# Unit I Fundamentals of Microprocessor

Introduction to Microprocessor

Microprocessor is a controlling unit of a micro-computer, fabricated on a small chip capable of performing ALU (Arithmetic Logical Unit) operations and communicating with the other devices connected to it.

Microprocessor consists of an ALU, register array, and a control unit. ALU performs arithmetical and logical operations on the data received from the memory or an input device. Register array consists of registers identified by letters like B, C, D, E, H, L and accumulator (register in which intermediate arithmetic and logic results are stored.). The control unit controls the flow of data and instructions within the computer.

Block Diagram of a Basic Microcomputer
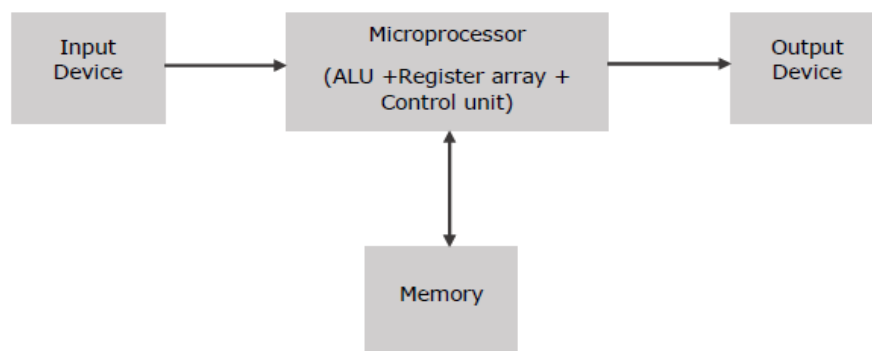
How does a Microprocessor Work?

The microprocessor follows a sequence: Fetch, Decode, and then Execute.

Initially, the instructions are stored in the memory in a sequential order. The microprocessor fetches those instructions from the memory, then decodes it and executes those instructions till STOP instruction is reached. Later, it sends the result in binary to the output port. Between these processes, the register stores the temporarily data and ALU performs the computing functions.

Features of a Microprocessor

Here is a list of some of the most prominent features of any microprocessor −

a) **Cost-effective** − The microprocessor chips are available at low prices and results its low cost.

b) **Size** − The microprocessor is of small size chip, hence is portable.

c) **Low Power Consumption** − Microprocessors are manufactured by using metaloxide semiconductor technology, which has low power consumption.

d) **Versatility** − The microprocessors are versatile as we can use the same chip in a number of applications by configuring the software program.

e) **Reliability** − The failure rate of microprocessors is very low, hence it is reliable.

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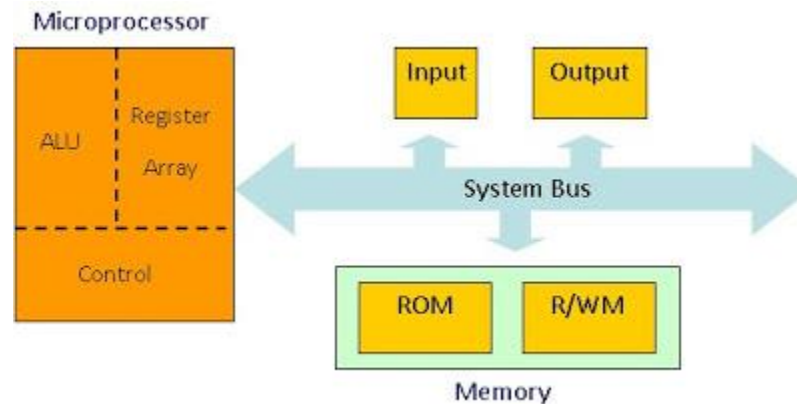
ALU (Arithmetic/Logic Unit) – It performs such arithmetic operations as addition and subtraction, and such logic operations as AND, OR, and XOR. Results are stored either in registers or in memory.

Register Array – It consists of various registers identified by letter such as B, C, D, E, H, L, IX, and IY. 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.

