Chapter 2: Organization of a Computer System and Evolution of HW/SW Components

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

- Understanding functions of various elements 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.
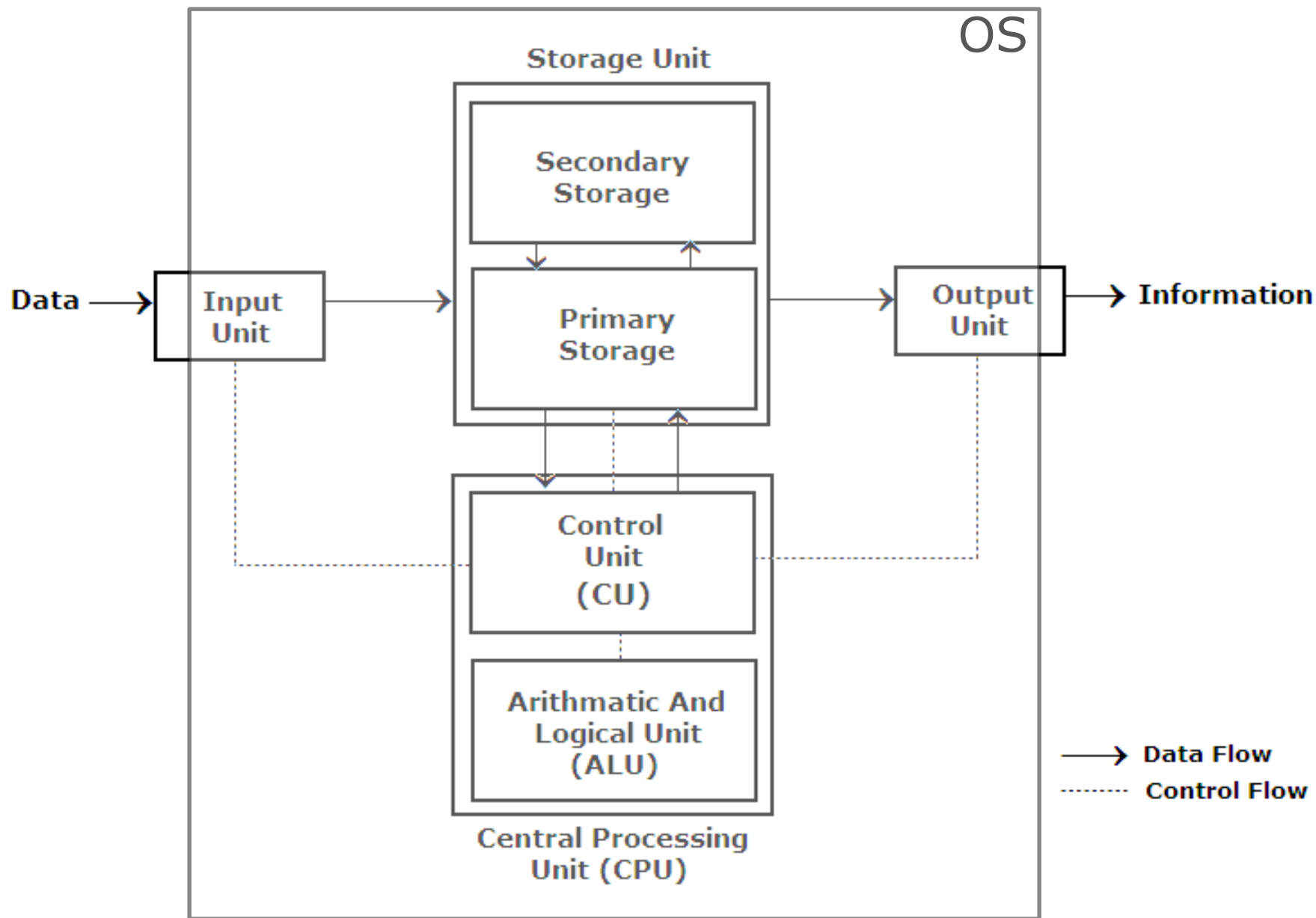
Basic computer Organization Block Diagram

Anatomy of a Computer

- Every computer has four basic parts, or units:
  - an <u>input unit</u> such as the keyboard, that feeds information into the computer
  - a <u>central processing unit</u> (CPU) that performs the various tasks of the computer
  - an <u>output unit</u> , such as a monitor , that displays the results;
  - a <u>memory</u> 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
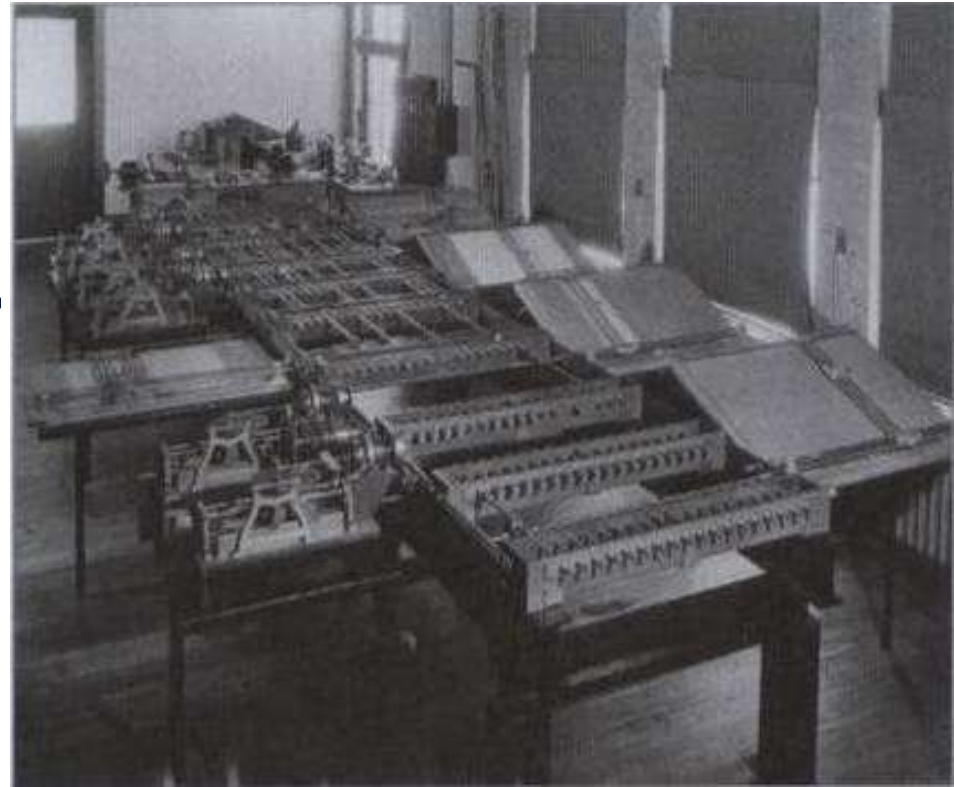
Harvard Mark I   (1944)

