Microprocessor

Semester: II

Course No: CSC162

Nature of the Course: Theory + Lab

Credit Hrs: 3

Full Marks: 60 + 20 + 20

Pass Marks: 24 + 8 + 8

Course Description: This course contains fundamental concepts of Microprocessor operations, basic I/O interfaces and Interrupts operations.

Course Objectives: The course objective is to introduce the operation, programming and application of microprocessor.

Unit 1: Introduction

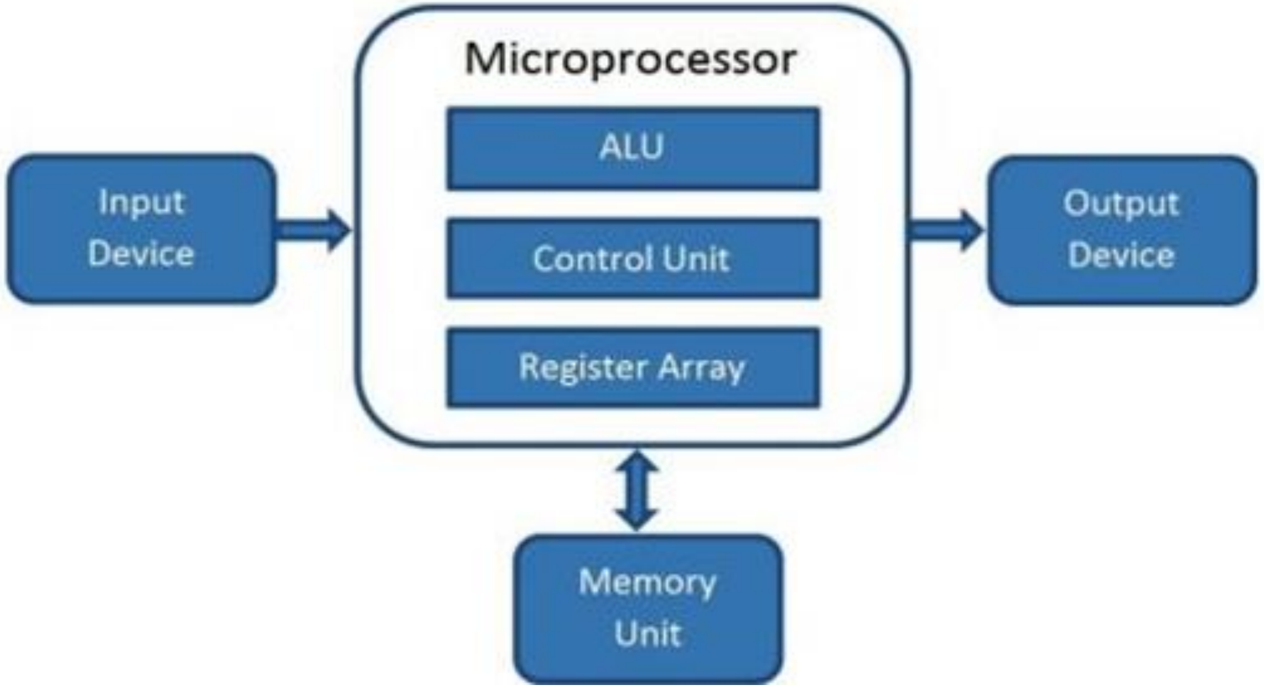
1. Definition of microprocessor and its application
2. Evolution of microprocessor, Von Neumann and Harvard architecture
3. Components of microprocessor
   i. Microprocessor: Arithmetic and Logic Unit (ALU), Control Unit (CU), Registers
   ii. Memory
   iii. Input / Output
4. System Bus: Data , Address and Control Bus
5. Microprocessor with Bus Organization

Microprocessor Definition

- ❖Computer's Central Processing Unit (CPU) built on a single Integrated Circuit (IC) is called a microprocessor.
- ❖A digital computer with one microprocessor which acts as a CPU is called microcomputer.
- ❖It is a **programmable**, **multipurpose**, **clock -driven**, **register-based** electronic device that reads binary instructions from a storage device called **memory**, accepts binary data as input and processes data according to those instructions and provides results as output.
- ❖The microprocessor contains millions of tiny components like transistors, registers, and diodes that work together.
- ❖Sometimes, microprocessor is written as **μP**.
  (**μ** is pronounced as **Mu**)

Block Diagram of a Microprocessor

- A microprocessor consists of an ALU, control unit and register array. Where **ALU** performs arithmetic and logical operations on the data received from an input device or memory.
- Control unit controls the instructions and flow of data within the computer.
- And, **register array** consists of registers identified by letters like B, C, D, E, H, L, and accumulator.s



Applications of Microprocessor

Today microprocessors can be found in almost every computing device. Microprocessor-based systems are used in every sphere of life and their applications are increasing day by day. Some of the applications are given below:-

1. Smartphones, tablets, and other mobile devices all rely on microprocessors to function. They execute instructions, process data, and perform various operations to make these devices work.
2. It is used in every computer, ranging from personal computers to supercomputers. All the instruction execution and operational execution work are done by microprocessors present inside them.
3. It is used in automobiles to control a wide range of functions including engine management, and entertainment systems.
4. Computers are used in database management and storing data through the internet. Microprocessors present inside the computing device store and manage the data according to the instructions given to it.

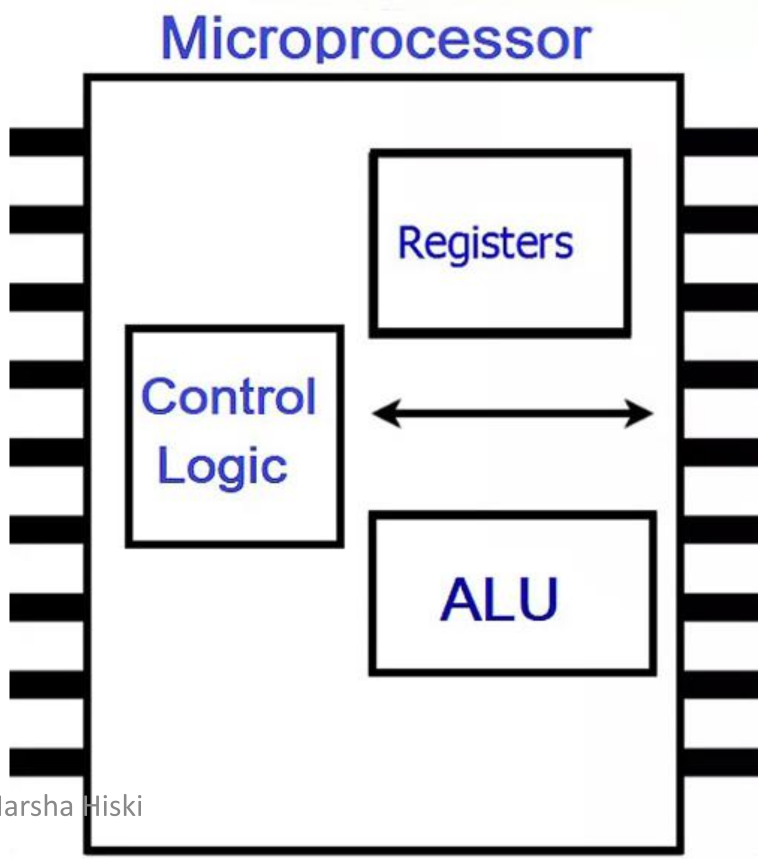
Applications of Microprocessor

6. It is used in robots, video games, smart cameras, etc.
7. Microprocessors having a single chip are known as microcontrollers, which are used for automatic control. For example, It is used to measure and control the temperature of the furnace and oven, the speed of the running car, the pressure of the boiler, etc.
8. Microprocessors are used in various aerospace applications, including aircraft navigation, guidance systems, and flight control systems.
9. It plays an important role in server management where it executes millions of data stores and retrieves instructions in milliseconds.

Overall, microprocessors play a crucial role in enabling the functionality and operation of many electronic devices and systems. They are an essential component of modern electronics and will continue to be so in the future.

Evolution of Microprocessors

- We can categorize the microprocessor according to the generations or according to the size of the microprocessor



First Generation (4 - bit Microprocessors)

- The first generation microprocessors were introduced in the year 1971-1972 by Intel Corporation. It was named **Intel 4004** since it was a 4-bit processor.
- It was a processor on a single chip. It could perform simple arithmetic and logical operations such as addition, subtraction, Boolean OR and Boolean AND.
- It had a control unit capable of performing control functions like fetching an instruction from storage memory, decoding it, and then generating control pulses to execute it.

Second Generation(8–bit Microprocessor)

- The second generation microprocessors were introduced in 1973 again by Intel. It was a first 8 - bit microprocessor which could perform arithmetic and logic operations on 8-bit words. It was Intel 8008, and another improved version was Intel 8088.

Third Generation(16 - bit Microprocessor)

- The third generation microprocessors, introduced in 1978 were represented by Intel's 8086, Zilog Z800 and 80286, which were 16 - bit processors with a performance like minicomputers.

Fourth Generation(32-bit Microprocessors)

- Several different companies introduced the 32-bit microprocessors, but the most popular one is the Intel 80386.

