Chapter 2

Intel 8085 Microprocessor Architecture

Learning Outcomes

After completion of this chapter, you will be able to understand the following:

- Pin details and logic schematic of the 8085 microprocessor
- Internal functional operation of 8085 microprocessor
- Flag register and the purpose of each flag bit.
- Purpose of registers, accumulators and the system bus used in 8085 microprocessor.

2.1 Introduction

The microprocessor is a semiconductor device consisting of electronic logic circuits manufactured by using either a large-scale integration (LSI) or very-large-scale integration (VLSI) technique. Any microprocessor basically contains registers, Arithmetic unit, logic unit, flip-flops and timing and control circuits. All the microprocessors work using Von Neumann Architecture. In this architectural working of a microprocessor, the CPU or the processor fetches instructions from the memory, decodes it (interprets the nature of instruction/command and develops clock by clock steps for execution), generates appropriate control signals and finally the instruction is executed. The program is stored consecutively in the memory locations. The execution steps are repeated for all the instructions of the program until the last instruction. The data required may either be taken from memory or from input ports and the results of the program will be stored in the memory or given out through output ports.

A program is a list of instructions for the microprocessor to carry out. Before the start of execution, the complete program must be stored in the memory. Let us assume that the starting address of the stored program is 8800H. While running the program the microprocessor must be directed to 'go' from 8800H. Once it has completed the instruction available at 8800H, it goes to the next address 8801H (assuming single byte instructions) and so on, until it reaches the end of the program.

Intel 8085 is an eight bit microprocessor of INTEL Corporation, usually called as a general purpose 8-bit Processor. It is upward compatible with microprocessor 8080, which was the earlier product of INTEL. There are several faster versions of 8085 microprocessor such as 8085AH, 8085AH-1, 8085AH-2 etc.

A microcomputer consists of three functional blocks viz., a Central Processing Unit (CPU), input/output, and memory units as shown in Fig.2.1. The CPU contains several registers, an Arithmetic and Logic unit (ALU), and a Control unit. The function of ALU is to perform operations related to arithmetic and logical operations. The Control unit translates the instructions and executes the desired task.

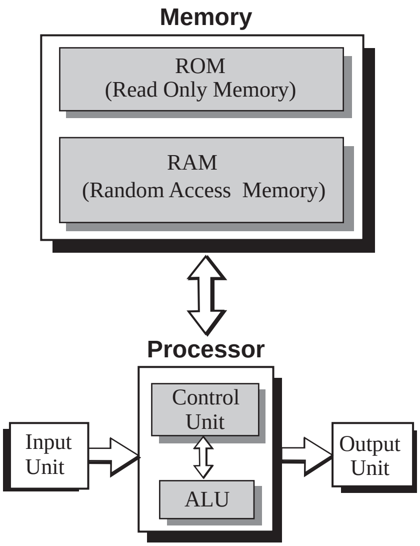

Fig. 2.1 A microprocessor system

2.2 ARCHITECTURE OF 8085

The block diagram explaining the architecture of Intel 8085 Microprocessor is shown in Fig.2.2. It is available generally as a 40 pin IC package and uses +5V for power. It can run at a maximum frequency of 3 MHz. The modified versions of the 8085 processor have these minimum common features and functional similarities.

8085 is called as an 8-bit processor since its data length is 8-bit and has a data bus of 8-bits wide. It has an addressing capability of 16-bit. i.e., it can address 2^{16} = 64 K bytes of memory (1 K byte =1024 byte). The processing unit or the processor consists of five functional units:

(i) Arithmetic and logic Unit
(ii) General purpose registers
(iii) Special Purpose Registers
(iv) Instruction register and decoder and,
(v) Timing and control unit.

