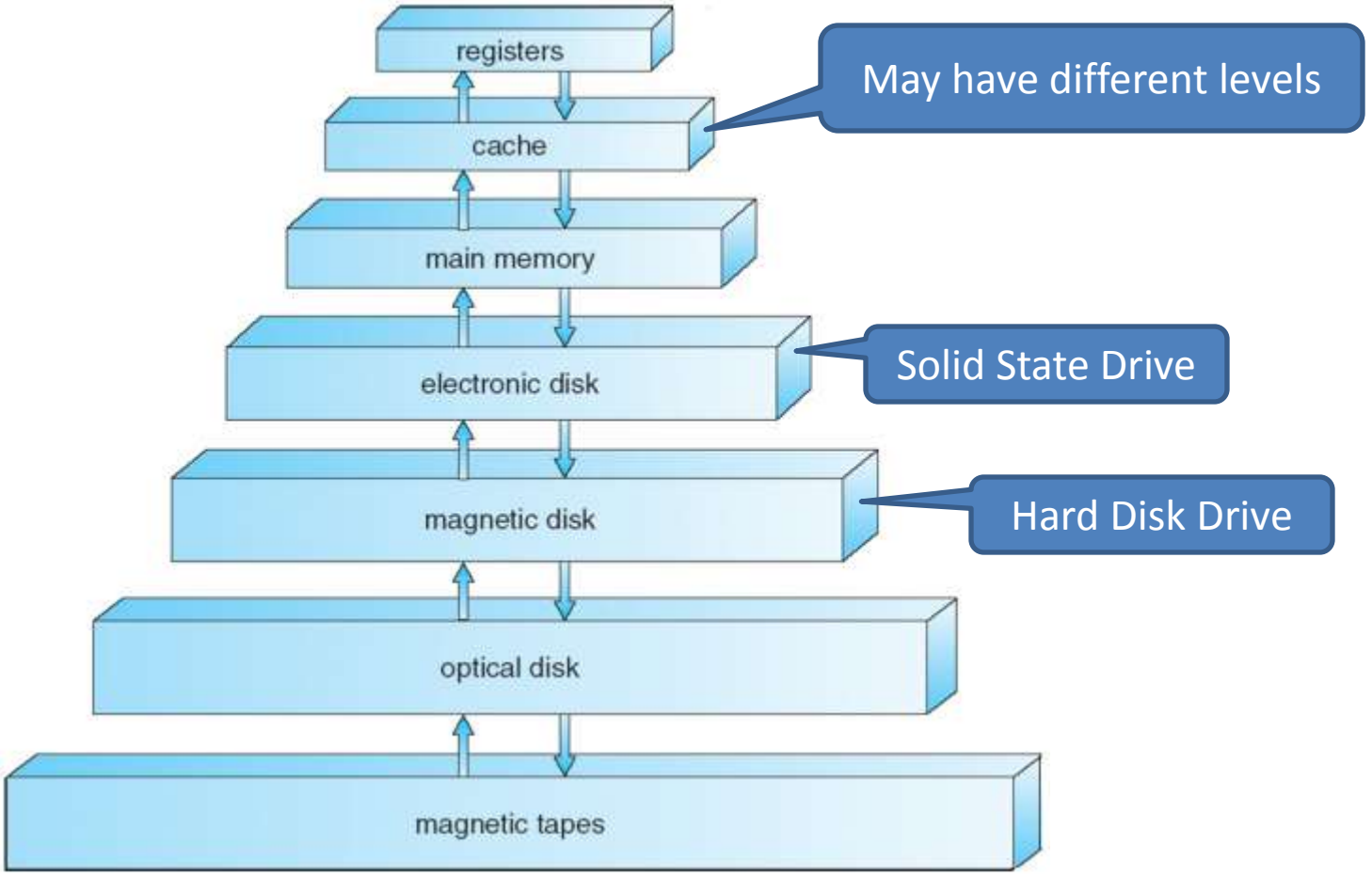
What Hardware Components Contribute to the Speed of a Computer?

Component	Speed measured by	Units	Description
CPU	Clock speed	gHz	The time it takes to complete a **cycle**
Motherboard	Bus speed	mHz	How much data can move across the bus simultaneously.
RAM	Data transfer rate	MB/s	The time it takes for data to be transferred from memory to system.
Hard Disk	Access time	ms	The time it takes before the disk can transfer data.
	Data transfer rate	MBit/s	The time it takes for data to be transferred from disk to system.

