MODULE IV

1. Introduction

A microprocessor incorporates the functions of a computer's central processing unit (CPU) on a single integrated circuit (IC), or at most a few integrated circuits. It is a multipurpose, programmable device that accepts digital data as input, processes it according to instructions stored in its memory, and provides results as output. It is an example of sequential digital logic, as it has internal memory. Microprocessors operate on numbers and symbols represented in the binary numeral system.

The microprocessor is one of the most important components of a digital computer.

- It acts as the brain of the computer system.
- As technology has progressed, microprocessors have become faster, smaller and capable of doing more work per clock cycle.
- Sometimes, microprocessor is written as ***μP***.(***μ*** is pronounced as ***Mu***)

Definition:

Microprocessor is the controlling unit or CPU of a micro-computer, fabricated on a very small chip capable of performing ALU operations and communicating with the external devices connected to it.

Microprocessor Characteristics

- **Instruction Set:** The set of instructions that a microprocessor can understand.
- **Bandwidth:** The number of bits processed in a single instruction.
- **Capability:** It depends upon the number of instructions and capability of each instruction.
- **Clock Speed:** The clock speed determines how many operations per second the processor can perform. It is also called **Clock Rate**. Every computer contains an internal clock that regulates the rate at which instructions are executed and synchronizes the various computer components. The faster the clock, the more instructions the CPU can execute per second. Clock speeds are expressed in megahertz (MHz) or gigahertz (GHz). The microprocessors of personal computers have clock speeds of anywhere from 300 MHz to over 3.8 GHz.
- **Word Length:** It depends upon the width of internal data bus, registers, ALU etc. An 8-bit microprocessor can process 8 bit data at a time. A processor with longer word length is more powerful and can process data at a faster speed as compared to

processor with shorter word length. The word length ranges from 4 bits for small microprocessor, to 64 bits for high-end microcomputers.

- **Width of Data Bus:** This is the size of the data bus. It defines the number of bits that can be transferred through data bus.
- **Width of Address Bus:** This parameter decides the memory addressing capability of the microprocessor. The maximum size of the memory unit is decided by this parameter.
- **Input / Output Addressing Capability:** The maximum number of the input/output ports accessed by the microprocessor depends upon the width of the input/output address provided in the input/output instruction.
- **Data Types:** The microprocessor handles various types of data formats like binary, BCD, ASCII, signed and unsigned numbers.
- **Interrupt Capability:** Interrupts are used to handle unpredictable and random events in the microcomputer. It is used to interrupt the microprocessor. Interrupt driven input/output improves the throughput of a system.

1.1 History of Microprocessors

During the 1960s, computer processors were constructed out of small and medium-scale ICs—each containing from tens to a few hundred transistors. These were placed and soldered onto printed circuit boards, and often multiple boards were interconnected in a chassis. The large number of discrete logic gates used more electrical power—and therefore produced more heat—than a more integrated design with fewer ICs. The distance that signals had to travel between ICs on the boards limited a computer's operating speed.

In the NASA Apollo space missions to the moon in the 1960s and 1970s, all on board computations for primary guidance, navigation and control were provided by a small custom processor called "The Apollo Guidance Computer". It used wire wrap circuit boards whose only logic elements were three-input NOR gates.

The integration of a whole CPU onto a single chip or on a few chips greatly reduced the cost of processing power. The integrated circuit processor was produced in large numbers by highly automated processes, so unit cost was low. Single-chip processors increase reliability as there are many fewer electrical connections to fail. As microprocessor designs get faster, the cost of manufacturing a chip (with smaller components built on a semiconductor chip the same size) generally stays the same.

Microprocessors integrated into one or a few large-scale ICs the architectures that had previously been implemented using many medium- and small-scale integrated circuits. Continued increases in microprocessor capacity have rendered other forms of computers almost completely obsolete (see history of computing hardware), with one or more microprocessors used in everything from the smallest embedded systems and handheld devices to the largest mainframes and supercomputers.

The first microprocessors emerged in the early 1970s and were used for electronic calculators, using binary-coded decimal (BCD) arithmetic on 4-bit words. Other embedded uses of 4-bit and 8-bit microprocessors, such as terminals, printers, various kinds of automation etc., followed soon after. Affordable 8-bit microprocessors with 16-bit addressing also led to the first general-purpose microcomputers from the mid-1970s on.

