Computer Organization

What is Computer

- The term computer has been borrowed from compute that means to calculate.

- Computer is an electronic device which is capable of receiving information (data) in a particular form and of performing a sequence of operations in accordance with a predetermined but variable set of procedural instructions (program) to produce a result in the form of information or signals.

Computer Organization:

Design of components and functional blocks using which computer systems are built.

Analogy:Civil Engineer’s task during building construction(cement, bricks, iron rods, and other building materials).

Computer Architecture:

How to integrate these components to build a computer system to achieve a desired level of performance.

Analogy:Architect’s task during the planning of building, layout, floorplan.

History of Computers

- Charles Babbage, an English mechanical engineer and polymath, originated the concept of a programmable computer.

First generation computers (1940-1954)

- The first generation computers used vacuum tubes for circuitry and magnetic drums for memory.
- They were often enormous and taking up entire room.
- First generation computers relied on machine language.
- They were very expensive to operate and in addition to using a great deal of electricity, generated a lot of heat, which was often the cause of malfunctions.
- The UNIVAC and ENIAC computers are examples of first-generation computing devices.

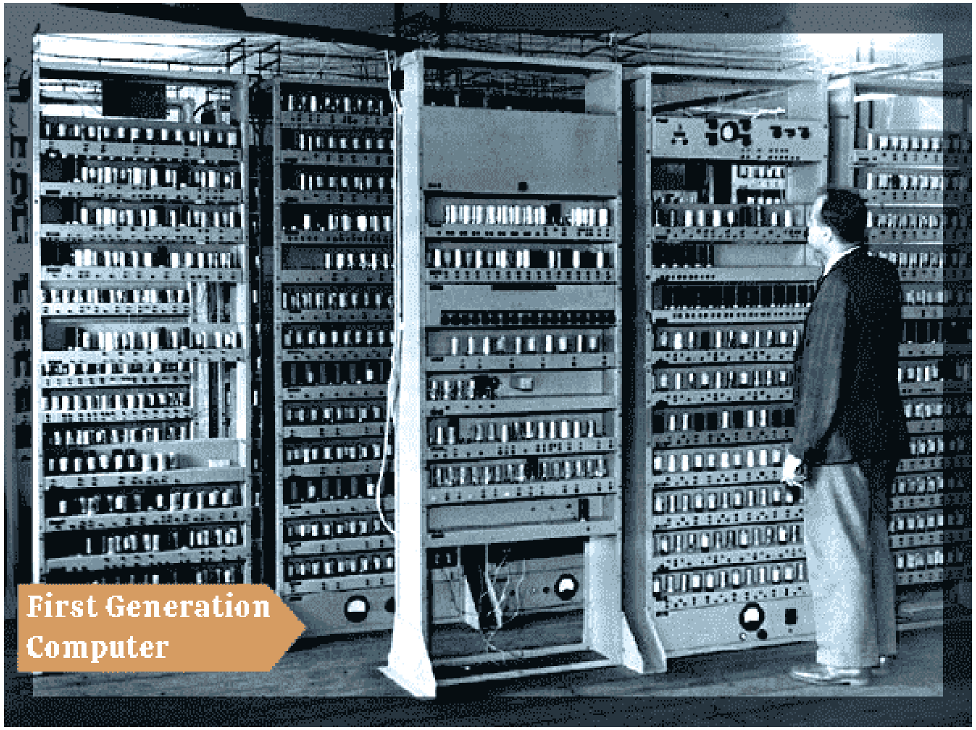
Note: Vacuum tube is a device that controls electric current between electrodes in an evacuated container in a tube.

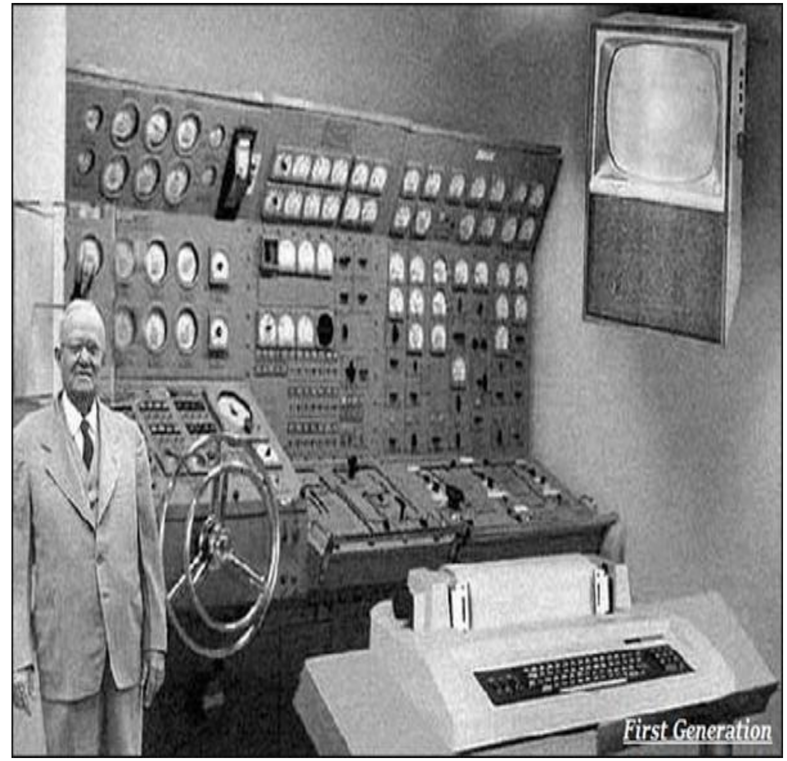
Advantages

- Vacuum tubes were the only electronic component available during those days.
  • Vacuum tube technology made possible to make electronic digital computers.
  • These computers could calculate **data in millisecond.**

Disadvantages

- The computers were very large in size.
  - They consumed a large amount of **energy.**
  - Non-portable.
  - Limited commercial use.
  - Very **slow speed.**
  - Used **machine language only.**
  - Used **magnetic drums** which provide very less **data storage.**


First Generation
Computer


First Generation

Second generation computers (1955-1964

- Transistors replaced vacuum tubes and ushered in the second generation of computers
- Second-generation computers moved from cryptic binary machine language to symbolic.
- High-level programming languages were also being developed at this time, such as early versions of COBOL and FORTRAN.
- These were also the first computers that stored their instructions in their memory.

Advantages :

- Smaller in size as compared to the first generation computers.
  • Used less energy and were not heated.
  • Better speed and could calculate data in microseconds
  • Used faster peripherals like **tape drives, magnetic disks,** printer etc.
  • Used **Assembly language instead of** machine language.

Disadvantages

- Cooling system was required
- Costly and not versatile
- Constant maintenance was required
- Only used for specific purposes


Third generation computers (1965-1974)

- The development of the integrated circuit was the hallmark of the third generation of computers.
- Transistors were miniaturized and placed on siliconchips, called semiconductors.
- Instead of punched cards and printouts, users interacted with third generation computers through keyboards and monitors and interfaced with an operating system.
- Allowed the device to run many different applications at one time.

An integrated circuit (IC), sometimes called a chip or microchip, is a semiconductor wafer on which thousands or millions of tiny resistors, capacitors, and transistors are fabricated.

Advantages

- Smaller in size as compared to previous generations.
  - More reliable.
  - Used less energy.
  - Better speed and could calculate data in nanoseconds.

Disadvantages

- Air conditioning was required.
- Highly sophisticated technology required for the manufacturing of IC chips.

Fourth generation computers (1975-1984)

- The microprocessor brought the fourth generation of computers, as thousands of integrated circuits were built onto a single silicon chip.
- The Intel 4004 chip, developed in 1971, located all the components of the computer.
- From the central processing unit and memory to input/output controls—on a single chip.
- Fourth generation computers also saw the development of GUIs, the mouse and handheld devices.

The fourth generation computers started with the invention of Microprocessor. The Microprocessor contains thousands of ICs. The LSI (Large Scale Integration) circuit and VLSI (Very Large Scale Integration) circuit was designed.

Advantages :

- More powerful and reliable than previous generations.
  - Small in size
  - Fast processing power with less power consumption
  - Fan for heat discharging and thus to keep cold.
  - Cheapest among all generations
  - All types of High level languages can be used in this type of computers

Fifth generation computers (1984-1990)

- Fifth generation computing devices, based on artificial intelligence.
- Are still in development, though there are some applications, such as voice recognition.
- The use of parallel processing and superconductors is helping to make artificial intelligence a reality.
- The goal of fifth-generation computing is to develop devices that respond to natural language input and are capable of learning and self-organization.

Generation	Main Technology	Representative Systems
First (1945-54)	Vacuum tubes, relays	Machine & assembly language ENIAC, IBM-701
Second (1955-64)	Transistors, memories, I/O processors	Batch processing systems, HLL IBM-7090
Third (1965-74)	SSI and MSI integrated circuits Microprogramming	Multiprogramming / Time sharing IBM 360, Intel 8008
Fourth (1975-84)	LSI and VLSI integrated circuits	Multiprocessors Intel 8086, 8088
Fifth (1984-90)	VLSI, multiprocessor on-chip	Parallel computing, Intel 486
Sixth (1990 onwards)	ULSI, scalable architecture, post-CMOS technologies	Massively parallel processors Pentium, SUN Ultra workstations

- First Generation (1940s-1950s): Vacuum tube-based computers.

- Second Generation (1950s-1960s): Transistor-based computers, smaller and more reliable than vacuum tube computers.

- Third Generation (1960s-1970s): Integrated circuits (ICs) replaced transistors, leading to more powerful and efficient computers.

- Fourth Generation (1970s-1980s): Introduction of microprocessors, which further miniaturized and improved computer performance.