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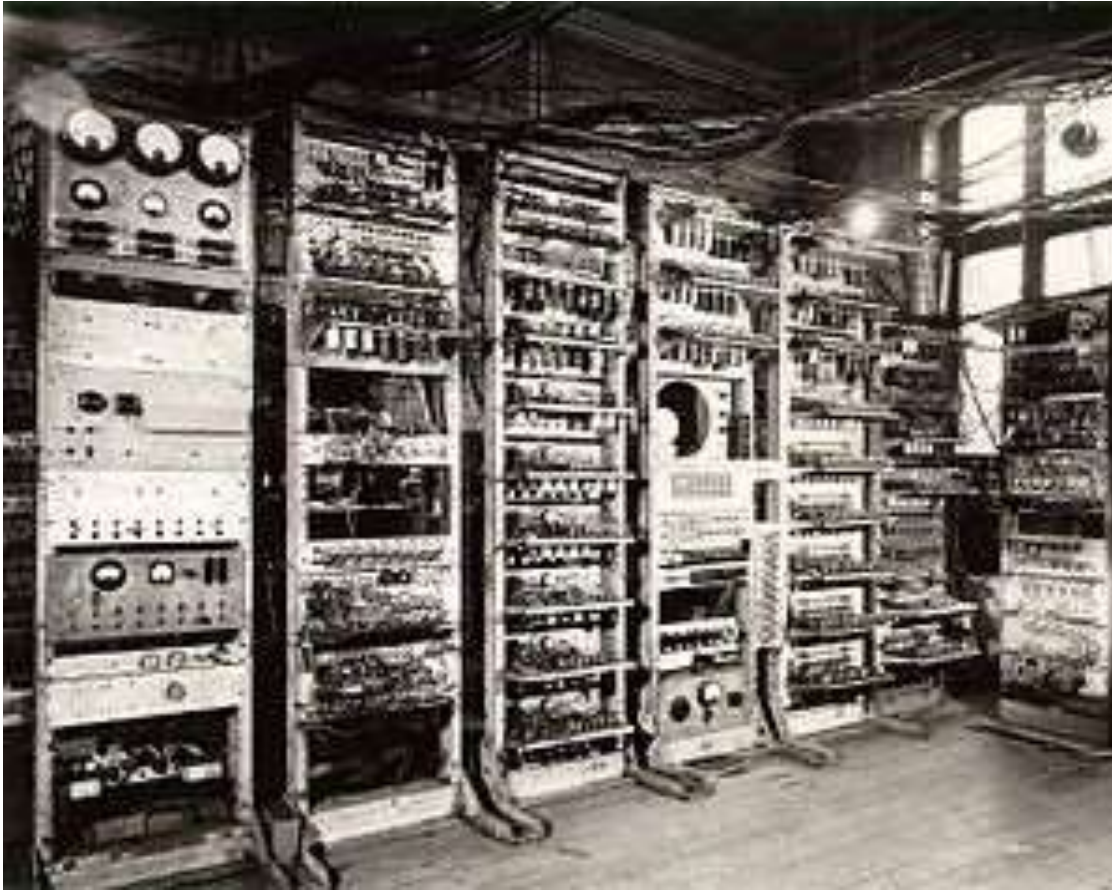 - Transistors   70,000
  - Capacitors   10,000
  - Hand soldered joints   1 million
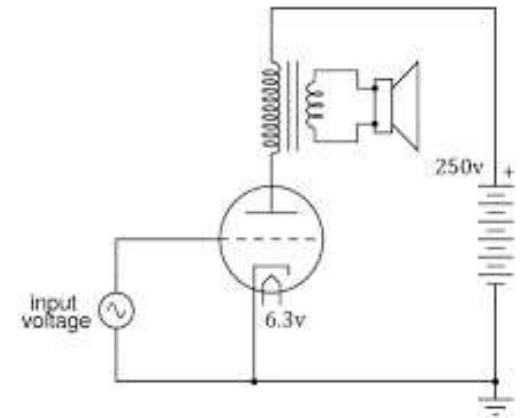
ENIAC

- 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
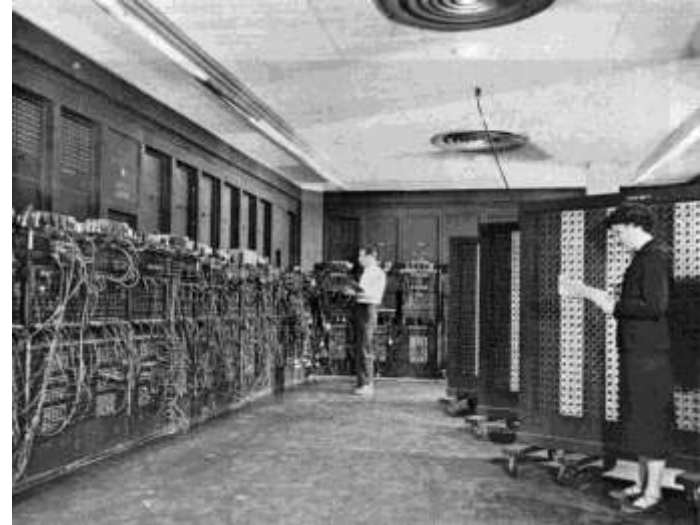
Used machine languages and magnetic tapes
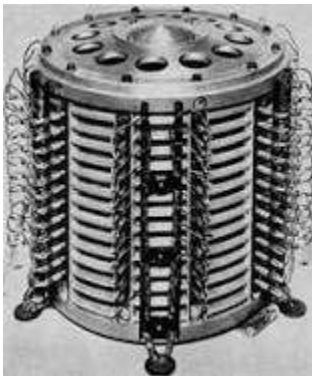
First Generation Hardware