Since the early 1970s, the increase in capacity of microprocessors has followed Moore's law; this originally suggested that the number of components that can be fitted onto a chip doubles every year. With present technology, it is actually in every two years, and as such Moore later changed the period to two years.

The first commercially available microprocessor was the Intel 4004 produced in 1971 and known as 4-bit processor. It contains 2300 PMOS transistors and mostly used with calculator.

In 1972 8008 microprocessor is produced known as 8-bit microprocessor but requires 20 or more additional devices to form a functional CPU.

In 1974, Intel introduced the 8-bit microprocessor which has much larger instruction set than 8008 and requires only two additional devices to form a functional CPU. After that Motorola came out with MC6800 as 8-bit general purpose CPU. It has the advantage that it requires only +5V power supply.

In 1977 Intel produced 8085 microprocessor. It was implemented with 6200 transition on a single chip NMOS device.

In 1978 to 1982 Intel introduced 16-bit microprocessors 8086 microprocessor. 0186/80286 which are used for embedded control applications. These processors were implemented with NMOS technology which was more faster than NMOS.

In 1985 to 1989 32-bit microprocessor 80386/80486 were produced. They can directly access up to 4 GB of memory and had multiuser and multitasking features. 80486 added more parallel execution capability with 5 pipeline stages. It also has built in math co-processor and 8 kB code and data cache.

Pentium produced in 1993 which has superscalar, super pipelined architecture. It has 2 pipelines where each one is a 4 stage pipeline.

Then Pentium Pro P-I, P-II, P-III and P-IV are developed. All are 64-bit microprocessor. It can directly address upto 64 GB memory.

P-II supports multimedia extension instruction.

P-III supports and has been developed by using 0.25 micro technology.

1.2Introduction to 8-bit Microprocessor – 8085

8085 microprocessor was introduced by Intel in the year 1976. This microprocessor is an update of 8080 microprocessor. The 8080 processor was updated with Enable/Disable instruction pins and Interrupt pins to form the 8085 microprocessor. 8085 microprocessor is an 8-bit microprocessor with a 40 pin dual in line package. The address and data bus are multiplexed in this processor which helps in providing more control signals. 8085 microprocessor has 1 Non-maskable interrupt and 3 maskable interrupts. It provides serial interfacing with serial input data (SID) and serial output data (SOD).

The main features of 8085 µp are:

- It is an 8 bit microprocessor.
- It is manufactured with N-MOS technology.
- It has 16-bit address bus and hence can address up to 2^{16} = 65536 bytes (64KB) memory locations through A_0-A_{15}.
- The first 8 lines of address bus and 8 lines of data bus are multiplexed $AD_0 – AD_7$.
- Data bus is a group of 8 lines $D_0 – D_7$.
- It supports external interrupt request.
- A 16 bit program counter (PC)

- A 16 bit stack pointer (SP)
- Six 8-bit general purpose register arranged in pairs: BC, DE, HL.
- It requires a signal +5V power supply and operates at 3.2 MHZ single phase clock.
- It is enclosed with 40 pins DIP (Dual in line package).

1.2.1 Architecture of 8085

8085 microprocessor can read or write or perform arithmetic and logical operations on 8-bit data at time.

- It is a single chip NMOS device implemented with 6200 transistors.
- It requires +5V power supply.
- It provides on chip clock generator.
- Maximum clock frequency is 3 MHz and minimum clock frequency is 500 kHz.
- It provides 74 instructions with five addressing modes.
- It provides 5 hardware interrupt and 8 software interrupts.
- It has 8 data lines and 16 address lines hence capacity is 216 = 64 kB of memory.
- It can generate 8-bit I/O address so 28 = 256 input and 256 output ports can be accessed.
- It provides two serial I/O lines SID and SOD so that serial peripherals can be interfaced directly with 8085 microprocessor.

The Figures 4.1 and 4.2 shows the Pin diagram and signal groups of 8085.