The computer system concept
A computer is a system of hardware components and functions



Storage-Device Hierarchy



Information about Various Levels of Storage

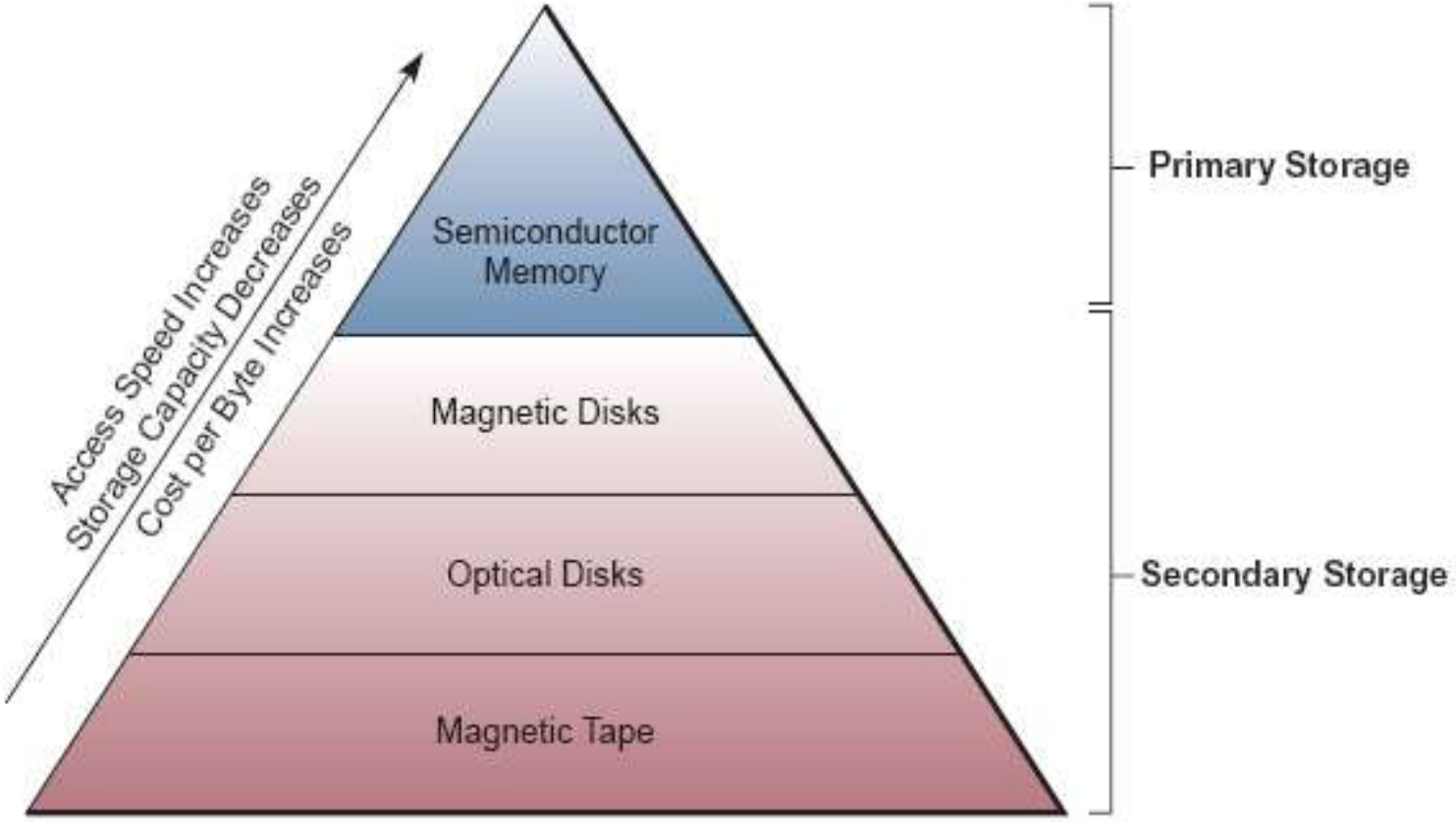
Level	1	2	3	4
Name	registers	cache	main memory	disk storage
Typical size	< 1 KB	> 16 MB	> 16 GB	> 100 GB
Implementation technology	custom memory with multiple ports, CMOS	on-chip or off-chip CMOS SRAM	CMOS DRAM	magnetic disk
Access time (ns)	0.25 – 0.5	0.5 – 25	80 – 250	5,000.000
Bandwidth (MB/sec)	20,000 – 100,000	5000 – 10,000	1000 – 5000	20 – 150
Managed by	compiler	hardware ??	operating system	operating system
Backed by	cache	main memory	disk	CD or tape

Storage capacities are frequently measured in kilobytes (KB), megabytes (MB), gigabytes (GB), or terabytes (TB). Although kilo means 1,000 in the metric system, the computer industry uses K to represent 1,024 (or 2^{10}) storage positions. For example, a capacity of 10 megabytes is really 10,485,760 storage positions, rather than 10 million positions. A petabyte is more than 1 quadrillion bytes (2^{50}).

byte	$\rightarrow$ 8 bits		
kilobyte (KB)	$\rightarrow 2^{10}$ bytes	=	1,024 bytes (= 8,192 bits)
megabyte (MB)	$\rightarrow 2^{20}$ bytes	=	1,048,576 bytes (= 8,388,608 bits)
gigabyte (GB)	$\rightarrow 2^{30}$ bytes	=	1,073,741,824 bytes (= 8,589,934,592 bits)
terabyte (TB)	$\rightarrow 2^{40}$ bytes	=	1,099,511,627,776 bytes (= 8,796,093,022,208 bits)

Storage media cost, speed, and capacity trade-offs.

