PERIYAR ARTS COLLEGE,CUDDALORE
DEPARTMENT OF PHYSICS

E-CONTENT MATERIAL FOR II MSC PHYSICS

MICROPROCESSOR & MICROCONTROLLER
(CODE: MPH 33)
UNIT 1 (Part -1)

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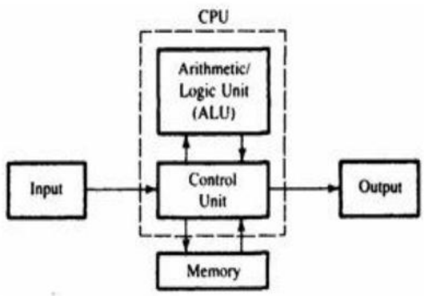
Introduction

Digital computer:

A programmable machine that processes binary data is called digital computer. It is traditionally represented by five components CPU (central processing unit), ALU (arithmetic logic unit) and Control unit, memory, input and output. Traditional block diagram of a computer and microprocessor are presented in Fig.1 and Fig.2 respectively.



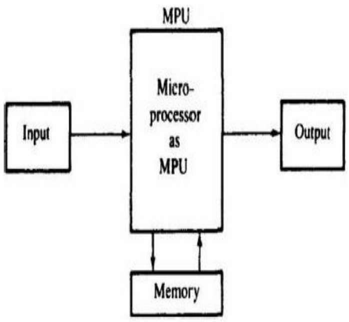


Fig.1 Block diagram of a computer   Fig.2 Block diagram of a microprocessor

Microprocessor as a CPU (MPU)

With advent of integrated circuit technology, it became possible to build the CPU on a single chip, this came to be known as a microprocessor and the traditional block diagram is shown in fig.2

Basic and important terms used in microprocessor

The microprocessor operates in binary digits 0 and 1, known as bits.

Bit: Bit is an abbreviation for the term binary digit.
A digit of the binary number or code is called bit.

Nibble: The 4-bit (4 digit) binary number is called nibble.

Byte: The 8-bit(8 digit) binary number is called byte.

Word: The 16-bit (16 digit) binary number is called word.

Double word: The 32-bit (32 digit) binary number is called double word.
Hexadecimal number system:

The hexadecimal number system has a base 16. The basic digits are 0,1,2,3,4,5,6,7,8,9,A,B,C,D,E,F. Table 1 give the hex code and the decimal equivalent.

HEX	**DEC**
0	0
1	1
2	2
3	3
4	4
5	5
6	6
7	7

HEX	**DEC**
8	8
9	9
A	10
B	11
C	12
D	13
E	14
F	15

Hardware: The physical component of computer/microprocessor is called hardware.

Instruction: A command in binary that is recognized and executed by the computer to accomplish a task.

Program &Software: A set of instructions writer for the microprocessor to perform a task is called a program and a group of programs is called software.

Operating system: The interaction between the hardware and the software is managed by a set of programs called an operating system. eg.MS-DOS, UNIX,Windows 95/98/2000/2007 etc.

Data: The quantity (binary number/code) operated by an instruction of a program is called data. The size of data is specified as bit, byte etc.

Memory: A medium that stores binary information (instruction and data).

Input: A device that transfers information from the outside world to the computer.

Output: A device that transfers information from the computer to the outside world.

Mnemonic: A combination of letters to suggest the operation of an instruction. e.g, MOV, MVI, ADD etc.

Machine language: The binary medium of communication with a computer through a designed set of instructions specific to each computer.

Assembly language: A medium of communication with a computer in which programs are written in mnemonics. A assembly language is specific to a given computer.

Low-level language: A medium of communication that is machine-dependent or specific to a given computer. The machine and the assembly languages of a computer are considered low level languages.

High-level language: A medium of communication that is machine independent of a computer. Programs are written in English-like words.

Compiler: A program that translates English-like words of a high-level language into the machine language of a computer.

Interpreter: A program that translates the English-like statements of a high-level language into the machine language of a computer.

Assembler: A computer program that translates an assembly language program from mnemonics to the binary machine code of a computer.

ASCII: American Standard Code for Information Interchange. This is a 7-bit alphanumeric code with 128 combinations.

SSI (small scale integration): The process of designing a few circuits on a single chip.

MSI (medium scale integration): The process of designing more than a hundred gates on a single chip.

LSI (large scale integration): The process of designing more than a thousand gates on a single chip.