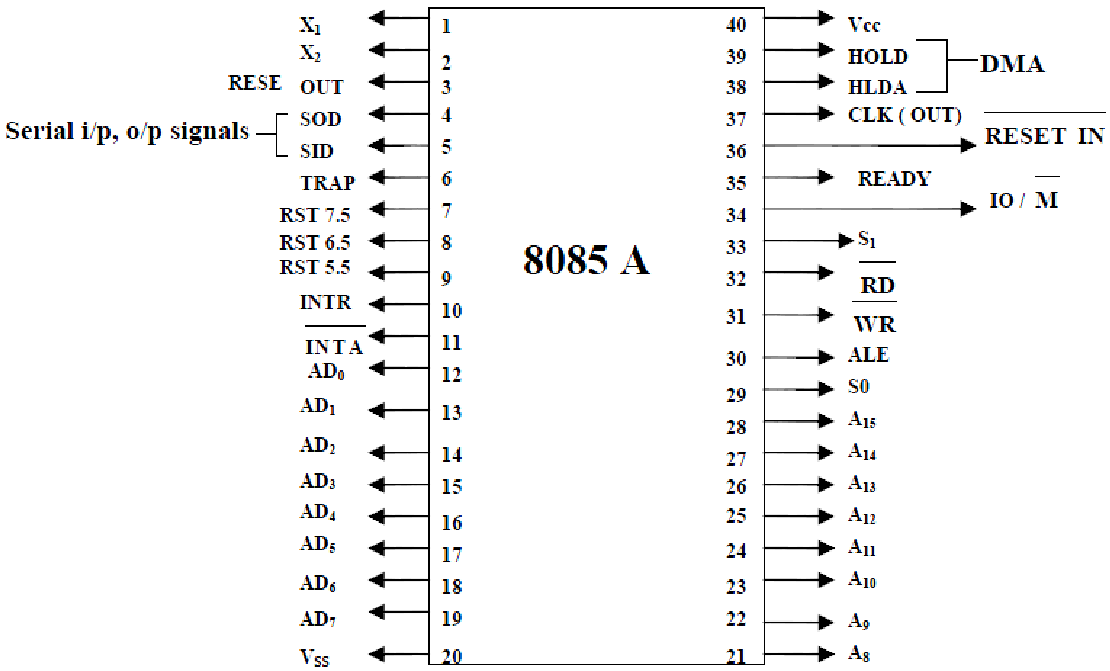

Fig.4.1 Pin Diagram of 8085

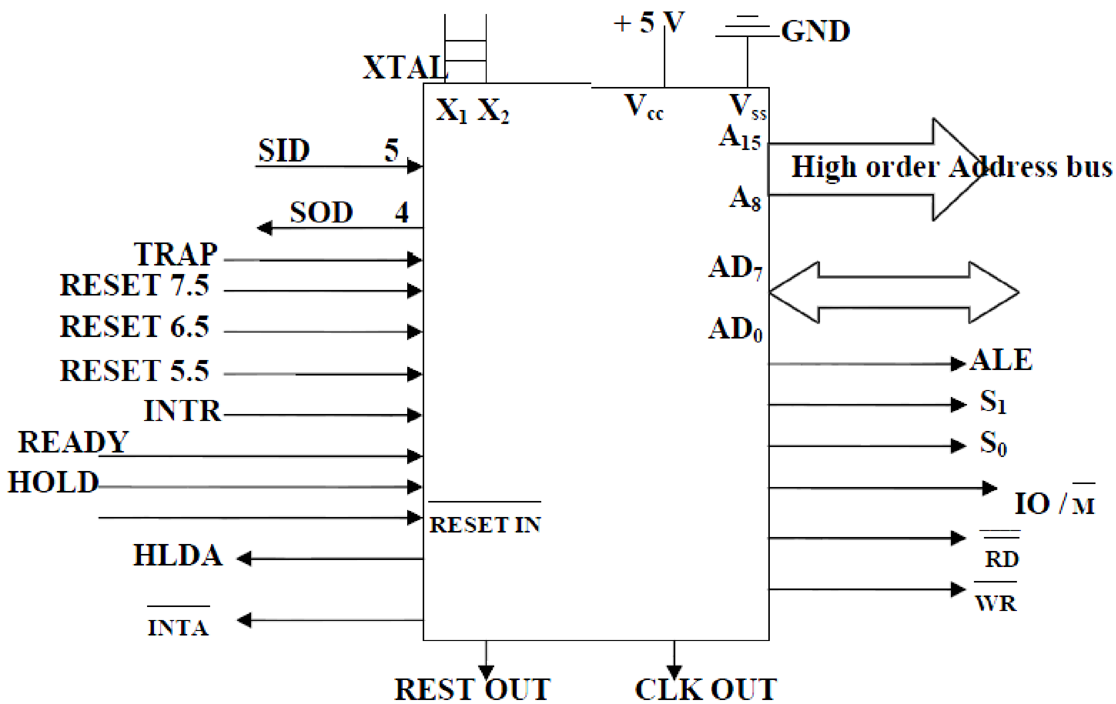

Fig4.2 Signal Groups of 8085

The Fig.4.3 shows the block diagram of 8085 Microprocessor.