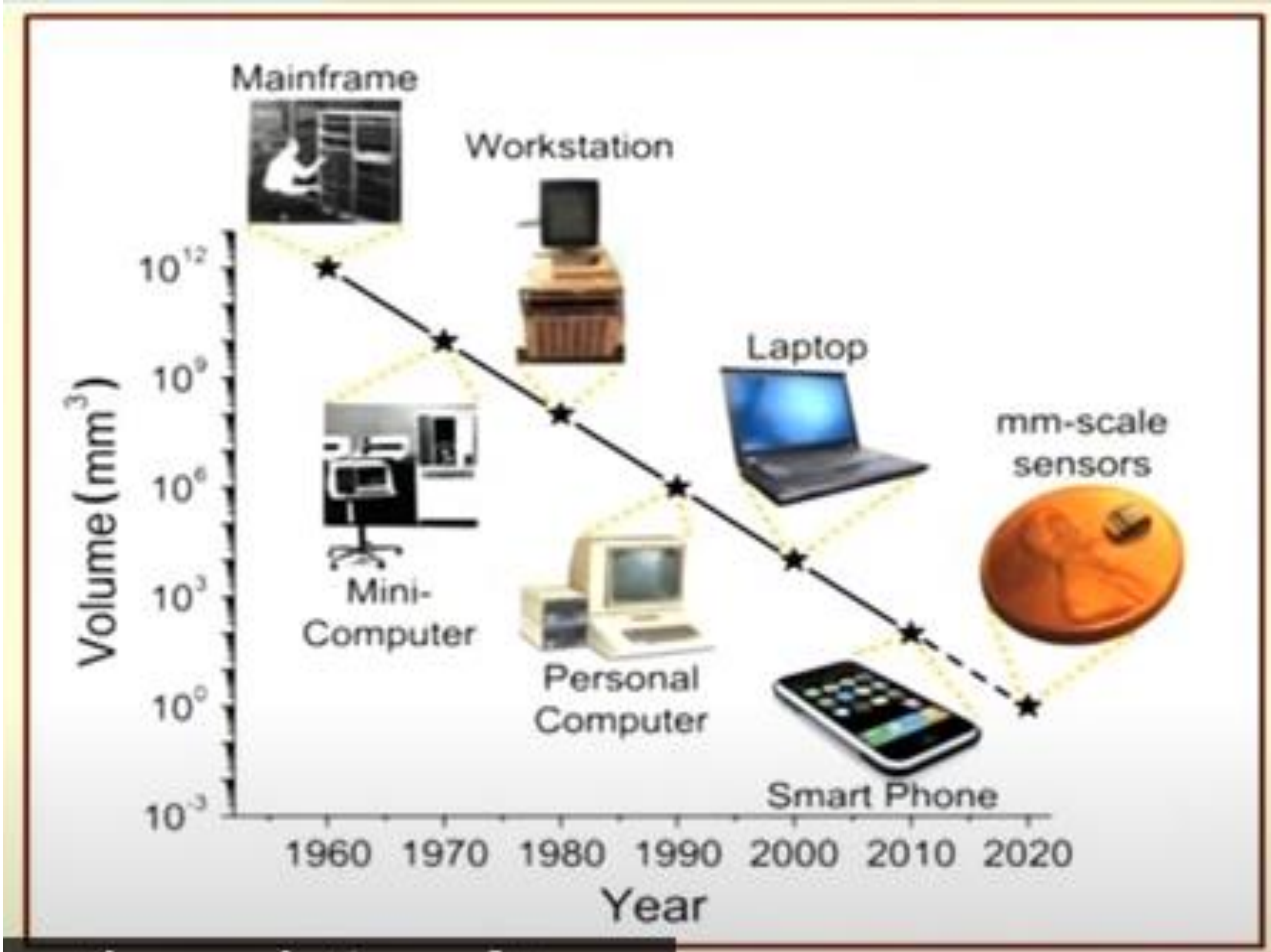
- Fifth Generation (1980s-1990s): Advancements in parallel processing, artificial intelligence, and high-level languages.

- Sixth Generation (1990s-present): Focus on parallel processing and integration of AI technologies.

- Seventh Generation (Present): Focus on cloud computing, mobile devices, and further advancements in AI and machine learning.

The generation of computer represents the broader stages of technological advancement in computer history.

while the generation of processor denotes the specific iterations or versions of a particular CPU family released by the manufacturer.

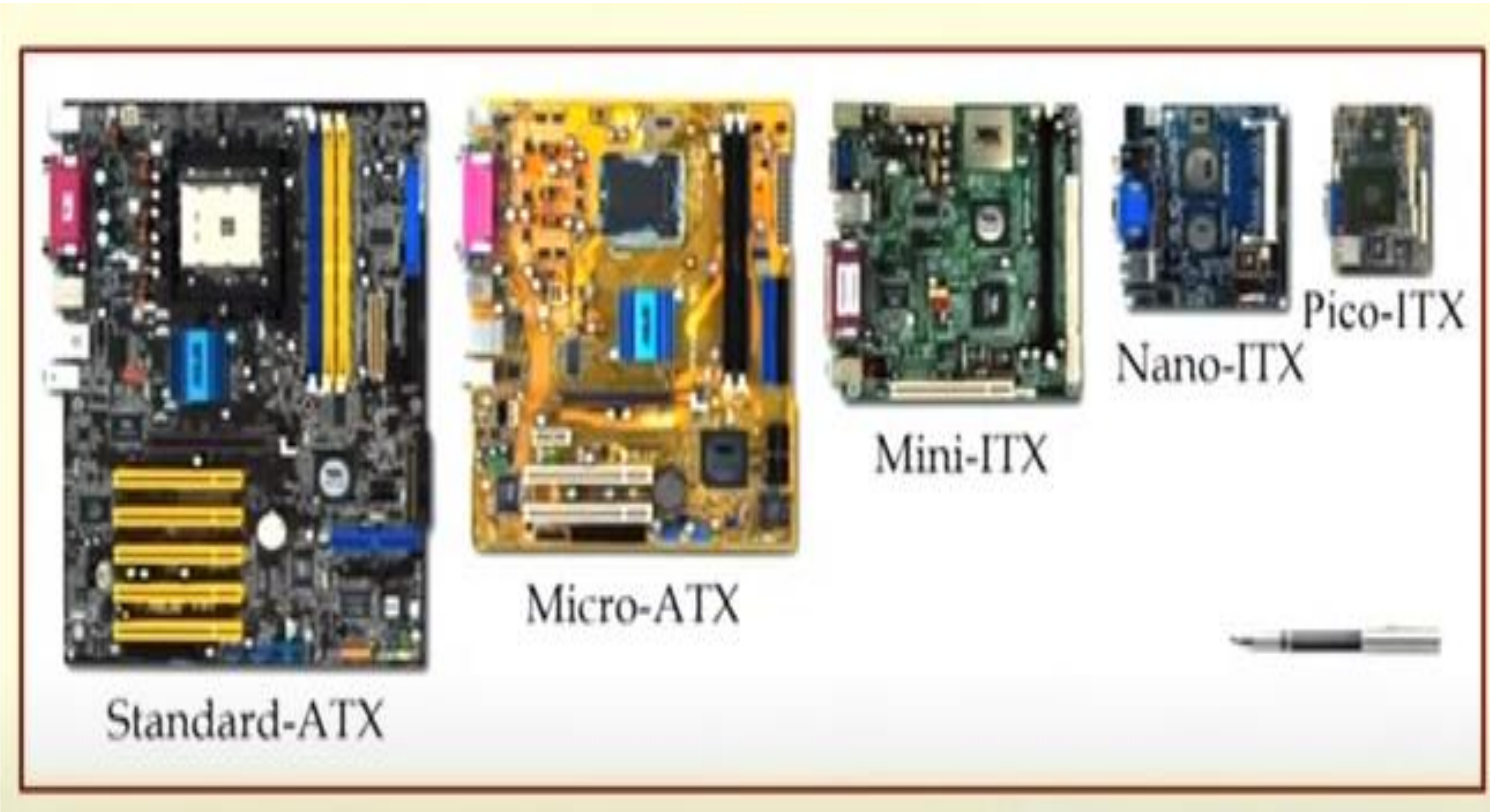


Milimeter scale sensors: These sensors are used to sense the data, process it and communicate also.

Future:

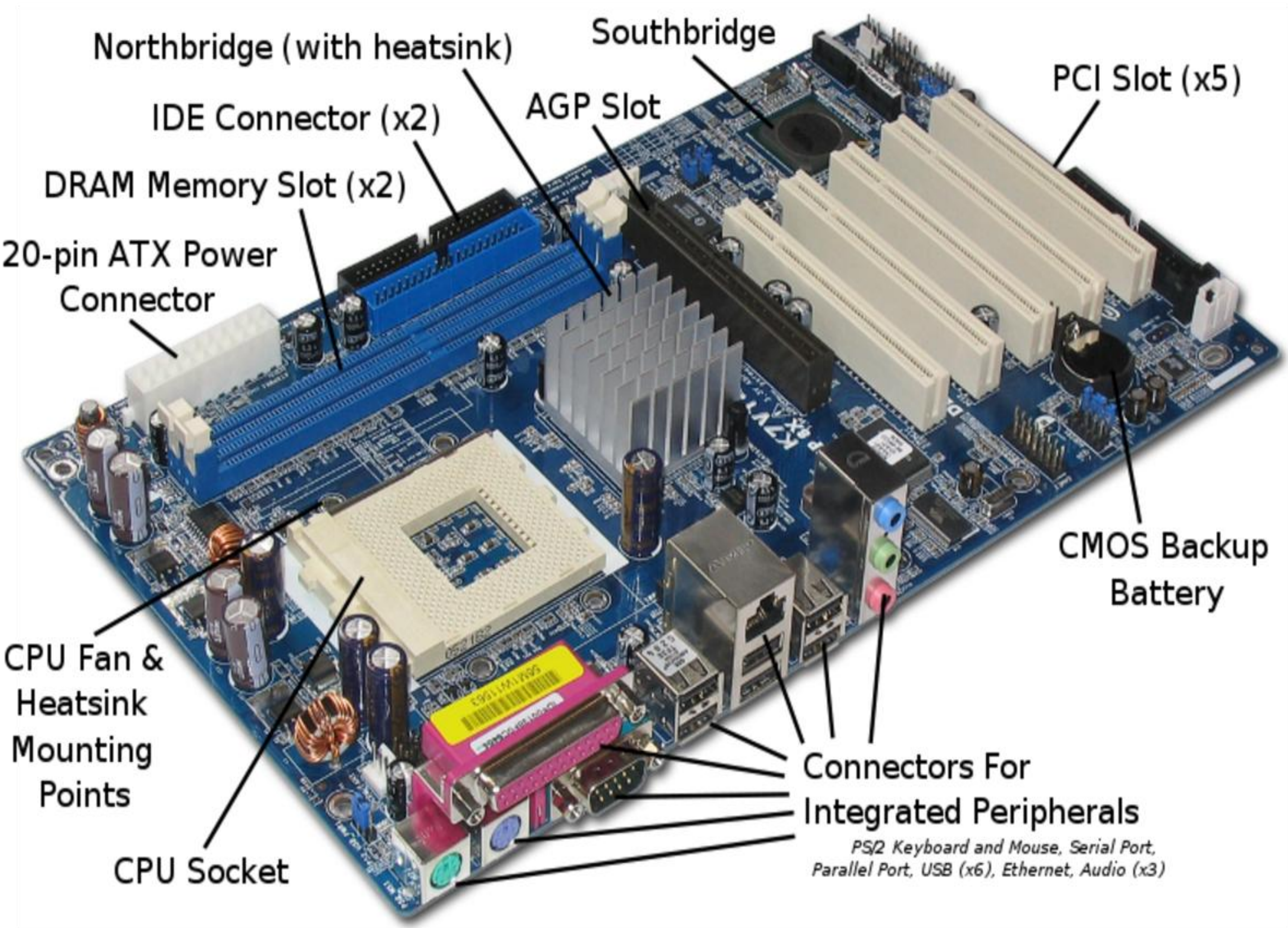
- Large scale IOT based systems.
- Wearable computing
- Intelligent Objects.