VLSI (very large scale integration): The process of designing millions of gates and billions of transistors on a single chip.

Microprocessor

Definition 1

It is a semiconductor device manufactured using the VLSI technique. It includes the ALU, register arrays and control units on a single chip.

Definition 2

It is a program controlled device, which fetches (from memory), decodes and executes instructions. It is used as CPU in computers. Most microprocessors are single chip devices.

Evolution of Microprocessor

The advent of the integrated circuit led to the development of the microprocessor and microprocessor based computer system.

First generation microprocessors

The microprocessor introduced between 1971 and 1973 were the first generation microprocessors using PMOS (P-metal oxide semiconductor) technology. INTEL 4004, INTEL 4040 are first generation microprocessor and they are ***4-bit*** processors.

Second generation microprocessors

The second generation microprocessors introduced in 1973 using NMOS (N-metal oxide semiconductor) technology. INTEL 8080, INTEL 8085 are second generation ***8-bit*** processors.

Third generation microprocessors

The third generation microprocessors introduced after 1978 using HMOS (High density-metal oxide semiconductor) technology. INTEL 8086, INTEL 80186 are third generation ***16-bit*** processors.

Fourth generation microprocessors

The fourth generation microprocessors introduced in 1980 using low power version of HMOS technology. INTEl 80386, INTEL 80486 are ***32-bit*** processors

Fifth generation microprocessors

The latest processor by INTEL is **Pentium** which is considered as fifth generation microprocessors. They are ***64-bit*** processors.

MICROPROCESSOR AND ITS OPERATIONS

All the various functions performed by the microprocessor can be classified in three general categories.

i) Microprocessor initiated operations
ii) Internal operations
iii) Peripheral or externally initiated operations

To perform these functions, the microprocessor requires a group of logic circuits and a set of signals called control signals. The term **microprocessor unit (MPU)** is defined as a group of device that can perform these functions with necessary set of signals. It is similar to CPU (Central processing unit) of a computer.

i) Microprocessor initiated operations and 8085 bus organization

The microprocessor unit (MPU) performs mainly four operations;

- Memory read: Reads data (or instructions) from memory
- Memory write: Writes data (or instructions) into memory
- I/O read: Accepts data from input devices
- I/O write: Sends data to output devices

All these operations are part of the communications process between the MPU and peripheral devices. To communicate with a peripheral (or a memory location), the MPU needs to perform the following steps

Step 1: Identify the peripheral or the memory location
Step 2: Transfer binary information (data and instruction)
Step 3: Provide timing or synchronization signals.

Bus structure:

The 8085 MPU performs these functions using ***buses***. A bus groups is group of conducting lines that carries address, data and control signals. There are

- Address bus
- Data bus
- Control bus

The bus structure is shown in fig.3

Address bus

- The group of conducting lines that carries address are called address bus.
- The address bus is a group of 16 lines generally identified as A_0 to $A_{15.}$
- It is ***unidirectional***- bits flow only in one direction i.e., from the MPU to peripheral devices.

- It performs the first function; identifying peripheral device or memory devices (step 1).
- Each peripheral or memory devices is identified by a binary number called address.
- Address bus is used to carry 16-bit address/lines.

Data bus

- The group of conducting lines that carries data are called data bus.
- The data bus is a group of 8 lines.
- It is a ***bidirectional***. i.e., data flow in both directions between the MPU and memory and peripheral devices.
- It performs the second function; transferring binary information (step 2).
- The eight data lines enable the MPU to manipulate 8-bit data ranging from 00_H to FF_H ($2^8 = 256$ numbers)
- The largest number that can appear on the data bus is 1111 1111 (255_{10}).
- The 8085 is known as 8-bit microprocessor.
- The 8086 has 16 data lines and it is known as 16-bit microprocessor.