Note how cost increases with faster access speeds but decreases with the increased capacity of storage media.



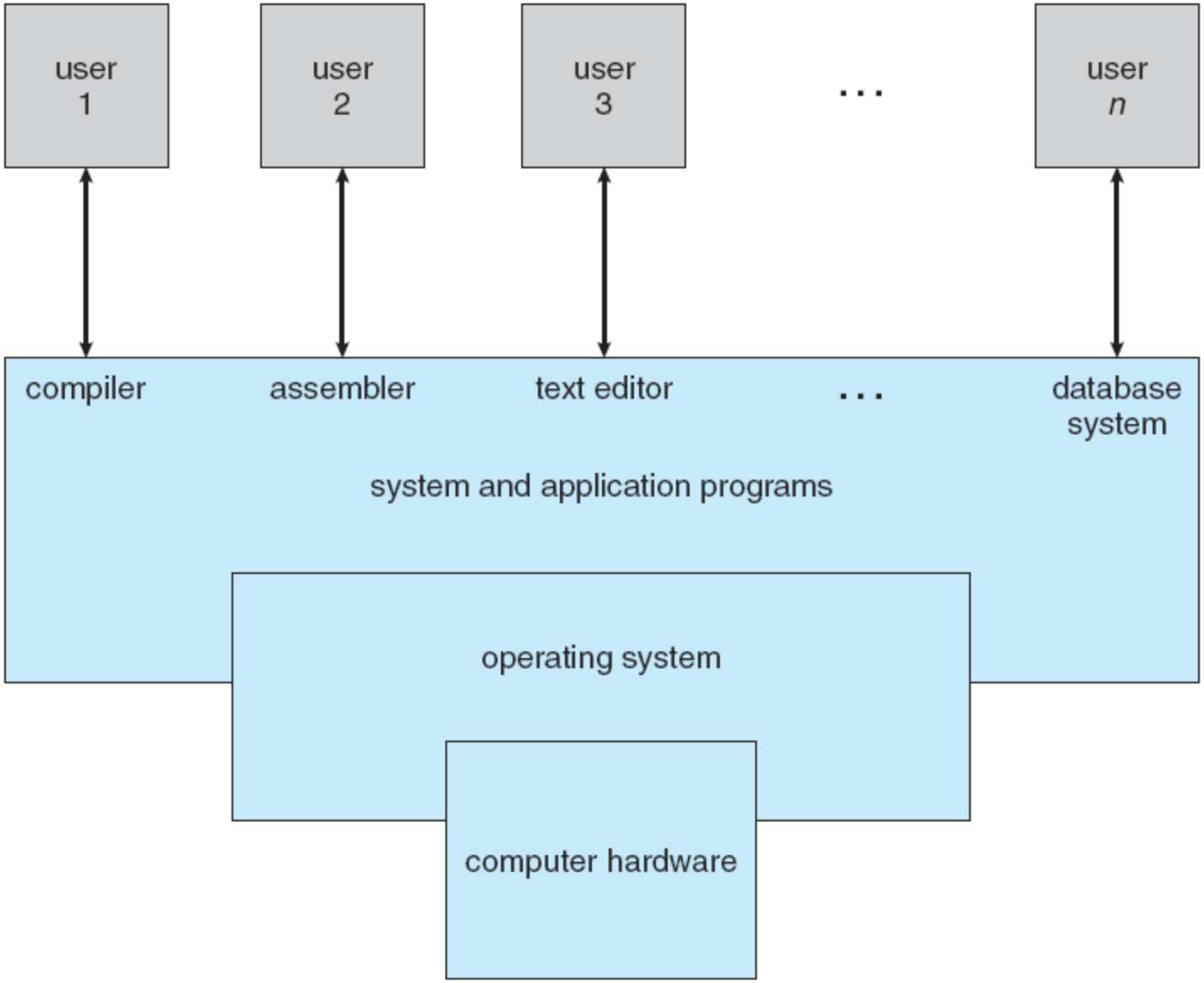
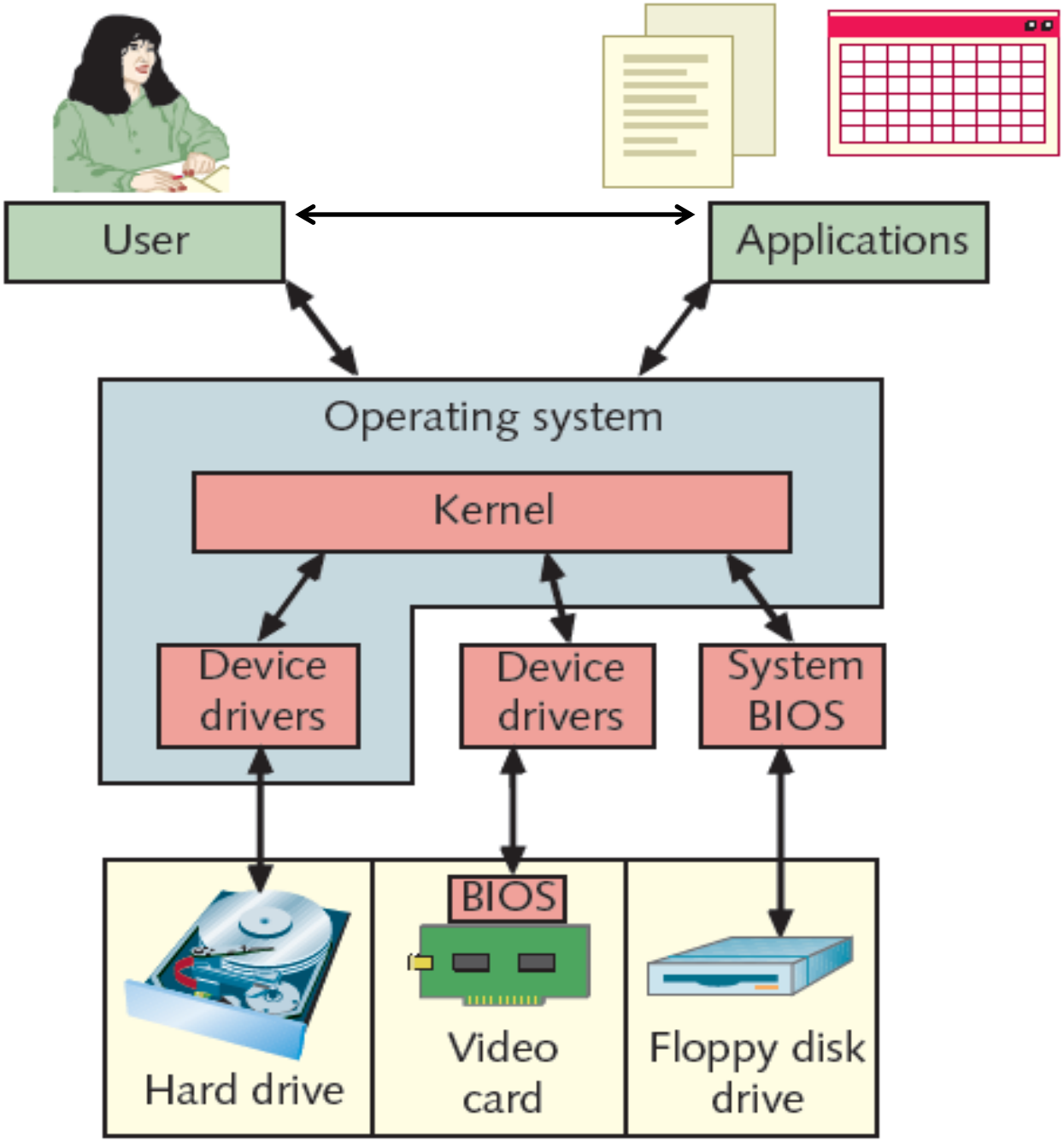