Evolution of PC form factors over the years



Today’s

- Miniaturization in feature sizes of all parts.
- Hard drive getting replaced by flash based memory devices.
- Cooling is major issue.

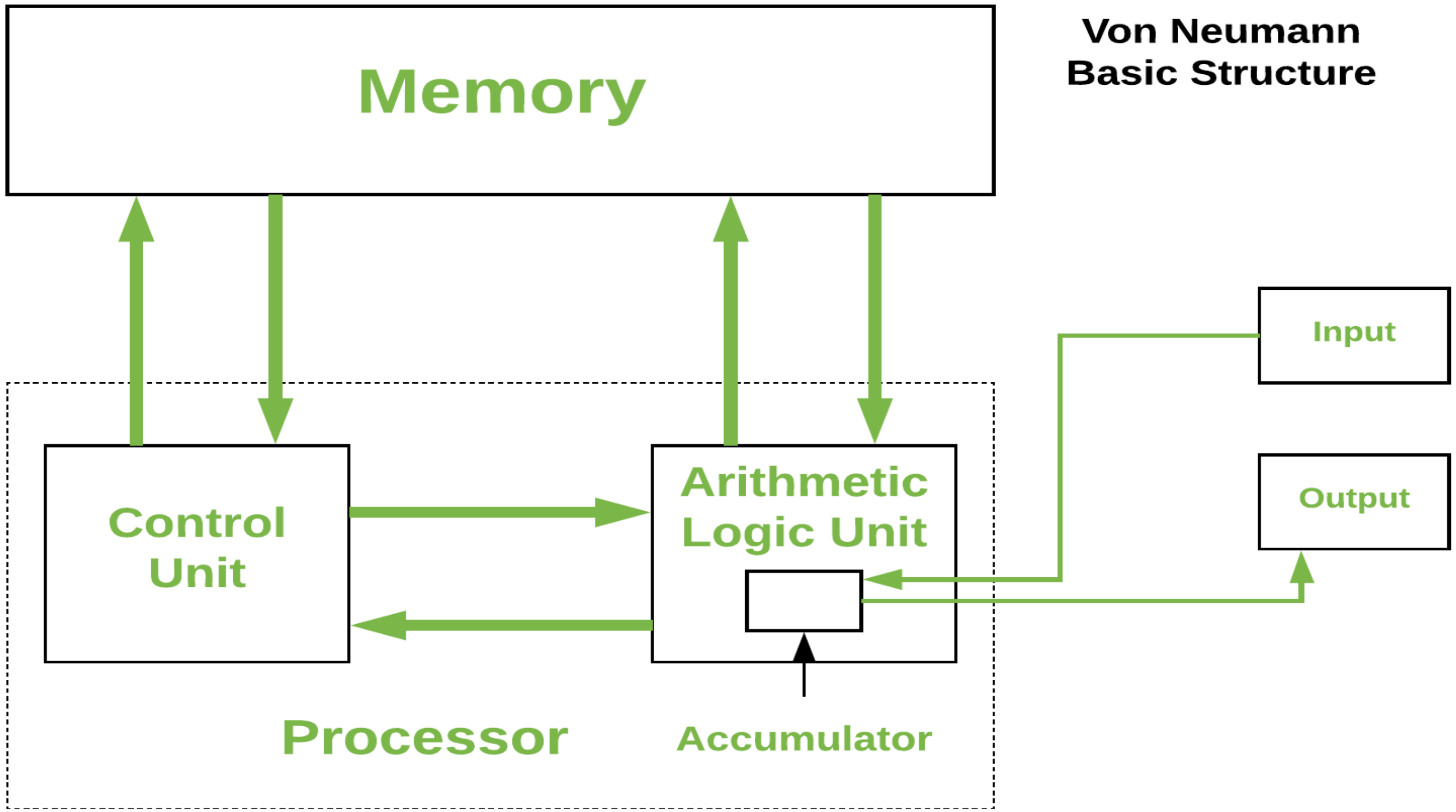

Northbridge (with heatsink)
Southbridge
PCI Slot (x5)
AGP Slot
IDE Connector (x2)
DRAM Memory Slot (x2)
20-pin ATX Power Connector
CMOS Backup Battery
CPU Fan & Heatsink Mounting Points
CPU Socket
Connectors For Integrated Peripherals
PS/2 Keyboard and Mouse, Serial Port, Parallel Port, USB (x6), Ethernet, Audio (x3)

- A PCI slot is a built-in slot on a device that allows for the attachment of various hardware components such as network cards, modems, sound cards, disk controllers and other peripherals.
- The CMOS battery powers your laptop's BIOS firmware, which is responsible for booting up your computer and configuring data flow. You can tell if your CMOS battery has died if your laptop has difficult booting up, if drivers disappear, and if your laptop's date and time are incorrect.

An Accelerated Graphics Port (AGP) is a point to point channel that is used for high-speed video output.

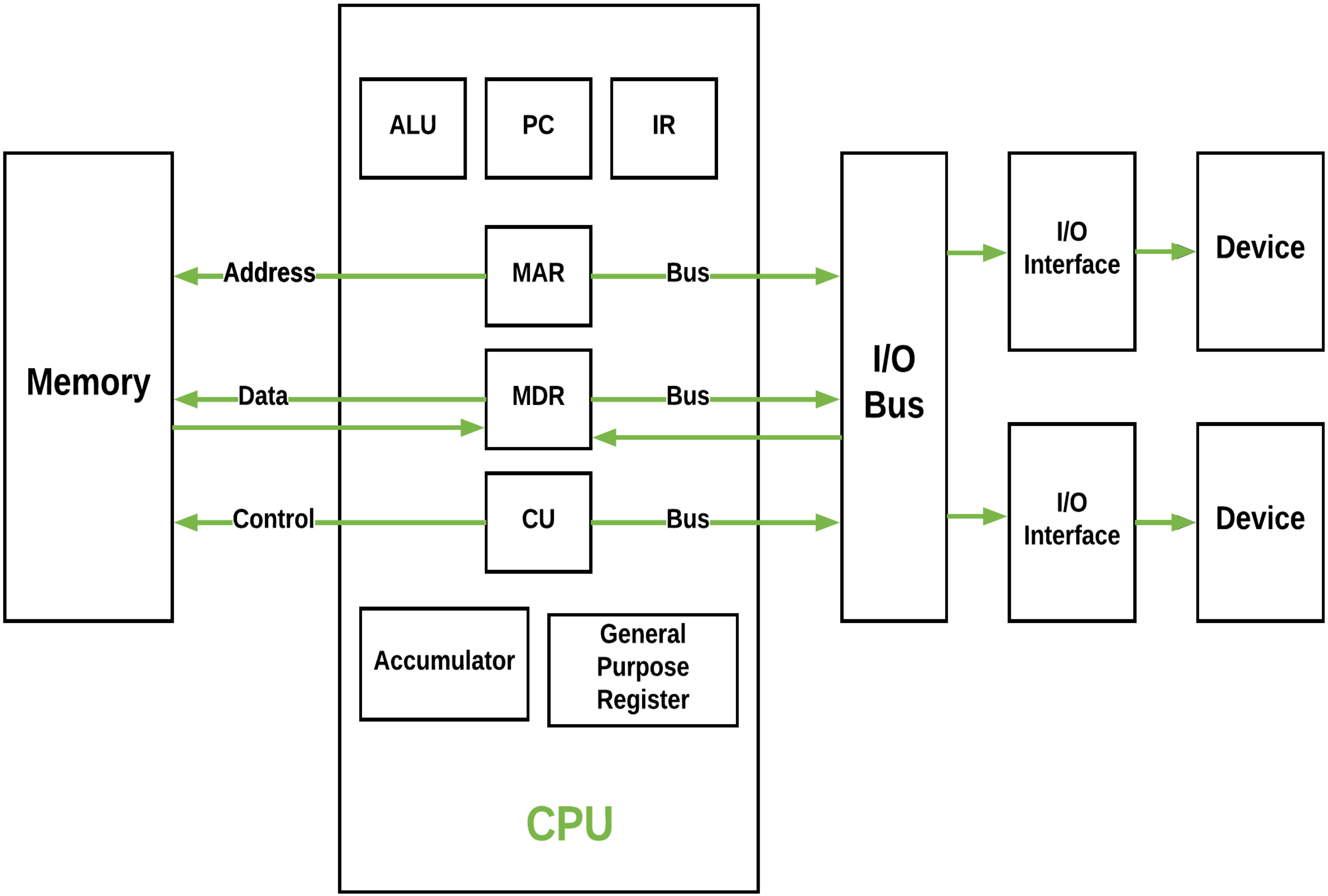
This port is used to connect graphic cards to a computer's motherboard.

Von-Neumann Architecture



- **Control Unit –**
  A control unit (CU) handles all processor control signals. It directs all input and output flow, fetches code for instructions, and controls how data moves around the system.
- **Arithmetic and Logic Unit (ALU) –**
  The arithmetic logic unit is that part of the CPU that handles all the calculations the CPU may need, e.g. Addition, Subtraction, Comparisons. It performs Logical Operations, Bit Shifting Operations, and Arithmetic operations.

