The Islamia University of Bahawalpur Pakistan

Computer System Architecture & Organization

Faculty of Computing

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بِسۡمِ اللّٰہِ الرَّحۡمٰنِ الرَّحِیۡمِ

ترجمہ: شُروع اَللہ کے پاک نام سے جو بڑا مہربان نہایت رحم والا ہے۔

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ترجمہ: اے میرے رب! میرے علم میں اضافہ فرما۔

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Computer System Architecture
&
Organization

Definition of Computer Architecture

- Computer architecture is a specification detailing how a set of software and hardware technology standards interact to form a computer system or platform.
- In short, computer architecture refers to how a computer system is designed and what technologies it is compatible with.

Computer Architecture Vs Computer Organization

- A **Computer's Architecture** is its abstract model and is the programmer's view in terms of instructions, addressing modes and registers.
- A **Computer's Organization** expresses the realization of the architecture.
- Architecture describes **"What"** the computer does and organization describes **"How"** it does it.
- Von Neumann Architecture - Stored Program Concept
- Harvard Architecture
- AC based Architecture

Difference Between Architecture and Organization

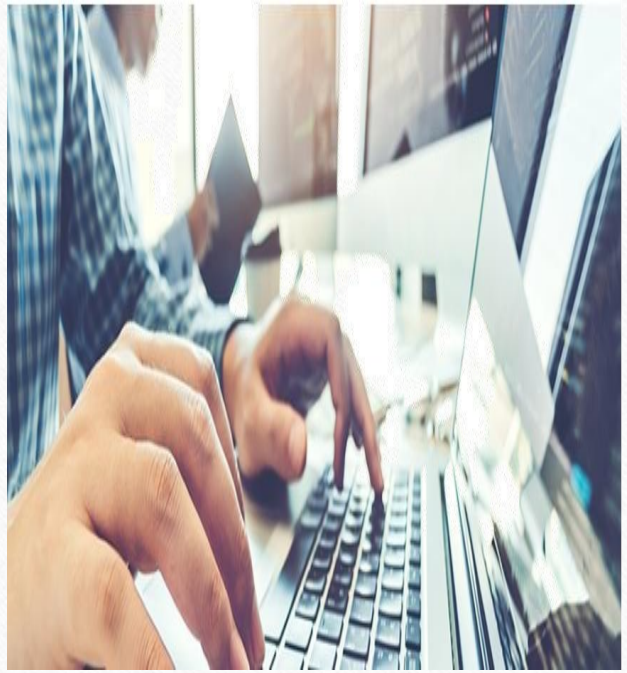
- **Computer Architecture:** A tells you what the system does. So, knowing about the architecture is basically knowing what functionalities will your system display. What you can expect to get out of it.
- **Computer Organization:** tells you how exactly all units in your system have been arranged and interconnected to help realize the architectural goals your system claims to have achieved.
- Say you are constructing a house, Plan, design and all low-level details come under computer architecture while building it brick by brick, connecting together keeping basic architecture in mind comes under computer organization.

Overview of Introduction to Computer Systems

1. Overview of Computer Systems

- ***Definition:*** *Computer is an advanced electronic device that takes raw data as an input from the user and processes it under the control of a set of instructions (called program), produces a result (output), and saves it for future use. This tutorial explains the foundational concepts of computer* ***hardware, software, operating systems, peripherals, etc.*** *along with how to get the most value and impact from computer technology.*

It defines how the ***various*** *parts of the computer work together to process information and execute programs.*



Details About Computer System

- An electronic device, operating through electrical signals under the control of instructions stored in its own memory unit, that can accept data (input), process data arithmetically and logically, produce output from the processing, and store the results for future use.
- A computer system is a combination of hardware and software designed to perform various tasks. It includes components such as the central processing unit (CPU), memory, storage, input/output devices, and the operating system. Understanding computer systems involves exploring how these components interact to process data and execute programs.

Computer Uses in Various Fields

- Business
- Finance
- Education
- Healthcare
- Manufacturing
- Marketing
- Retail
- Transportation
- Telecommunications
- Science and Research
- Entertainment
- Government
- Agriculture
- Construction
- Legal
- Weather Forecasting
- Cloud Services
- Network Security

Name Types of Computer Systems

1) Personal Computers
2) Workstations
3) Servers
4) Mainframe
5) Supercomputers
6) Embedded Systems
7) Tablets
8) Smartphones
9) Gaming Consoles
10) Wearable Computers
11) Cloud Computers
12) Quantum Computers
13) Hybrid Computers
14) Portable Computers
15) Thin Clients
16) Virtual Machines
17) Digital Assistants

Personal Computer (Pcs)

1)**Personal Computers (PCs):** It is a small, affordable computer designed for individual use. It allows users to perform various tasks such as various perform Alphanumeric, Mathematical or Logical Calculations, browsing, internet, creating documents, playing games, and more **etc.** It includes both traditional models and modern variations like.

1) **Desktops**
2) **Laptops**
3) **Notebooks**
4) **Ultrabook's**
5) **Netbooks**
6) **Tablets**
7) **Convertible Laptops**
8) **All-in-One PCs**

Types of Personal Computer (Pcs)

- **Desktops**: Stationary computers with separate components (monitor, CPU, keyboard).
- **Laptops**: Portable computers with built-in screens and keyboards.
- **Notebooks**: Thin and lightweight laptops designed for easy transport.
- **Ultrabooks**: High-performance, sleek laptops with long battery life.
- **Netbooks**: Small, budget-friendly laptops primarily for web browsing.
- **All-in-One PCs**: Compact systems with all components integrated into the monitor.
- **Tablets**: Touchscreen devices that are portable and often run mobile operating systems.
- **Convertible Laptops**: Devices that can switch between laptop and tablet modes.

Workstation Computer

2) Workstation Computer: A workstation computer is a high-performance computer designed for technical or scientific applications. It is more powerful than a regular personal computer (PC) and is used for tasks that require significant processing power, graphics capability, and memory.

Types of Workstations

1)**Desktop Workstations:** Standard workstations designed to sit on a desk, often customizable.

2)**Mobile Workstations:** Portable laptops with workstation-level performance for on-the-go use.

3)**Virtual Workstations:** Cloud-based workstations that can be accessed remotely.

Server Computer

3) Servers Computers (PCs): A **server computer** is a powerful computer designed to manage, store, and distribute data and resources to other computers over a network. Servers play a crucial role in providing services and applications to users and devices.

Types of Servers Computers:

1) **File Servers**
2) **Web Servers**
3) **Database Servers**
4) **Application Server**
5) **Mail Servers**
6) **Virtual Server**

Types of Server Computers

1) **File Server:** Stores and manages files for users on a network.
2) **Web Server:** Hosts websites and delivers web pages to users' browsers.
3) **Database Server:** Manages databases and allows users to access and manipulate data.
4) **Application Server:** Hosts applications and provides services to client computers.
5) **Mail Server:** Manages and delivers email for users.
6) **Virtual Server:** Uses virtualization technology to run multiple servers on a single physical machine.

Mainframe Computer

4) Mainframe Computers: A mainframe computer is a large, powerful computer designed to handle and process vast amounts of data quickly and efficiently. These computers are used primarily by large organizations for critical applications, bulk data processing, and large-scale transaction processing.

Types of Mainfram Computers:

1) **Traditional Mainframes:** Large, room-sized computers used in data centers.