Figure 1.1 Abstract view of the components of a computer system.

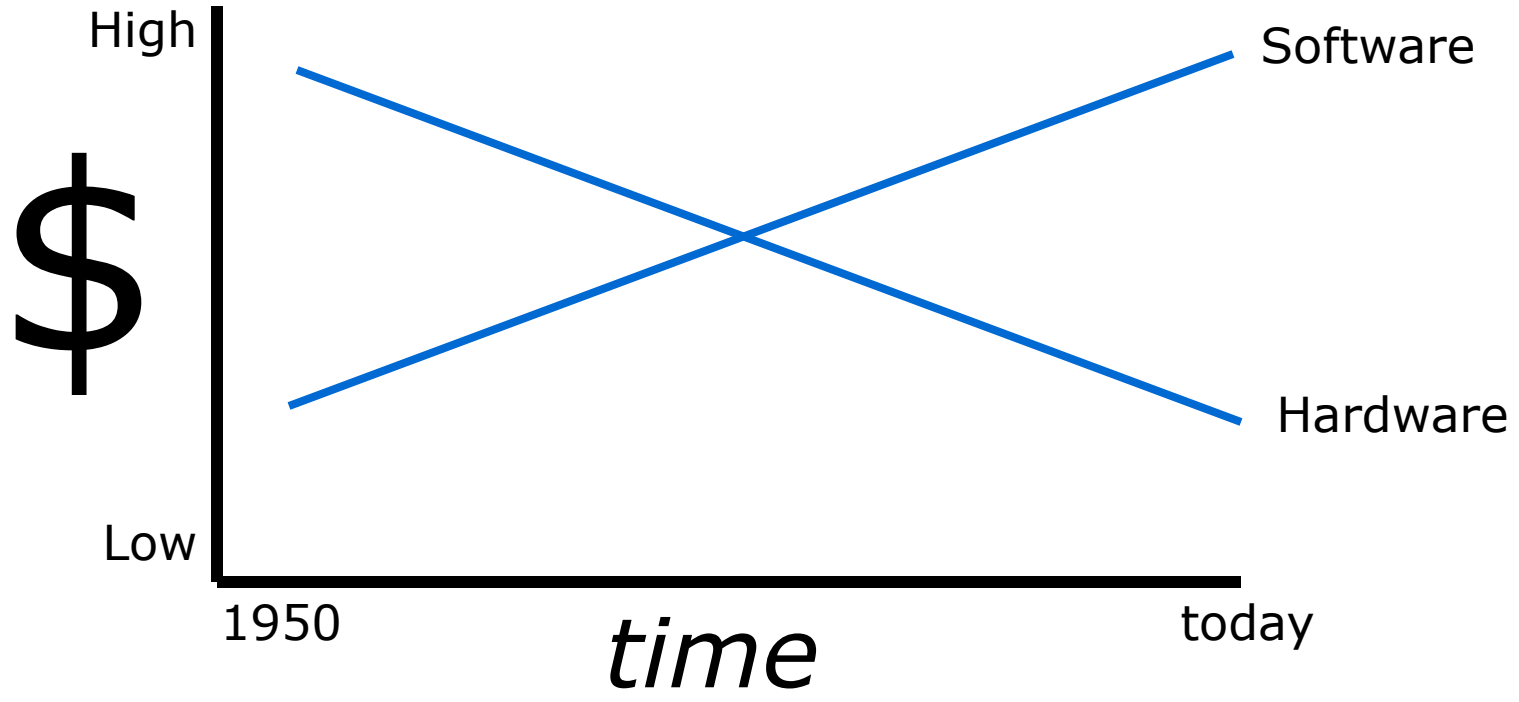


An OS relates to hardware by way of BIOS and device drivers

Software Generations

Software is the general term for various kinds of programs used to operate and manipulate computers and their peripheral devices. One common way of describing **hardware and software** is to say that **software** can be thought of as the **variable (complex)** part of a computer and **hardware** as the **invariable** (**stable**) part.

Cost against Time graph for Software and Hardware Development



Why is the cost of software development expensive, and always getting more expensive?

First Generation Software (1951-1959)

Machine Language

Computer programs written in binary (1s and 0s)

Assembly Languages and Translators

Programs written using mnemonics, which were translated into machine language

Programmer Changes

Programmers divided into two groups: application programmers and systems programmers

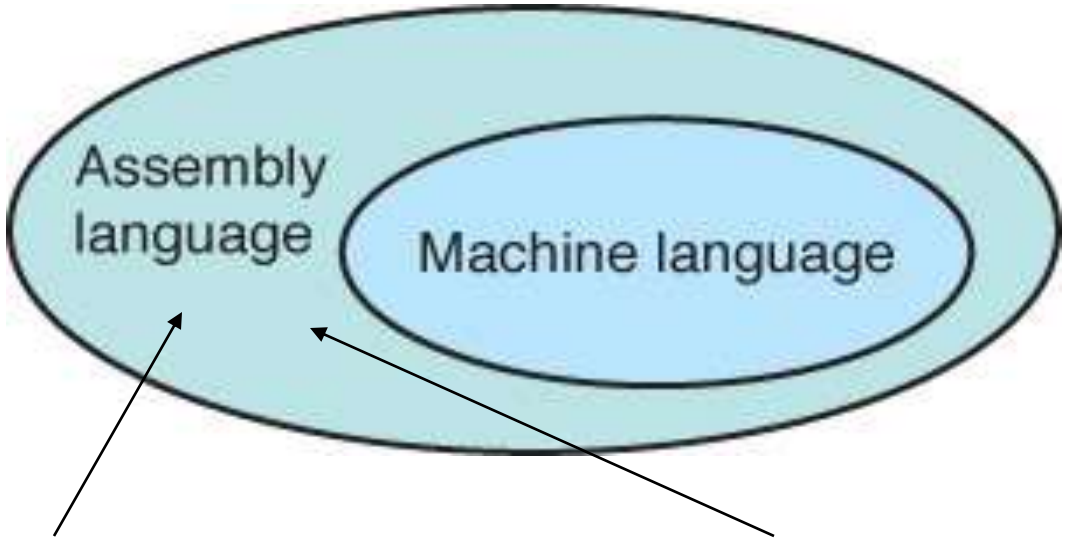
- Computers only for programmers, professionals, expert users
- Not for the general public and novice users (**not affordable and requires skill**)
- Universities, big organizations, military were using computers

First Generation Software Cont...