2.2.1 Arithmetic Logic Unit (ALU)

ALU is the circuitry which performs the actual numerical and logical operations. Addition (ADD), subtraction (SUB), increment (INR), decrement (DCR) and comparison (CMP) are the arithmetic operations available in 8085 microprocessor. The possible logical operations

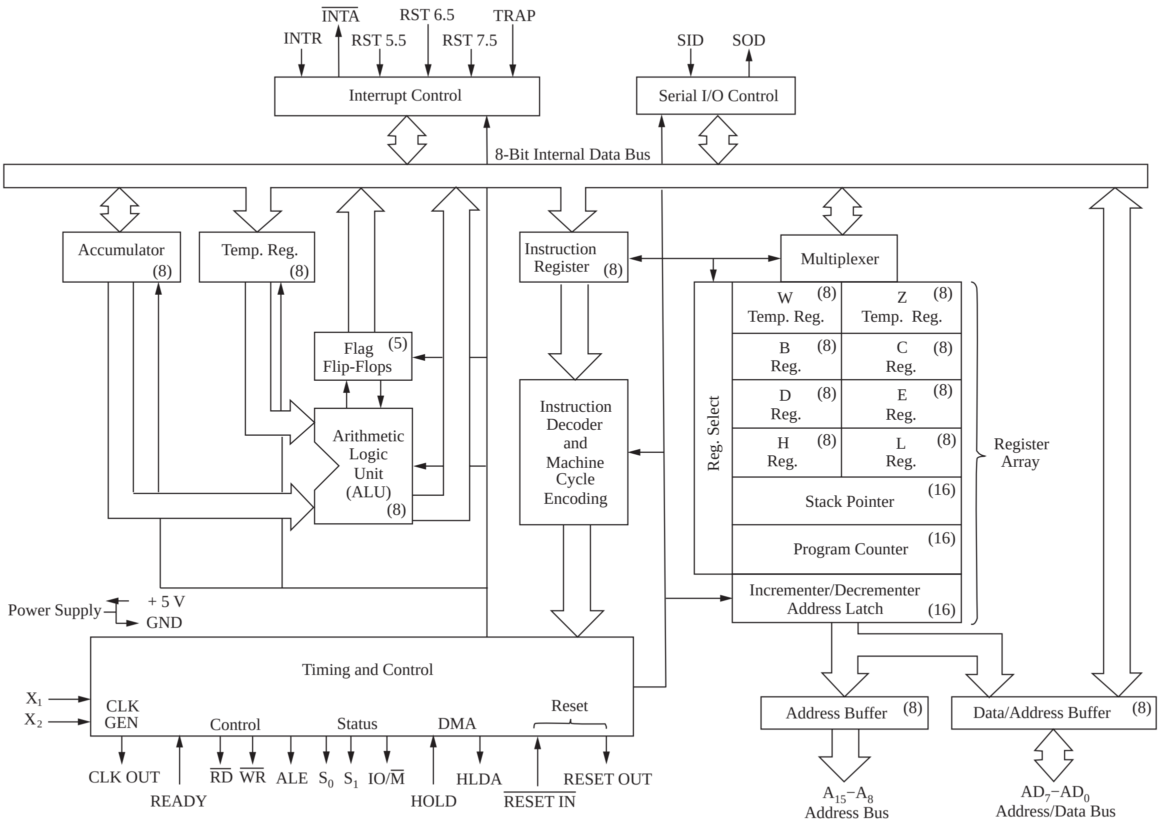

Fig.2.2 Functional Block of Intel 8085

in 8085 are AND (AND), OR (OR), EXCLUSIVE OR (XOR), COMPLEMENT (CMA) etc. While the data is drawn from the memory, the operation executed with the content of the accumulator and the results stored in the Accumulator. ALU of 8085 is called accumulator oriented ALU as the one of the data for arithmetic and logic operations must be stored in accumulator. If the operation needs only one data, then that data must be stored in accumulator.

2.2.2 The general-purpose registers

A register is a collection of 8 D type flip-flops with parallel in and parallel out operation. A flip-flop can only store one bit at a time. Therefore to handle 8 bits at a time, 8 flip-flops are required and hence the term 8-bit register. Though the registers are also storage areas inside the microprocessor, they differ by the purpose of storage. The general purpose registers are used to store only the data that is used by the currently running program or the results obtained from the currently running program. These general purpose registers are user accessible by programs.