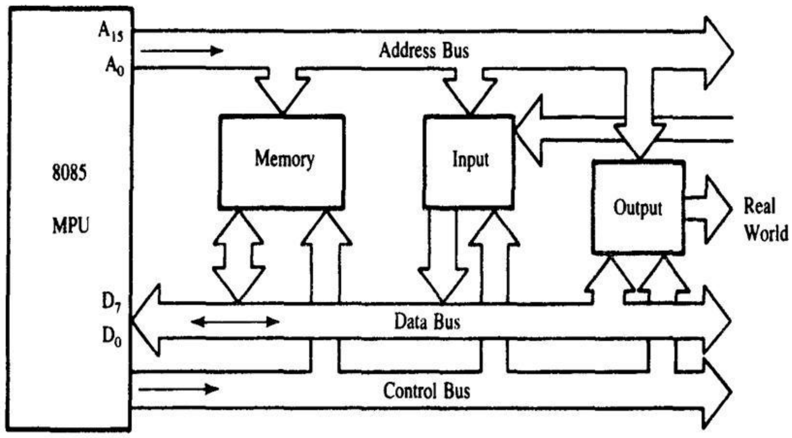


Fig.3 8085 Bus structure

Control bus

- The group of conducting lines that carries control signals are called control bus.
- It is ***unidirectional***.
- The control bus is comprised of various single lines that carry synchronization signals.
- It performs the third function; providing timing signals (step 3).
- It is not group of lines but individual lines that provide a pulse to indicate an MPU operation.

❖ The four control signals are memory read, memory write, I/O read and I/O write.

ii) Internal operations

The microprocessor determines how and what operations can be performed with the data. These operations are;

- Store 8-it data
- Perform arithmetic and logical operations
- Test for condition
- Sequence the execution of instructions
- Store data temporarily during execution in the defined R/W memory locations called *stack*

To perform these operations, the microprocessor requires registers, an arithmetic/logic unit (ALU), control logic and internal buses. Fig.4 shows the programming model of 8085 displaying the internal registers and the accumulator.

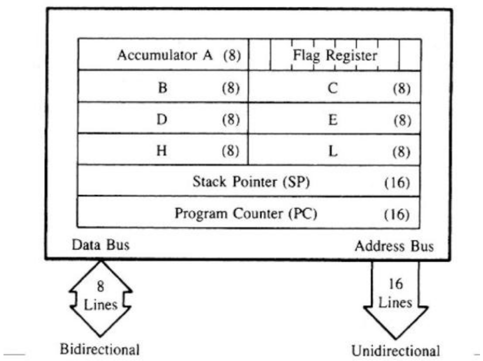


Fig.4 8085 programmable registers

iii) Peripheral or externally initiated operations

External devices (or signals) can initiate the following operations

- Reset
- Interrupt
- Ready
- Hold

8085 MICROPROCESSOR PINOUT AND SIGNALS

- The 8085A (commonly known as the 8085) is an 8-bit general purpose microprocessor capable of 64K (2^{16} =65536 rounded off to 64,000 = 64K) of memory.

- The device has 40 pins. Fig.5 shows the pinout of 8085 microprocessor.

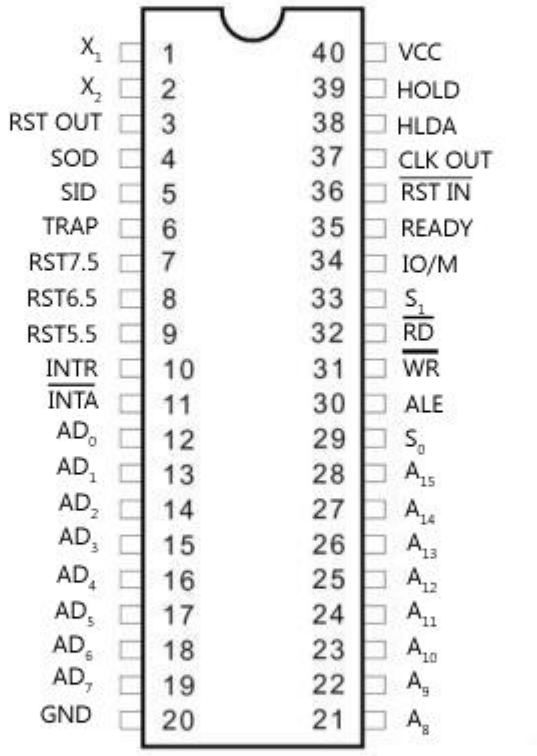


Fig.5 8085 pin diagram

In 8085, all the signals can be classified into six groups

i) Address bus
ii) Multiplexed Address/Data bus
iii) Control and status signals
iv) Power supply and frequency signals
v) Externally initiated signals and
vi) Serial I/O ports

i) Address bus

- ✓ The 8085 has 16 signal lines (pins) that are used as the address bus.
- ✓ These lines are split into two segments; A_{15}-A_8 and AD_7-AD_0.
- ✓ The eight signals lines A_{15}-A_8 are unidirectional and used for the most significant bits (MSB), called the high-order address.

ii) Multiplexed Address/Data bus

- ✓ The signal lines AD_7-AD_0 are bidirectional.
- ✓ They are used the low-order address bus as well as the data bus.
- ✓ In executing an instruction, during the earlier part of the cycle, these lines are used as the low-order address bus.
- ✓ During the later part of the cycle, these lines are used as the data bus.
- ✓ Hence it is known as multiplexing the bus.

iii) Control and Status signals

This group of signals includes two control signals ($\overline{RD}$ and $\overline{WR}$), three status signals (IO/$\overline{M}$, S_0 and S_1) and one special signal ALE.