- Batch orientation
- Limited distribution
- Custom (tailor-made) software
- Proprietary software ultimately used by the same person or organization
- Implementation but not engineering (no well established set of rules followed)

First Generation Software

Assembly/Machine



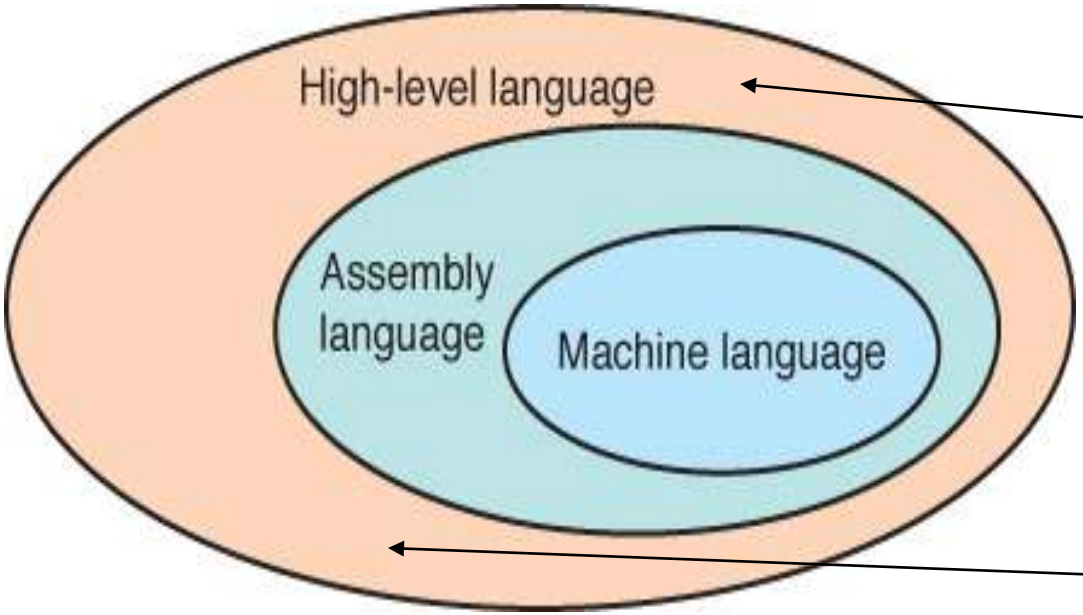
Systems programmers *write* the assembler (translator)

Applications programmers *use* assembly language to solve problems

Second Generation Software (1959-1965)

High-level Languages

English-like statements made programming easier:
Fortran, COBOL, Lisp



Systems programmers *write* translators for high-level languages

Application programmers *use* high-level languages to solve problems

Third Generation Software (1965-1971)