Registers B, C, D, E, H and L are the general purpose registers of 8085 as shown in figure 2.3. They can also be called as Scratch Pad registers. Almost in all arithmetic and logic operations these registers are used as the second operands while the first operand being the accumulator (A). The general-purpose registers are all 8-bit registers but they can be handled as 16-bit registers as well. This can be achieved by combining the register pairs as B and C, D and E, and H and L — to perform 16-bit operations. They are named respectively as register pairs BC, DE, and HL respectively.

Among these pairs, HL has a special significance. A few memory related instructions of 8085 (refer instruction set) use the HL pair as a memory pointer. For example, the instruction "MOV A, M" transfers the content of memory location pointed by the HL pair to accumulator. The HL pair is pre-loaded with the memory address in which data is available.

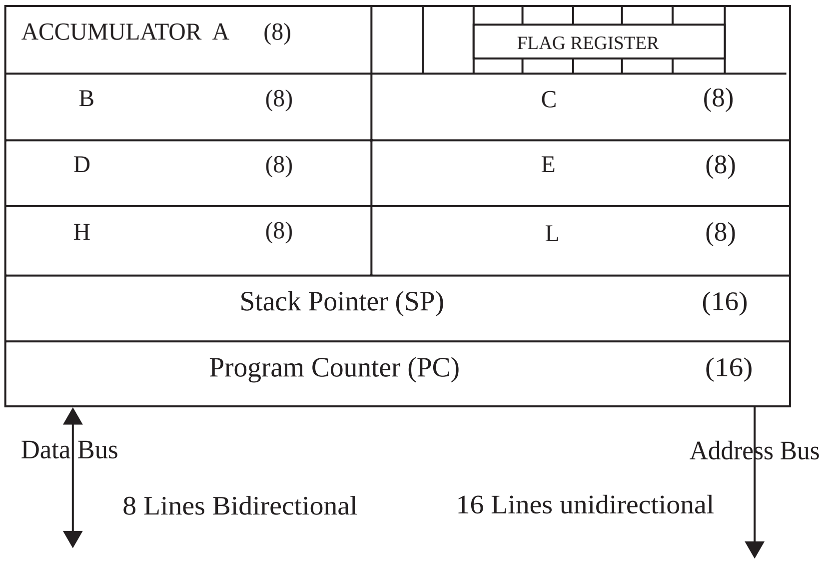

Fig. 2.3 Registers of Intel 8085

2.2.3 The special-purpose registers

There are also special purpose registers that are dedicated to a specific function. The Accumulator, flag register, Program Counter (PC) and Stack Pointer (SP) constitute the special registers in the 8085 Microprocessor.

2.2.3.1 Accumulator

The accumulator is an 8-bit register which is a part of arithmetic/logic unit (ALU) and it is the most important register. It is used to store 8-bit data and serves to perform arithmetic and logical operations. The result of an operation is also stored in the accumulator. The accumulator is identified as register A in the instruction set of 8085. The programmer can use it at any time to store an 8-bit binary number. Being only an 8-bit register, it can only hold one byte at a time. Any previous data stored in this register will be overwritten as soon as new data is stored. Also the 8085 microprocessor communicates with input/output devices only through A.

2.2.3.2 The flag register

This is a special 8-bit register. Each bit of flag register is quite independent of each other. In all other registers, each bit is just part of a single binary byte value and hence each bit would have a numerical value. The flag is an 8-bit register used to indicate the status of the recent arithmetic or logic operation. It may be set or reset after an arithmetic or logical operation according to the condition of the processed data. The five flag bits are Zero (Z), Carry (CY), Sign (S), Parity (P), and Auxiliary Carry (AC) flags and their bit positions in the flag register are shown in Figure 2.4. The remaining three bits (D1, D3 and D5) of the flag register remain unassigned and they are marked with an X to show that they are not used and are don't cares.

Any flag register bit is said to be 'set' when its value is 1 and is said to be 'cleared' when its value is 0. The most commonly used flags are Zero, Carry, and Sign. AC flags can not be accessed externally.