Inside Architecture of Processor

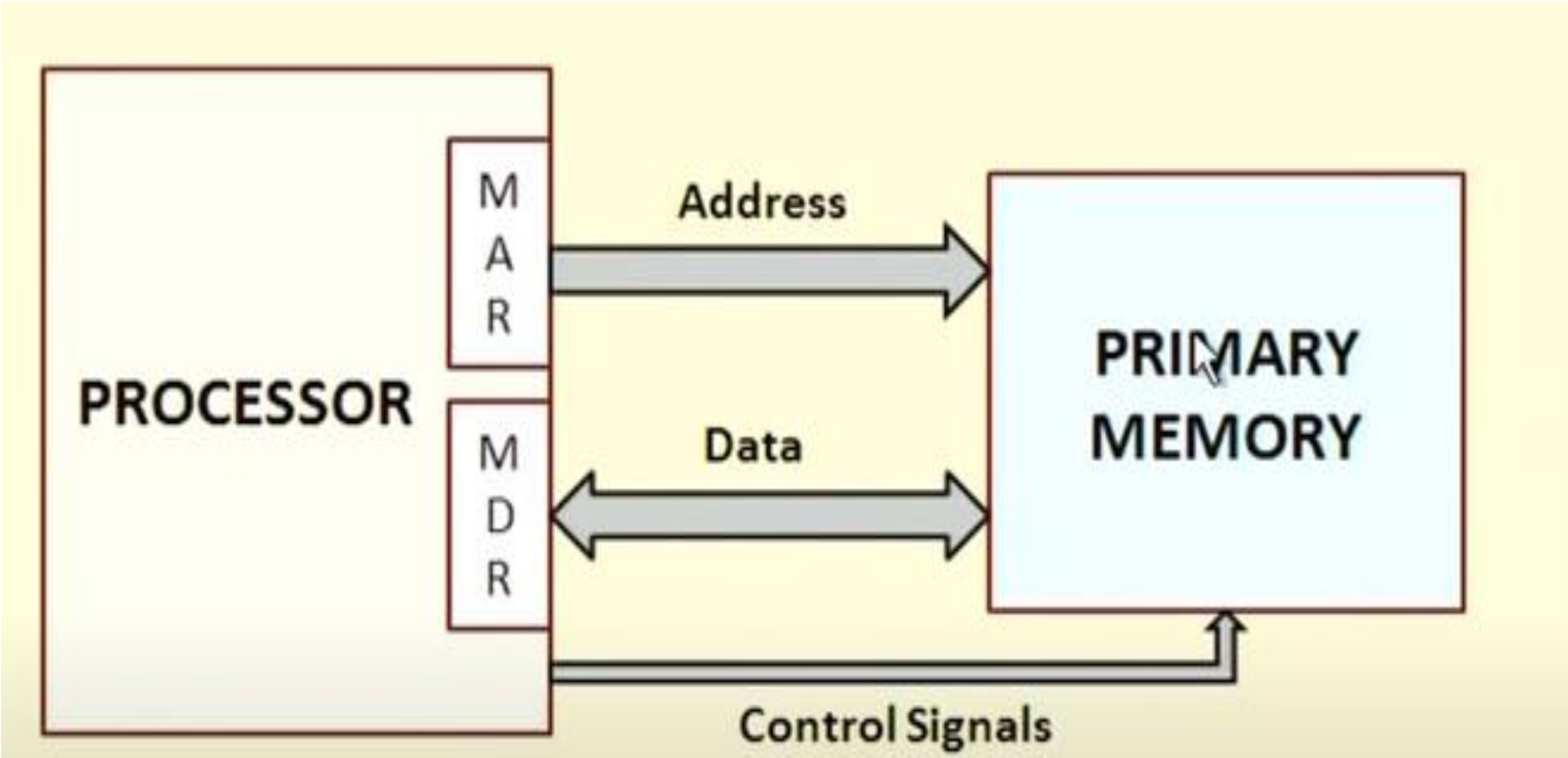


For Keeping Track of Program / Instructions

- Two special-purpose registers are used:
  - *Program Counter (PC)*: Holds the memory address of the next instruction to be executed.
    - Automatically incremented to point to the next instruction when an instruction is being executed.
  - *Instruction Register (IR)*: Temporarily holds an instruction that has been fetched from memory.
    - Need to be decoded to find out the instruction type.
    - Also contains information about the location of the data.

Main Memory Unit (Registers) –

- **Accumulator:** Stores the results of calculations made by ALU.
- **Program Counter (PC):** Keeps track of the memory location of the next instructions to be dealt with. The PC then passes this next address to Memory Address Register (MAR).
- **Memory Address Register (MAR):** It stores the memory locations of instructions that need to be fetched from memory or stored into memory.
- **Memory Data Register (MDR):** It stores instructions fetched from memory or any data that is to be transferred to, and stored in, memory.
- **Current Instruction Register (CIR):** It stores the most recently fetched instructions while it is waiting to be coded and executed.
- **Instruction Buffer Register (IBR):** The instruction that is not to be executed immediately is placed in the instruction buffer register IBR.



PROCESSOR
M
A
R
M
D
R
Address
Data
PRIMARY
MEMORY
Control Signals

- To read data from memory
  a) Load the memory address into MAR.
  b) Issue the control signal *READ*.
  c) The data read from the memory is stored into MDR.
- To write data into memory
  a) Load the memory address into MAR.
  b) Load the data to be written into MDR.
  c) Issue the control signal *WRITE*.

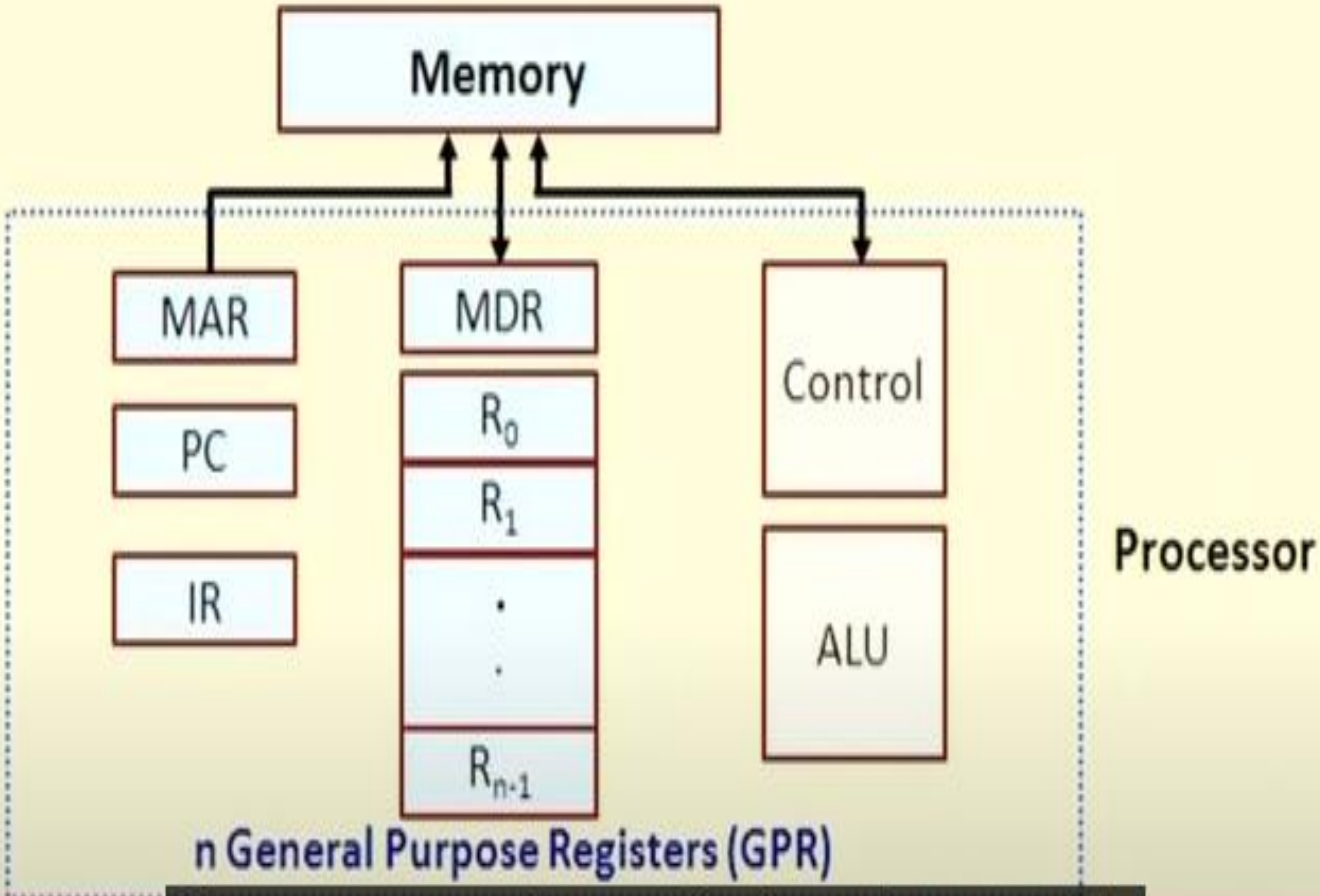
Execution of *ADD R1,LOCA*

- Assume that the instruction is stored in memory location 1000, the initial value of R1 is 50, and LOCA is 5000.
- Before the instruction is executed, PC contains 1000.
- Content of PC is transferred to MAR. MAR ← PC
- READ request is issued to memory unit.
- The instruction is fetched to MDR. MDR ← Mem[MAR]
- Content of MDR is transferred to IR. IR ← MDR
- PC is incremented to point to the next instruction PC ← PC + 4
- The instruction is decoded by the control unit.

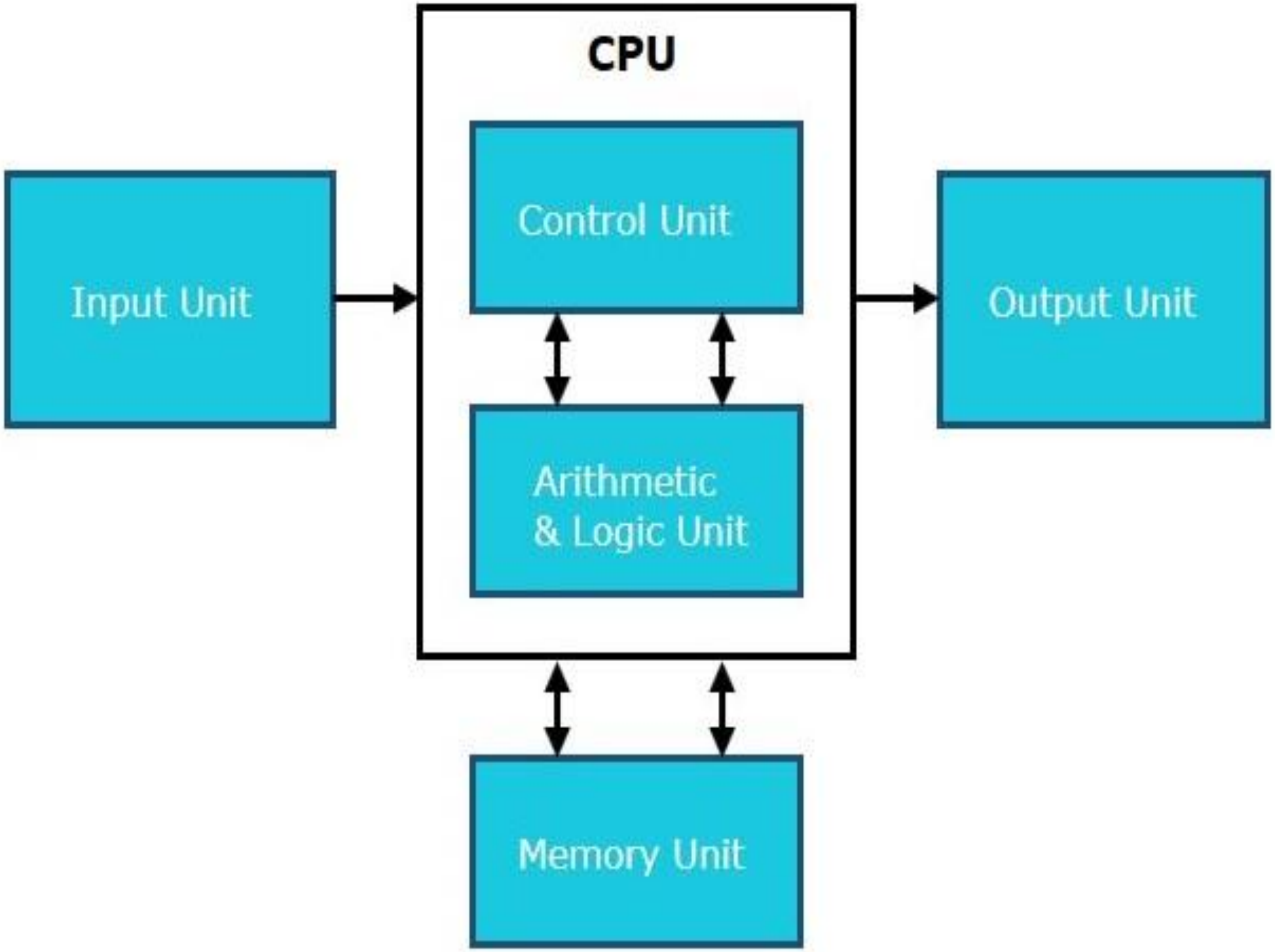
ADD R1	5000

- **Buses –** Data is transmitted from one part of a computer to another, connecting all major internal components to the CPU and memory, by the means of Buses. Types:
  - **Data Bus:** It carries data among the memory unit, the I/O devices, and the processor.
  - **Address Bus:** It carries the address of data (not the actual data) between memory and processor.
  - **Control Bus:** It carries control commands from the CPU (and status signals from other devices) in order to control and coordinate all the activities within the computer.