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

Magnetic drum

19

Generation 2: IBM7094
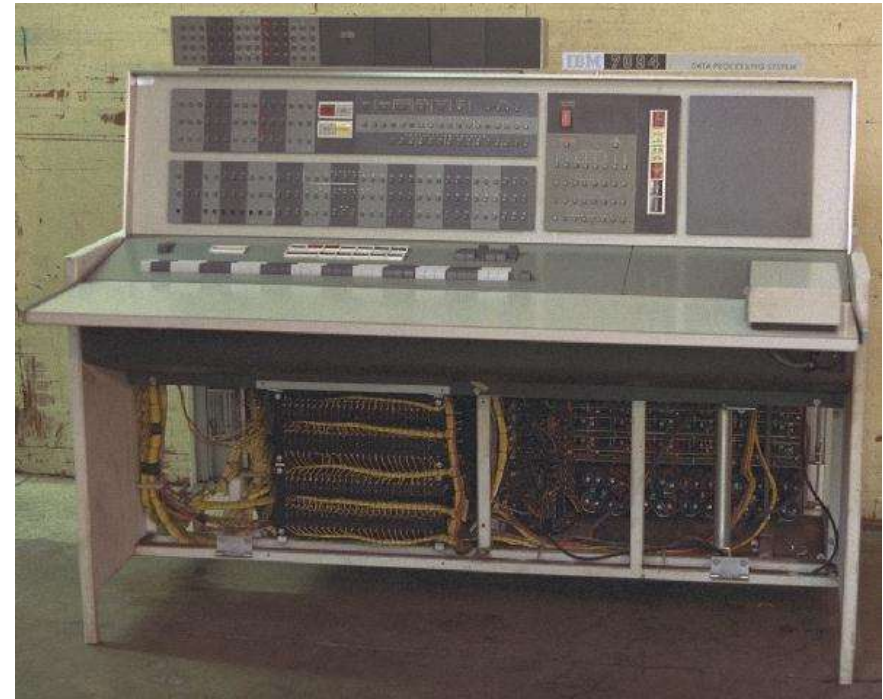
These machines used assembly language.

Second Generation Hardware

Transistor
Replaced vacuum tube, fast, small, durable, cheap, consumes less energy
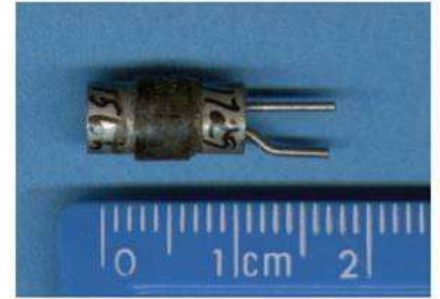
Magnetic Cores
Replaced magnetic drums, information available instantly. How?

Magnetic Disks
Replaced magnetic tapes, data can be accessed directly. What does this mean?

Magnetic core
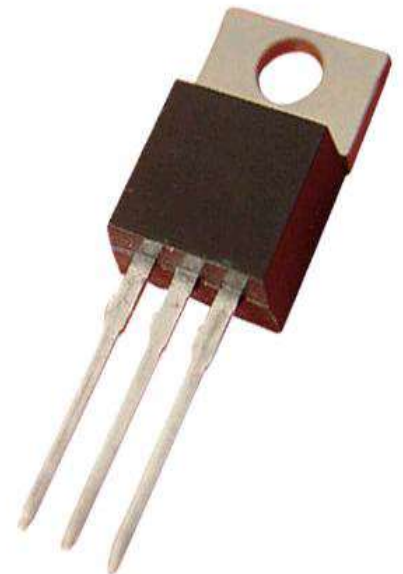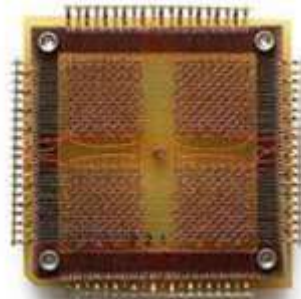
Generation 3: Integrated Circuits

Seymour Cray created the Cray Research Corporation
Cray-1: $8.8 million, 160 **million instructions per second** 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
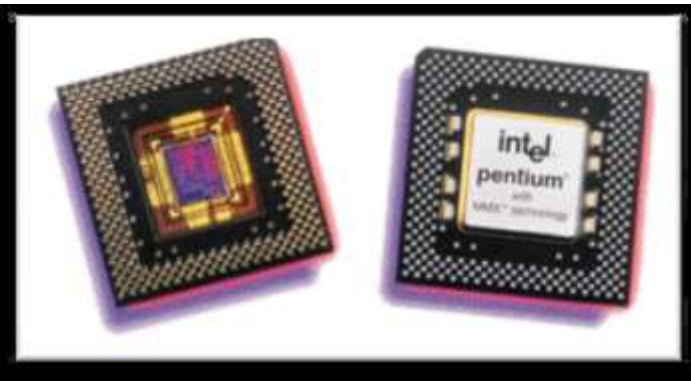
Microprocessors

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 and present 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, and price

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

  * The details are left as a Reading Assignment

  - Microcontrollers
  - Microcomputers
  - Minicomputers (Workstations)
  - Mainframe Computers
  - Super computers