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.

Bus organization of 8085 microprocessor

Bus is a group of conducting wires which carries information, all the peripherals are connected to microprocessor through Bus.
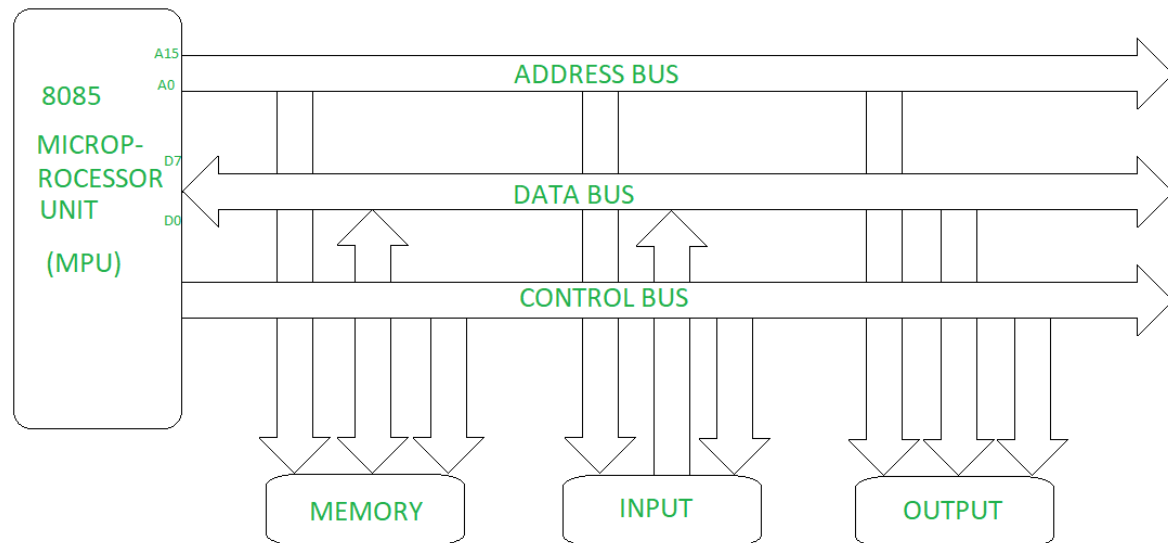
Bus organization system of 8085 Microprocessor

There are three types of buses.

a) **Address bus** – 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).

b) **Data bus –**
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.

c) **Control bus –**
It is a group of 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. Some control signals are:
- Memory read
- Memory write
- I/O read
- I/O Write

8085 Microprocessor & its Operation

8085 is pronounced as "eighty-eighty-five" microprocessor. It is an 8-bit microprocessor designed by Intel in 1977 using NMOS technology.

It has the following configuration –
- 8-bit data bus
- 16-bit address bus, which can address up to 64KB
- A 16-bit program counter
- A 16-bit stack pointer
- Six 8-bit registers arranged in pairs: BC, DE, HL
- Requires +5V supply to operate at 3.2 MHZ single phase clock

It is used in washing machines, microwave ovens, mobile phones, etc.