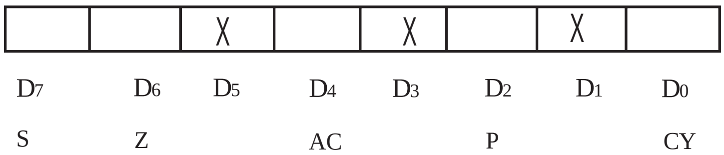

Fig. 2.4 Flag register

Sign flag (S) The S flag is just a copy of the bit D7 (Most Significant Bit-MSB) of the accumulator. A negative number has a 1 in bit 7 and a positive number has a 0 in bit 7. So this flag indicates the sign of the number. It may be recalled that signed magnitude numbers use a 1 to indicate a negative number and 0 to indicate a positive number. This flag can be used in signed arithmetic operations.

Zero flag (Z) The zero flag is set if an arithmetic operation results in a zero. It 'sets' or changes to a binary 1 if it sees a zero result in accumulator otherwise it always stays at binary 0. The Z flag only goes to a one state if all bits in the latest result (available at accumulator) are zero.

Carry flag (C) The carry flay is set when a carry is generated in the process of an arithmetic operation out of accumulator. When addition is carried out, it sometimes results in a 9^{th} bit being carried over to the next byte. The C flag copies the value of the carry from D7, which is an extra bit. It also reflects the value of the 'borrow' in subtractions.

Auxiliary carry flag (AC) The auxiliary carry flag is set when an auxiliary carry is generated in the process of an arithmetic operation in the accumulator, i.e., when a carry results from bit D3 and passes on to D4 (from the lower nibble to the higher nibble). This carry which is resulted from addition of lower nibble is also called as half-carry. It may also occur in the process of a subtraction operation. In other words this flag is set if the subtraction operation results in borrow.

Parity flag (P) The parity flag is set if the content of the accumulator after an arithmetic operation has an even number of 1's. Otherwise the parity flag is reset. It is set for operation in the even parity mode.

2.2.3.3 Program counter (PC)

PC is a 16-bit register, which always points to the address of next instruction to be executed. In other words, this register is used to sequence the execution of the instructions. At the end of execution of any instruction, the content of the memory location indicated by PC is moved to instruction register and the PC is loaded with the new address to indicate the next address. It keeps track of a program by always counting the memory address from which the next byte is to be fetched, and hence the name program counter.

2.2.3.4 Stack Pointer (SP)

Stack is an array of memory locations organized in the form of 'Last In First Out' (LIFO) or 'First In Last Out' (FIFO) fashion. Stack is very much essential in any microprocessor based system. Stack is mainly used to store the return address of the main program when subroutines are called. Stack Pointer (SP) is a 16-bit register that holds the address of the memory location of top of the stack. The architecture of 8085 offers flexibility to define the stack locations by the programmer. The programmer can reserve and allocate a series of RAM locations to be used as a stack and an address counter must be employed to keep track of what address of the stack is to be used next. This counter, called stack pointer (SP) points to the next free location in the stack to be used. The users are allowed to use the stack but the microprocessor takes priority and also uses the stack. Care must be taken by the programmer that the data stored in the stack is retrieved properly so that the data stored in the stack by the processor is not affected. Also the range of stack memory locations must be chosen carefully such that it would not affect the program space.

2.2.3.5 Instruction Register/Decoder

It is an 8-bit register which usually offers a temporary storage for the instructions drawn from memory locations before the actual execution of it. The content of the register is decoded by the decoder circuitry, where the nature of the operation to be performed is decided (interpreted). The internal machine command is interpreted to decide the next course of action.

In addition, there are two temporary registers W and Z which are controlled internally and not available for user access.

2.2.4 Timing and Control Unit

The timing and control unit gets the command from the instruction decoder and issues proper signals on the address bus, data bus and the control bus. The following section gives the operation of the various buses and the timing.

2.2.4.1 Data Bus

The microprocessor performs its functions using wires or lines called buses. For example, an 8-bit microprocessor normally uses 8 wires to carry the data between the microprocessor and the memory. To make representations simple, the data wires with common function are grouped together and referred as the data bus. A typical microprocessor communicates with memory and other devices (input and output) using these busses. There are three types of buses namely the address bus, the data bus and the control bus.