Fifth Generation(64-bit Microprocessors)

- From 1995 to now we are in the fifth generation. After 80856, Intel came out with a new processor namely Pentium processor followed by Pentium Pro CPU, which allows multiple CPUs in a single system to achieve multiprocessing.
- Other improved 64-bit processors are Celeron, Dual, Quad, Octa Core, i3, i5, i7, i9 processors.

Evolution of Microprocessors: INTEL Series

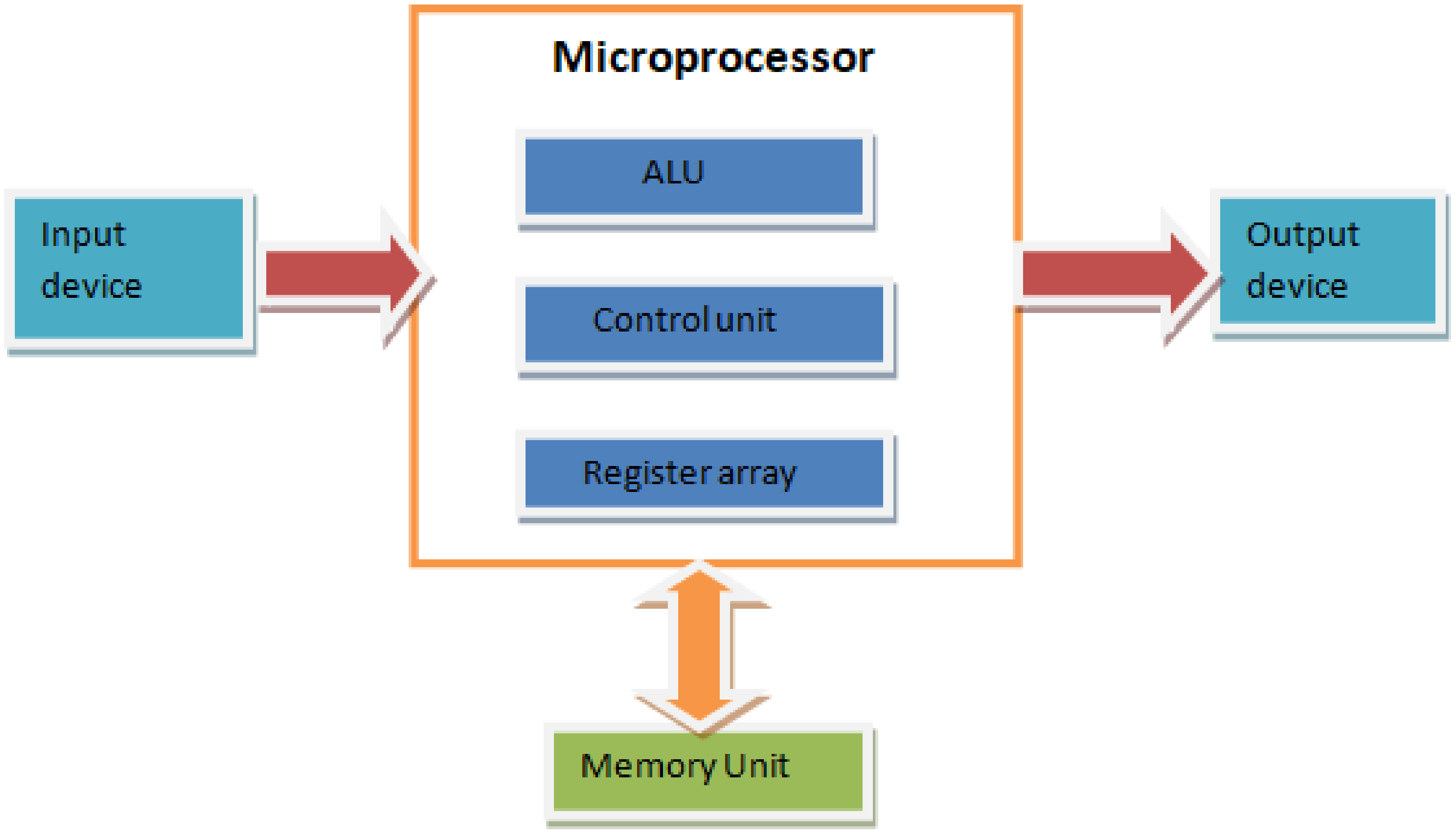
Intel Microprocess				
Name	**Year**	**Transistors**	**Clock speed**	**Data width**
8080	1974	6,000	2 MHz	8 bits
8085	1976	6,500	5 MHz	8 bits
8086	1978	29,000	5 MHz	16 bits
8088	1979	29,000	5 MHz	8 bits
80286	1982	134,000	6 MHz	16 bits
80386	1985	275,000	16 MHz	32 bits
80486	1989	1,200,000	25 MHz	32 bits
Pentium	1993	3,100,000	60 MHz	32/64 bits
Pentium II	1997	7,500,000	233 MHz	64 bits
Pentium III	1999	9,500,000	450 MHz	64 bits
Pentium IV	2000	42,000,000	1.5 GHz	64 bits
Pentium IV "Prescott"	2004	125,000,000	3.6 GHz	64 bits
Intel Core 2	2006	291 million	3 GHz	64 bits
Pentium Dual Core	2007	167 million	2.93 GHz	64 bits
Intel 64 Nchalem	2009	781 million	3.33 GHz	64 bits

Table: Important Intel Microprocessors

Manufacturer	Processor	Date of introduction	Number of transistors	Process	Area [mm^2]
Intel	Intel4004	1971	2,300	10 µm	12
	Intel8008	1972	3,500	10 µm	14
	Intel8080	1974	4,400	6 µm	20
	Intel8085	1976	6,500	3 µm	20
	Intel8086	1978	29,000	3 µm	33
	Intel80286	1982	134,000	1.5 µm	44
	Intel80386	1985	275,000	1.5 µm	104
	Intel80486	1989	1,180,235	1 µm	173
	Pentium	1993	3,100,000	0.8 µm	294
	Pentium Pro	1995	5,500,000	0.5 µm	307
	Pentium II	1997	7,500,000	0.35 µm	195
	Pentium III	1999	9,500,000	0.25 µm	128
	Pentium 4	2000	42,00,000	180 nm	217
	Itanium 2 McKinely	2002	220,000,000	180 nm	421
	Core 2 Duo	2006	291,000,000	65 nm	143
	Core i7 (Quad)	2008	731,000,000	45 nm	263
	Six-Core Core i7	2010	1,170,000,000	32 nm	240
	Six-Core Core i7/8-Core Xeon E5	2011	2,270,000,000	32 nm	434
	8-Core Itanium Poulson	2012	3,100,000,000	32 nm	544

MIPS	R2000	1986	110,000	2.0 μm	80
	R3000	1988	150,000	1.2 μm	56
	R4000	1991	1,200,000	0.8 μm	213
	R10000	1994	2,600,000	0.5 μm	299
	R10000	1996	6,800,000	0.35 μm	299
	R12000	1998	7,1500,000	0.25 μm	229
IBM	POWER3	1998	15,000,000	0.35 μm	270
	POWER4	2001	174,000,000	180 nm	412
	POWER4+	2002	184,000,000	130 nm	267
	POWER5	2004	276,000,000	130 nm	389
	POWER5+	2005	276,000,000	90 nm	243
	POWER6+	2009	790,000,000	65 nm	341
	POWER7	2010	1.200,000,000	45 nm	567
	POWER7+	2012	2.100,000,000	32 nm	567

Components of Microprocessor



Components of Microprocessor

The functions of various components of a microprocessor-based system can be summarized as follows:

1. **The Microprocessor**
   - reads instruction from memory.
   - communicates with all peripherals (memory and I/Os) using the system bus.
   - controls the timing of information flow.
   - performs the computing tasks specified in a program.
2. **The Memory**
   - stores the binary information, called instructions and data.
   - provides the instructions and data to the microprocessor on request.
   - stores results and data for the microprocessor.