8085 Microprocessor Architecture & Functional Units
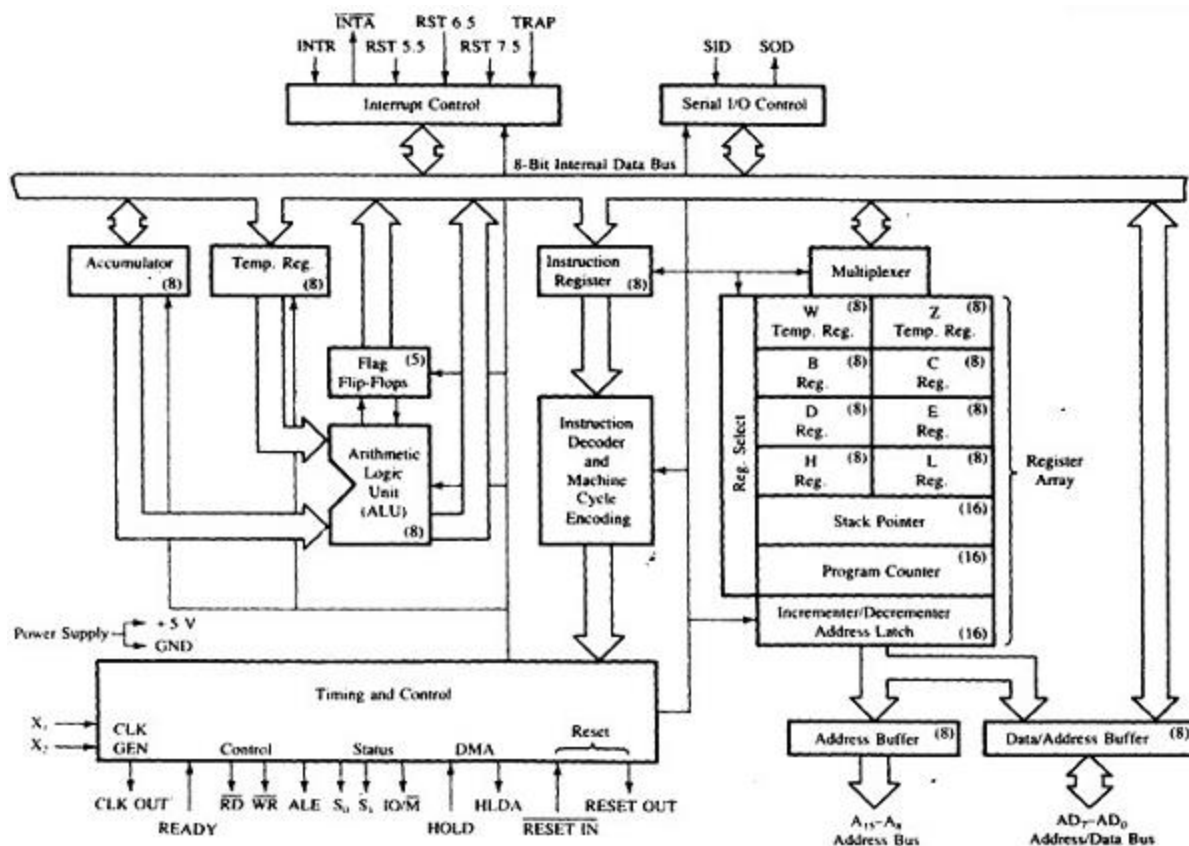
Fig: Block Diagram of 8085 Microprocessor

8085 consists of the following functional units –

1) **Accumulator**
   It is an 8-bit register used to perform arithmetic, logical, I/O & LOAD/STORE operations. It is connected to internal data bus & ALU.

2) **Arithmetic and logic unit**
   As the name suggests, it performs arithmetic and logical operations like Addition, Subtraction, AND, OR, etc. on 8-bit data.

3) **General purpose register**
   There are 6 general purpose registers in 8085 processor, i.e. B, C, D, E, H & L. Each register can hold 8-bit data. These registers can work in pair to hold 16-bit data and their pairing combination is like B-C, D-E & H-L.

4) **Program counter**
   It is a 16-bit register used to store the memory address location of the next instruction to be executed. Microprocessor increments the program whenever an instruction is being executed, so that the program counter points to the memory address of the next instruction that is going to be executed.

5) **Stack pointer**
   It is also a 16-bit register works like stack, which is always incremented/decremented by 2 during push & pop operations.

6) **Temporary register**
   It is an 8-bit register, which holds the temporary data of arithmetic and logical operations.

7) **Flag register**
   It is an 8-bit register having five 1-bit flip-flops, which holds either 0 or 1 depending upon the result stored in the accumulator.
   These are the set of 5 flip-flops –
   - Sign (S)
   - Zero (Z)
   - Auxiliary Carry (AC)
   - Parity (P)
   - Carry (C)

   Its bit position is shown in the following table –

D7	D6	D5	D4	D3	D2	D1	D0
S	Z		AC		P		CY

8) **Instruction register and decoder**

It is an 8-bit register. When an instruction is fetched from memory then it is stored in the Instruction register. Instruction decoder decodes the information present in the Instruction register.