➢ The three directions of computer development are **miniaturization**, **speed**, and **affordability** **due to**

➢ **Integration, Mass Production, Core Technology** **(Multiprocessors); Cost reduction by half every 2 years**

➢ The three directions of communications development are **connectivity**, **interactivity**, and **multimedia**

CPU core$_0$

registers

cache

CPU core$_1$

registers

cache

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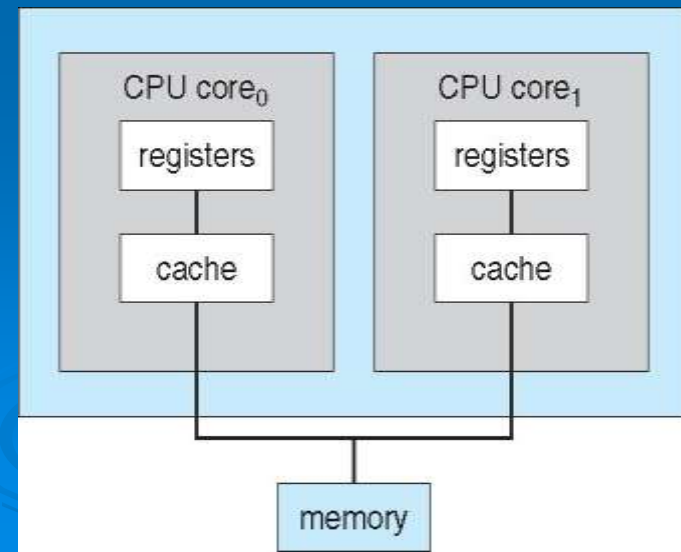
Moore's law suggests that computer power will double every 18 to 24 months. So far, it has.

Moore's Law

Processor	Approximate Year
Intel® Itanium® 2 Processor	
Intel® Itanium® Processor	
Intel® Pentium® 4 Processor	
Intel® Pentium® III Processor	
Intel® Pentium® II Processor	
Intel® Pentium® Processor	
Intel486™ Processor	
Intel386™ Processor	
286	
8086	
8080	
8008	
4004	

Transistors: 1,000,000,000 — 100,000,000 — 10,000,000 — 1,000,000 — 100,000 — 10,000 — 1,000

1970 1975 1980 1985 1990 1995 2000 2005

Curve shows transistor count doubling almost every two years

Computer HW & SW

- Capabilities of Computers
  - Huge Data Storage
  - Input and Output
  - Processing Power
  - *Hardware stores and transmits data, supports software, and software processes data.*
  - *But, a processor (CPU) is a hardware that can also process data!*

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
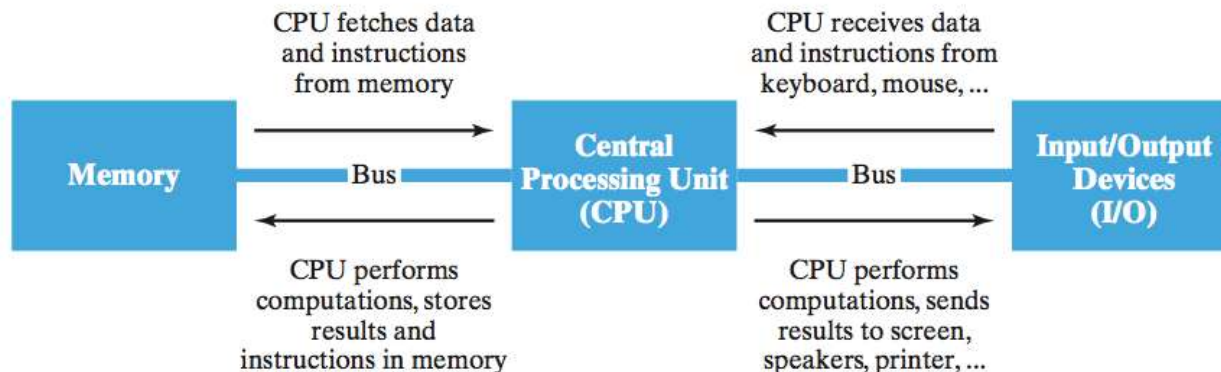
von Neumann Architecture

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

CPU fetches data and instructions from memory

CPU receives data and instructions from keyboard, mouse, ...

Memory — Bus — **Central Processing Unit (CPU)** — Bus — **Input/Output Devices (I/O)**

CPU performs computations, stores results and instructions in memory

CPU performs computations, sends results to screen, speakers, printer, ...

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*

CPU ⟷ Memory

I/O System
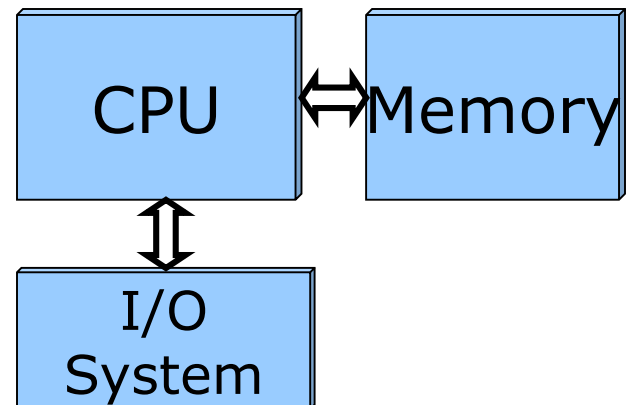
What Hardware Components Contribute to the Speed of a Computer?