Systems Software

Utility programs

Language translators

Operating systems, which decides which programs to run and when

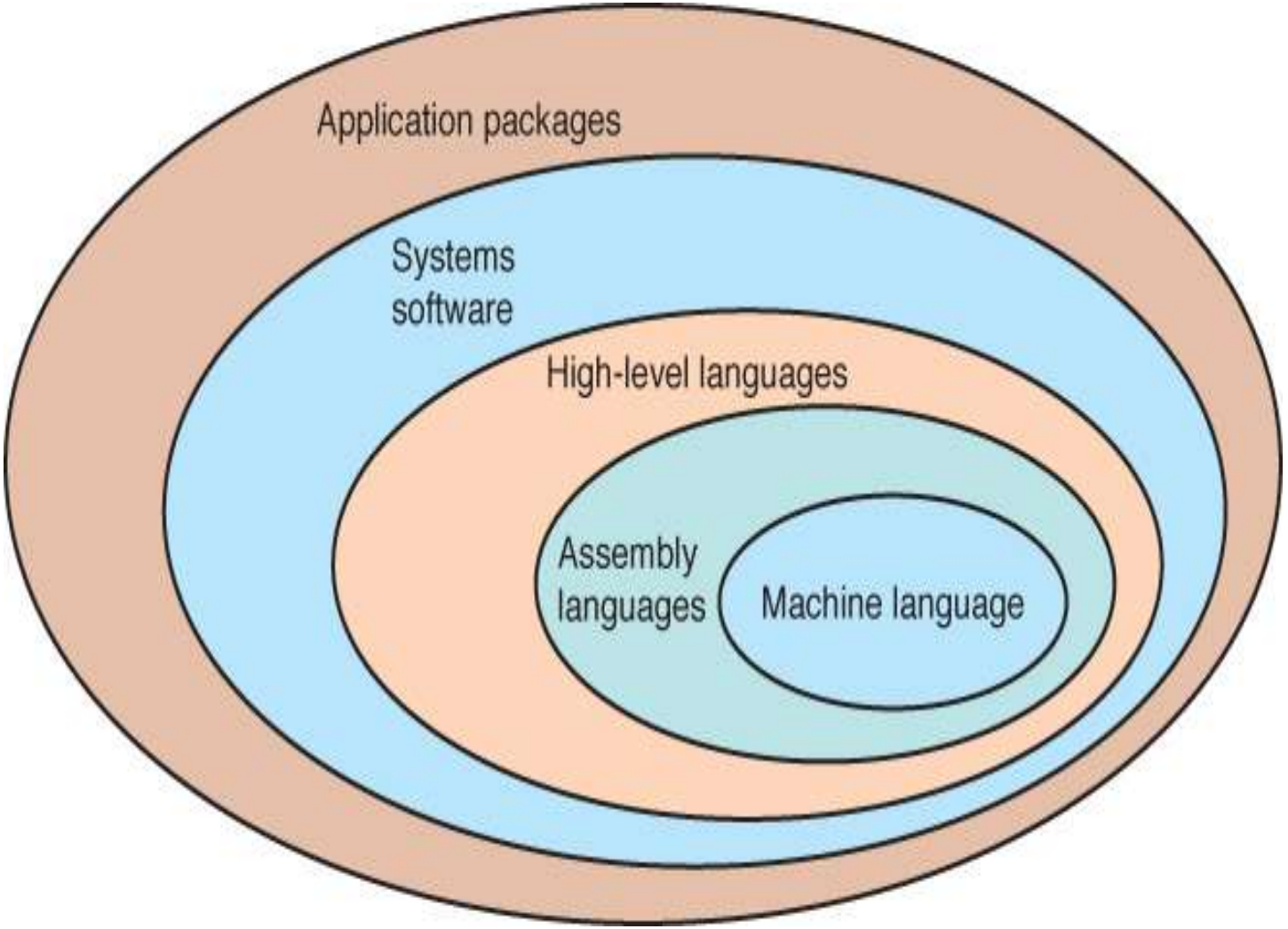
Separation between Users and Hardware

- Computer programmers write programs to be used by general public (i.e., nonprogrammers);
- Computer programmers began to write programs to be used by people who did not know how to program

Third Generation Software Cont...

- Multi-user and multi-processing
- Real-time
- Database
- Product software
- HCI (DOS, WINDOWS)
- Control process (Software Engineering)
- Introduction of software houses

Third Generation Software (1965-1971)



The layers of software surrounding hardware continue to grow

Fourth Generation Software (1971-1989)

Structured and OOP Programming

Pascal
C++
Java (Some functionalities overlap with fifth generation)

New Application Software for Users

Spreadsheets
Word processors
Database management systems

- **Convenience, affordability, usability, portability**

Fourth Generation Software

- Distributed systems (networked systems)
- Embedded “intelligence”
- Low cost hardware (mass production)
- Customer impact
- Concurrency
- Global and local area network
- High bandwidth
- **Heavy demand on software developers**

Fifth Generation Software
(1990- present)

Microsoft

Windows operating system and other Microsoft application programs dominate the market

Object-Oriented Design

Based on a hierarchy of data objects (Ex. Java)

World Wide Web

Allows easy global communication through the Internet

New Users

Today's user needs no computer knowledge
Computer is like commodity

Fifth Generation Software

- Powerful desktop systems
- Object Oriented Technology
- Expert systems
- Artificial Neural Networks (implanted in beings)
- Parallel computing
- Pattern recognition and human like information processing capability
- Knowledge engineering
- Replacing conventional Software Development approaches

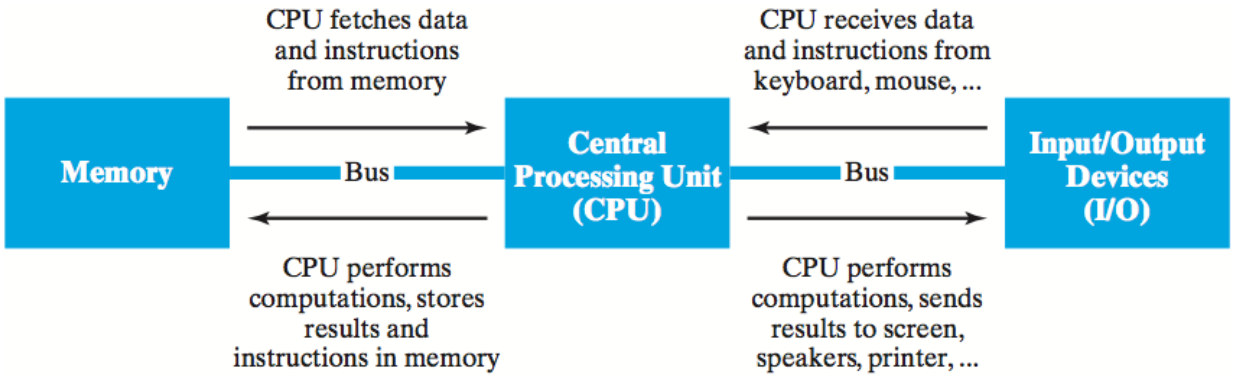
von Neumann Architecture

although specific components may vary, virtually all modern computers have the same underlying structure