Components of Microprocessor

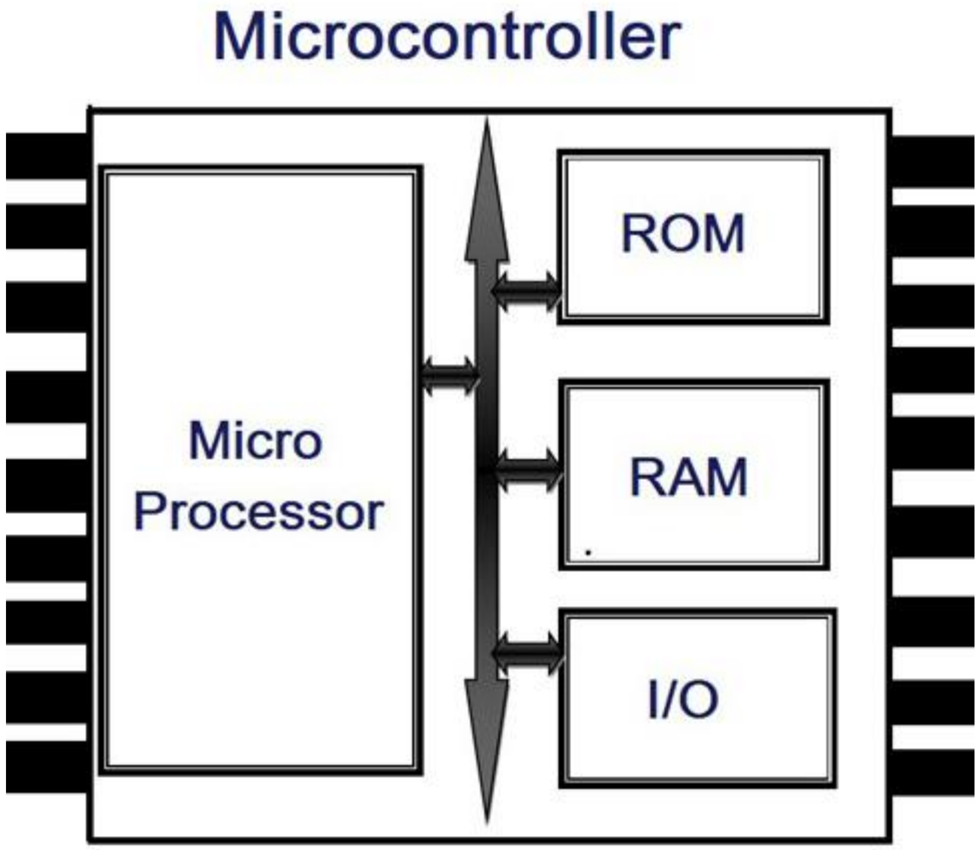
3. **The input device**
   - ❑ enters data and instructions under the control of a program such as a monitor program.
4. **The output device**
   - ❑ accepts data from the microprocessor as specified in a program.
5. **The bus**
   - ❑ carries bits between the microprocessor and memory and I/Os.

Features of Microprocessor

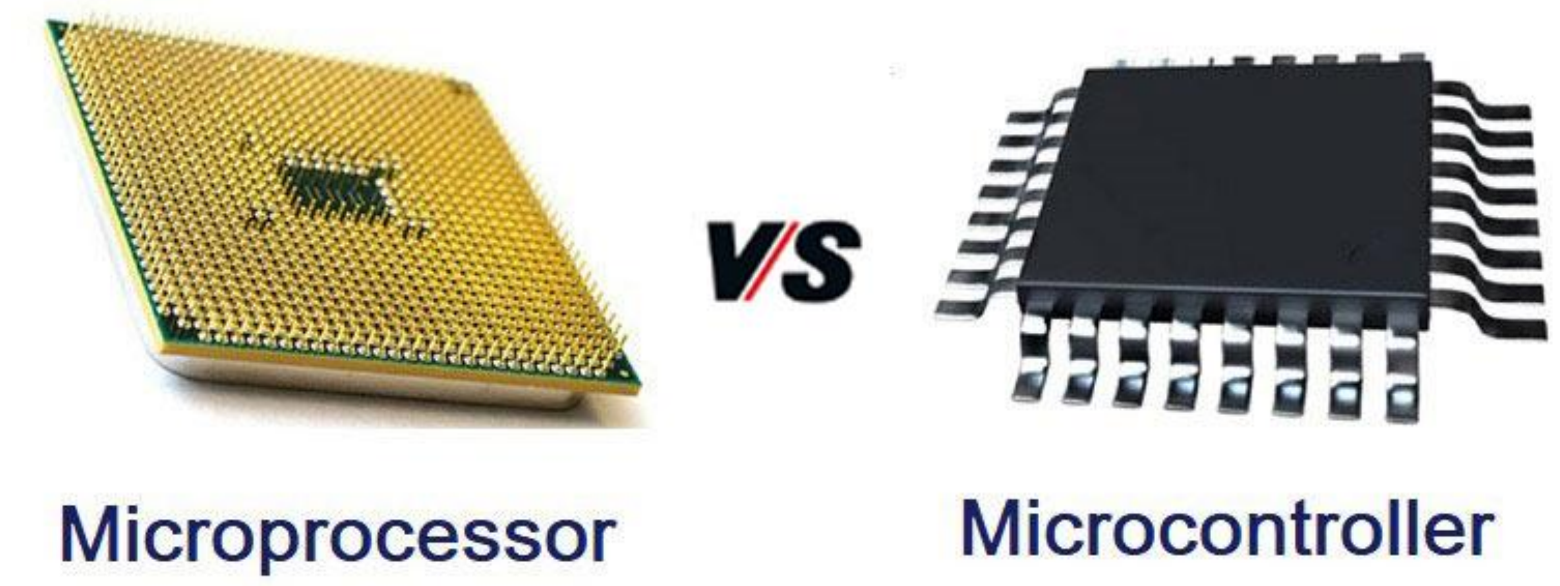
- **Cost-effective** – The microprocessor chips are available at low prices and results its low cost.
- **Size** – The microprocessor is of small size chip, hence is portable.
- **Low Power Consumption** – Microprocessors are manufactured by using metaloxide semiconductor technology, which has low power consumption.
- **Versatility** – The microprocessors are versatile as we can use the same chip in a number of applications by configuring the software program.
- **Reliability** – The failure rate of an IC in microprocessors is very low, hence it is reliable.

Microcontroller

- ❖A microcontroller is a compact integrated circuit designed to govern a specific operation in an embedded system.
- ❖ A typical microcontroller includes a processor, memory and input/output (I/O) peripherals on a single chip.
- ❖Sometimes referred to as an embedded controller or microcontroller unit (MCU), microcontrollers are found in vehicles, robots, office machines, medical devices, mobile radio transceivers, vending machines and home appliances, among other devices.



Microprocessor Vs. Microcontroller



Microprocessor Vs. Microcontroller

Microprocessor	Microcontroller
Microprocessor is the heart of Computer system.	Micro Controller is the heart of an embedded system.
It is only a processor, so memory and I/O components need to be connected externally	Micro Controller has a processor along with internal memory and I/O components.
Memory and I/O has to be connected externally, so the circuit becomes large.	Memory and I/O are already present, and the internal circuit is small.
You can’t use it in compact systems	You can use it in compact systems.
Cost of the entire system is high	Cost of the entire system is low
Due to external components, the total power consumption is high. Therefore, it is not ideal for the devices running on stored power like batteries.	As external components are low, total power consumption is less. So it can be used with devices running on stored power like batteries.
Most of the microprocessors do not have power saving features.	Most of the microcontrollers offer power-saving mode.

Microprocessor Vs. Microcontroller

Microprocessor	Microcontroller
It is mainly used in personal computers.	It is used mainly in a washing machine, MP3 players, and embedded systems.
Microprocessor has a smaller number of registers, so more operations are memory-based.	Microcontroller has more register. Hence the programs are easier to write.
Microprocessors are based on Von Neumann model	Micro controllers are based on Harvard architecture
It is a central processing unit on a single silicon-based integrated chip.	It is a byproduct of the development of microprocessors with a CPU along with other peripherals.
It has no RAM, ROM, Input-Output units, timers, and other peripherals on the chip.	It has a CPU along with RAM, ROM, and other peripherals embedded on a single chip.
It uses an external bus to interface to RAM, ROM, and other peripherals.	It uses an internal controlling bus.
Microprocessor-based systems can run at a very high speed because of the technology involved.	Microcontroller based systems run up to 200MHz or more depending on the architecture.
It’s used for general purpose applications that allow you to handle loads of data.	It’s used for application-specific systems.
It’s complex and expensive, with a large number of instructions to process.	It’s simple and inexpensive with less number of instructions to process.

Microprocessor Vs. Microcontroller

	Microprocessor	Microcontroller
Application	It used where intensive processing is required. It is used in personal computers, laptops, mobiles, video games, etc.	It used where the task is fixed and predefined. It is used in the washing machine, alarm, etc.
Structure	It has only the CPU in the chip. Other devices like I/O port, memory, timer is connected externally. The structure of the microprocessor is flexible. Users can decide the amount of memory, the number of I/O port and other peripheral devices.	CPU, Memory, I/O port and all other devices are connected on the single chip. The structure is fixed. Once it is designed the user cannot change the peripheral devices.
Clock speed	The clock speed of the microprocessor is high. It is in terms of the GHz. It ranges between 1 GHz to 4 GHz.	The clock speed of the microcontroller is less. It is in terms of the MHz. it ranges between 1 MHz to 300 MHz.
RAM	The volatile memory (RAM) for the microprocessor is in the range of the 512 MB to 32 GB.	The volatile memory (RAM) for the microcontroller is in the range of 2 KB to 256 KB.
ROM	The hard disk (ROM) for the microprocessor is in the range of the 128 GB to 2 TB.	The hard drive or flash memory (ROM) is in the range of the 32 KB to 2 MB.
Peripheral interface	The common peripheral interface for the microprocessor is USB, UART, and high-speed Ethernet.	The common peripheral interface for the microcontroller is I2C, SPI, and UART.
Programming	The program for the microprocessor can be changed for different applications. The programming of the microprocessor is difficult compared to the microcontroller.	The program for the microcontroller is fixed once it is designed.
Bit size	It is available in 32-Bit and 64-bit.	It is available in 8-bit, 16-bit, and 36-bit.
Cost	The cost of the microprocessor is high compared to the microcontroller.	It is cheaper.
Power consumption	The power consumption for the microprocessor is high.	The power consumption for the microcontroller is less.
Size	The overall size of the system is large.	The overall size of the system is small.