2) **Modular Mainframes:** Scalable systems that can be expanded with additional components as needed.

3) **Cloud-Based Mainframes:** Mainframe capabilities offered through cloud services, allowing remote access and scalability.

Supercomputers

5) Supercomputers: A supercomputer is an extremely powerful computer designed to perform complex calculations at very high speeds. These computers are used for tasks that require immense processing power, such as scientific simulations, weather forecasting, and advanced data analysis.

Types of Supercomputers:

1) **Traditional Mainframes:** Large, room-sized computers used in data centers.

2) **Modular Mainframes:** Scalable systems that can be expanded with additional components as needed.

3) **Cloud-Based Mainframes:** Mainframe capabilities offered through cloud services, allowing remote access and scalability.

Embedded Systems

6) Embedded Systems: An embedded system is a special-purpose computer designed to perform dedicated functions within a larger system. Unlike general-purpose computers, embedded systems are built to control specific tasks and are often found in devices we use daily.

Types of Embedded Systems:

1) **Standalone Embedded Systems:** **Operate independently without needing a host device (e.g., microwave ovens).**
2) **Networked Embedded Systems:** **Connect to other devices or networks for communication (e.g., smart home devices).**
3) **Real-Time Embedded Systems:** **Respond to inputs or events within a specific time frame (e.g., anti-lock braking systems in cars).**

Tablets

7) Tablets Systems: A tablet is a portable touchscreen computer that is larger than a smartphone but smaller than a laptop. Tablets are designed for easy use and are popular for browsing the internet, watching videos, playing games, and reading e-books.

Types of Tablets Systems:

1) **Standard Tablets:** **General-purpose tablets for everyday use (e.g., Apple iPad, Samsung Galaxy Tab).**
2) **2-in-1 Tablets:** **Can function as both a tablet and a laptop with a detachable keyboard (e.g., Microsoft Surface Pro).**
3) **E-Readers:** **Specialized tablets designed primarily for reading e-books (e.g., Amazon Kindle).**

Smartphones

8) Smartphones: A smartphone is a mobile phone that includes advanced features beyond making phone calls and sending texts. It combines the functionality of a computer with the portability of a phone, allowing users to access the internet, run applications, and perform various tasks on the go.

Types of Smartphones:

1) **Flagship Smartphones: High-end devices with the latest technology and features (e.g., iPhone, Samsung Galaxy, series).**
2) **Mid-Range Smartphones: Offer good performance at a more affordable price (e.g., Google Pixel A series).**
3) **Budget Smartphones: Basic phones with essential features, ideal for cost-conscious consumers (e.g., Moto G series).**

Gaming Consoles

9) Gaming Consoles: A **gaming console** is a specialized device designed for playing video games. Unlike computers, gaming consoles are built specifically for gaming and often connect to a TV or monitor, providing an immersive gaming experience.

Types of Gaming Consoles:

1) **Home Consoles: Designed for use in the living room, connected to a TV (e.g., PlayStation, Xbox, Nintendo Switch).**
2) **Handheld Consoles: Portable devices that can be played anywhere (e.g., Nintendo Switch Lite, PlayStation Vita).**
3) **Hybrid Consoles: Can be used as both home and handheld devices (e.g., Nintendo Switch).**

Wearable Computers

10) Wearable Computers: Wearable computers are small electronic devices that can be worn on the body, often designed to track health, fitness, or provide information. They combine technology with clothing or accessories, allowing users to access features hands-free.

Types of Wearable Computers:

1)**Smartwatches:** **Watches that offer features like notifications, fitness tracking, and apps (e.g., Apple Watch, Samsung Galaxy Watch).**

2)**Fitness Trackers:** **Devices focused on health and activity monitoring (e.g., Fitbit, Garmin).**

3)**Smart Glasses:** **Glasses that display information and can include augmented reality features (e.g., Google Glass).**

4)**Health Monitors:** **Wearable devices that track specific health metrics, like glucose levels or ECG (e.g., continuous glucose monitors).**

Cloud Computers

11) Cloud Computers: refer to computing services and resources that are delivered over the internet ("the cloud") instead of being stored on a local computer or server. This allows users to access data and applications from anywhere, using any device connected to the internet.

Types of Cloud Computers:

1) **Infrastructure as a Service (IaaS): Provides virtualized computing resources over the internet (e.g., Amazon Web Services, Microsoft Azure).**
2) **Platform as a Service (PaaS): Offers a platform for developers to build, test, and deploy applications without managing the underlying infrastructure (e.g., Google App Engine).**
3) **Software as a Service (SaaS): Delivers software applications over the internet, accessible through web browsers (e.g., Google Workspace, Microsoft 365).**

Quantum Computers

12) Quantum Computers : Quantum computers are advanced computing devices that use the principles of quantum mechanics to process information. Unlike traditional computers, which use bits (0s and 1s) to represent data, quantum computers use qubits that can represent multiple states simultaneously, allowing for much faster and more complex calculations.

Types of Quantum Computers:

1) **Superconducting Qubits:** **Use superconducting circuits to create qubits, commonly used by companies like IBM and Google.**
2) **Trapped Ions:** **Use ions trapped in electromagnetic fields as qubits, manipulated with lasers (e.g., IonQ).**
3) **Topological Qubits:** **A theoretical type that uses particle-like excitations to achieve robustness against errors.**

Portable Computers

13) Portable Computers: Portable computers are lightweight and compact computing devices designed for easy transport and use in various locations. They allow users to work, browse the internet, and perform tasks without being tied to a specific location.

Uses of Portable Computers:

1) **Laptops:** Full-featured computers with a screen, keyboard, and battery, suitable for most computing tasks.
2) **Tablets:** Touchscreen devices that are slim and lightweight, often used for browsing, reading, and media consumption.
3) **Ultrabooks:** Thin and lightweight laptops with high performance, designed for mobility and long battery life.
4) **2-in-1 Devices:** Hybrid devices that can function as both a laptop and a tablet, featuring a detachable keyboard.

Hybrid Computers

14) Hybrid Computers: Hybrid computers are systems that combine the features of both analog and digital computers. They can process both continuous data (like physical measurements) and discrete data (like numbers and symbols), making them versatile for various applications.

Uses of Hybrid Computers:

1) **Simulation:** Used in engineering and scientific research to simulate physical systems (e.g., flight simulators).
2) **Control Systems:** Employed in industrial automation for controlling machinery and processes.
3) **Medical Applications:** Used in devices like ECG machines to monitor and analyze heart activity in real-time.

Thin Clients

15) Thin Clients: Thin clients are lightweight computing devices that rely on a central server to perform most of their processing tasks. They have minimal hardware and software, making them simple and cost-effective solutions for accessing applications and data over a network.

Uses of Thin Clients:

1) **Business Environments:** Commonly used in offices where multiple users need access to the same applications and data.
2) **Educational Institutions:** Used in computer labs and classrooms to provide students with access to online resources and learning applications.
3) **Healthcare:** Employed in hospitals and clinics for accessing patient records and medical applications securely.

Virtual Machines

16) Virtual Machines: Virtual machines **(VMs)** are software-based emulations of physical computers. They allow you to run multiple operating systems on a single physical machine, enabling users to perform various tasks without needing separate hardware for each system.