Component	Speed measured by	Units	Description
CPU	Clock speed	gHz	The time it takes to complete a **cycle**
Motherboard (Data Buses)	Bus **& (Bus Width)** speed	mHz *** Bits**	How much data can move across the bus simultaneously**/s**
RAM	Data transfer rate	MB/s **– GB/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

Input Devices
Enter Data and Instructions into the CPU

Central Processing Unit

Control Unit
Interprets Instructions and Directs Processing

Arithmetic-Logic Unit
Performs Arithmetic Operations and Makes Comparisons

System Bus

Special Purpose Processors

Cache Memory

Primary Storage (Memory)
Stores Data and Program Instructions during Processing

Output Devices
Communicate and Record Information

Secondary Storage Devices
Store Data and Programs for Processing

Magnetic Disk and Tape Units, Optical Disks

- Keyboard
- Mouse
- Touch Screen
- Optical Scanner
- Voice Recognition

- Visual Display Unit
- Printer
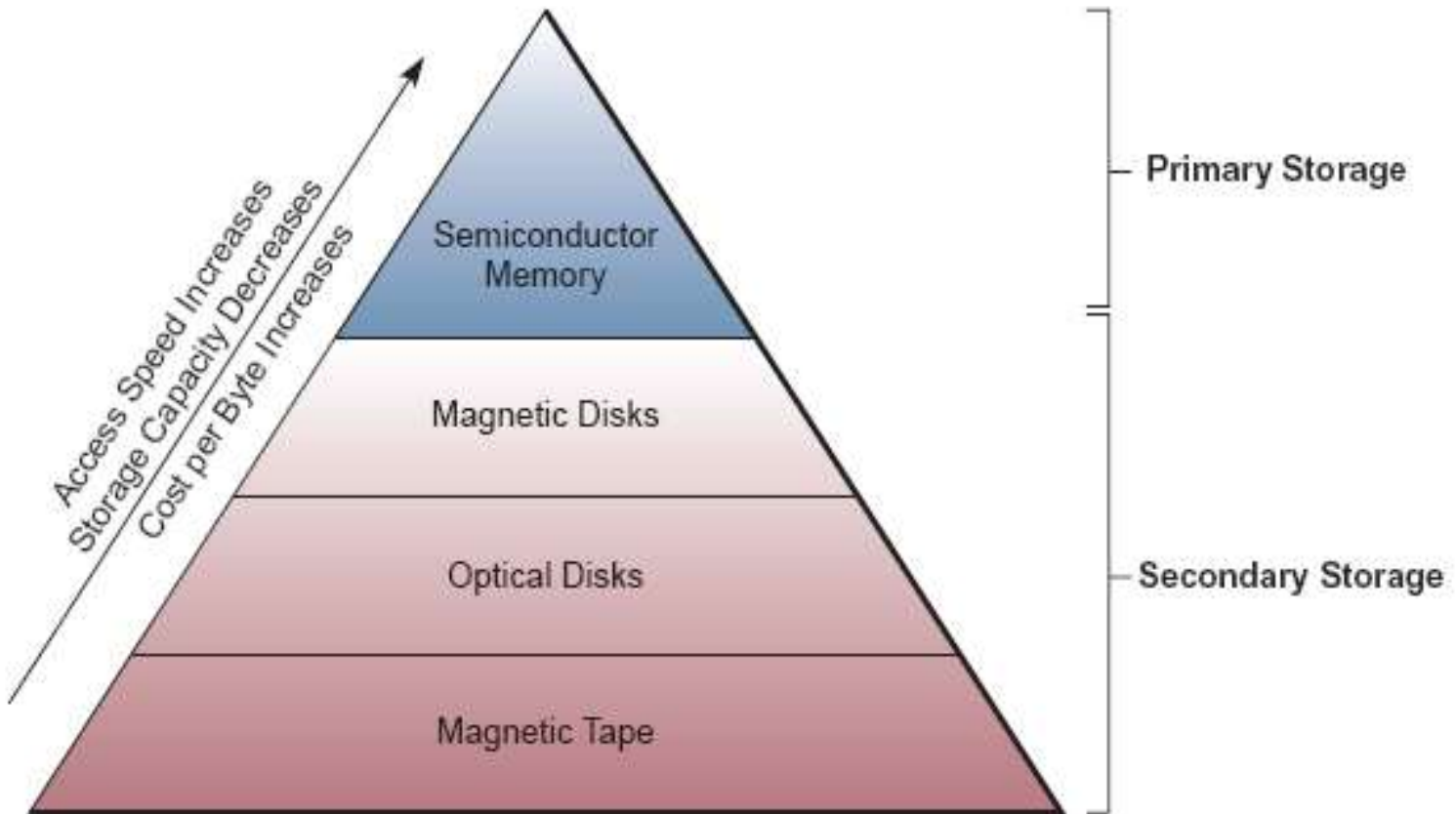- Audio-Response
- Physical Control Devices