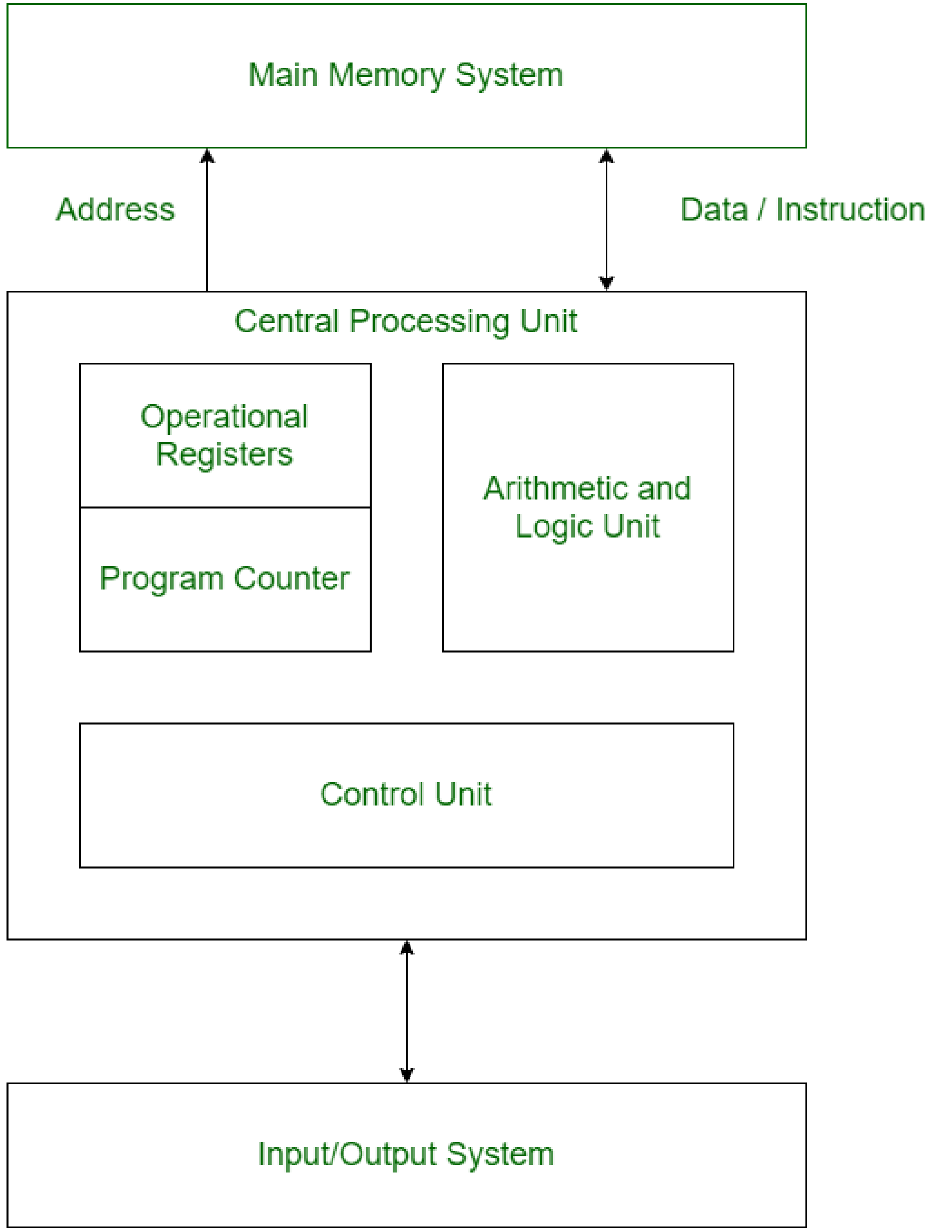
Computer Architecture

- ❖Computer architecture comprises rules, methods, and procedures that describe the execution and functionality of the entire computer system.
- ❖In general terms, computer architecture refers to how a computer system is designed using compatible technologies.

Von-Neumann Architecture(Neumann Model or Princeton Architecture)

- Von Neumann Architecture is a digital computer architecture whose design is based on the concept of stored program computers where program data and instruction data are stored in the same memory.
- This architecture was designed by the famous mathematician and physicist John Von Neumann in 1945.
- It is used in personal computers and small computers.

Von-Neumann Architecture

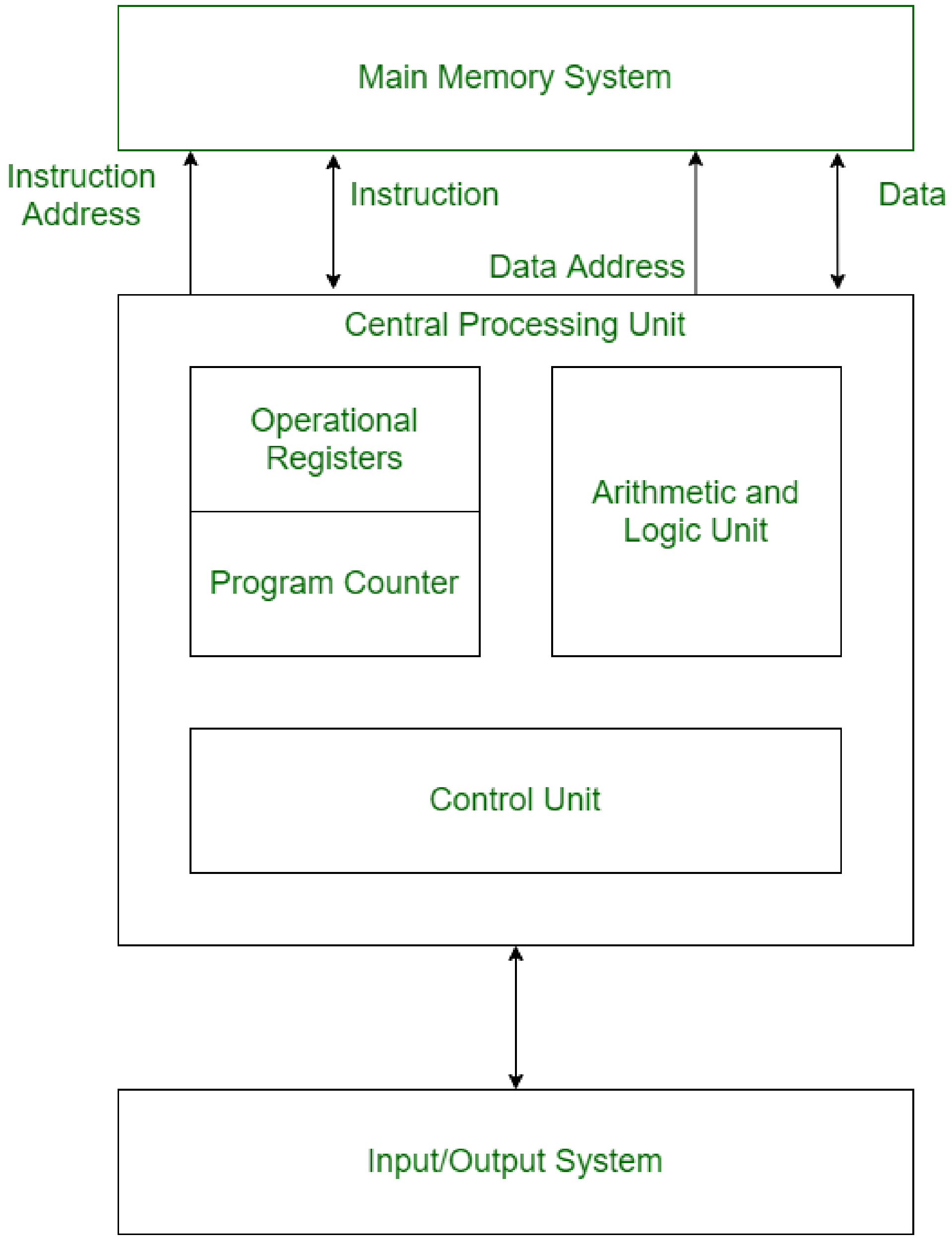


Von Neumann Architecture

Harvard Architecture

- Harvard Architecture is the digital computer architecture whose design is based on the concept where there are separate storage and separate buses (signal path) for instruction and data.
- It was basically developed to overcome the bottleneck of Von Neumann Architecture.
- It is used in micro controllers and signal processing.