Architecture of the Example Processor



Computer Component



Input Unit

- This unit contains devices with the help of which we enter data into the computer. This unit creates a link between the user and the computer.

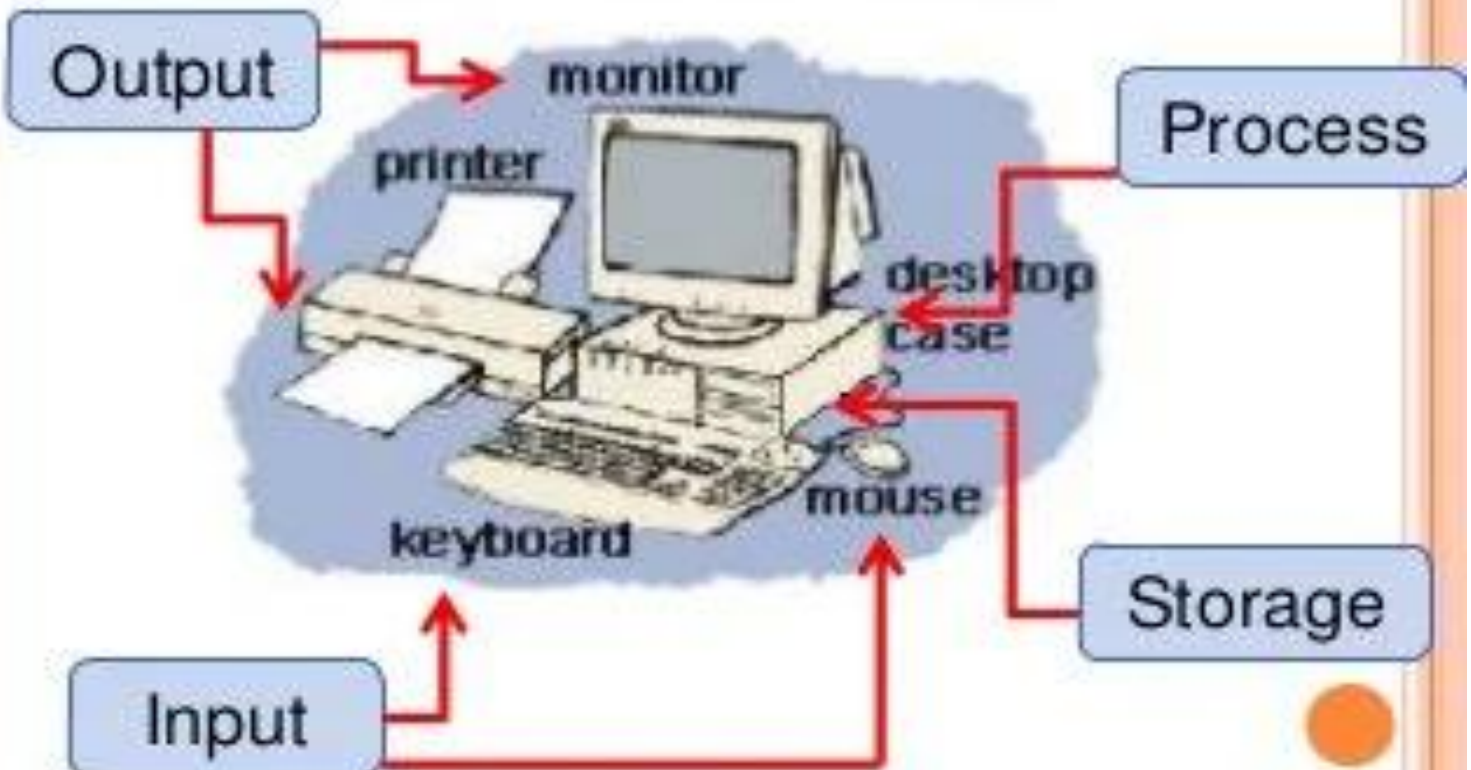
CPU (Central Processing Unit)

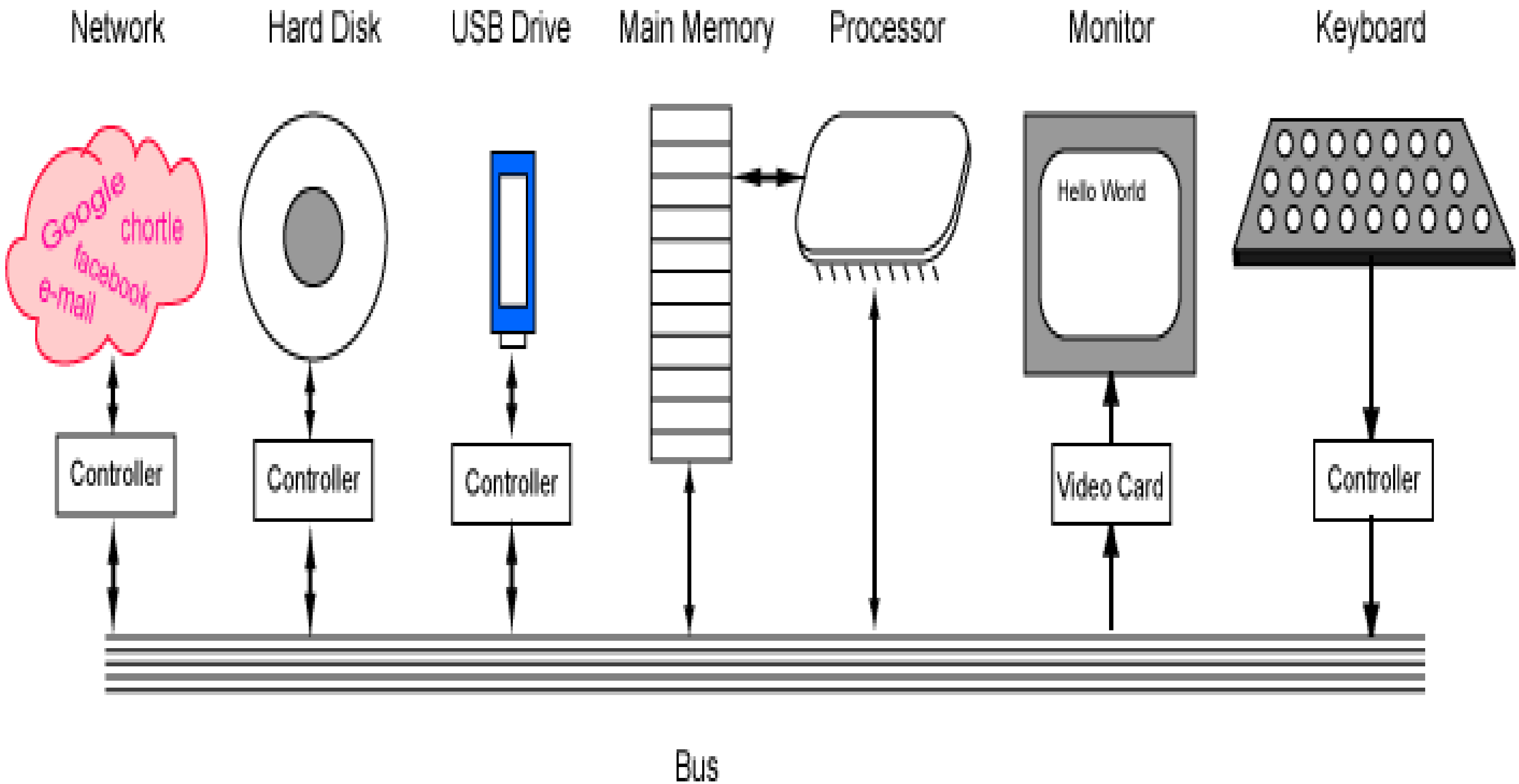
- CPU is considered as the brain of the computer. CPU performs all types of data processing operations. It stores data, intermediate results, and instructions (program). It controls the operation of all parts of the computer.
- CPU itself has the following components −
- ALU (Arithmetic Logic Unit)
- Control Unit