ALE: (Address Latch Enable)

- *This is positive going pulse generated every time the 8085 begins an operation (machine cycle).*
- *It indicates that the bits on AD_7-AD_0 are address bits.*
- *This signal is used primarily to latch the low-order address from the multiplexed bus and generate a separate set of eight address lines A_7-A_0.*

$\overline{RD}$-Read:

- *This is a Read control signal (active low).*
- *This signal indicates that the selected I/O or memory device is to be read and data are available on the data bus.*
- *$\overline{RD}$ – A over bar on the signal, indicates that it is active low. (i.e., the signal is normally high and when the signal is activated it is low).*

$\overline{WR}$-Write:

- *This is a Write control signal (active low).*
- *This signal indicates that the data on the data bus are to be written into a selected memory or I/O location.*

IO/$\overline{M}$:

- *This is a status signal used to differentiate between I/O and memory operation.*
- *When it is high, it indicates an I/O operation; when it is low, it indicates a memory operation.*

S_1 and S_0:

This status signals sent by microprocessor and can be used to know the type of current operation the 8085 performs. This is given in Table.

S_1	S_0	Status
0	0	Halt
0	1	write
1	0	read
1	1	Opcode fetch

iv) Power supply and frequency signals:

- *V_{cc} : +5 V power supply*
- *V_{ss} : Ground reference*
- *X_1, X_2: A crystal is connected at these two pins. The frequency is internally divided by two; to operate a system at 3 MH_z, the crystal should have a frequency of 6 MH_z.*
- *CLK (OUT)- Clock Output: This signal can be used as the system clock for other devices.*

v) Externally initiated signals:

The 8085 has five interrupt signals that can be used to interrupt a program execution.

- *INTR (Input): Interrupt Request- this used as a general purpose interrupt.*
- $\overline{INTA}$ *(Output): Interrupt Acknowledge-this is used to acknowledge an interrupt.*
- *RST 7.5(Inputs): Restart Interrupts: These are vectored interrupts that transfer the program control to specific memory locations. They have higher priorities than the INTR interrupt. Among these three, the priority order is 7.5,6.5 and 5.5.*
- *TRAP (Input): This is a nonmaskable interrupt and has the highest priority.*

In addition to the interrupts, three pins-RESET, HOLD and READY-accept the externally initiated signals as inputs.

- *HOLD (Input): This signal indicates that a peripheral such as a DMA (Direct Memory Access) controller is requesting the used of the address and data buses.*
- *HLDA (Output): Hold Acknowledge- this signal acknowledges the HOLD request.*
- *READY (Input): This signal is used to delay the microprocessor Read or Write cycles until a slow responding pehripheral is ready to send or accept data. When this signal goes low, the microprocessor waits for an integral number of clock cycles until it gives high.*

- $\overline{RESET\ IN}$*: When the signal on this pin goes low, the program counter is set to zero, the buses are tri-stated and the MPU is reset.*

- *RESET OUT: This signal indicates that the MPU is being reset. The signal can be used to reset other devices.*

vi) Serial I/O Ports:

- *The 8085 has two signals to implement the serial transmission; SID (serial input data) and SOD (serial output data).*
- *In serial transmission, data bits are sent over a single line, one bit at a time, such as the transmission over telephone lines.*
-

8085 MICROPROCESSOR AND ITS ARCHITECTURE

The process of data manipulation and communication is determined by the logic design of the microprocessor is called the ***architecture***. Fig.6 shows the internal architecture/ functional block diagram of the 8085. It includes the following units.

i) Register array

ii) ALU and associated circuitry
iii) Instruction register and decoder
iv) Timing and control unit
v) Interrupts and Serial I/O

i) Register array

- The 8085 has six general purpose registers named as B,C,D,E,H and L.
- Each register can hold an 8 bit-data.
- The six registers can also be combined as register pairs BC,DE and HL.
- A register pair now, can hold a 16-bit data or a 16-bit address.
- When used as a 8-bit register, each register can store a data ranging from 00_H to FF_H.
- When used as a 16-bit register, each register can store a data ranging from 0000_H to $FFFF_H$.
- These registers are used for temporary storage of data.