The data bus (D0-D7) is a two-way bus carrying data around the system. Information going into the microprocessor and results coming out of the microprocessor are through this data bus. It is used for transfer of binary information between the microprocessor, memory and peripherals. The lower group of eight address lines A0-A7 is multiplexed with the data bus in order to reduce the pin count. Therefore the multiplexed lower group of address lines and data lines is more generally denoted as AD0-AD7.

2.2.4.2 Address Bus

The address bus carries addresses and is a one-way bus from the microprocessor to the memory or other devices. It is a group of sixteen unidirectional lines that allow flow of address from the processor to its peripheral devices. Each peripheral or a memory location is identified by a 16 bit binary number called an address. It follows that the maximum addressing capability of the 8085 processor 2^{16}=64KB. Its basic function is to identify a peripheral or memory location.

The address bus is a group of 16 lines generally identified as A0 to A15. The address bus has 8 higher order address lines A8 – A15 which are unidirectional. The lower order 8 lines are multiplexed (time shared) with the 8 data bits (AD0 – AD7) and hence they are bidirectional. During the execution of the instruction, these lines carry the address bits during the early part, and then during the later parts of the execution, they carry the 8 data bits. In order to separate the address from the data, a latch is used externally to save the address before the function of the bits changes.

2.2.4.3 Control Bus

The control bus comprises of various single lines that have specific functions for coordinating and controlling microprocessors operations. For example, a Read / Write control signal will indicate whether memory is being ‘written to’ (data stored in memory) or ‘read from’ (data taken out of memory). Thus, they are individual lines which provide a pulse to indicate operation of the microprocessor. In fact the microprocessor generates specific control signals for every operation, which in turn is used to identify the type of device the processor intends to communicate. The microprocessor cannot function correctly without these vital control signals. The Control Bus carries control signals which are partly unidirectional, partly bi-directional.

Typically microprocessor has 10 control lines.

There are four main control and status signals. They are:

- ALE: Address Latch Enable. It is a pulse that is provided when an address appears on the AD0 – AD7 lines, after which it becomes 0. This signal can be used to enable a latch to save the address bits from the AD lines and thereby it demultiplexes the address and data bus.
- RD: Read - Active low. It indicates that the data is read from the selected IO or memory device and the data available on the data bus.
- WR: Write - Active low. It indicates that the data on the data bus are to be written into a selected memory or IO location.
- IO/ M: It is a signal that distinguishes between a memory operation and an IO operation. An active low on this signal shows it is a memory operation (IO/M=0) and a high on this line indicates an IO operation (IO/M=1).
- S1 and S0: They are status signals, used to specify the kind of operation being performed. The status signals combined with IO signals to govern the different operations are listed in Table 2.1. If both S0 and S1 are low, the operation of the processor tends to halt. If S1 low and S0 is high, the processor reads the data. While the processor writes data on to a memory or IO, S1 is high and S0 is low. If both S0 and S1 are high, the instruction fetch operation is performed.

Table 2.1 Status signal and operation

S1	S0	States
O	O	HALT
0	1	WRITE
1	0	READ
1	1	FETCH

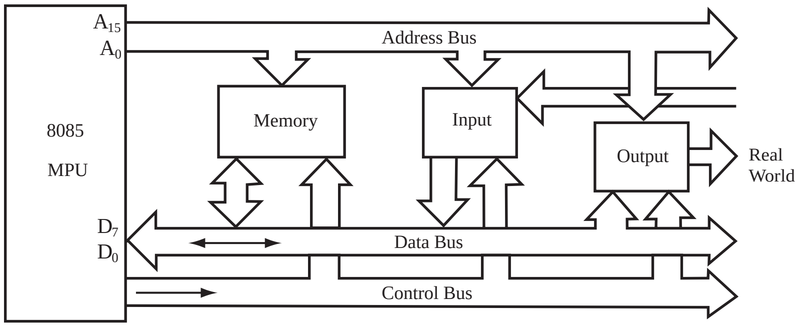

Fig. 2.7 Schematic representation of 8085 bus structure

The schematic representation of the 8085 bus structure is shown in Fig. 2.7, which explains how the movement of data within the computer is accomplished by a series of buses. Address information, data and control signals have to be carried around inside the microprocessor as well as in the external system and hence the buses will be seen both internal as well as external.