Uses of Virtual Machines:

1) **Development and Testing:** **Developers can create isolated environments to test applications without affecting their main system.**
2) **Server Consolidation:** **Businesses can run multiple servers on a single physical machine, reducing hardware costs.**
3) **Training and Education:** **Used in training environments where users can practice skills on different operating systems without needing separate devices.**
4) **Disaster Recovery:** **VMs can be easily backed up and restored, making them useful for disaster recovery plans.**

Digital Assistants

17) Digital Assistants: Digital assistants are software programs that use artificial intelligence (AI) to help users perform tasks, answer questions, and manage information through voice or text commands. They are designed to make everyday tasks easier and more efficient.

Popular Digital Assistants:

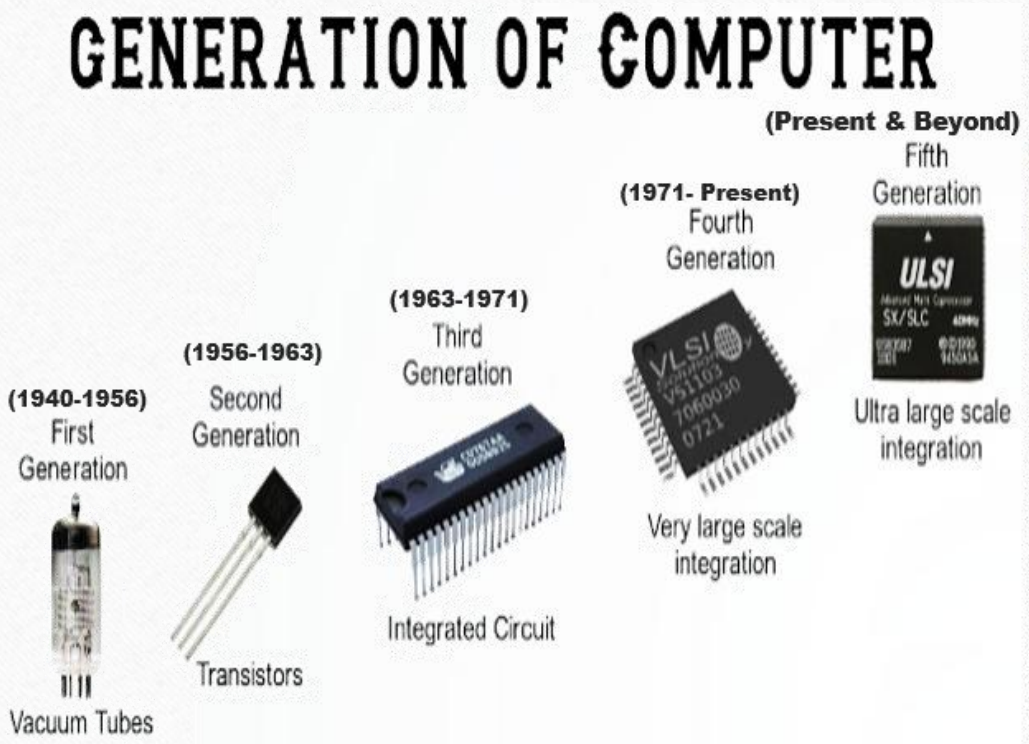
1) **Siri:** **Apple's digital assistant, available on iPhones, iPads, and Macs.**
2) **Google Assistant:** **Google's assistant, available on Android devices and Google Home products.**
3) **Alexa:** **Amazon's assistant, primarily used in Echo devices and other smart home products.**
4) **Cortana:** **Microsoft's assistant, integrated into Windows computers and other Microsoft services.**

Standards Organizations

- Institute of Electrical and Electronics Engineering
  - Standards for electronic and computing engineering
- International Telecommunications Union
  - Interoperability of telecommunications systems
- American National Standards Institute
- British Standard Institute
- Comite European de Normalisation
- International Organization for Standardization

List of Name Generation of Computers Systems

1. First Generation (1940-1956)
2. Second Generation (1956-1963)
3. Third Generation (1964-1971)
4. Fourth Generation (1971-Present)
5. Fifth Generation (Present and Beyond)



First Generation (1940-1956) - Vacuum Tubes

- Historical Development – First Generation
  - Electronic Numerical Integrator and Computer (1946)
    - 17468 Vacuum tubes (control flow of electrons in electrical systems)
    - 1800 Square feet
    - 30 Tons
    - 1000 bits (20 10-digit Decimal Nos) punched cards.
  - John Mauchly (1907-1980)
  - J. Presper Eckert (1929 – 1995)
  - WWII trajectories of ballistic armaments

First Generation (1940-1956) - Vacuum Tubes

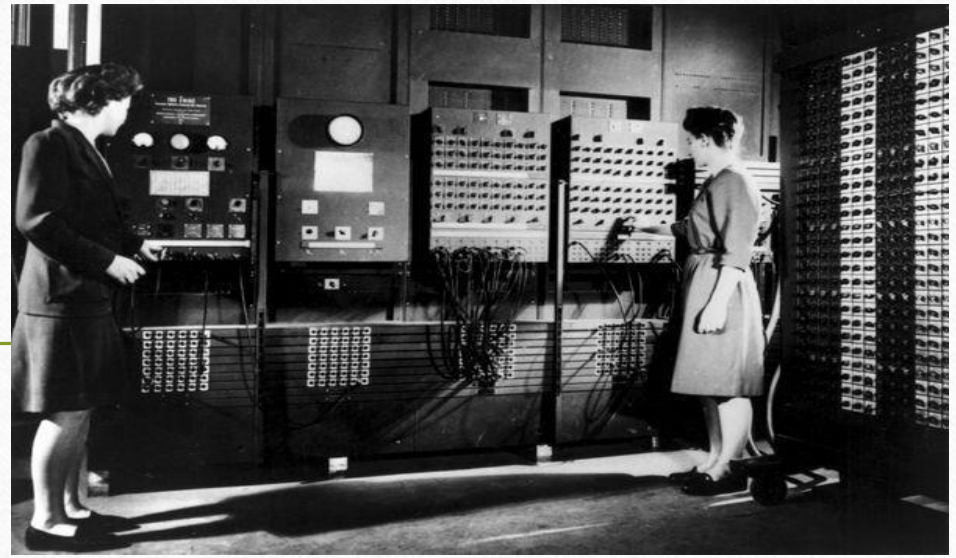
The main features of the first generation are:

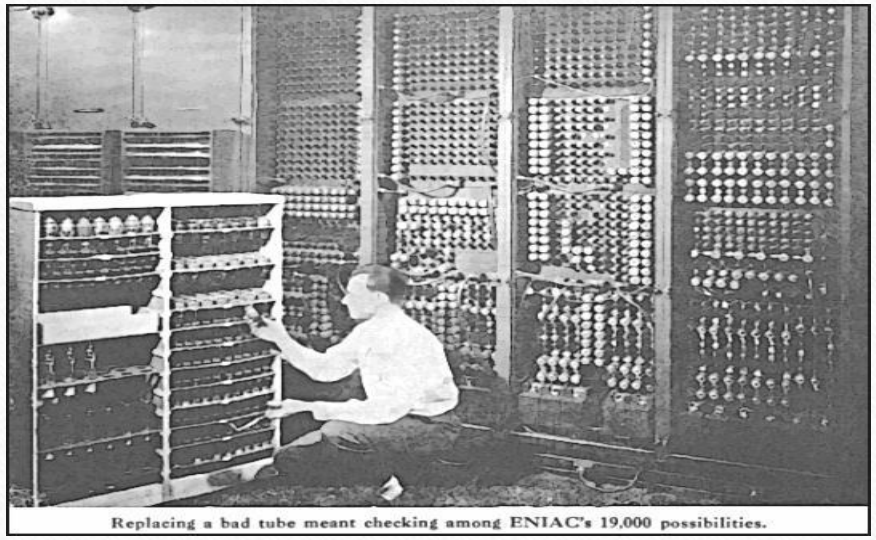
- Vacuum tube technology, unreliable, supported machine language only, very costly, generated a lot of heat, slow input and output devices, huge size, need for A.C., non-portable, consumed a lot of electricity.
- **Some computers of this generation were:**

ENIAC, EDVAC, UNIVAC, IBM-701, IBM-650.