Program counter (PC)

- *It is a 16-bit register.*
- *The PC holds the 16-bit address of the memory from which the next byte is to be fetched.*
- *When a byte is being fetched, the PC is automatically incremented by on to point to the next memory location.*

Stack pointer (SP)

- *The stack pointer is also a 16-bit register.*
- *It holds the address of the stack top.*
- *A stack is a group of memory locations in RAM (random access memory) defined by the programmer.*
- *It is used to save the contents of the registers and during interrupts.*

Address latch-Incrementer/Decrementer

- *The address latch is useful in selecting the address of the memory to be sent out from program counter or stack pointer or any of the register pairs.*
- *An incrementer and decrementer allows the contents of any of the 16-bit regiseters which hold the address to be incremented or decremented.*

Two additional registers W and Z are included in the register array. These registers are used to hold 8-bit data during the execution of some instructions.

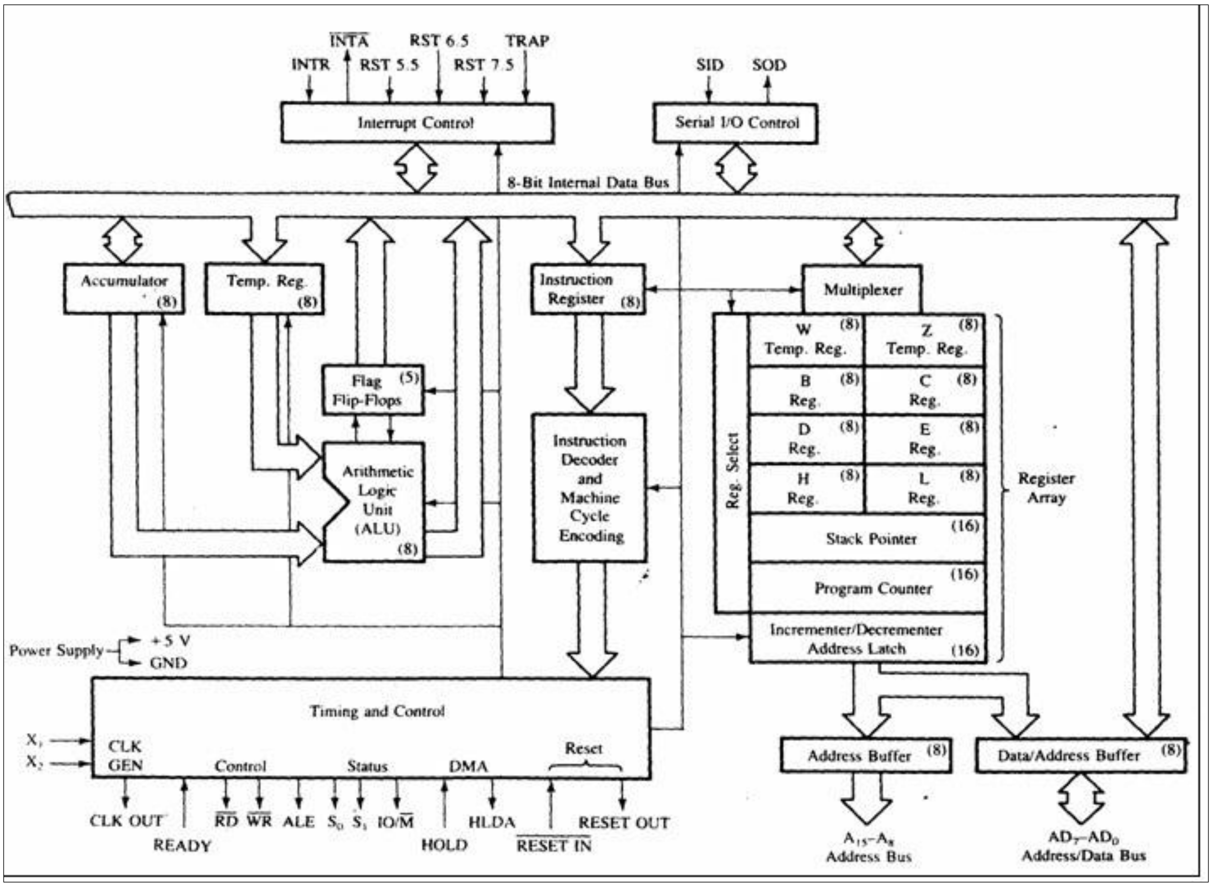


Fig.6 Internal architecture/ functional block diagram of the 8085

ii) ALU and associated circuitry

- The Arithmetic Logic Unit (ALU) of 8085 performs arithmetic and logic operations on two 8-bit data.
- It includes the accumulator, temporary register and five flags.
- The temporary register is used to hold data during an arithmetic/logic operation. The result is stored in the accumulator and the flags (flip-flops) are set or reset according to the result of the operation.