- known as the *von Neumann architecture*
- named after computer pioneer, John von Neumann, who popularized the design in the early 1950's

the von Neumann architecture identifies 3 essential components

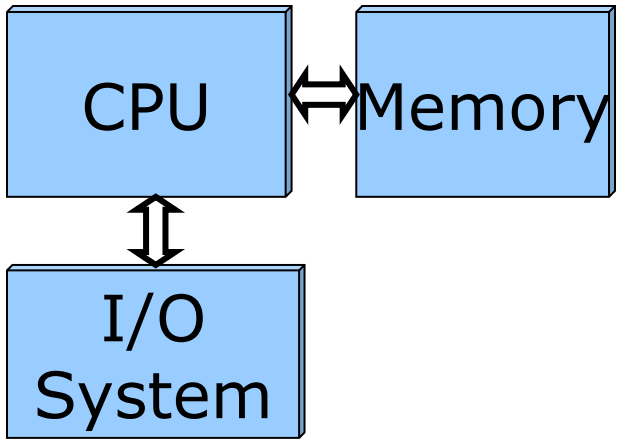
1. *Input/Output Devices (I/O)* allow the user to interact with the computer
2. *Memory* stores information to be processed as well as programs (instructions specifying the steps necessary to complete specific tasks)
3. *Central Processing Unit (CPU)* carries out the instructions to process information

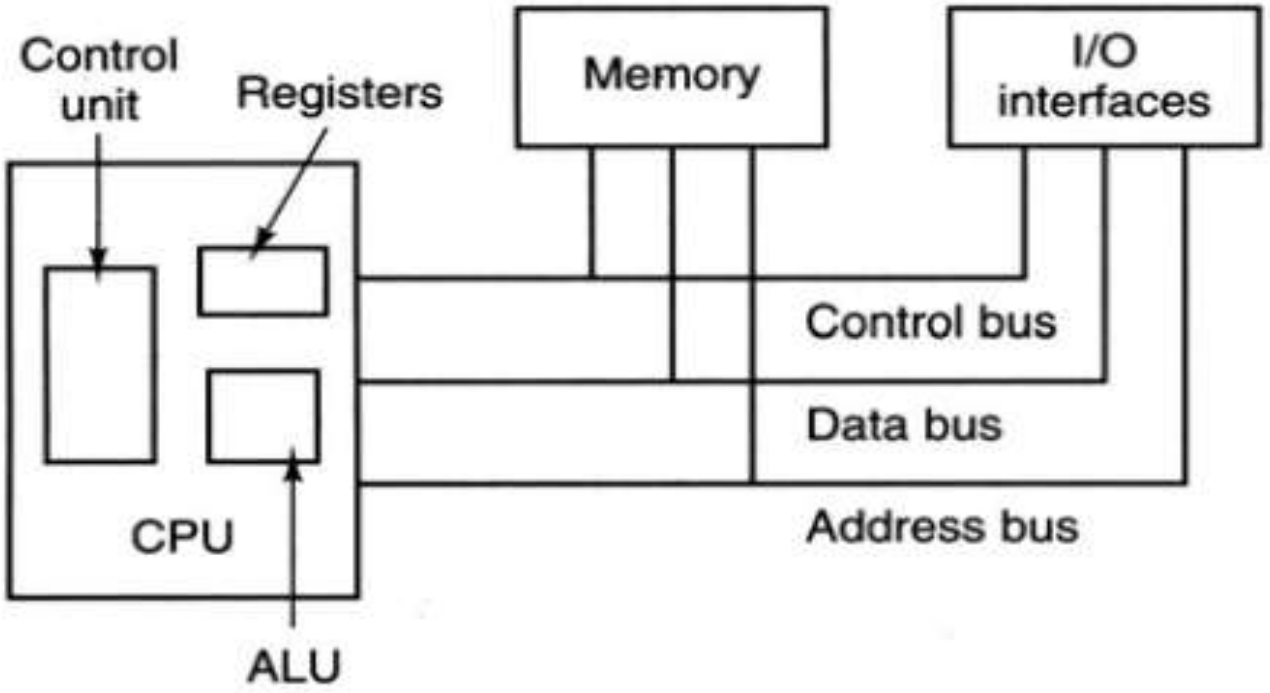


von Neumann popularized the idea of a "stored program" computer

- store both data and programs in Memory
- Central Processing Unit (CPU) executes by loading program instructions from memory and executing them in sequence
- interact with the user via Input / Output devices

virtually all modern machines follow this *von Neumann Architecture*





Basic Computer Components

Busses are copper wires that connect computer-hardware components to each other