Output Unit

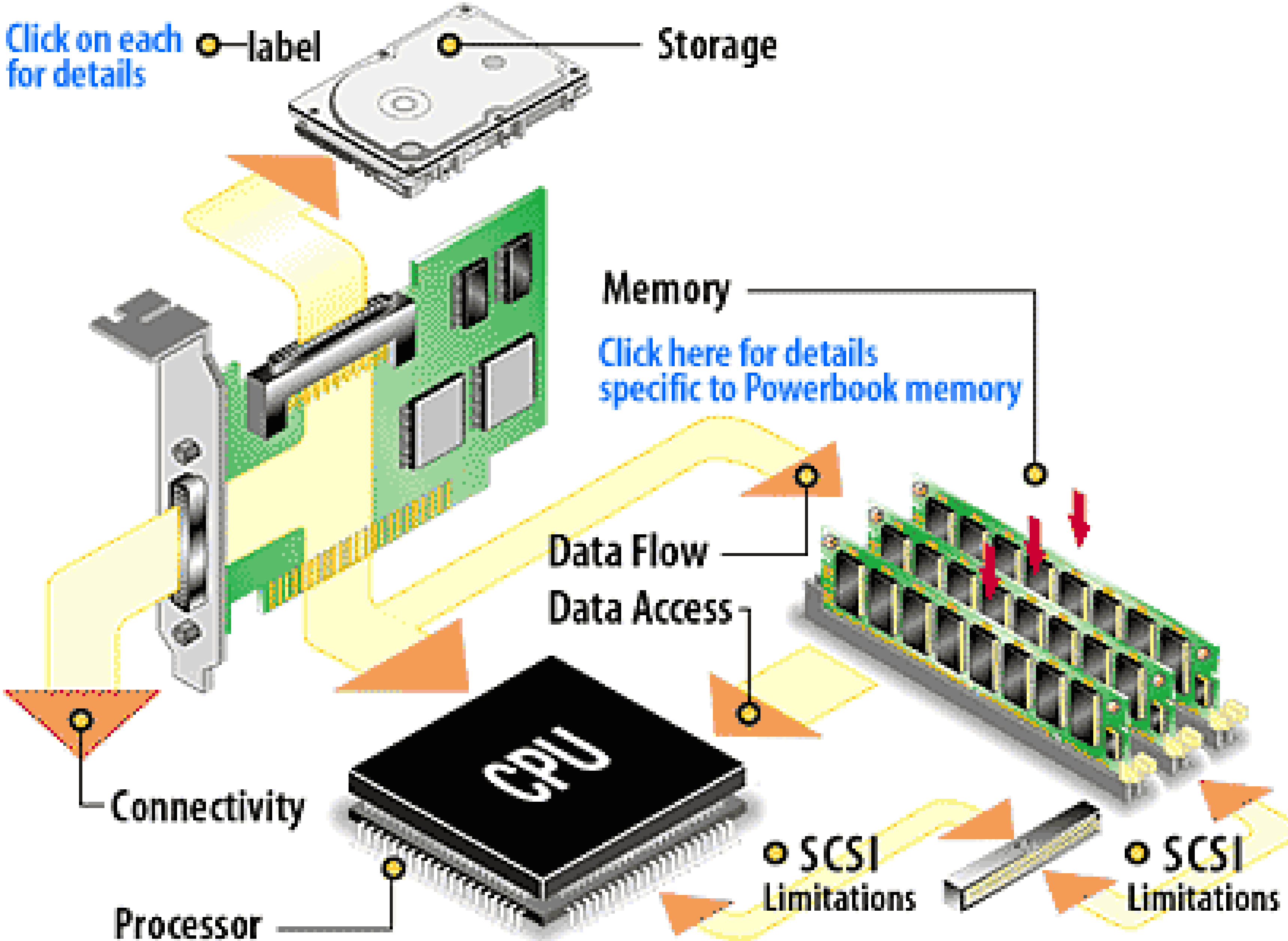
The output unit consists of devices with the help of which we get the information from the computer. This unit is a link between the computer and the users.

COMPUTER TECHNOLOGY





Main Components of a Computer System


Click on each
for details
label
Storage
Memory
Click here for details
specific to Powerbook memory
Data Flow
Data Access
CPU
Connectivity
Processor
SCSI
Limitations
SCSI
Limitations

Bus Structure

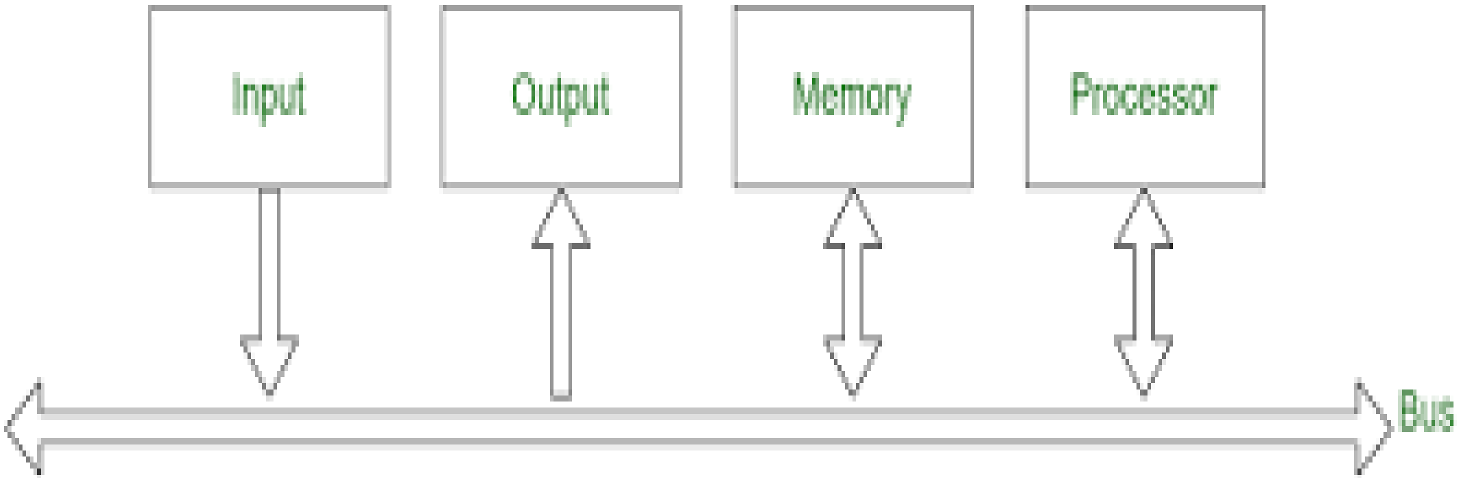
- A Bus is said to be group of lines that serves as a connecting path for several devices .

- In addition to the lines that carry the data, the bus must have lines for address and control purposes.

Bus Architecture

- The different functional modules must be connected in an organized manner to form an operational system.
- Bus refers to a group of lines that serves as a connecting path for several devices.
- The simplest way to connect the functional unit is to use the single bus architecture.
  - Only one data transfer allowed in one clock cycle.
  - For multi-bus architecture, parallelism in data transfer is allowed.

