Chapter – 1

Fundamental of Microprocessor 1.1 Introduction to Microprocessor

A Microprocessor is a multipurpose programmable, clock driven, register based electronic device that reads binary instructions from a storage device called memory, accepts binary data as input, processes data according to those instructions and provide result s as output. The microprocessor operates in binary 0 and 1 known as bits are represented in terms of electrical voltages in the machine that means 0 represents low voltage level and 1 represents high voltage level. Each microprocessor recognizes and processes a group of bits called the word and microprocessors are classified according to their word length such as 8 bits microprocessor with 8 bit word and 32 bit microprocessor with 32 bit word etc.

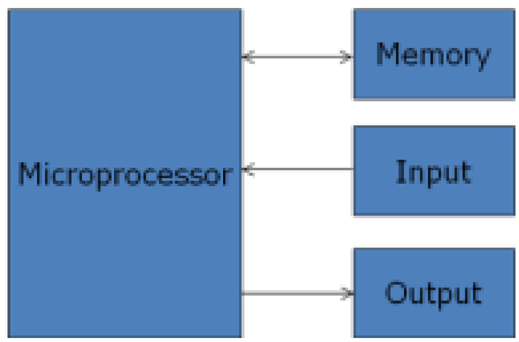

Fig 1.1: A Programmable Machine

Terms used

- CPU: - Central processing unit which consists of ALU and control unit.
- Microprocessor: - Single chip containing all units of CPU.
- Microcomputer: - Computer having microprocessor as CPU.
- Microcontroller: single chip consisting of MPU, memory, I/O and interfacing circuits. • MPU: - Micro processing unit – complete processing unit with the necessary control signals.

Evolution of Microprocessors (Intel series)

The CPU of a computer consists of ALU, CU and memory. If all these components can be organized on a single chip by means of SSI, MSI, LSI, VLSI, ULSI technology, then such chip is called microprocessor. It can fetch instructions from memory, decode and execute them, perform logical and arithmetic functions, accept data from input devices and send results to the output devices. The evolution of microprocessor is dependent on the development of integrated circuit technology from single scale integration (SSI) to giga scale integration (GSI).

Date	Microprocessor	Data bus	Address Bus	Memory
1971	4004	4-bit	10-bit	640 Bytes
1972	8008	8-bit	14-bit	16k

1974	8080	8bit	16bit	64k
1976	8085	8bit	16b it	64k
1978	8086	16bit	20bit	1M
1979	8088	8bit	20bit	1M
1982	80286	16bit	24bit	16M
1985	80386	32bit	32bit	4G
1989	80486	32bit	32bit	4G
1993	Pentium	32/64bit	32bit	4G
1995	Pentium pro	32/64bit	36bit	64G
1997	Pentium II	64bit	36bit	64G
1998	Celeron	64bit	36bit	64G
1999	Pentium III	64bit	36bit	64G
2000	Pentium IV	64bit	36bit	64G
2001	Itanium	128 bit	64bit	64G
2002	Itanium 2	128 bit	64bit	64G
2003	Pentium M/Centrino (wireless capability) for Mobile version e.g. Laptop			
	Core 2: X86 – 64 Architecture			
Latest	Intel Core i5, i7, i9, Apple M1 processor etc.			

Advantages of Microprocessor:

- Computational/Processing speed is high
- Intelligence has been brought to systems
- Automation of industrial process and office automation
- Flexible
- Compact in size
- Maintenance is easier

Applications of Microprocessors:

Microcomputer: Microprocessor is the CPU of the microcomputer.

Embedded system: Used in microcontrollers.

Measurements and testing equipment: used in signal generators, oscilloscopes, counters, digital voltmeters, x-ray analyzer, blood group analyzers baby incubator, frequency synthesizers, data acquisition systems, spectrum analyzers etc.

Scientific and Engineering research.

Industry: used in data monitoring system, automatic weighting, batching systems etc.

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Security systems: smart cameras, CCTV, smart doors etc.

Automatic system

Communication system

Some Examples are:

Calculators

Accounting system

Games machine

Complex Industrial Controllers

Traffic light Control

Data acquisition systems

Military applications

1.1.1 Basic Block Diagram of a Computer

Traditionally, the computer is represented with four components such as memory, input, output and central processing unit (CPU) which consists of arithmetic logic unit (ALU) and control unit (CU).