Harvard Architecture



Harvard Architecture

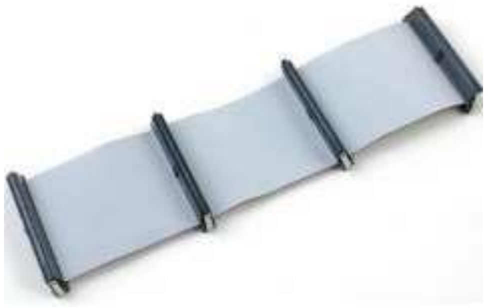
VON NEUMANN ARCHITECTURE
VERSUS
HARVARD ARCHITECTURE

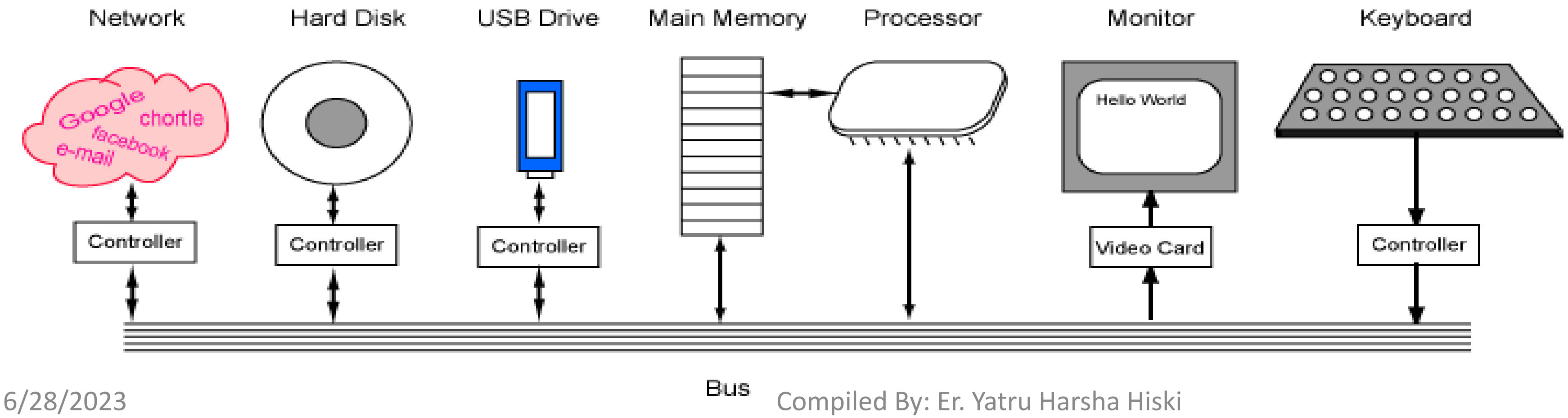
It is a theoretical design based on the stored-program computer concept.	It is a modern computer architecture based on the Harvard Mark I relay-based computer model.
It uses same physical memory address for instructions and data.	It uses separate memory addresses for instructions and data.
Processor needs two clock cycles to execute an instruction.	Processor needs one cycle to complete an instruction.
Simpler control unit design and development of one is cheaper and faster.	Control unit for two buses is more complicated which adds to the development cost.
Data transfers and instruction fetches cannot be performed simultaneously.	Data transfers and instruction fetches can be performed at the same time.
Used in personal computers, laptops and workstations.	Used in microcontrollers and signal processing.

System Bus

- A bus is a communication pathway which can connect two or more devices (CPU, memory and I/O).
- The network of wires or electronic pathways is known as **'Bus'**.
- The technique was developed to reduce costs and improve modularity.
- Classification:

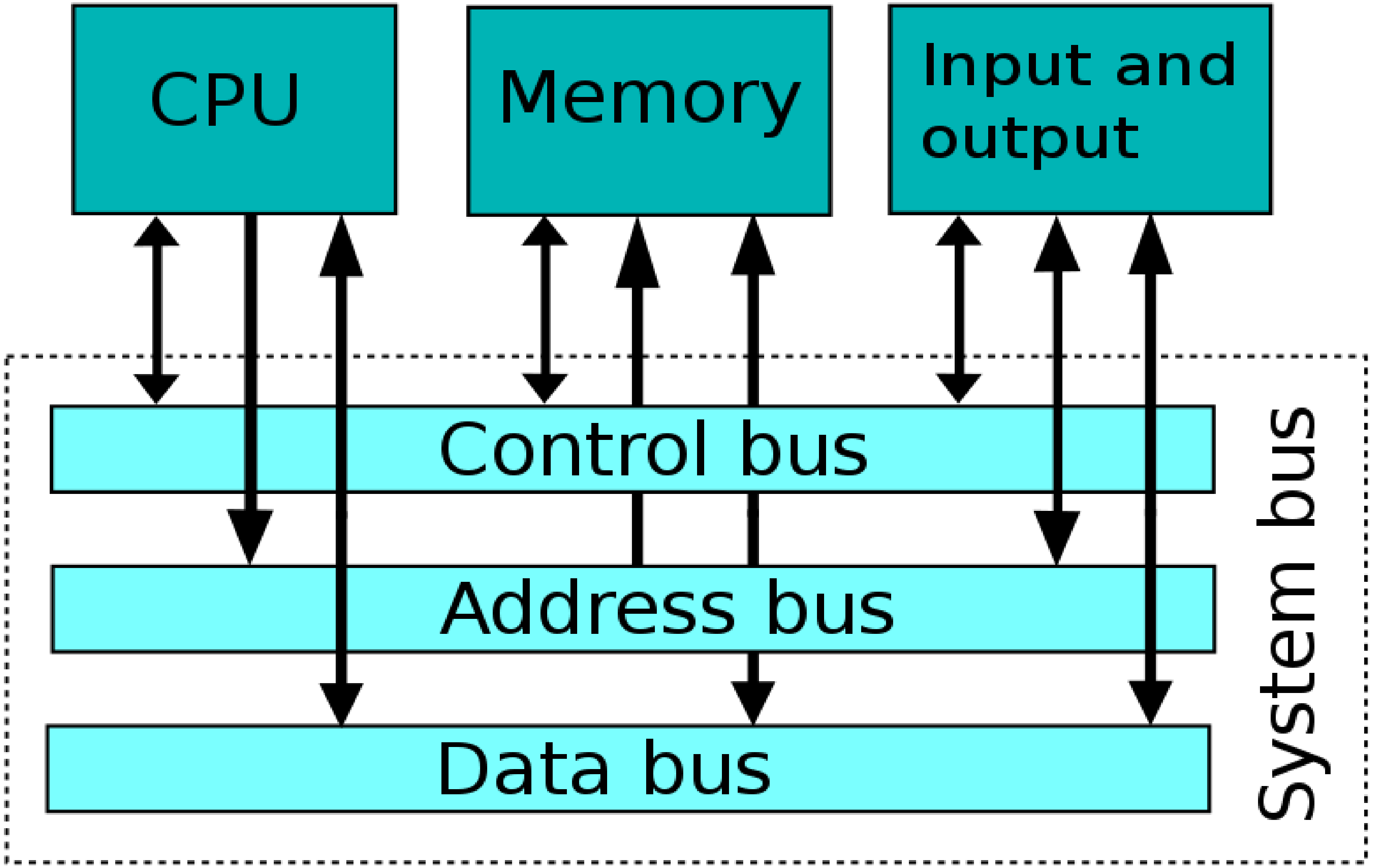
  1. **Address Bus –** Transfer Address
  2. **Data Bus –** Traansfer Data
  3. **Control Bus –** Transfer Control Signal