9) **Timing and control unit**

It provides timing and control signal to the microprocessor to perform operations. Following are the timing and control signals-
- Control Signals: READY, RD', WR', ALE
- Status Signals: S0, S1, IO/M'
- DMA Signals: HOLD, HLDA
- RESET Signals: RESET IN, RESET OUT

10) **Interrupt control**

As the name suggests it controls the interrupts during a process. When a microprocessor is executing a main program and whenever an interrupt occurs, the microprocessor shifts the control from the main program to process the incoming request. After the request is completed, the control goes back to the main program.
There are 5 interrupt signals in 8085 microprocessor: INTR, RST 7.5, RST 6.5, RST 5.5, TRAP.

11) **Serial Input/output control**

It controls the serial data communication by using these two instructions: SID (Serial input data) and SOD (Serial output data).

12) **Address buffer and address-data buffer**

The content stored in the stack pointer and program counter is loaded into the address buffer and address-data buffer to communicate with the CPU. The memory and I/O chips are connected to these buses; the CPU can exchange the desired data with the memory and I/O chips.

13) **Address bus and data bus**

Data bus carries the data to be stored. It is bidirectional, whereas address bus carries the location to where it should be stored and it is unidirectional. It is used to transfer the data & Address I/O devices.

8085 Pin Configuration
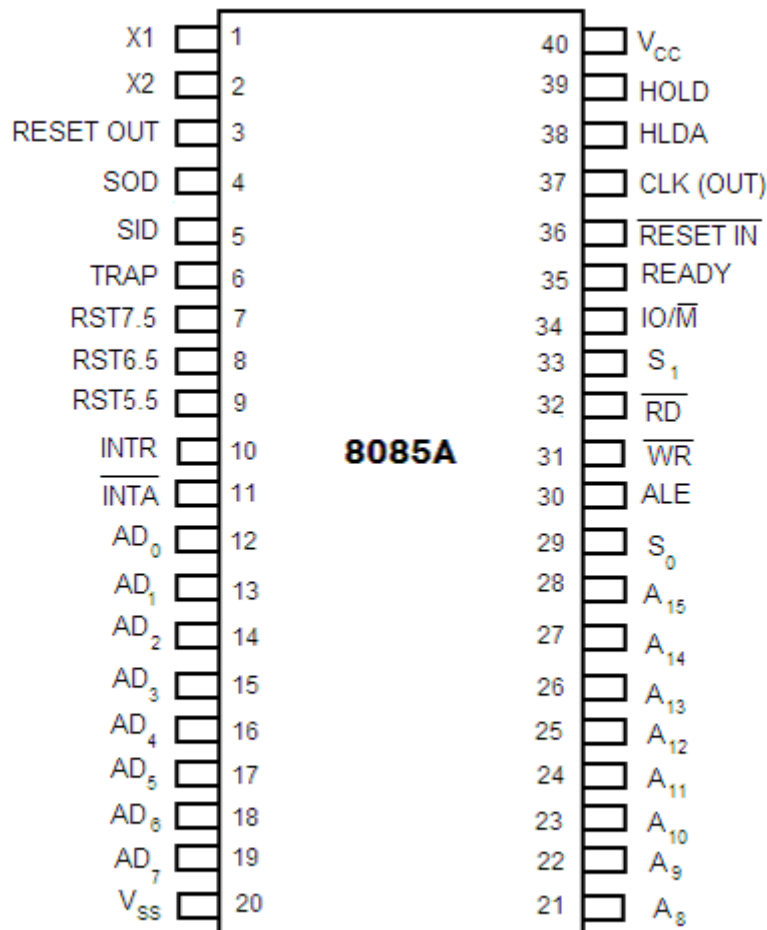
The pins of a 8085 microprocessor can be classified into seven groups –

1) **Address bus**

   A15-A8, it carries the most significant 8-bits of memory/IO address.