Introduction

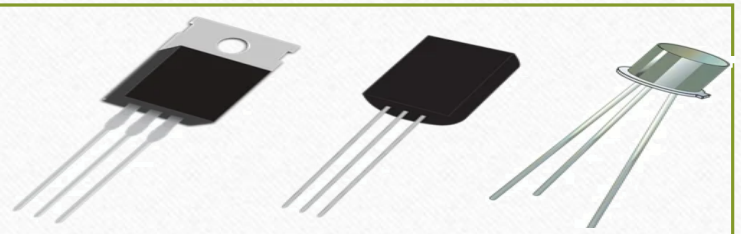
ENIAC lost one vacuum tube roughly every day or two. With almost 18,000 tubes, locating and replacing the failed one was challenging. Over time, however, the maintenance team developed the skill to fix a problem in just 15 minutes.





Replacing a bad tube meant checking among ENIAC's 19,000 possibilities.

ENIAC programmers Frances Bilas (later Frances Spence) and Betty Jean Jennings (later Jean Bartik) stand at its main control panels. Both held degrees in mathematics. Bilas operated the Moore School's Differential Analyzer before joining the ENIAC project.

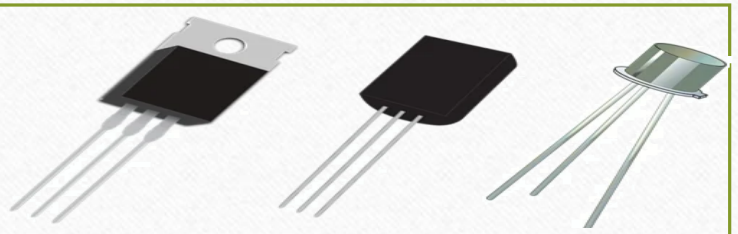


Second Generation (1956-1963) – Transistors

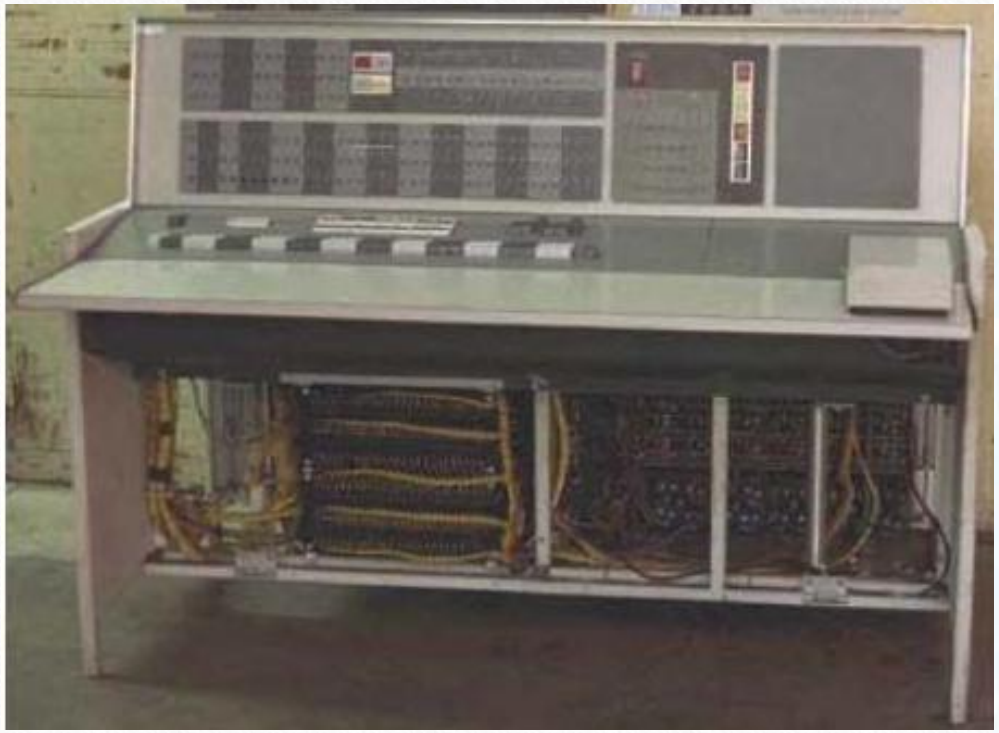
- The main features of the second generation are: Use of transistors, reliable in comparison to first generation computers, smaller size, generated less heat, consumed less electricity, faster, still very costly, A.C. needed, supported machine and assembly languages.

➢ Some computers of this generation were:

IBM 1620, IBM 7094, CDC 1604, CDC 3600, UNIVAC 1108.



Second Generation (1956-1963) – Transistors



Third Generation (1964-1971) - Integrated Circuits

- The main features of the third generation are:

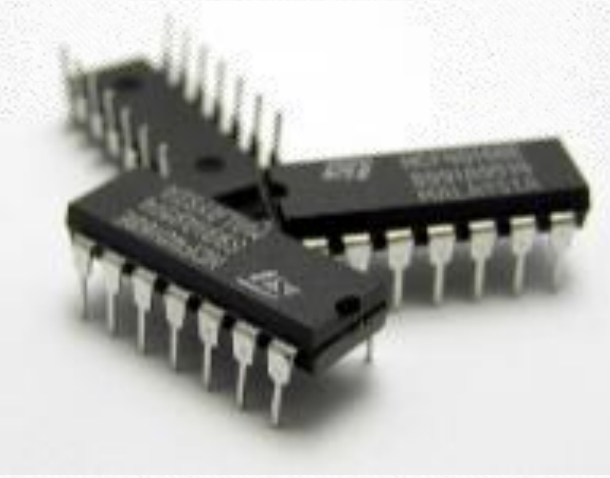
IC used, more reliable in comparison to previous two generations, smaller size, generated less heat, faster, lesser maintenance, still costly, A.C. needed, consumed lesser electricity, supported high-level language.