Accumulator

- *The accumulator is a special 8-bit register.*
- *This register is used to store 8-bit data as well as to perform arithmetic and logic operations.*
- *This register is identified as A.*
-

Temporary register

The temporary register simply receives one of the operands from the internal data bus and sends it to the ALU.

Flags (flip-flops)

There are five flip-flops that are set or reset after each arithmetic or logic operation. They are called as flag registers.

Carry flag (CY)

- ✓ The carry flag is set to 1 if a carry is produced by an arithmetic or logic operation and reset to 0 for no carry.
- ✓ For example, if an instruction adds two numbers and if the result is less than FF_H, then no carry is produced and the CY flag is reset to 0.
- ✓ On the other hand, if the result exceeds FF_H, then a carry is produced and CY flag is set to 1.
- ✓ It serves as a borrow flag for subtraction.

Zero-flag (z)

- ✓ The zero flag is set to 1 if the result of an arithmetic or a logic operation is zero and reset to 0 if the result is non-zero.
- ✓ For example, if A register and B register have the same data, and if we perform SUB B operation, the result is zero.
- ✓ Now the zero flag Z is set to 1.
- ✓ When the data in A and B registers are not equal, after SUB B operation, the result in the accumulator is not zero and hence the zero flag is reset to 0.

Parity flag (P)

- ✓ *After an arithmetic or logical operation, if the results have an even number of 1s, the flag is set to 1.*
- ✓ *If it has an odd number of 1s, the flag is reset to 0.*
- ✓ *For example the data byte 0000 0011 has even parity.*
- ✓ *It is useful for error checking during serial communication.*

Sign flag (S)

- ✓ *The sign flag is used when working with 8-bit signed (positive and negative) numbers.*
- ✓ *The most significant bit (MSB), D_7 is used as a sign bit.*
- ✓ *If D_7 bit is o, then the number is taken as a positive number and if D_7 bit is 1, the number is taken as a negative number in 2's complement form.*
- ✓ *In 8085, the sign flag is set to 1 if the MSB D_7 is 1 and the sign flag is reset to 0 if the MSB D_7 is 0.*

Auxiliary carry flag (AC)

- ✓ The auxiliary flag is set to 1, when a carry is generated at digit D_3 position and passed on to digit D_4.
- ✓ This flag is used only internally for BCD (binary coded decimal) operations and not available for the programmer.

- ✓ That is the programmer cannot used the auxiliary carry flag condition to change the sequence of the program.

The relative bit position of different flags in an 8-bit flag register is shown in below.

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
S	**Z**		**AC**		**P**		**CY**

Among the five flags, Z flag and CY flag will be widely used to learn assembly language programs. The sign flag S muse be used only with signed numbers.

iii) Instruction register and decoder

- The instruction register and the decoder are part of the ALU. When an instruction fetched from memory, it is loaded in the instruction register.
- The decoder decodes the instruction and establishes the sequence of events to follow.
- The instruction register is not programmable and cannot be accessed through any instruction.

iv) Timing and control unit

- The instruction is decoded and necessary information is passed on to the timing and control unit of 8085.
- Depending on the instruction, the timing and control unit generates the required timing and control signals for executing the instructions.

v) Interrupts serial I/O

- The 8085 microprocessor can be interrupted by any one of five interrupt input pins namely, INTR, TRAP, RST 7.5, RST 6.5 and RST 5.5.
- Two pins SID and SOD are used for the serial communication.

Courtesy: (Referred from the following books)

1. R.S. Gaonkar, Microprocessor Architecture, programming and Application with the 8085, 3rd Edition, Penram International Publishing, Mumbai, 1997.
2. V.Vijayendran, Fundamentals of Microprocessor 8085 - Architecture, programming and interfacing, Viswanathan Publication, Chennai, 2002.
3. web sources