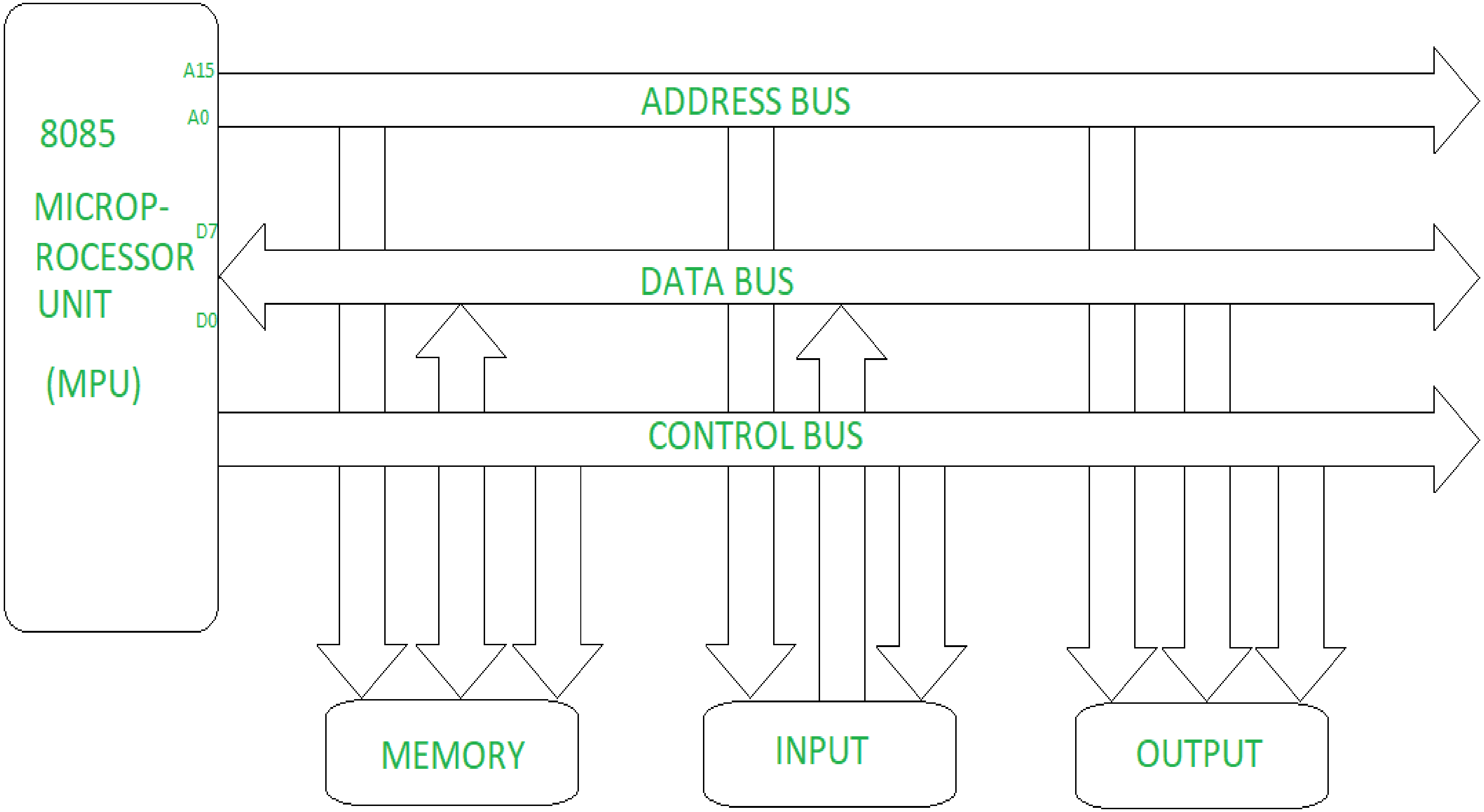
Single Bus Structure



Single Bus Structure

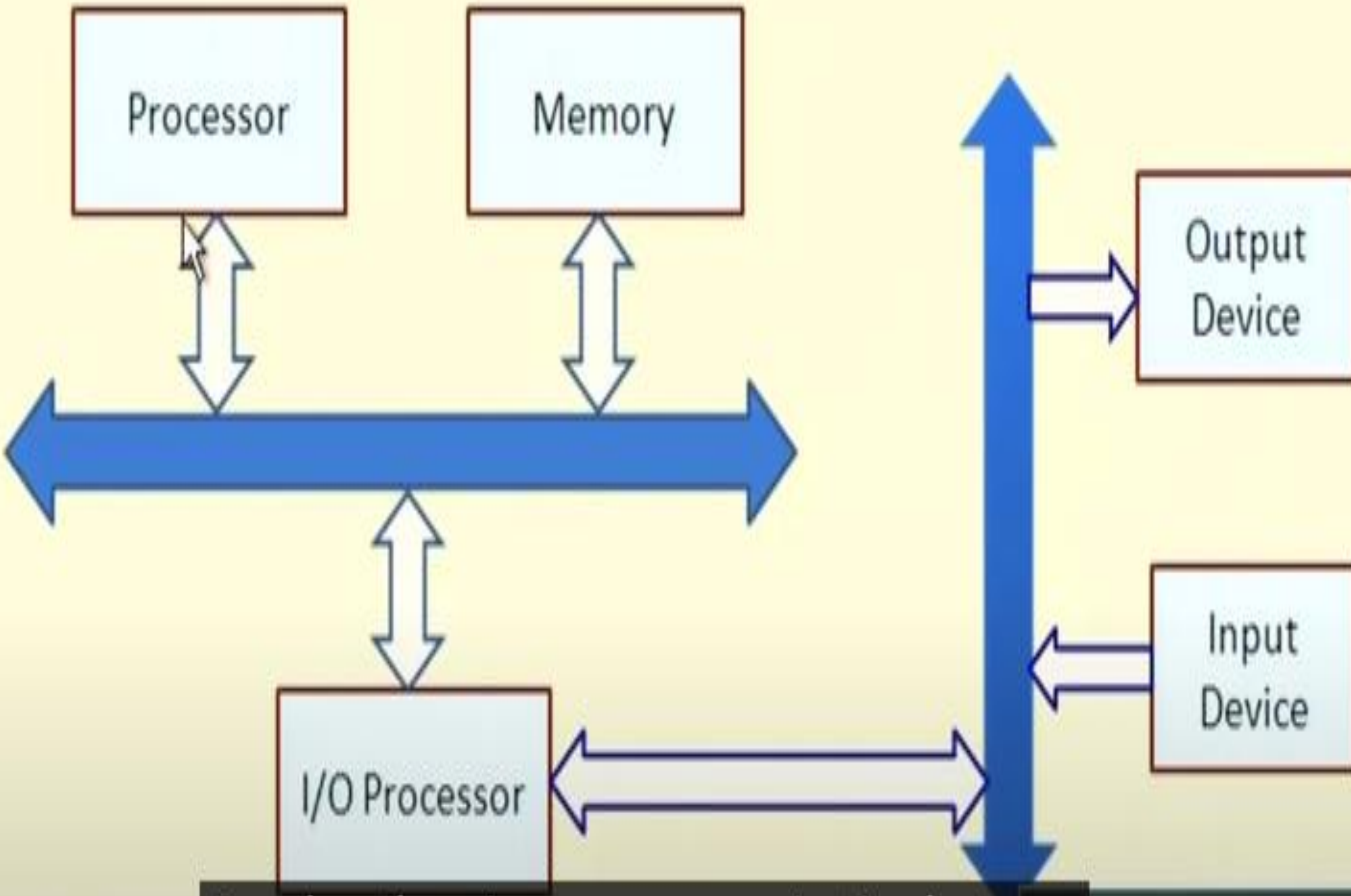
- In a single bus structure, one common bus is used to communicate between peripherals and microprocessors. It has disadvantages due to the use of one common bus.
- Because the bus can be used for only one transfer at a time,
- only two units can actively use the bus at any given time.
- Bus control lines are used to arbitrate multiple requests for use of the bus.
- The main virtue of the single-bus structure is its low cost and is flexibility for attaching peripheral" devices.

Bus Structure with different buses



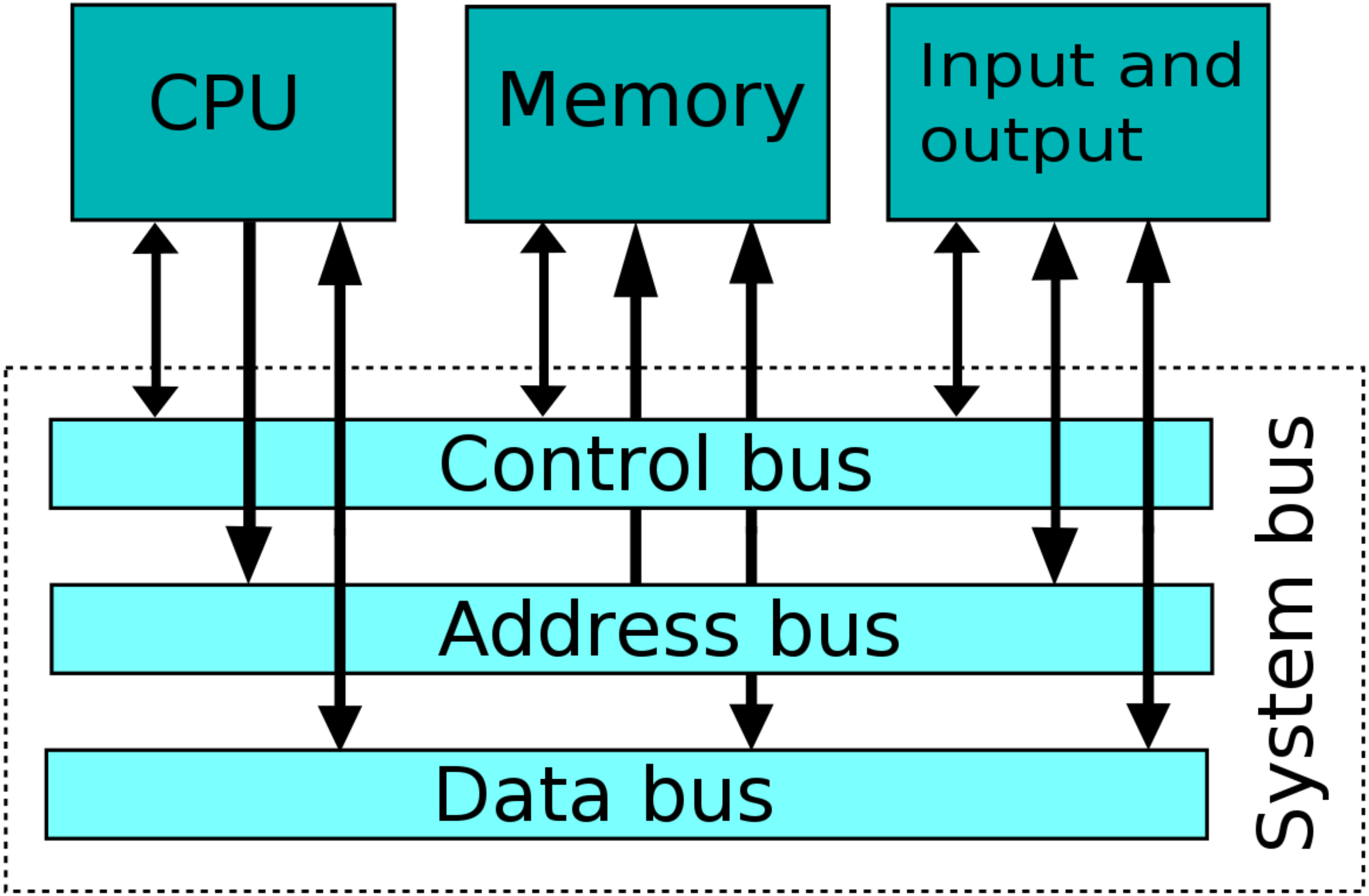
Bus organization system of 8085 Microprocessor

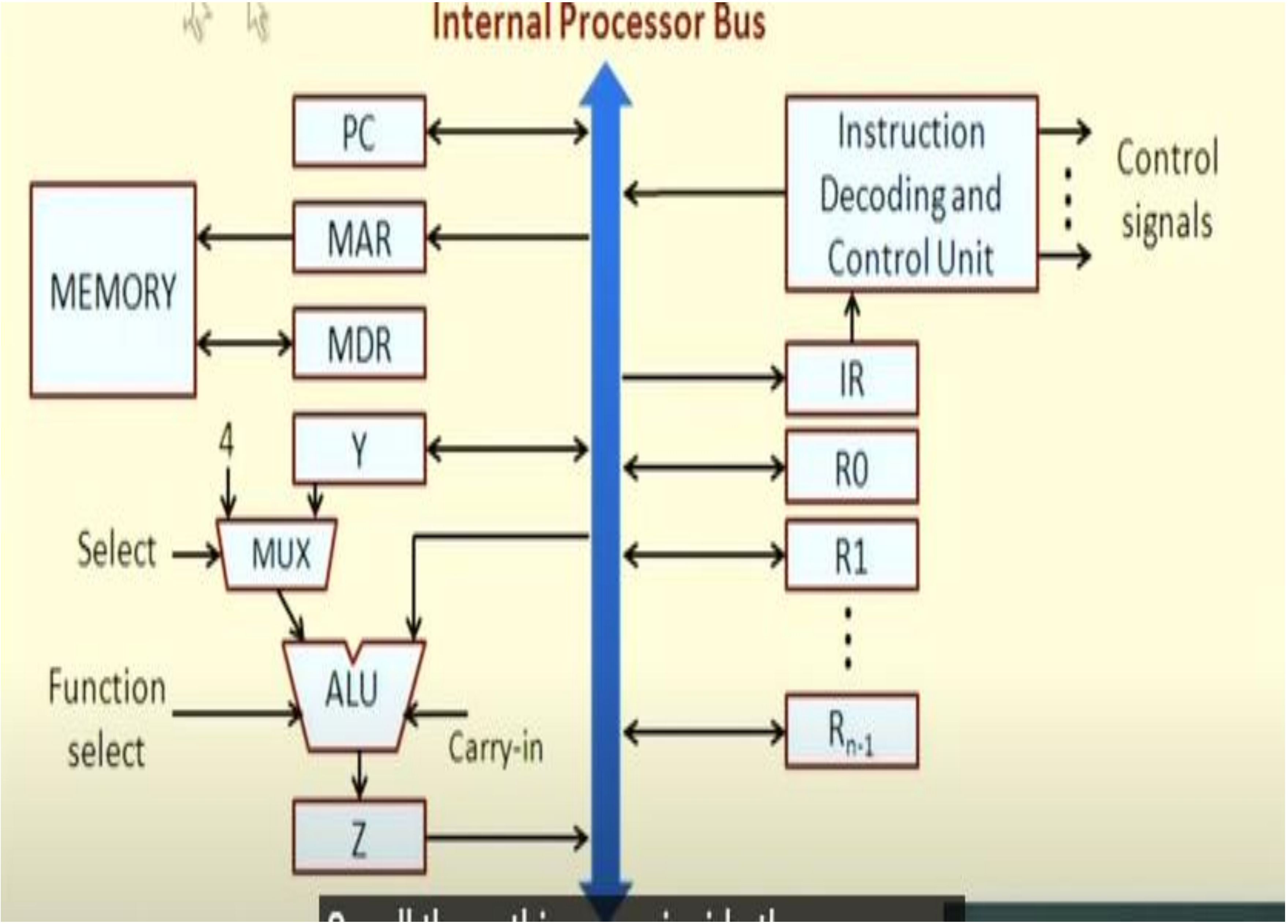
System-Level Two-Bus Architecture



- Systems that contain multiple buses achieve more concurrency in operations by allowing two or more transfers to be carried out at the same time.

- This leads to better performance but at an increased cost.