Storage-Device Hierarchy
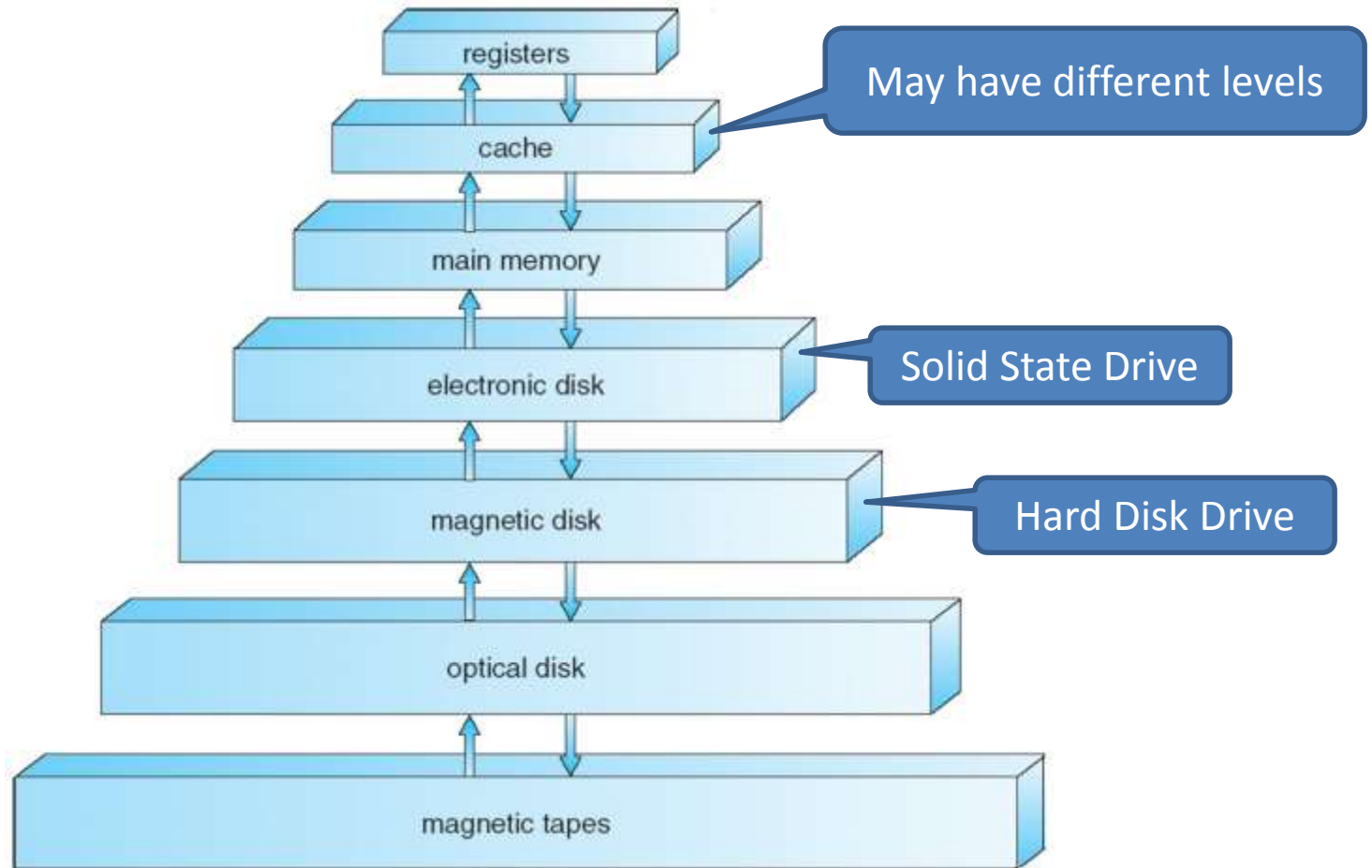
# Storage media cost, speed, and capacity trade-offs.

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

Performance of Various Levels of Storage

Level	1	2	3	4	5
Name	registers	cache	main memory	solid state disk	magnetic disk
Typical size	< 1 KB	< 16MB	< 64GB	< 1 TB	< 10 TB
Implementation technology	custom memory with multiple ports CMOS	on-chip or off-chip CMOS SRAM	CMOS SRAM	flash memory	magnetic disk
Access time (ns)	0.25 - 0.5	0.5 - 25	80 - 250	25,000 - 50,000	5,000,000
Bandwidth (MB/sec)	20,000 - 100,000	5,000 - 10,000	1,000 - 5,000	500	20 - 150
Managed by	compiler	hardware	operating system	operating system	operating system
Backed by	cache	main memory	disk	disk	disk or tape

Cost against Time graph for Software and Hardware Development
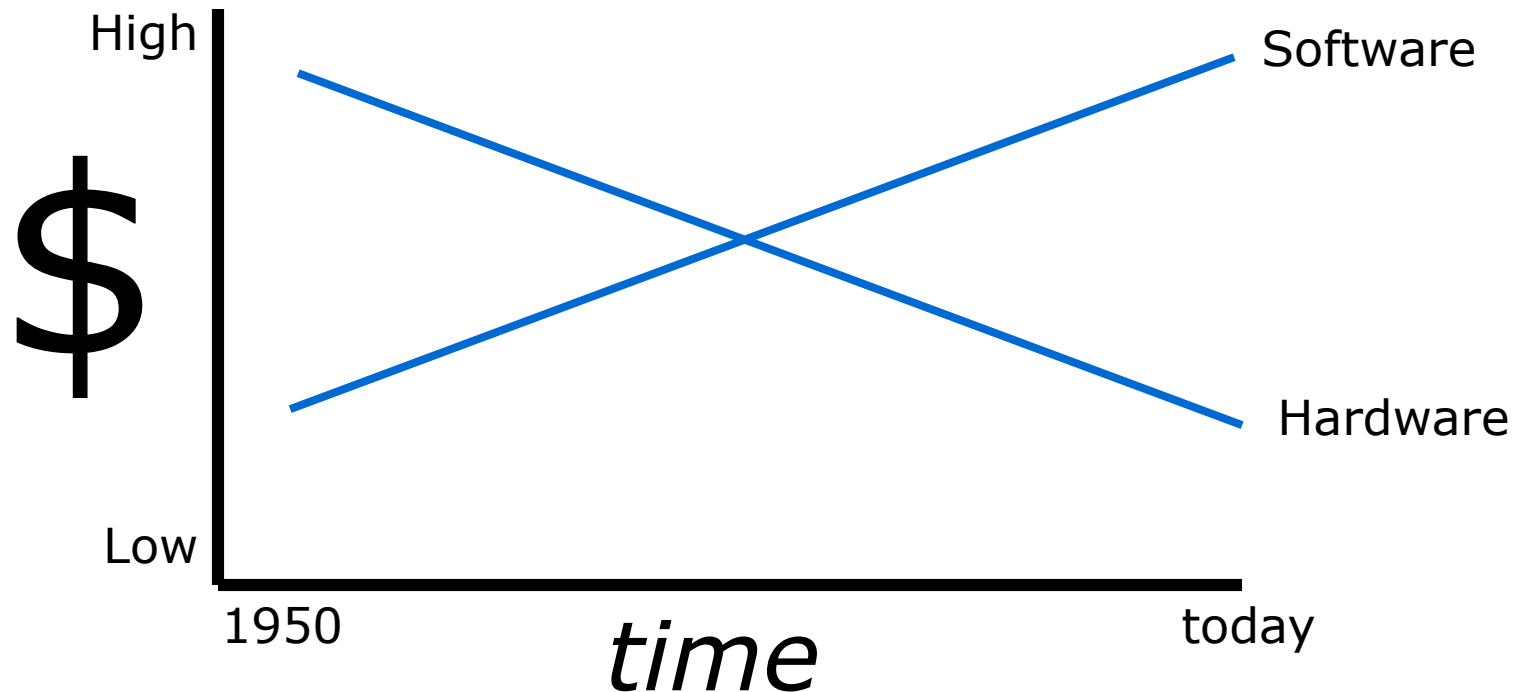
Why is software development always getting more expensive?