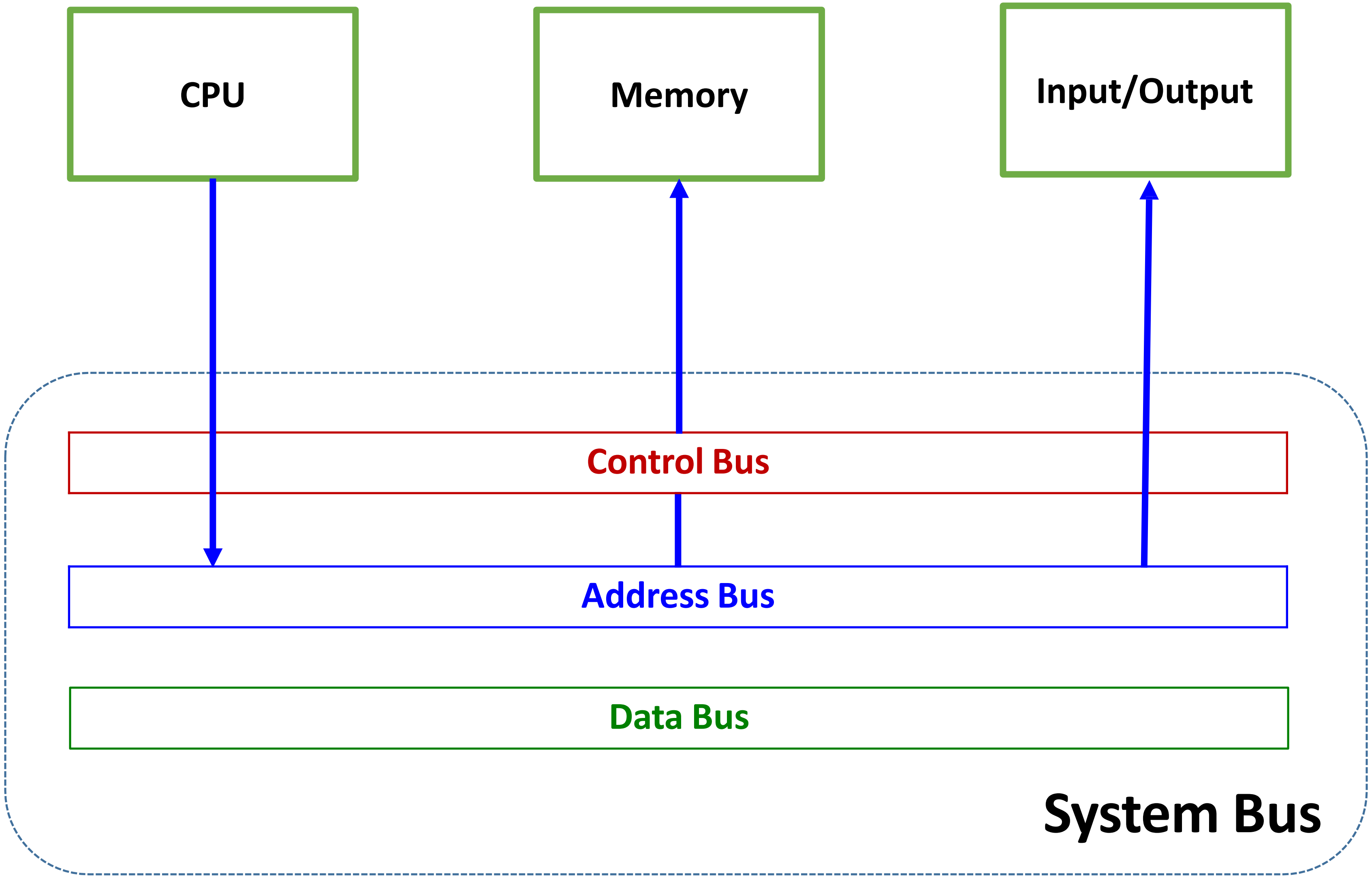


Main Components of a Computer System

System Bus


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

Address Bus



CPU
Memory
Input/Output
Control Bus
Address Bus
Data Bus
System Bus

Address Bus

- Address bus is used to carry the memory or I/O device address to which the data is to be transferred.
- It is a group of conducting wires which carries address only
- Address bus is unidirectional because data flow in one direction, from microprocessor to memory or from microprocessor to Input/output devices (That is, Out of Microprocessor).

- Themaximum address capacity is equal to two to the power of the number of lines present ($2^{\text{address lines}}$).

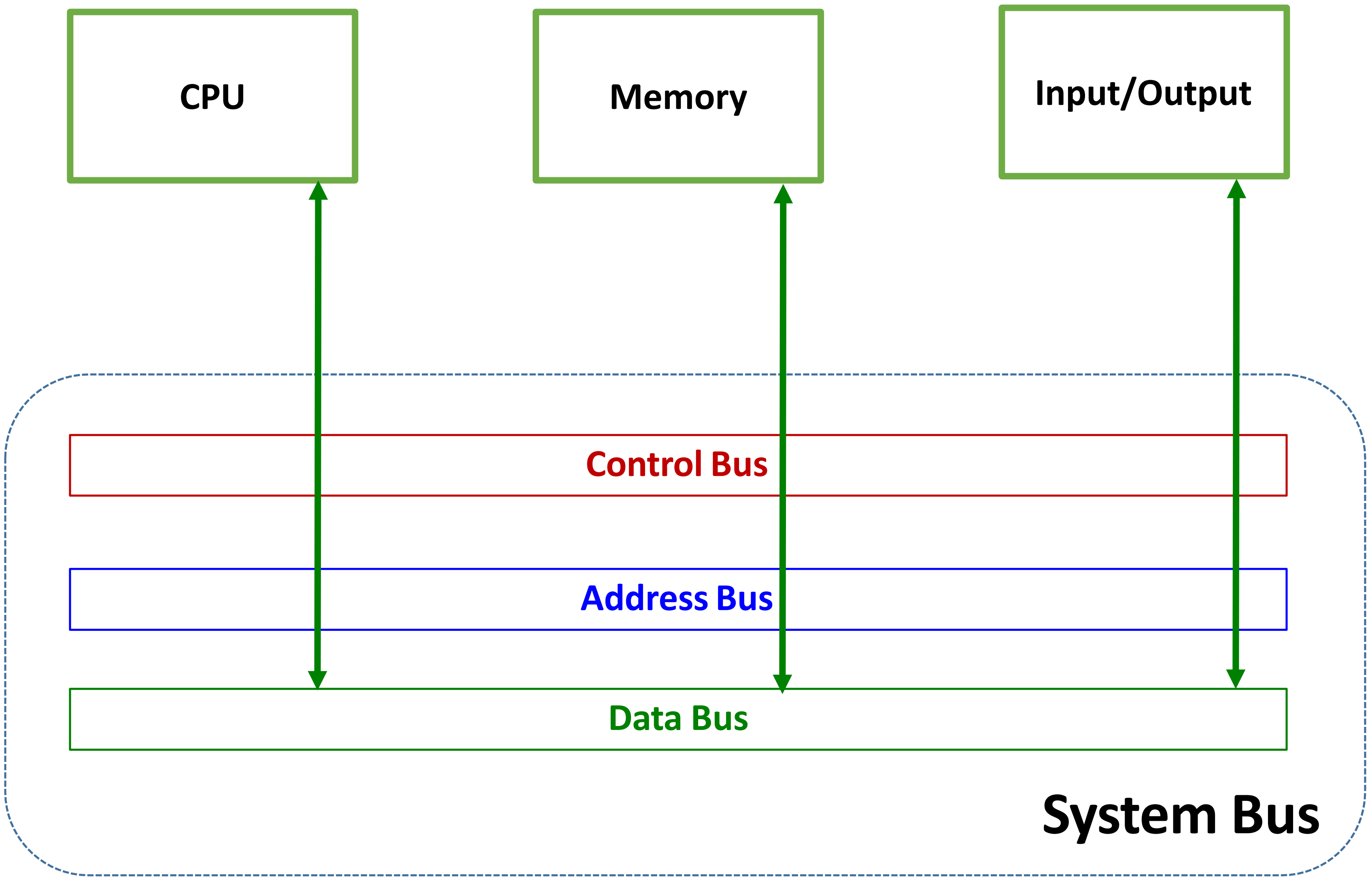
E.g. 8085 has 16 - address lines

$\therefore$ Maximum address capacity => $2^{16} = 65536$ bytes

Address Bus

- Length of Address Bus of 8085 microprocessor is 16 Bit (That is, Four Hexadecimal Digits), ranging from 0000 H to FFFF H, (H denotes Hexadecimal).
- The microprocessor 8085 can transfer maximum 16 bit address which means it can address 65, 536 different memory location.
- The Length of the address bus determines the amount of memory a system can address.
- Such as a system with a 32-bit address bus can address 2^{32} memory locations.
- If each memory location holds one byte, the addressable memory space is 4 GB.
- However, the actual amount of memory that can be accessed is usually much less than this theoretical limit due to chipset and motherboard limitations.

Data Bus


CPU
Memory
Input/Output
Control Bus
Address Bus
Data Bus
System Bus

Data Bus

- Data bus is used to transfer data between the microprocessor and other components such as memory and I/O devices.
- It is used to carry data to or from the memory or input/output devices.
- It is a group of conducting wires which carries Data only.
- Data bus is bidirectional because data flow in both directions, from microprocessor to memory or Input/Output devices and from memory or Input/Output devices to microprocessor
- Each wire of data bus is used to transfer the data corresponding to a single bit of binary data.