Some computers of this generation were:

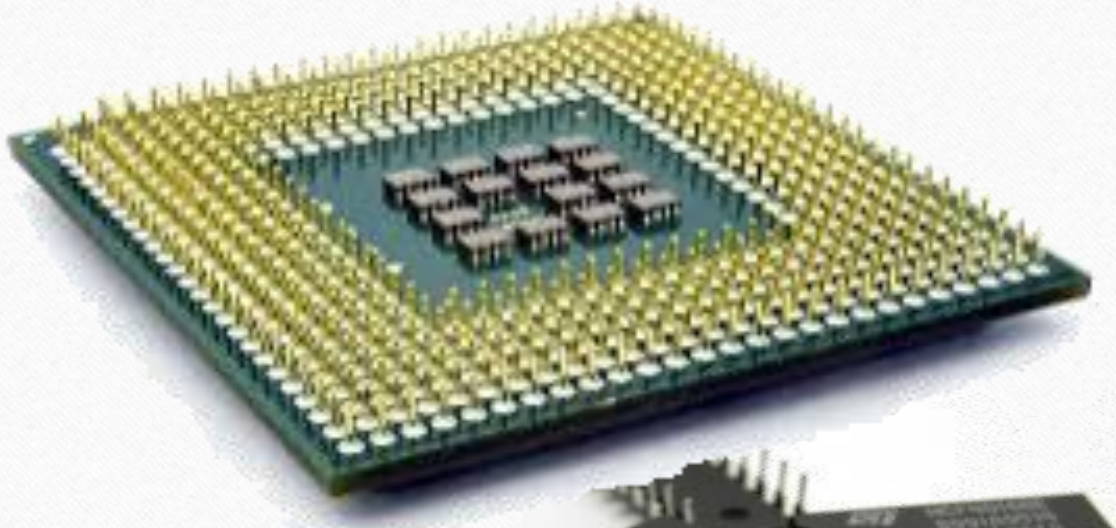
IBM-360 series, Honeywell-6000 series,

PDP (Personal Data Processor), IBM-370/168,

TDC-316.



Third Generation (1964-1971) - Integrated Circuits



Fourth Generation (1971-Present) – Microprocessors

- The main features of the fourth generation are: VLSI technology used, very cheap, portable and reliable, use of PCs, very small size, pipeline processing, no A.C. needed, concept of internet introduced, great developments in networks, computers became easily available.

Some computers of this generation were:

- **DEC 10, STAR 1000, PDP 11, CRAY-1 (Super Computer), CRAY-X-MP (Super Computer).**

Fourth Generation (1971-Present) – Microprocessors

Fifth Generation (Present and Beyond)

Artificial Intelligence and Quantum Computing

- AI refers to the simulation of human intelligence in machines that are programmed to think, learn, and make decisions.

Key Features:

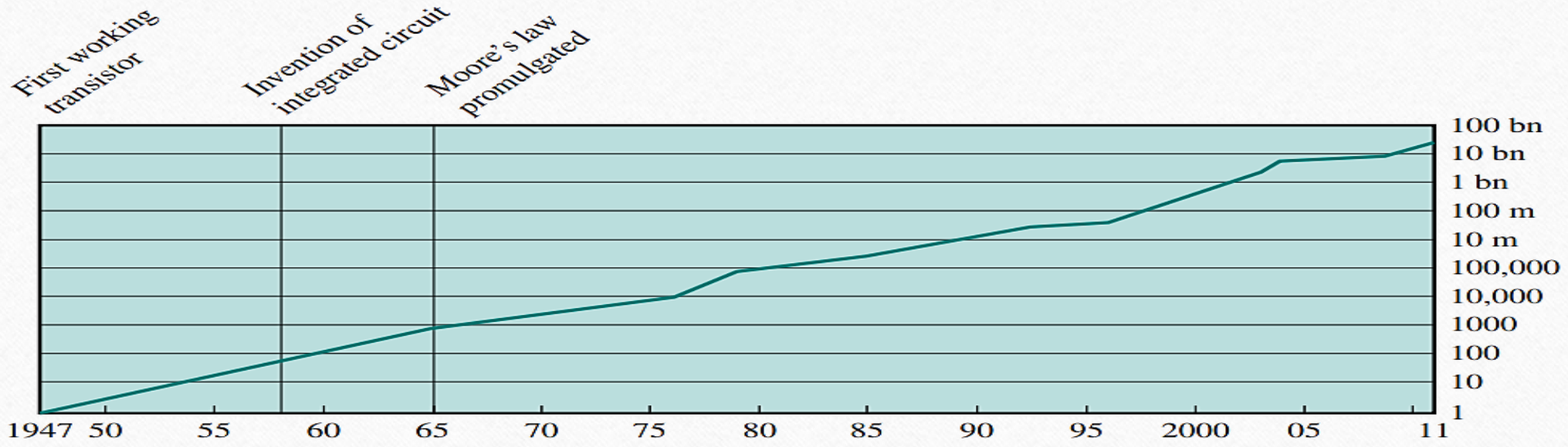
- **Machine Learning:** Systems learn and improve from experience without explicit programming.
- **Natural Language Processing (NLP):** Enables machines to understand and respond to human language (e.g., voice assistants like Siri).
- **Expert Systems:** AI systems mimic the decision-making ability of human experts in specific fields.
- **Robotics:** Use of AI in developing autonomous machines capable of performing complex tasks.

Fifth Generation (Present and Beyond)

Artificial Intelligence and Quantum Computing

Transistor Count on Integrated Circuits

Generation	Approximate Dates	Technology	Typical Speed (operations per second)
1	1946–1957	Vacuum tube	40,000
2	1958–1964	Transistor	200,000
3	1965–1971	Small- and medium-scale integration	1,000,000
4	1972–1977	Large-scale integration	10,000,000
5	1978–1991	Very-large-scale integration	100,000,000
6	1991–	Ultra-large-scale integration	1,000,000,000



Evolution of Intel Microprocessor

(a) 1970s Processors

	4004	8008	8080	8086	8088
Introduced	1971	1972	1974	1978	1979
Clock speeds	108 kHz	108 kHz	2 MHz	5 MHz, 8 MHz, 10 MHz	5 MHz, 8 MHz
Bus width	4 bits	8 bits	8 bits	16 bits	8 bits
Number of transistors	2300	3500	6000	29,000	29,000
Feature size (μm)	10		6	3	6
Addressable memory	640 Bytes	16 kB	64 kB	1 MB	1 MB

(b) 1980s Processors

	80286	386TM DX	386TM SX	486TM DX CPU
Introduced	1982	1985	1988	1989
Clock speeds	6 MHz–12.5 MHz	16 MHz–33 MHz	16 MHz–33 MHz	25 MHz–50 MHz
Bus width	16 bits	32 bits	16 bits	32 bits
Number of transistors	134,000	275,000	275,000	1.2 million
Feature size (μm)	1.5	1	1	0.8–1
Addressable memory	16 MB	4 GB	16 MB	4 GB
Virtual memory	1 GB	64 TB	64 TB	64 TB
Cache	—	—	—	8 kB