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** part of a computer and hardware as the **invariable** part.

For instance, in the first and second software generations there was **no multitasking**, only **batch programming** was possible.

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)
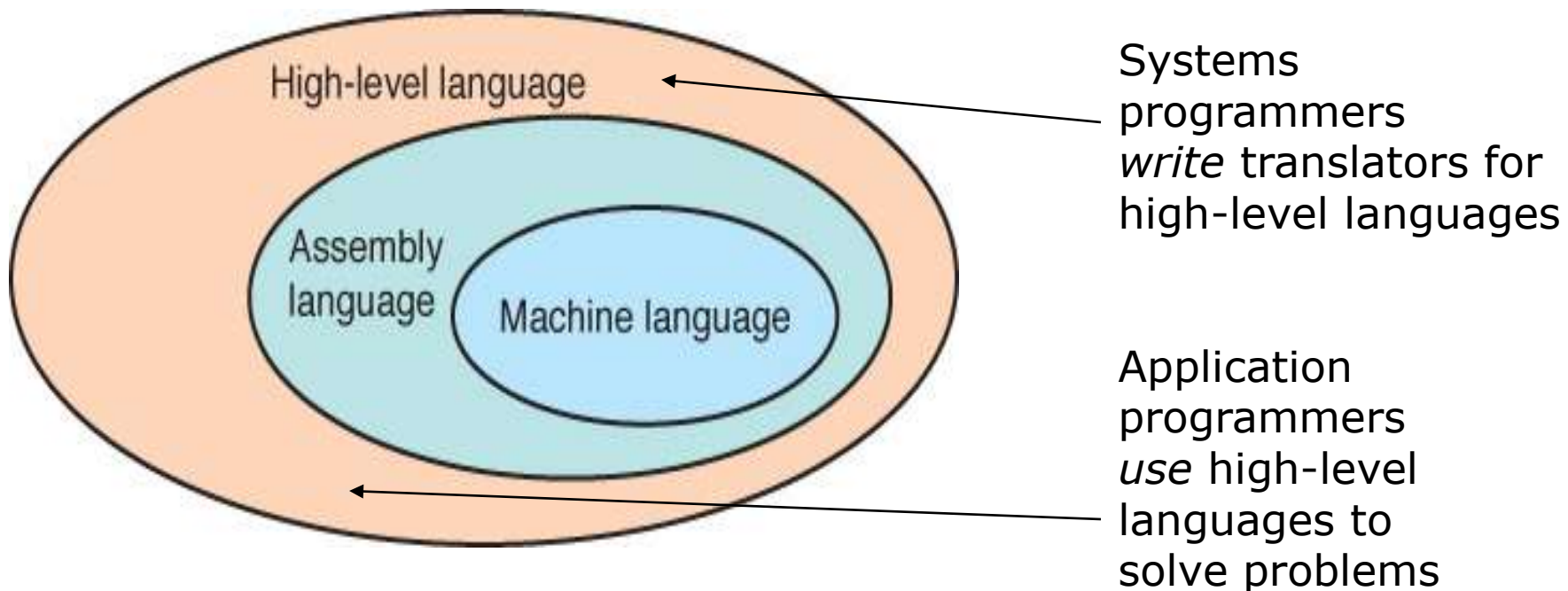
First Generation Software
Assembly/Machine

Systems programmers *write* the assembler (translator)

Applications programmers *use* assembly language to solve problems
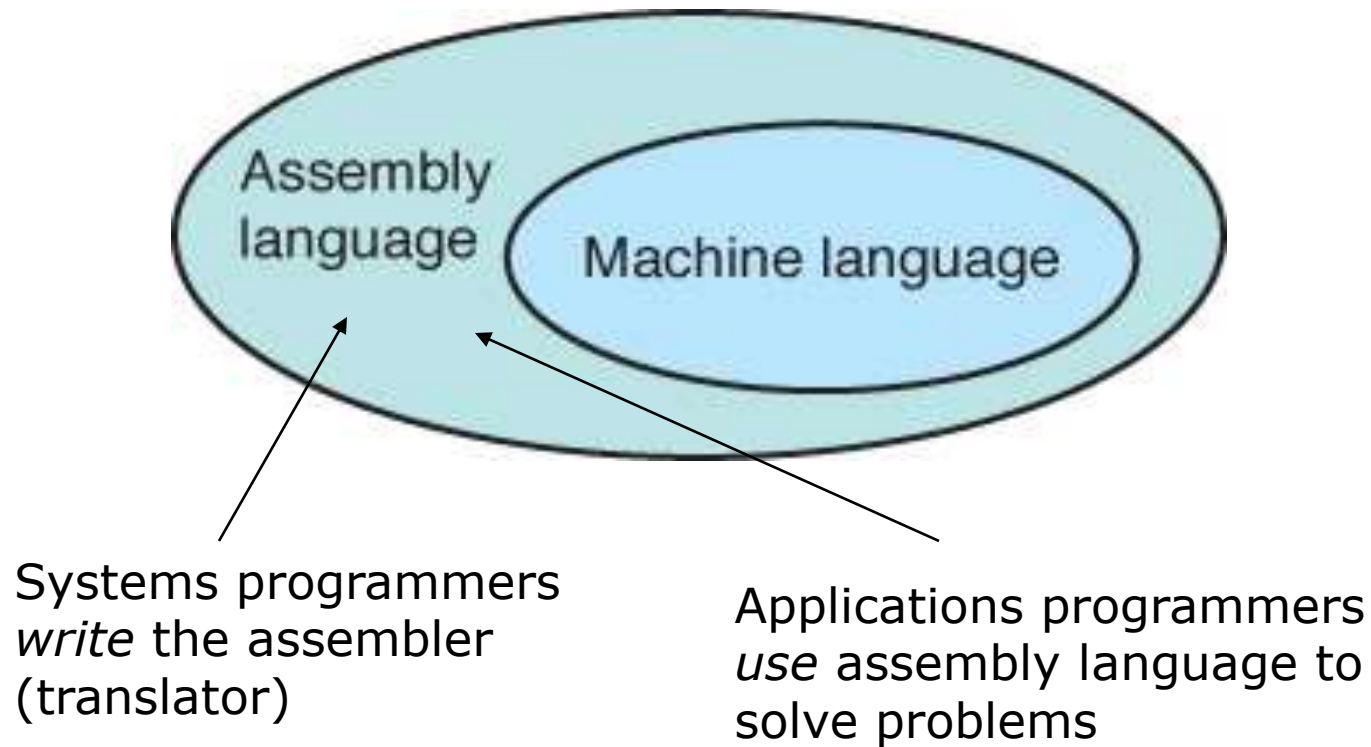
Second Generation Software (1959-1965)