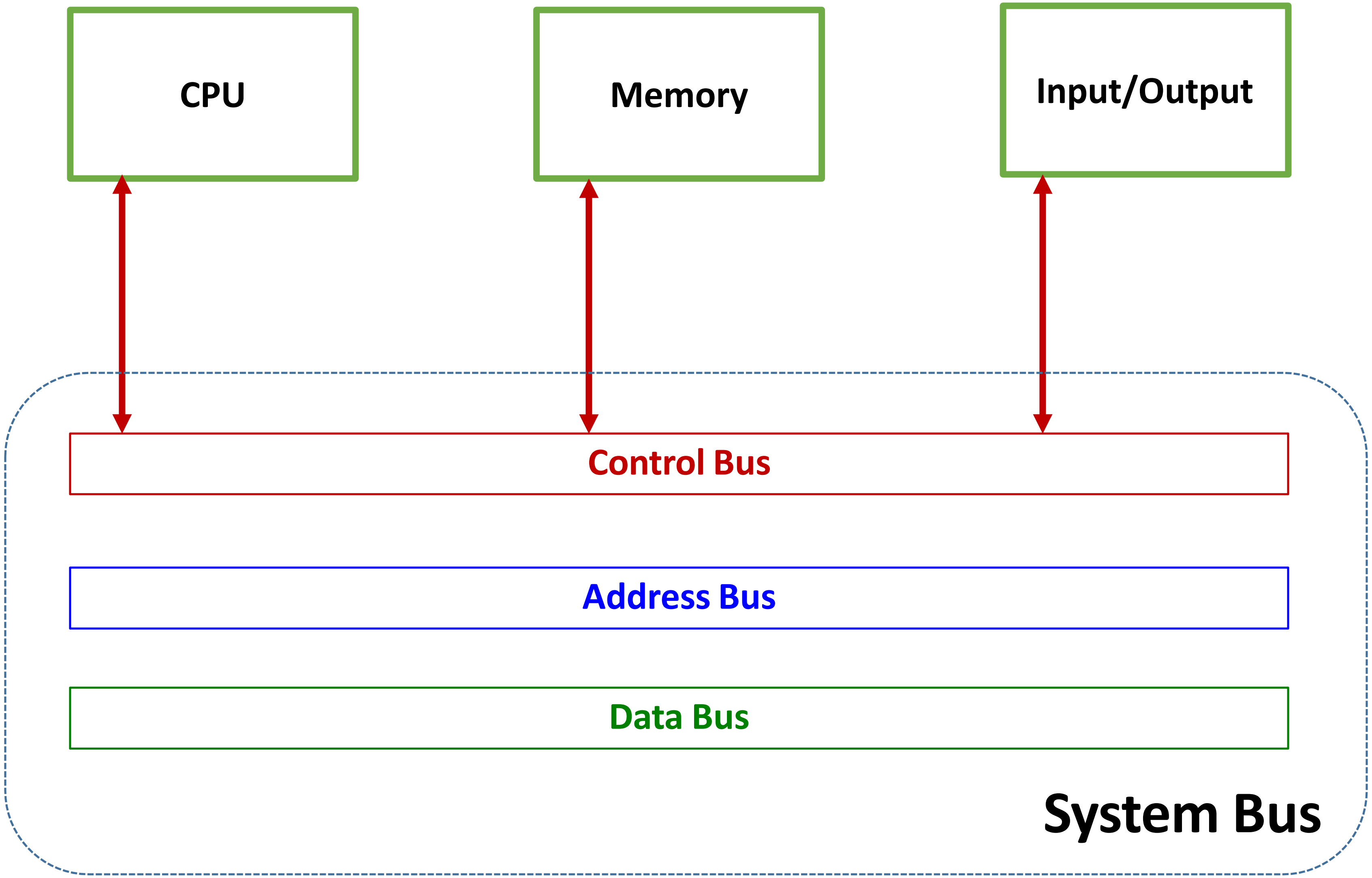
E.g. 8085 has 8 - data lines

$\therefore$ 8085 is known as 8-bit processor

Data Bus

- Length of Data Bus of 8085 microprocessor is 8 Bit (That is, two Hexadecimal Digits), ranging from 00 H to FF H. (H denotes Hexadecimal)
- When it is write operation, the processor will put the data (to be written) on the data bus
- When it is read operation, the memory controller will get the data from specific memory block and put it into the data bus.
- The width of the data bus is directly related to the largest number that the bus can carry, such as an 8 bit bus can represent 2 to the power of 8 unique values, this equates to the number 0 to 255.
- A 16 bit bus can carry 0 to 65535.

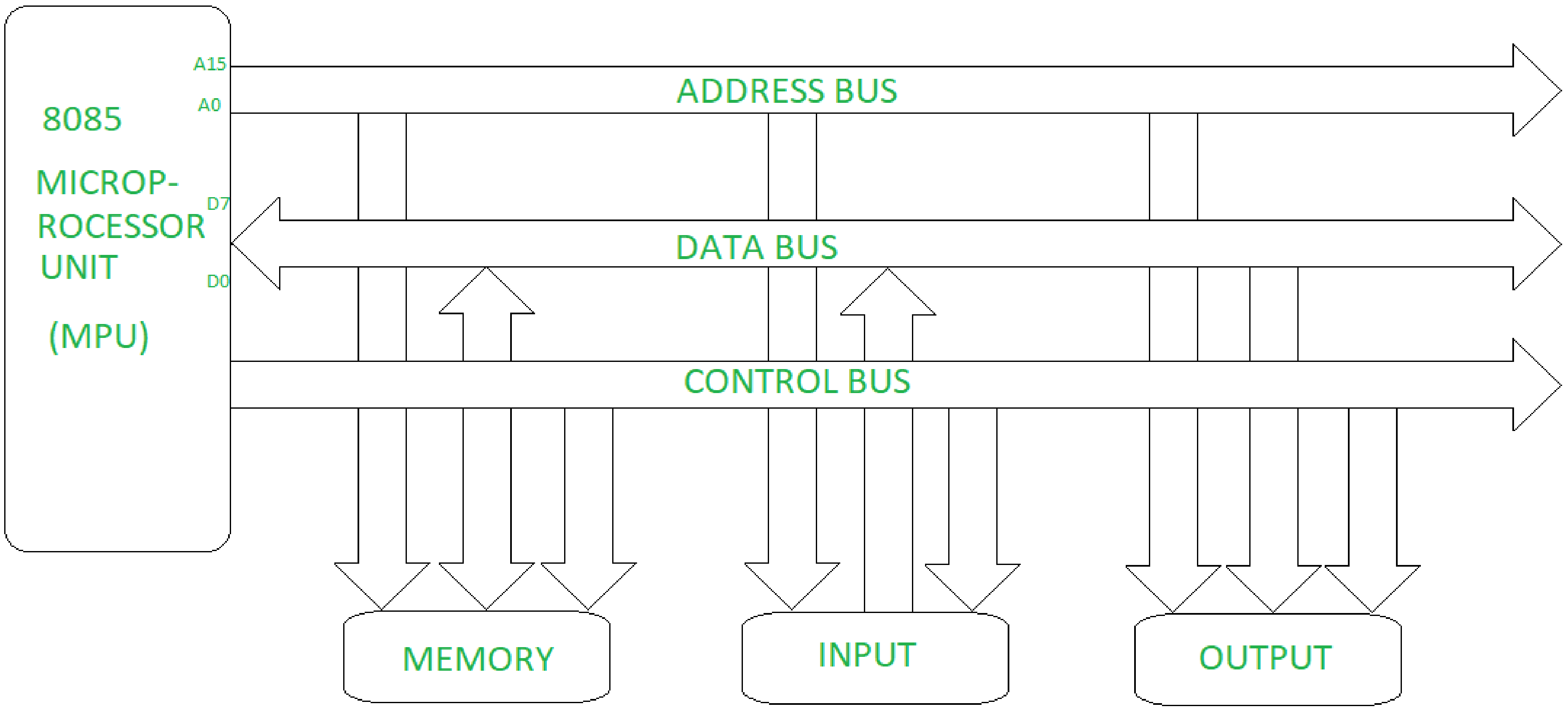
Control Bus


CPU
Memory
Input/Output
Control Bus
Address Bus
Data Bus
System Bus

Control Bus

- It is a group of conducting wires, which is used to generate timing and control signals to control all the associated peripherals, microprocessor uses control bus to process data, that is what to do with selected memory location.
- The control bus is used to carry control signals between the microprocessor and other components such as memory and I/O devices.
- It is used to transmit commands to the memory or I/O devices for performing specific operations.
- Some control signals are Memory read, Memory write , I/O Read, I/O Write and Opcode fetch etc.
- Control Bus is a bidirectional bus.

Bus organization of 8085 microprocessor



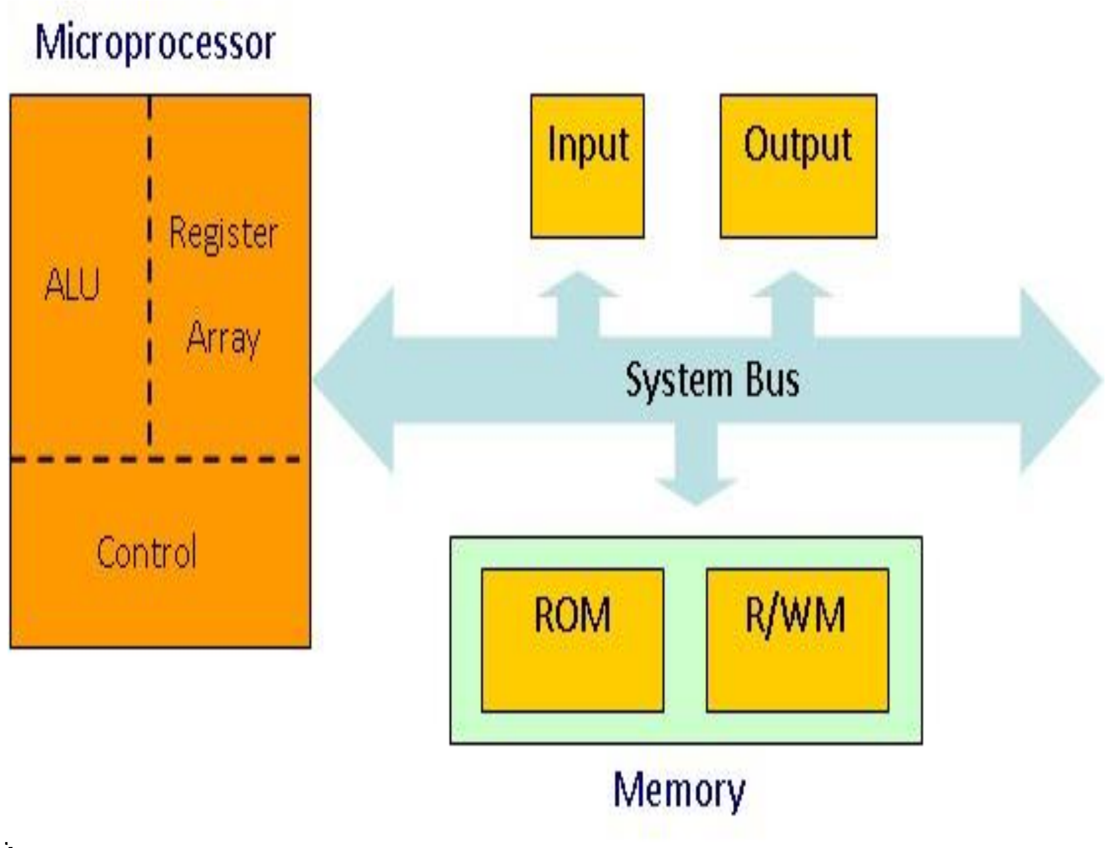
Bus organization system of 8085 Microprocessor

Microprocessor-Based System with Bus Architecture

- **ALU (Arithmetic/Logic Unit)** – It performs such arithmetic operations as addition and subtraction, and such logic operations as AND, OR, and XOR, etc. Results are stored either in registers or in memory.