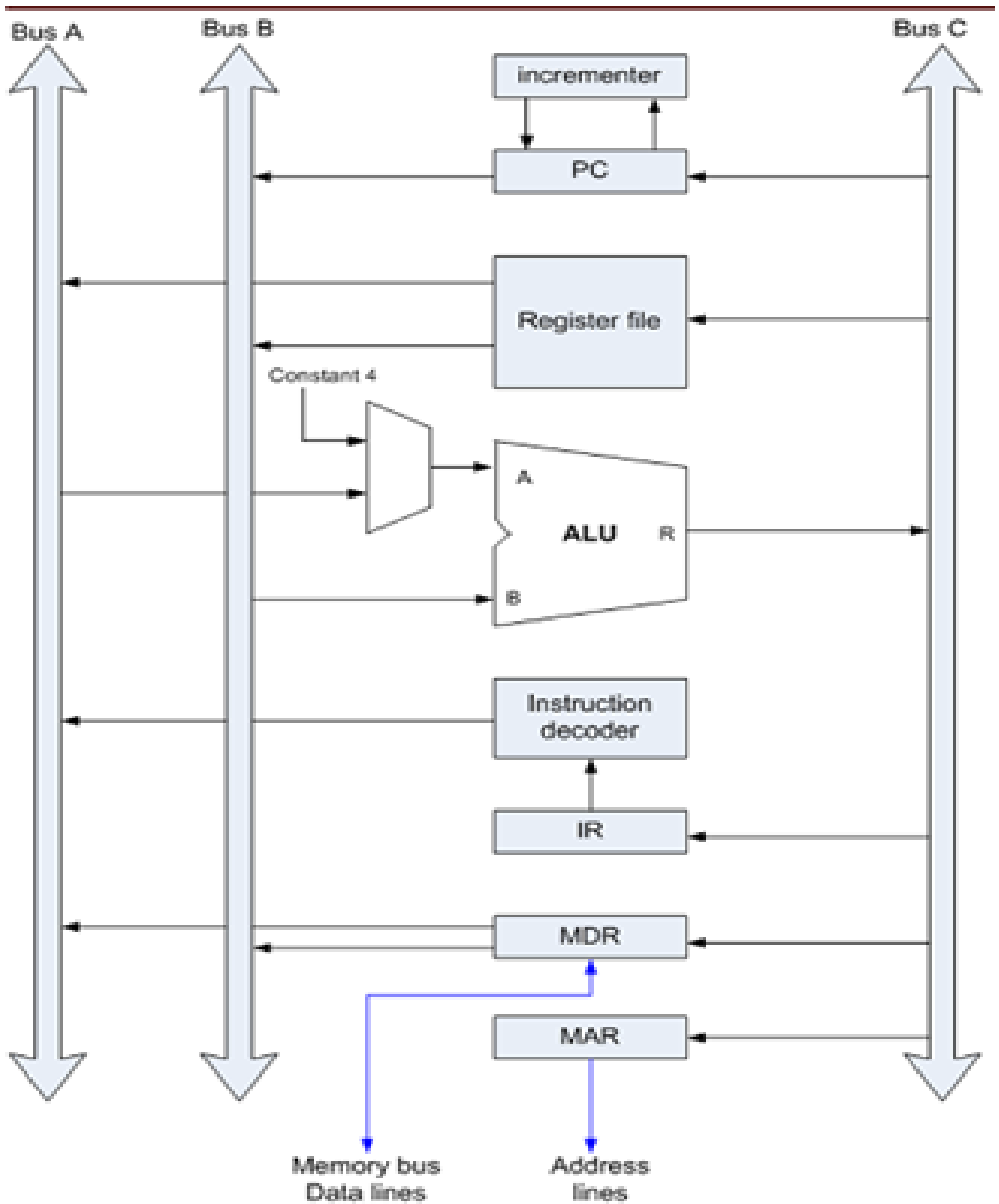

CPU
Memory
Input and output
Control bus
Address bus
Data bus
System bus


Internal Processor Bus
PC
MAR
MDR
MEMORY
Y
4
Select
MUX
Function
select
ALU
Carry-in
Z
Instruction
Decoding and
Control Unit
Control
signals
IR
R0
R1
R_{n-1}

Multi-Bus Architectures

- Modern processors have multiple buses that connect the registers and other functional units.
  - Allows multiple data transfer micro-operations to be executed in the same clock cycle.
  - Results in overall faster instruction execution.
- Also advantageous to have multiple shorter buses rather than a single long bus.
  - Smaller parasitic capacitance, and hence smaller delay.

Multiple Bus Architecture inside the processor



Signed and unsigned Numbers

- Variables such as integers can be represent in two ways, i.e., signed and unsigned.
- Signed numbers use sign flag or can be distinguish between negative values and positive values.
- Whereas unsigned numbers stored only positive numbers but not negative numbers.

- We represent the positive numbers without adding any sign before them and the negative number with - (minus) sign before them.

- But in the digital system, it is not possible to use negative sign before them because the data is in binary form in digital computers.

- For representing the sign in binary numbers, we require a special notation.

- The signed numbers have a sign bit so that it can differentiate positive and negative integer numbers.

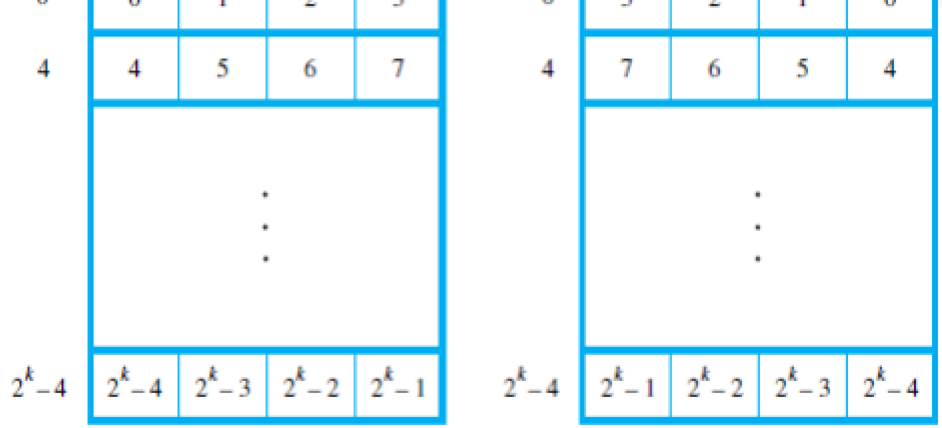
- The signed binary number technique has both the sign bit and the magnitude of the number. For representing the negative decimal number, the corresponding symbol in front of the binary number will be added.

There are the following types of representation of signed binary numbers:

- **Sign-Magnitude form**
  In this form, a binary number has a bit for a sign symbol. If this bit is set to 1, the number will be negative else the number will be positive if it is set to 0. Apart from this sign-bit, the n-1 bits represent the magnitude of the number.

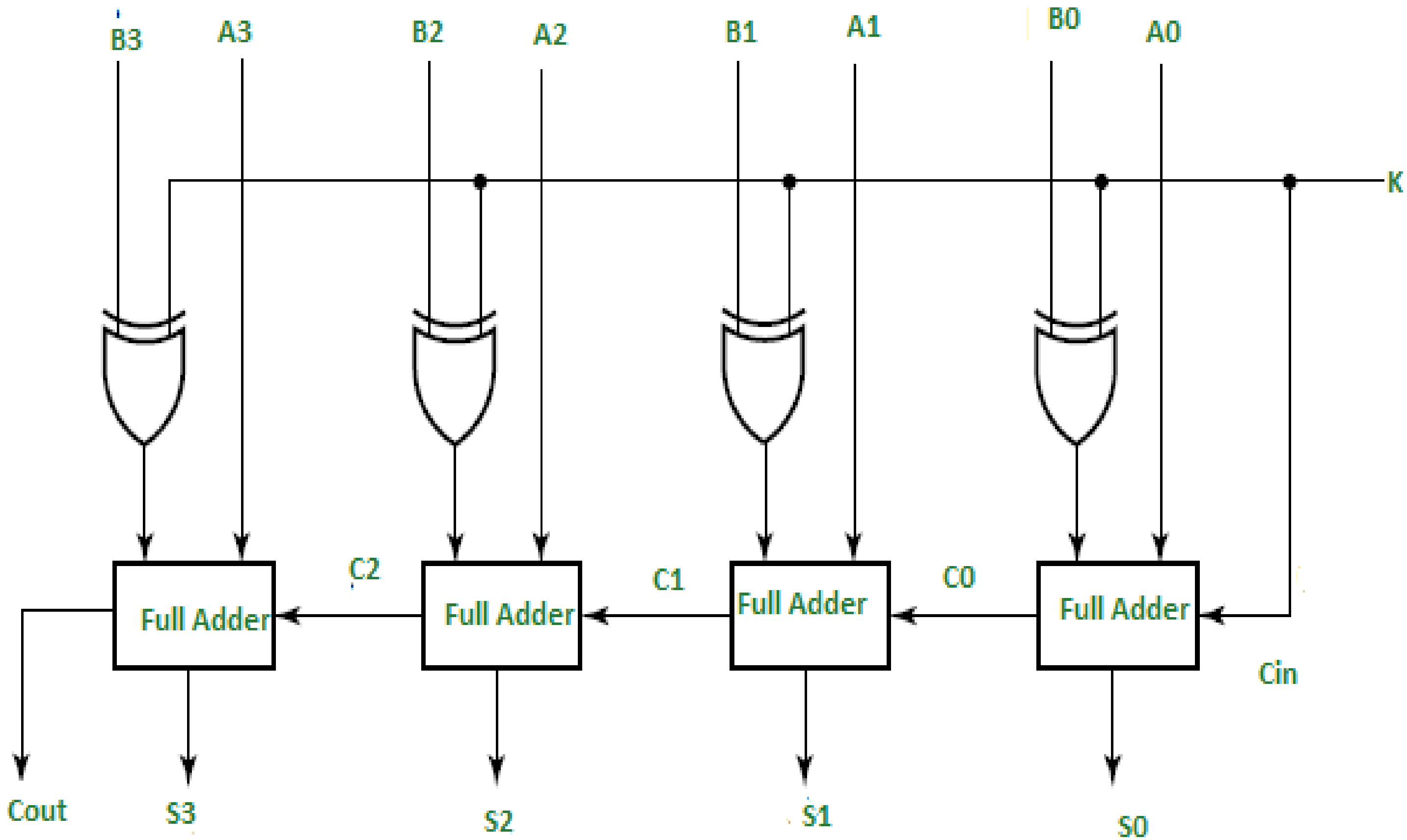
- **1's Complement**
  By inverting each bit of a number, we can obtain the 1's complement of a number. The negative numbers can be represented in the form of 1's complement. In this form, the binary number also has an extra bit for sign representation as a sign-magnitude form.

- **2's Complement**
  By inverting each bit of a number and adding plus 1 to its least significant bit, we can obtain the 2's complement of a number. The negative numbers can also be represented in the form of 2's complement. In this form, the binary number also has an extra bit for sign representation as a sign-magnitude form.



(a) Big-endian assignment (b) Little-endian assignment

Figure 2.3 Byte and word addressing.



B3
A3
B2
A2
B1
A1
B0
A0
K
C2
C1
C0
Full Adder
Full Adder
Full Adder
Full Adder
Cin
Cout
S3
S2
S1
S0