Evolution of Intel Microprocessor

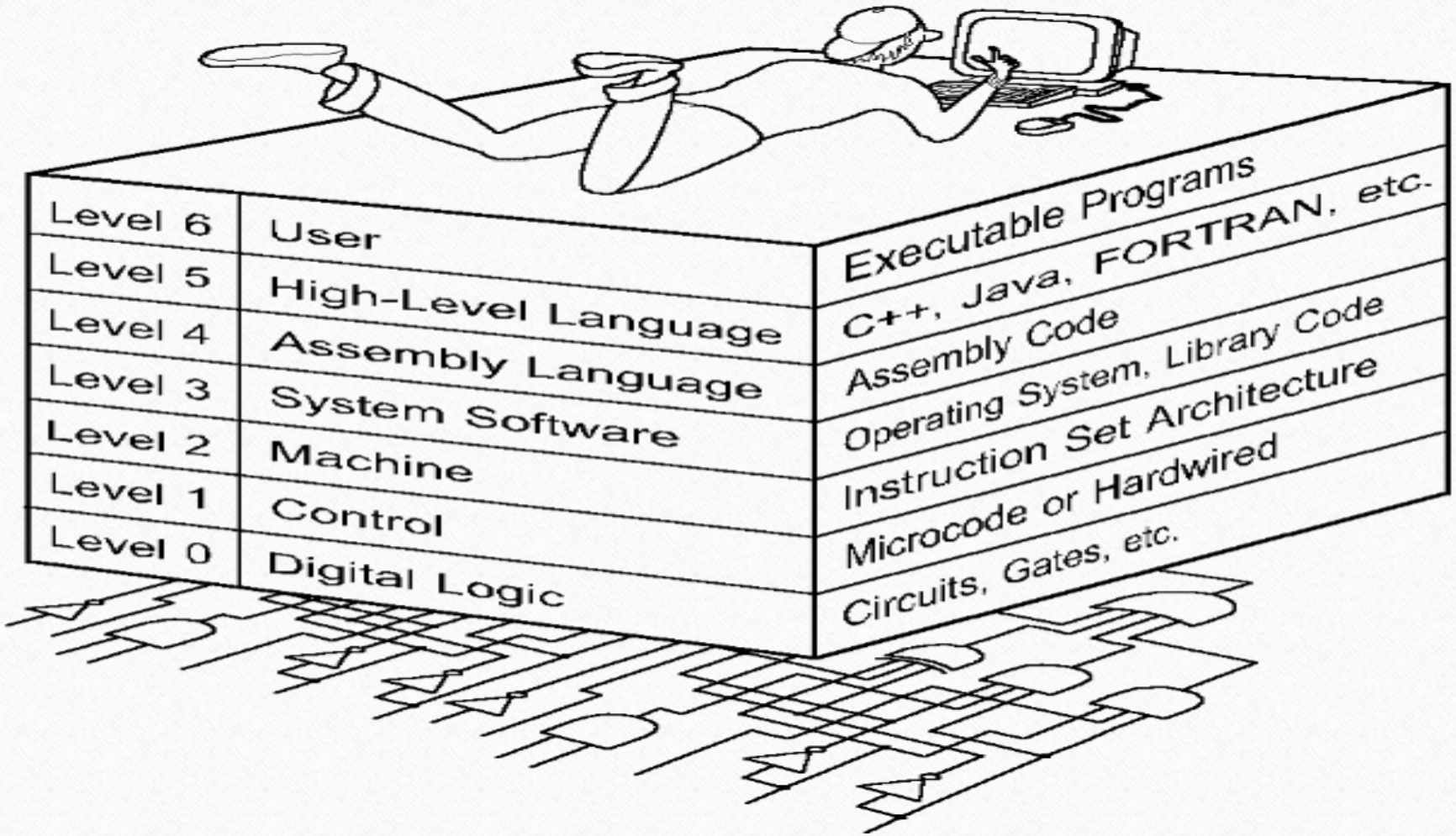
(c) 1990s Processors

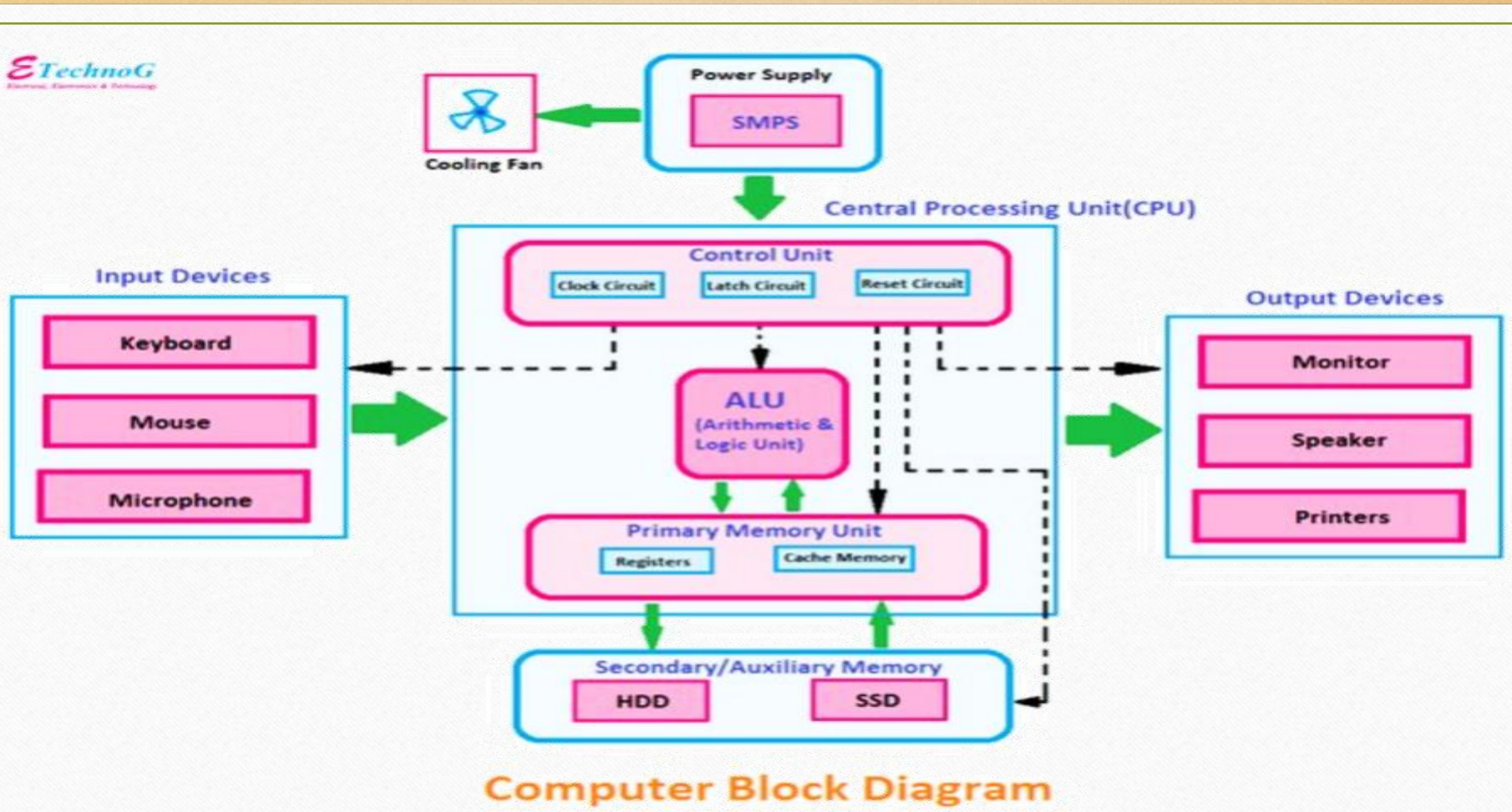
	486TM SX	Pentium	Pentium Pro	Pentium II
Introduced	1991	1993	1995	1997
Clock speeds	16 MHz–33 MHz	60 MHz–166 MHz,	150 MHz–200 MHz	200 MHz–300 MHz
Bus width	32 bits	32 bits	64 bits	64 bits
Number of transistors	1.185 million	3.1 million	5.5 million	7.5 million
Feature size (μm)	1	0.8	0.6	0.35
Addressable memory	4 GB	4 GB	64 GB	64 GB
Virtual memory	64 TB	64 TB	64 TB	64 TB
Cache	8 kB	8 kB	512 kB L1 and 1 MB L2	512 kB L2