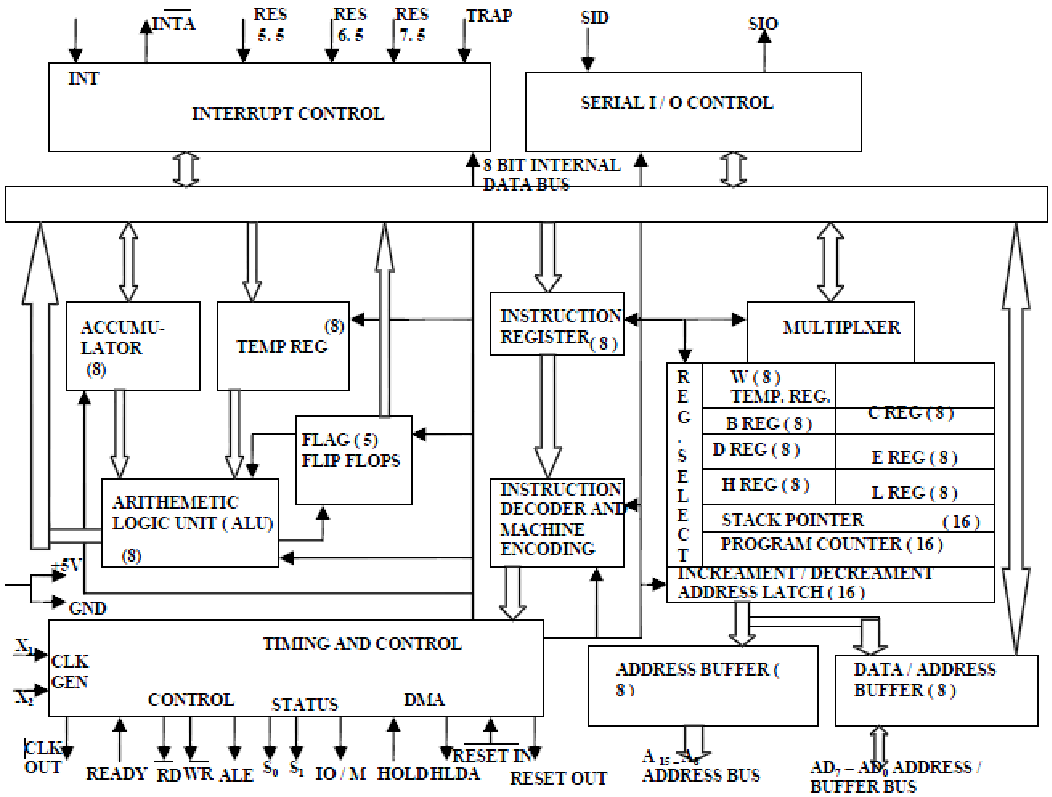

Fig.4.3 Block Diagram of 8085 Microprocessor

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

Fig.4.4 Flag Registers of 8085

INDIVIDUAL	B, C, D, E, H, L
COMBININATON	B & C, D & E, H & L

Fig.4.5 General Purpose Registers of 8085

The Fig.4.4 shows the Flag Registers of 8085 and Fig.4.5 shows the general purpose registers of 8085.

All the signal can be classified into six groups

1. **Address bus** : The 8085 microprocessor has 8 signal line, A15 - A8 which are unidirectional & used as a high order address bus.
2. **Data bus**: The signal line AD7 - AD0 are bidirectional for dual purpose. They are used as low order address bus as well as data bus.
3. **Control signal and Status signal**

   Control Signal

   RD bar - It is a read control signal (active low). It is active then memory read the data.

   WR bar - It is write control signal (active low). It is active when written into selected memory.

   Status signal

   ALU (Address Latch Enable) - When ALU is high. 8085 microprocessor is use address bus. When ALU is low. 8085 microprocessor is use data bus.

   IO/M bar - This is a status signal used to differentiate between i/o and memory operation. When it is high, it indicate an i/o operation and low, it indicate memory operation.