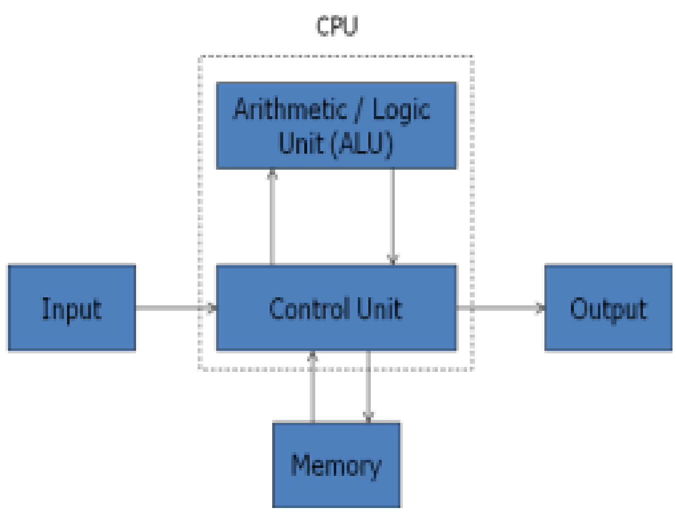

Fig : Traditional Block diagram of a computer

The CPU contains various registers to store data, the ALU to perform arithmetic and logical operations, instruction decoders, counters and control lines.

The CPU reads instructions from memory and performs the tasks specified. It communicates with input/output (I/O) devices either to accept or to send data, the I/O devices is known as peripherals.

Later on around late 1960's, traditional block diagram can be replaced with computer having

microprocessor as CPU which is known as microcomputer. Here CPU was designed using integrated circuit technology (IC's) which provided the possibility to build the CPU on a single chip.

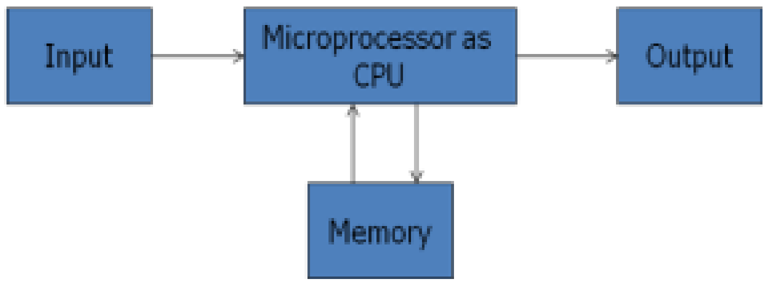

Fig: Block Diagram of a computer with the Microprocessor as CPU

Later on semiconductor fabrication technology became more advanced, manufacturers were able to place not only MPU(Micro processing Unit) but also memory and I/O interfacing circuits on a single chip known as microcontroller, which also includes additional devices such as A/D(Analog-to-digital) converter, serial I/O, timer etc.

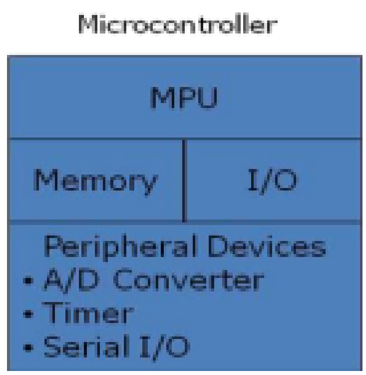

Fig 1.2 (c): Block Diagram of a Microcontroller

1.1.2 Organization of a microprocessor based system

Microprocessor based system includes there components microprocessor, input/output and memory (read only and read/write). These components are organized around a common communication path called a bus.

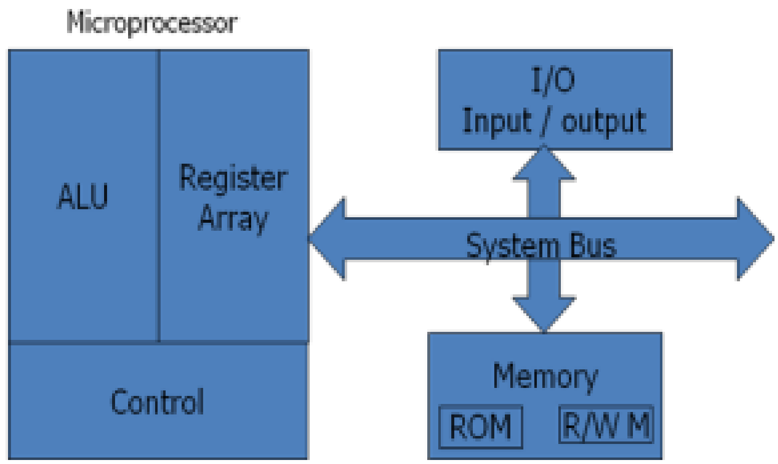

Fig 1.3: Microprocessor Based System with Bus Architecture

Microprocessor:

It is 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. It is capable of performing various computing functions and making decisions to change the sequence of program execution. It can be divided in to three segments.

A. Arithmetic/Logic unit: It performs arithmetic operations as addition and subtraction and logic operations as AND, OR & XOR.