(d) Recent Processors

	Pentium III	Pentium 4	Core 2 Duo	Core i7 EE 990
Introduced	1999	2000	2006	2011
Clock speeds	450–660 MHz	1.3–1.8 GHz	1.06–1.2 GHz	3.5 GHz
Bus width	64 bits	64 bits	64 bits	64 bits
Number of transistors	9.5 million	42 million	167 million	1170 million
Feature size (nm)	250	180	65	32
Addressable memory	64 GB	64 GB	64 GB	64 GB
Virtual memory	64 TB	64 TB	64 TB	64 TB
Cache	512 kB L2	256 kB L2	2 MB L2	1.5 MB L2/12 MB L3

Computer Level Hierarchy





Computer Block Diagram

Functions of the Components

- Hardware (Power Supply, Motherboard, I/O)
- CPU (Central Processing Unit)
- Control Unit (CU)
- Arithmetic Logic Unit (ALU)
- Bus System

Functions of the Components:

- **Hardware:** The Physical Electronics components of Computer System That we Can Touch & Feel are known as Hardware. Its operates on electrical signals.
- Examples of Computer Hardware Are CPU, Memory, input/output devices and storage, etc.
- **CPU (Central Processing Unit):** The brain of the computer, responsible for executing instructions, performing calculations, and controlling other components. As the brain of the computer, the CPU executes instructions, performs calculations, and manages data manipulation. It consists of: **Control Unit (CU), Arithmetic Logic Unit (ALU)**

CPU (Central Processing Unit)

- **Control Unit (CU):** The Control Unit coordinates and manages the flow of data and instructions within the computer. It fetches instructions from memory, decodes them, and directs the CPU and other components to execute the required operations.
- **Arithmetic Logic Unit (ALU):** Performs arithmetic and logical operations. ALU handles arithmetic and logical operations, while the CU manages instructions and coordination.

Bus System

- **Bus System:** A bus consists of parallel electrical wire lines. It is used to transfer data between different components of computer system. One line can transfer one bit at a time