High-level Languages

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

High-level language

Assembly language

Machine language

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

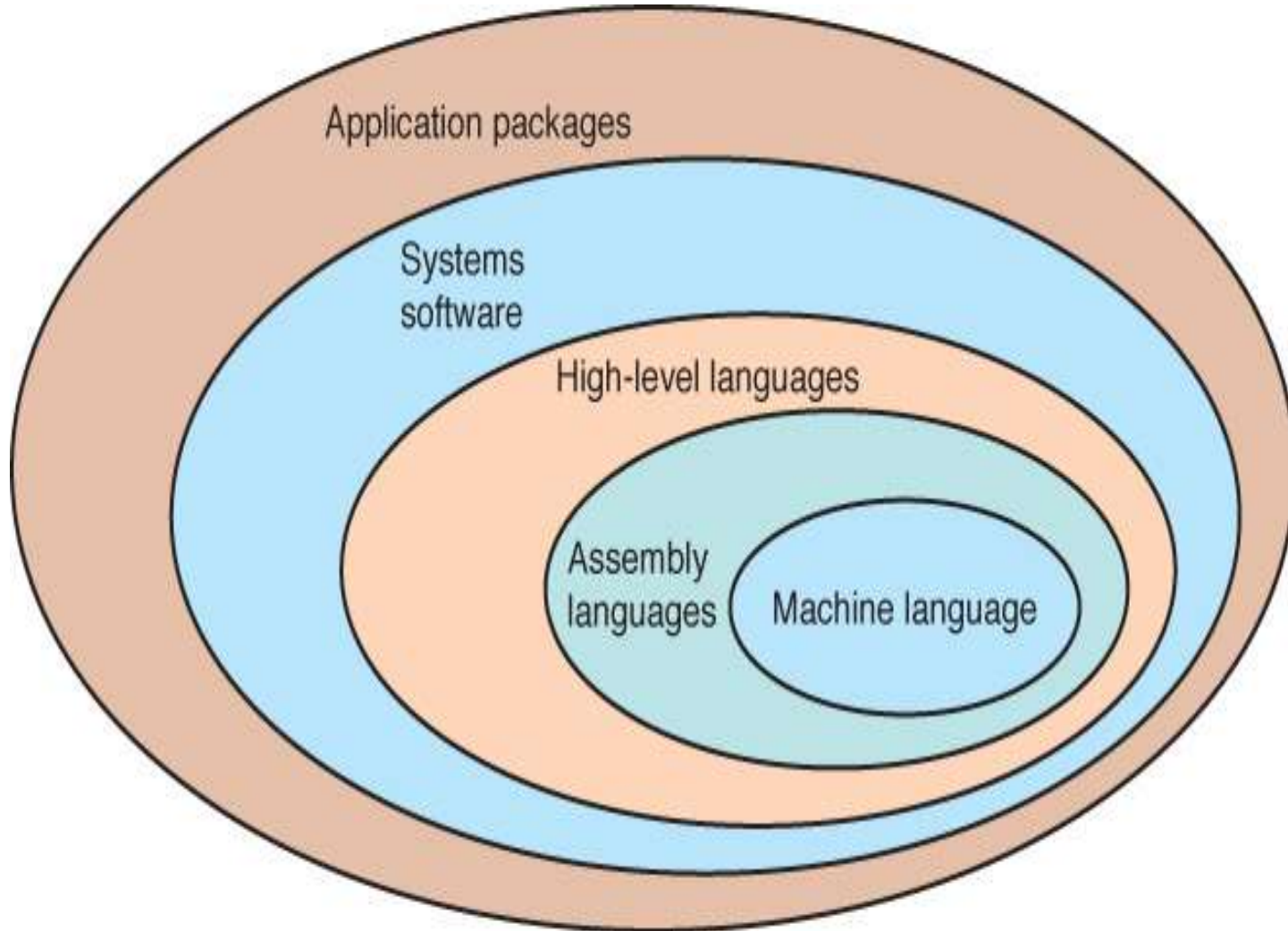Operating systems; Decides which programs to run and when

Separation between Users and Hardware

- Computer programmers write programs to be used by the 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-programming

– Real-time

– Database

– Product software

– HCI (DOS, WINDOWS)

– Control process (Software Engineering)

– Introduction of software houses

Third Generation Software
(1965-1971)

Application packages

Systems software

High-level languages

Assembly languages

Machine language

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 (i.e. Java and C#)

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