2) **Data bus**

   AD7-AD0, it carries the least significant 8-bit address and data bus.

3) **Control and status signals**

   These signals are used to identify the nature of operation. There are 3 control signal and 3 status signals.

   Three control signals are RD, WR & ALE.

a) **RD** – This signal indicates that the selected IO or memory device is to be read and is ready for accepting data available on the data bus.

b) **WR** – This signal indicates that the data on the data bus is to be written into a selected memory or IO location.

c) **ALE** – It is a positive going pulse generated when a new operation is started by the microprocessor. When the pulse goes high, it indicates address. When the pulse goes down it indicates data.

Three status signals are IO/M, S0 & S1.

IO/M
This signal is used to differentiate between IO and Memory operations, i.e. when it is high indicates IO operation and when it is low then it indicates memory operation.

S1 & S0
These signals are used to identify the type of current operation.

4) **Power supply**
There are 2 power supply signals – VCC & VSS. VCC indicates +5v power supply and VSS indicates ground signal.

5) **Clock signals**
There are 3 clock signals, i.e. X1, X2, CLK OUT.

6) **Interrupts & externally initiated signals**
Interrupts are the signals generated by external devices to request the microprocessor to perform a task. There are 5 interrupt signals, i.e. TRAP, RST 7.5, RST 6.5, RST 5.5, and INTR.

7) **Serial I/O signals**
There are 2 serial signals, i.e. SID (Serial output data line) and SOD (Serial input data line) and these signals are used for serial communication.
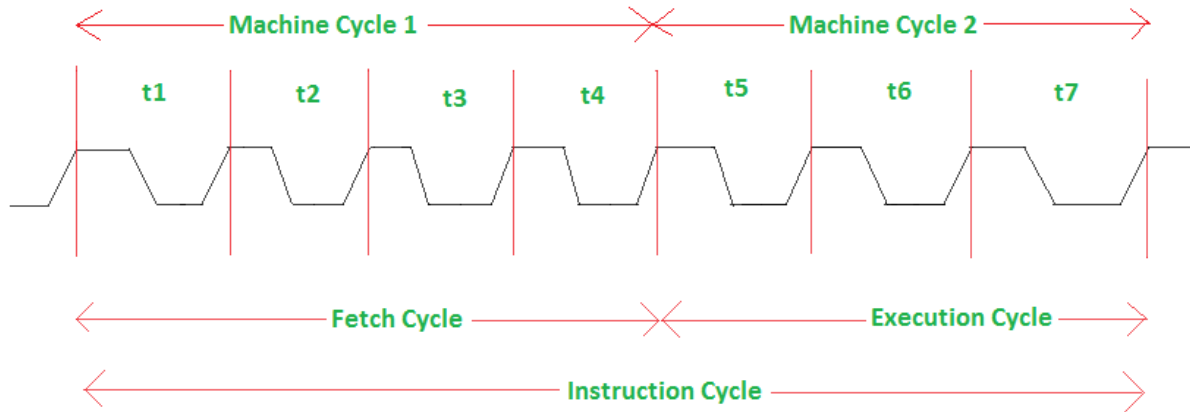
Instruction cycle, Machine Cycle & T State in 8085 microprocessor
Time required to execute and fetch an entire instruction is called instruction cycle.
It consists:
   a) **Fetch cycle** – The next instruction is fetched by the address stored in program counter (PC) and then stored in the instruction register.
   b) **Decode instruction** – Decoder interprets the encoded instruction from instruction register.
   c) **Reading effective address** – The address given in instruction is read from main memory and required data is fetched. The effective address depends on direct addressing mode or indirect addressing mode.
   d) **Execution cycle** – consists memory read (MR), memory write (MW), input output read (IOR) and input output write (IOW).