- **Register Array** – It consists of various registers identified by letters such as B, C, D, E, H, L, etc. These registers are used to store data and addresses temporarily during the execution of a program.

- **Control Unit** – The control unit provides the necessary timing and control signals to all the operations in the microcomputer. It controls the flow of data between the microprocessor and memory and peripherals.



Microprocessor-Based System with Bus Architecture

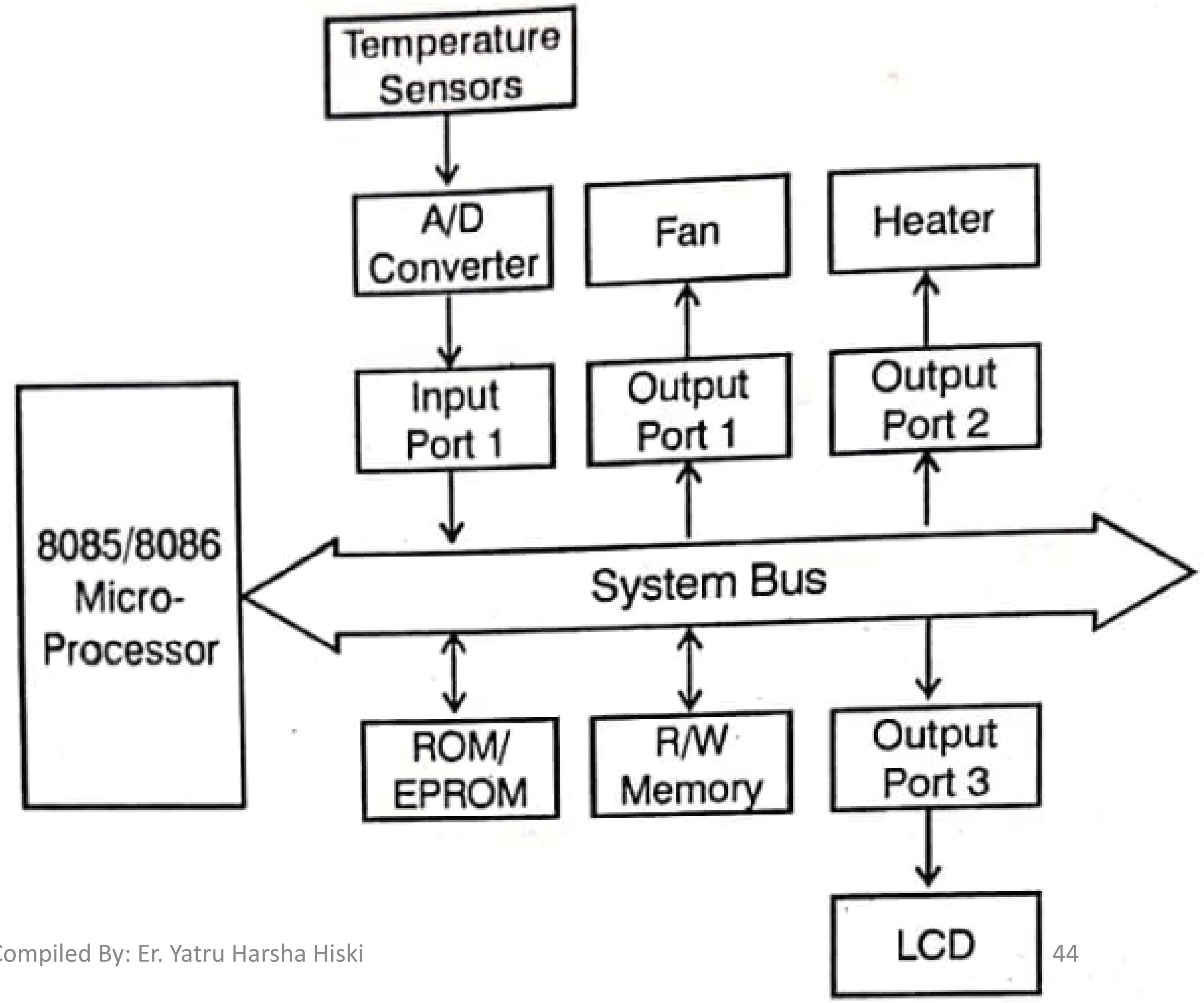
- ❖ **Input** – The input section transfers data and instructions in binary from the outside world to the microprocessor. It includes such devices as a keyboard, switches, a scanner, and an analog-to-digital converter.
- ❖ **Output** – The output section transfers data from the microprocessor to such output devices as LED, CRT, printer, magnetic tape, or another computer.
- ❖ **Memory** – It stores such binary information as instructions and data, and provides that information to the microprocessor. To execute programs, the microprocessor reads instructions and data from memory and performs the computing operations in its ALU section. Results are either transferred to the output section for display or stored in memory for later use.
- ❖ **System bus** – It is a communication path between the microprocessor and peripherals. The microprocessor communicates with only one peripheral at a time. The timing is provided by the control unit of the microprocessor.

Microprocessor Controlled Temperature System

Microprocessor – controlled temperature system is used to

i. Read the temperature in a room
ii. Display the temperature at LCD/LED panel
iii. Turn-on a fan if the temperature is above the limit.
iv. Turn-on a heater if the temperature is below the limit.

This system has a temperature sensor as an input device to sense room temperature and three output devices: a fan, a heater and display panel.



Microprocessor Controlled Temperature System

Microprocessor

- ❖Fig shows an 8085/8086 processor with a system bus; The processor will read the binary instructions from memory and execute those instructions continuously. It will read the temperature, display it at the LCD display panel, and turn on/off the fan and the heater based on the temperature.

Memory

- ❖The system includes two types of memory ROM and R/W memory.
- ❖ROM (read-only memory) will be used to store the program, called the monitor program, that is responsible for providing the necessary instructions to the processor to monitor the system. This will be a permanent program stored in ROM and will not be altered.
- ❖The R/W (read-write) memory is needed for temporary storage of data.

Microprocessor Controlled Temperature System

Input

- In this system, we need a device that can translate temperature (measurement of heat) into an equivalent electrical signal
- a device that translates one form of energy into another form is called a transducer.
- A temperature sensor is a three terminal semiconductor electronic device (a chip) that generates a voltage signal that is proportional to the temperature.
- However, this is an analog signal and our processor is capable of handling only binary bits. Therefore, this signal must be converted into digital bits. The analog to digital converter (ADC) performs that function.
- The ADC is an electronic semiconductor chip that converts an input analog signal into the equivalent eight binary output signals.
- In microprocessor based systems, devices that provide binary inputs (data) are connected to the processor using devices such as buffers called input ports.
- In this system, this ADC is an input port, and it will be assigned a binary number called an address. The microprocessor reads this digital signal from the input port.

Microprocessor Controlled Temperature System

Output

- ❖ Fig shows three output devices: fan, heater and liquid crystal display (LCD). These devices are connected to the processor using latches called output ports.
- ❖ Fan is an output device, identified as Port 1 , that is turned on by the processor when the temperature reaches a set higher limit.
- ❖ Heater is also an output device, identified as Port 2, that is turned on by the processor when the temperature reaches a set lower limit.
- ❖ LCD is made of crystal material placed between two plates in the form of a dot matrix or segments. It can display letters, decimal digits, or graphic characters. The LCD will be used to display temperatures.

System Software (Programs)

- ❖ The program that runs the system is called a monitor program or system software.
- ❖ Generally, the entire program is divided into subtasks and written as independent modules, and it is stored in ROM (or EPROM).
- ❖ When the system is reset, the microprocessor reads the binary command (instruction) from the first memory location of ROM and continues in sequence to execute the program.

Micron

- ❖A unit of length equal to one millionth of a meter.
- ❖It is denoted by **µ**(Mu).
- ❖For Example:
  - ❑If we pluck a hair from the head, it is very thin.
  - ❑But a hair is more than 2000 times wider than a transistor on a microprocessor.
  - ❑Wires between transistors are even thinner.
  - ❑They're more than 4000 times thinner than a hair.
  - ❑A hair is about 100 microns in diameter.
  - ❑That means, a transistor is just 0.045 microns wide.

END Of Unit 1

Thank You