   S1 and S0 - These status signal, similar to i/o and memory bar, can identify various operation, but they are rarely used in small system.
4. **Power supply and frequency signal**

   Vcc - +5v power supply.

   Vss - ground reference.

   X, X - A crystal is connected at these two pins. The frequency is internally divided by two operate system at 3-MHz, the crystal should have a frequency of 6-MHz.

   CLK out - This signal can be used as the system clock for other devices.
5. **Externally initiated signal**

   INTR(i/p) - Interrupt request.

   INTA bar (o/p) - It is used as acknowledge interrupt.

   TRAP(i/p) - This is non maskable interrupt and has highest priority.

   HOLD(i/p) - It is used to hold the executing program.

   HLDA(o/p) - Hold acknowledge.

   READY(i/p) - This signal is used to delay the microprocessor read or write cycle until a slow responding peripheral is ready to accept or send data.

RESET IN bar - When the signal on this pin goes low, the program counter is set to zero, the bus are tri-stated, & MPU is reset.

RESET OUT - This signal indicate that MPU is being reset. The signal can be used to reset other devices.

RST 7.5, RST 6.5, RST 5.5 (Request interrupt) - It is used to transfer the program control to specific memory location. They have higher priority than INTR interrupt.

6. **Serial I/O ports**

   The 8085 microprocessor has two signals to implement the serial transmission serial input data and serial output data.

Control Unit

Generates signals within ***μ***P to carry out the instruction, which has been decoded. In reality causes certain connections between blocks of the uP to be opened or closed, so that data goes where it is required, and so that ALU operations occur.

Arithmetic Logic Unit

The ALU performs the actual numerical and logic operation such as 'add', 'subtract', 'AND', 'OR', etc.Uses data from memory and from Accumulator to perform arithmetic. Always stores result of operation in Accumulator.

Registers

The 8085/8080A-programming model includes six registers, one accumulator, and one flag register, as shown in Figure. In addition, it has two 16-bit registers: the stack pointer and the program counter. They are described briefly as follows. The 8085/8080A has six general-purpose registers to store 8-bit data; these are identified as B,C,D,E,H, and L as shown in the figure. They can be combined as register pairs - BC, DE, and HL - to perform some 16-bit operations. The programmer can use these registers to store or copy data into the registers by using data copy instructions.

Accumulator

The accumulator is an 8-bit register that is a part of arithmetic/logic unit (ALU). This register is used to store 8-bit data and to perform arithmetic and logical operations. The result of an operation is stored in the accumulator. The accumulator is also identified as register A.

Flags

The ALU includes five flip-flops, which are set or reset after an operation according to data conditions of the result in the accumulator and other registers. They are called ***Zero(Z), Carry***

(CY), Sign (S), Parity (P), and Auxiliary Carry (AC) flags; they are listed in the Table and their bit positions in the flag register are shown in the Figure below. The most commonly used flags are Zero, Carry, and Sign. The microprocessor uses these flags to test data conditions.

For example, after an addition of two numbers, if the sum in the accumulator id larger than eight bits, the flip-flop uses to indicate a carry -- called the Carry flag (CY) – is set to one. When an arithmetic operation results in zero, the flip-flop called the Zero(Z) flag is set to one. In the Figure shows an 8-bit register, called the flag register, adjacent to the accumulator. However, it is not used as a register; five bit positions out of eight are used to store the outputs of the five flip-flops. The flags are stored in the 8-bit register so that the programmer can examine these flags (data conditions) by accessing the register through an instruction.

These flags have critical importance in the decision-making process of the microprocessor. The conditions (set or reset) of the flags are tested through the software instructions. For example, the instruction JC (Jump on Carry) is implemented to change the sequence of a program when CY flag is set. The thorough understanding of flag is essential in writing assembly language programs.

Program Counter (PC)

This 16-bit register deals with sequencing the execution of instructions. This register is a memory pointer. Memory locations have 16-bit addresses, and that is why this is a 16-bit register.

The microprocessor uses this register to sequence the execution of the instructions.The function of the program counter is to point to the memory address from which the next byte is to be fetched. When a byte (machine code) is being fetched, the program counter is incremented by one to point to the next memory location.

Stack Pointer (SP)

The stack pointer is also a 16-bit register used as a memory pointer. It points to a memory location in R/W memory, called the stack. The beginning of the stack is defined by loading 16-bit address in the stack pointer. The stack concept is explained in the chapter "Stack and Subroutines."