2.2.5 Interrupt

It is an important function to make the microprocessor to respond to the high priority externally initiated signals. Whenever an interrupt signal is sensed by the processor, the processor suspends the current program execution and executes the program corresponding to the interrupt signal. There are five interrupt signals (INTR, RST 5.5, RST 6.5, RST 7.5 and TRAP) that are available to facilitate the processor to realize and acknowledge the interrupt call of peripherals. In addition there are three other signals- RESET, HOLD and READY that accepts the externally initiated signals as inputs.

INTR: (Input) It is a general purpose interrupt request signal. It is an active high signal

INTA: (output) It is used to acknowledge a interrupt. It is an active low signal.

Restart Interrupts: (Input) These are vectored interrupts that transfer the program control to specific memory locations. They have higher priority than INTR interrupts. The priority order is RST 7.5, RST 6.5 and RST 5.5

TRAP: (Input) It is a non-maskable restart interrupt and has the highest priority.

RESET-IN: When the signal on this pin goes low the program counter set to zero and the processor is reset. It is active low signal.

RESET-OUT: This signal can be used to reset other device. It is an active high signal.

HOLD (INPUT): This signal indicate that a peripheral such as a Direct Memory Access (DMA) is requesting the use of address and data bus.

HLDA (OUTPUT): It is a acknowledge signal that response to the HOLD request.

During HOLD state, the peripheral (I/O) devices get control over the data and address buses for data transfer with memory. This operation is called as direct memory access (DMA). DMA is useful when high speed peripherals want data transfer with memory, during which the processor need not make any intervention.

READY: It is a signal that serves to delay the microprocessor RD/WR signals until a slow responding peripheral is ready to send or accept data. If this signal goes low, then the processor is allowed to wait for an integral number of clock cycles until READY becomes high. The READY signal must be synchronized with the processor clock.

SUMMARY

- The microprocessor is a clock-driven semiconductor device consisting of electronic logic circuits manufactured by using either a large-scale integration (LSI) or very-large-scale integration (VLSI) technique.
- The 8085 has a multiplexed bus $AD_7 – AD_0$ used as the lower order address bus and the data bus.
- The bus $AD_7 – AD_0$ can be de-multiplexed by using a latch and the ALE signal.
- The 8085 has 5 flags and they are sign, zero, auxiliary carry, parity and carry.
- A bus is simply a collection of wires connecting two or more chips.
- A typical microprocessor communicates with memory and other devices (input and output) using three busses: Address Bus, Data Bus and Control Bus.
- Data Bus carries 'data', in binary form, between microprocessor and other external units, such as memory.

KEY TERMS

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.

Flag Flip flop used to store the information about the status of the processor and the status of the instruction executed most recently.

Data Bus carries 'data', in binary form, between microprocessor and other external units, such as memory. Typical size is 8 or 16 bits.

Control Bus The Control Bus has various lines which have specific functions for coordinating and controlling microprocessors operations. E.g.: Read/Not Write line, single binary digit

Address bus Binary number carried alerts memory to 'open' the designated box. Data (binary) can then be put in or taken out. The Address Bus consists of 16 wires, therefore 16 bits. Its "width" is 16 bits

Bus Bus is a group of conducting lines that carries data, address and control signals

The IO/M is used to differentiate memory access and I/O access.

For IN and OUT instruction it is high. For memory reference instructions it is low.

READY Ready is an input signal to the processor, used by the memory or I/O devices to get extra time for data transfer or to introduce wait states in the bus cycles.

HOLD and HLDA These signals are used for the Direct Memory Access (DMA) type of data transfer.

■ REVIEW QUESTIONS ■

1. Name any three features of the 8085.
2. What are the operations performed by ALU of 8085?
3. What are the various registers in 8085?
4. What is a flag and list its type?
5. List the 16-bit registers of 8085 microprocessor.
6. What is meant by a bus?
7. Why data bus is bi-directional?