Instruction cycle in 8085 microprocessor

The time required by the microprocessor to complete an operation of accessing memory or input/output devices is called machine cycle.

One time period of frequency of microprocessor is called t-state. A t-state is measured from the falling edge of one clock pulse to the falling edge of the next clock pulse.

Fetch cycle takes four t-states and execution cycle takes three t-states.

Addressing Modes in 8085

To perform any operation, we have to give the corresponding instructions to the microprocessor. In each instruction, programmer has to specify 3 things:

1. Operation to be performed.
2. Address of source of data.
3. Address of destination of result.

The method by which the address of source of data or the address of destination of result is given in the instruction is called Addressing Modes. The term addressing mode refers to the way in which the operand of the instruction is specified.

Intel 8085 uses the following addressing modes:

1) Direct Addressing Mode
2) Register Addressing Mode
3) Register Indirect Addressing Mode
4) Immediate Addressing Mode
5) Implicit Addressing Mode

Direct Addressing Mode
In direct addressing mode, the data to be operated is available inside a memory location and that memory location is directly specified as an operand. The operand is directly available in the instruction itself.
Example:
LDA 2050 (load the contents of memory location into accumulator A)
Register Addressing Mode
In register addressing mode, the data to be operated is available inside the register(s) and register(s) is(are) operands. Therefore, the operation is performed within various registers of the microprocessor.
Examples:
MOV A, B (move the contents of register B to register A)
ADD B (add contents of registers A and B and store the result in register A)
INR A (increment the contents of register A by one)

Register Indirect Addressing Mode
In register indirect addressing mode, the data to be operated is available inside a memory location and that memory location is indirectly specified by a register pair.
Example:
MOV A, M (move the contents of the memory location pointed by the H-L pair to the accumulator)

Immediate Addressing Mode
In immediate addressing mode the source operand is always data. If the data is 8-bit, then the instruction will be of 2 bytes, if the data is of 16-bit then the instruction will be of 3 bytes.
Example:
MVI B 45 (move the data 45H immediately to register B)

Implied/Implicit Addressing Mode
In implied/implicit addressing mode the operand is hidden and the data to be operated is available in the instruction itself.
Examples:
RRC (rotate accumulator A right by one bit)
RLC (rotate accumulator A left by one bit)

Introduction to 8086
8086 Microprocessor is an enhanced version of 8085Microprocessor that was designed by Intel in 1976. It is a 16-bit Microprocessor having 20 address lines and16 data lines that provides up to 1MB storage. It consists of powerful instruction set, which provides operations like multiplication and division easily.

It supports two modes of operation, i.e. Maximum mode and Minimum mode. Maximum mode is suitable for system having multiple processors and Minimum mode is suitable for system having a single processor.

Features of 8086

a) It has an instruction queue, which is capable of storing six instruction bytes from the memory resulting in faster processing.
b) It was the first 16-bit processor having 16-bit ALU, 16-bit registers, internal data bus, and 16-bit external data bus resulting in faster processing.
c) It uses two stages of pipelining, i.e. Fetch Stage and Execute Stage, which improves performance. **Fetch stage** can prefetch up to 6 bytes of instructions and stores them in the queue. **Execute stage** executes these instructions.
d) It consists of 29,000 transistors.

Comparison between 8085 & 8086 Microprocessor

a) **Size** – 8085 is 8-bit microprocessor, whereas 8086 is 16-bit microprocessor.
b) **Address Bus** – 8085 has 16-bit address bus while 8086 has 20-bit address bus.
c) **Memory** – 8085 can access up to 64Kb, whereas 8086 can access up to 1 Mb of memory.
d) **Instruction** – 8085 doesn't have an instruction queue, whereas 8086 has an instruction queue.
e) **Pipelining** – 8085 doesn't support a pipelined architecture while 8086 supports a pipelined architecture.
f) **I/O** – 8085 can address 2^8 = 256 I/O's, whereas 8086 can access 2^{16} = 65,536 I/O's.
g) **Cost** – The cost of 8085 is low whereas that of 8086 is high.