Types Of Busses

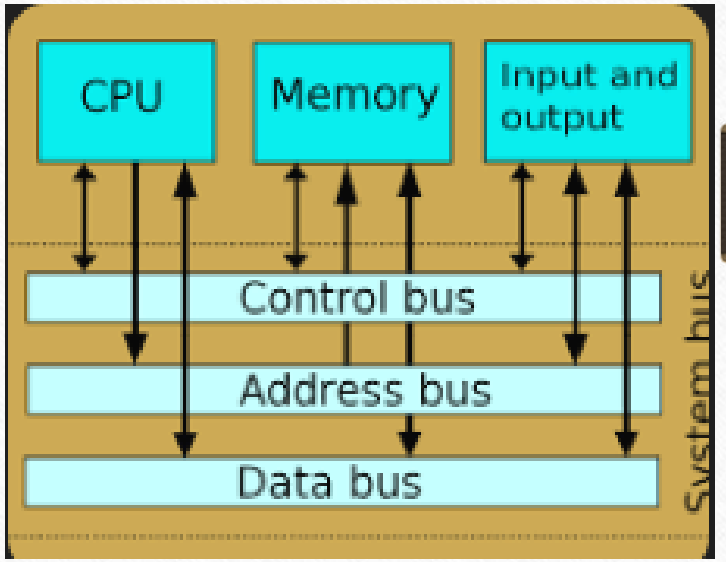
1) Data Bus **2) System Bus**

3) Address Bus **4) Control Bus**

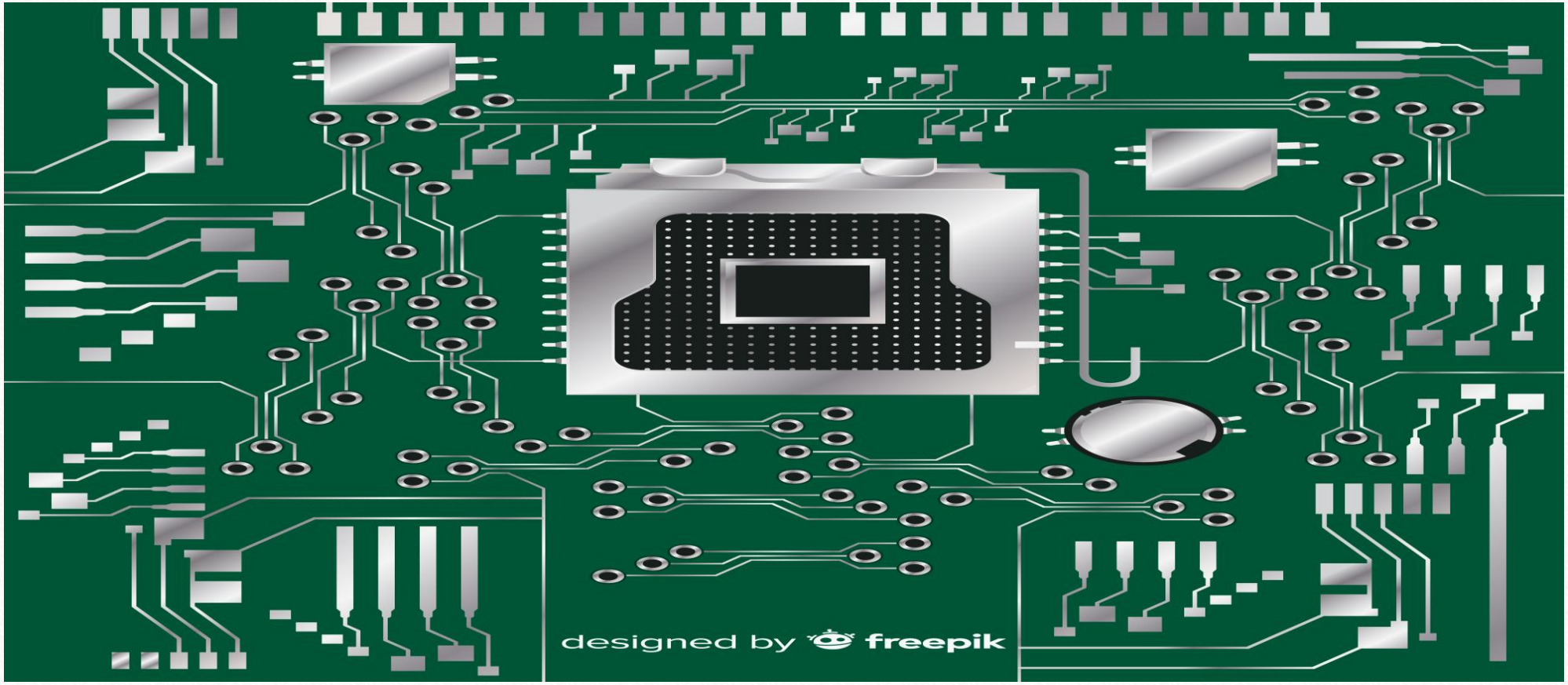
5) Expansion Bus **6) Memory Bus**

7) Video Bus **8)USB (Universal Serial Bus)**

9) Serial Bus **10)Parallel Bus**



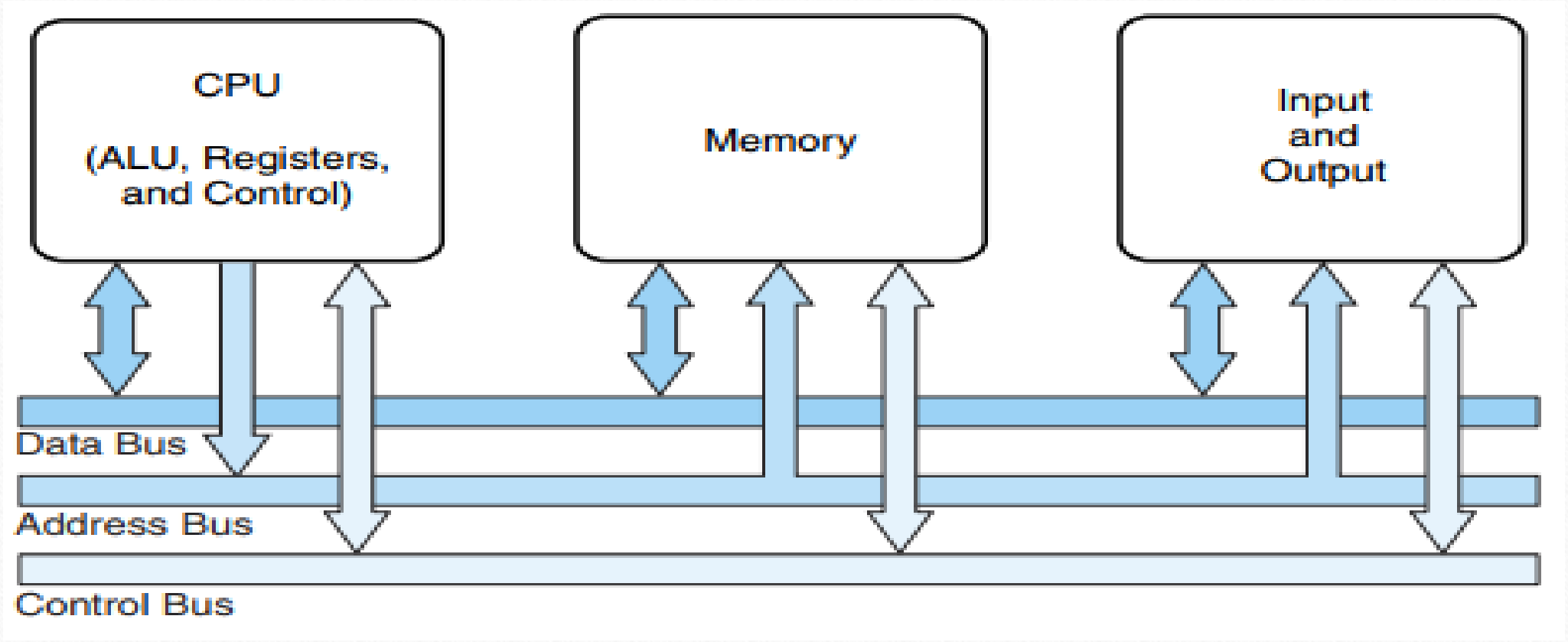
View Bus System in (PCB)



System Bus

- **System Bus:** The system bus is used to connect main components of computer system such as cpu & main memory. System Buses are the part of main mother board.

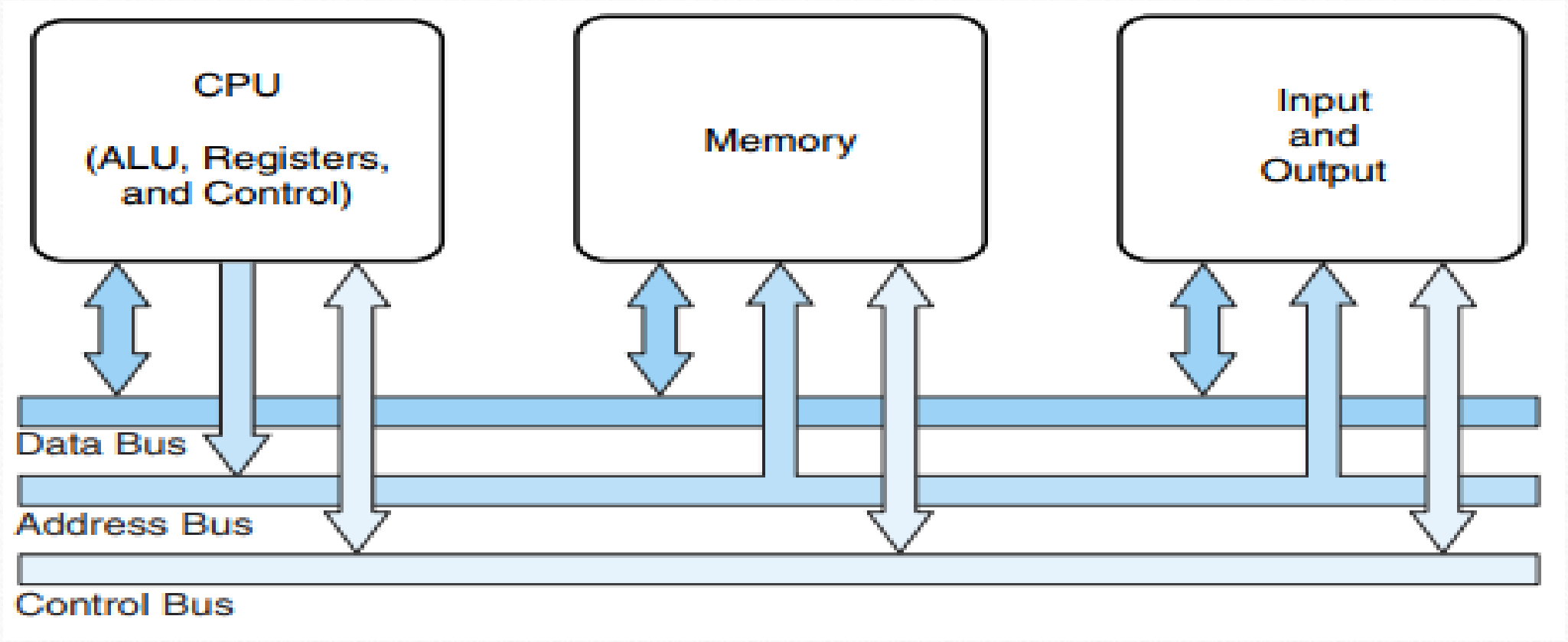
Types Of System Bus



Types Of System Bus

- **Data Bus:** The data bus is used to transfer data between different components of computer systems.
- **Address Bus:** Many Components are connected with each other through buses. Each component has a unique id. This id is called address of that component. These components use address bus to communicate with each other. It unidirectional as it carries address from source to destination.
- **Control Bus:** Control bus is used to transmit different commands or signals from one component to another.

Types Of System Bus



Types Of System Bus

- **Expansion Bus:** The expansion bus is used to connect cpu with external devices such as mouse,keyboard, printer, scanner & modems etc.
- **Memory Bus:** Special bus used to connect the CPU directly to the main memory (RAM). Characteristics: Bandwidth and speed can significantly affect system performance.
- **Video Bus:** Specifically designed for graphics data transfer.

Example: AGP, used to connect video cards to a system for improved graphics performance.

- **USB Bus:** Transfers data one bit at a time over a single channel.
- **Examples**: USB, SATA (Serial ATA), and RS-232.

Types Of System Bus

- **Parallel Bus:** Transfers multiple bits simultaneously across multiple channels.
- Examples: Older connections like the PCI bus and various printer interfaces.


Thank
You