B. Register Array: The registers are primarily used to store data temporarily during the execution of a program and are accessible to the user through instruction. The registers can be identified by letters such as B, C, D, E, H and L.

C. Control Unit: It providesthe necessary timing and control signals to all the operations in the microcomputer. It controls the flow of data between the microprocessor and memory & peripherals.

Memory:

Memory stores binary information such as instructions and data, and provides that information to the up whenever necessary. To execute programs, the microprocessor reads instructions and data from memory and performs the computing operations in its ALU. Results are either transferred to the output section for display or stored in memory for later use. Memory has two sections.

A. Read only Memory (ROM): Used to store programs that do not need alterations and can only read.
B. Read/Write Memory (RAM): Also known as user memory which is used to store user programs and data. The information stored in this memory can be easily read and altered.

Input/Output:

1.1.3 It communicates with the outside world using two devices input and output which are also Known as peripherals.

1.1.4 The input device such as keyboard, switches, and analog to digital converter transfer binary information from outside world to the microprocessor.

1.1.5 The output devices transfer data from the microprocessor to the outside world. They include the devices such as LED, CRT, digital to analog converter, printer etc.

System Bus:

It is a communication path between the microprocessor and peripherals; it is nothing but a group of wires to carry bits.

1.2 Microprocessor system with Bus organization

Bus is a common channel through which bits from any sources can be transferred to the destination. A typical digital computer has many registers and paths must be provided to transfer instructions from one register to another. The number of wires will be excessive if separate lines are used between each register and all other registers in the system. A more

efficient scheme for transferring information between registers in a multiple register configuration is a common bus system. A bus structure consists of a set of common lines, one for each bit of a register, through which binary information is transferred one at a time. Control signals determine which register is selected by the bus during each particular register transfer.

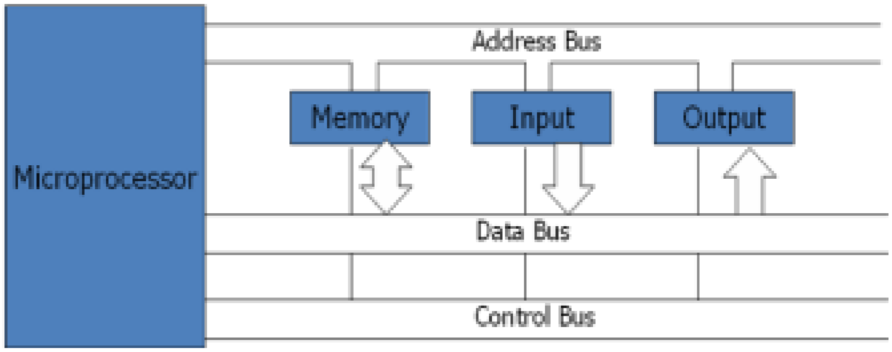

Fig: Bus Organization

A very easy way of constructing a common bus system is with multiplexers. The multiplexers select the source register whose binary information is then pleased on the bus.

A system bus consists of about 50 to 100 of separate lines each assigned a particular meaning or function. Although there are many different bus designers, on any bus, the lines can be classified into three functional groups; data, address and control lines. In addition, there may be power distribution lines as well.

1.2.1 The data lines provide a path for moving data between system modules. These lines are collectively called data bus.

1.2.2 The address lines are used to designate the source/destination of data on data bus. **1.2.3** The control lines are used to control the access to and the use of the data and address lines. Because data and address lines are shared by all components, there must be a means of controlling their use. Control signals transmit both command and timing signals indicate the validity of data and address information. Command signals specify operations to be performed. Control lines include memory read/write, I/O read/write, busrequest/grant, clock, reset, interrupt request/acknowledge etc.

Bus Structure of 8085 Microprocessor

The microprocessor MPU performs various operations with peripheral devices or a memory location by using three sets of communication lines called buses: the address bus, the data bus and the control bus. And these three combined lines is called as system bus.

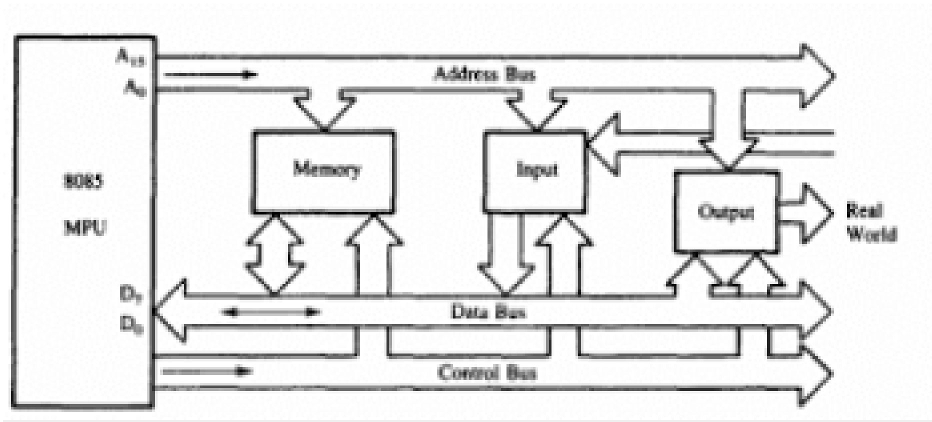

Fig: The 8085 Bus Structure

Address bus:

The address bus is a group of 16 lines generally called as A0 – A15 to carry a 16-bit address of memory location.

In a computer system, each peripheral or memory location is identified by a binary number called an address. This is similar to the postal address of a house.

The address bus is unidirectional, that means bit flow in only one direction from MPU to peripheral.

MPU carries 16-bit address i.e. 2^{16} = 65,536 or 64K memory locations.

Data Bus:

The data bus is a group of eight bidirectional lines used for data flow in both the directions between MPU and peripheral devices.

The 8 data lines are manipulating 8-bit data ranging from 00 to FF i.e. (2^8 = 256) numbers from 0000 0000 -1111 1111

This 8 bit data is called as word length and the register size of a microprocessor and MPH is called 8–bit microprocessor.

Control bus:

Control bus is having various single lines used for sending control signals in the form of pulse to the memory and I/O devices. This is the set of signals that is used to synchronize the activities of the separate μp elements.

The MPU generates specific control signals to perform a particular operations. Some of these control signals are memory read, memory write, I/O read and I/O write.

1.3 Microprocessor Architecture

Von-Neumann Architecture:

The task of entering and altering the programs for ENIAC was tedious. It could be facilitated if the program could be represented in a form suitable for storing in memory alongside the data. So the computer could get its instructions by reading from the memory and program could be set or altered by setting the values of a portion of memory. This approach is known as 'stored program concept' was first adopted by John Von Neumann and such architecture is named as von-Neumann architecture as shown in figure below.

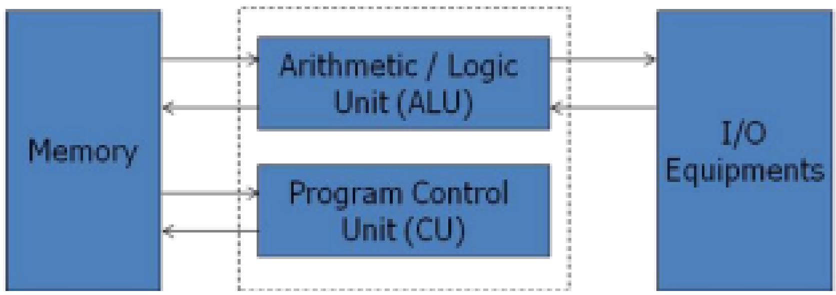

Fig: Von –Neumann Architecture

The main memory is used to store both data and instructions. The arithmetic and logic unit is capable of performing arithmetic and logical operation on binary data. The program control unit interprets the instruction in memory and causes them to be executed. The I/O unit gets operated from the control unit. In this architecture processor needs two clock cycle to complete an instruction. In the first clock cycle processor gets the instruction from memory and decodes it. In next clock cycle the required data is taken from memory.

The Von–Neumann architecture is the fundamental basis for the architecture of modern digital computers. It consisted of 1000 storage locations which can hold words of 40 binary digits and both instructions as well as data are stored in it. The storage location of control unit and ALU are called registers and the various models of registers are:

MAR – memory address register – contains the address in memory of the word to be written into or read from MBR.

MBR – memory buffer register – consists of a word to be stored in or received from memory. **IR** – instruction register – contains the 8-bit op-code instruction to be executed. **IBR** – instruction buffer register – used to temporarily hold the instruction from a word in memory.

PC - program counter - contains the address of the next instruction to be fetched from memory.

AC & MQ (Accumulator and Multiplier Quotient) - holds the operands and results of ALU after processing.

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Harvard Architecture

In von-Neumann architecture, the same memory is used for storing instructions and data. Similarly, a single bus called data bus or address bus is used for reading data and instructions from or writing to memory. It also had limited the processing speed for computers.

The Harvard architecture based computer consists of separate memory spaces for the programs (instructions) and data. Each space has its own address and data buses. So instructions and data can be fetched from memory concurrently and provides significance processing speed improvement.

In figure below, there are two data and two address buses multiplexed for data bus and address bus. Hence, there are two blocks of RAM chips one for program memory and another for data memory addresses.

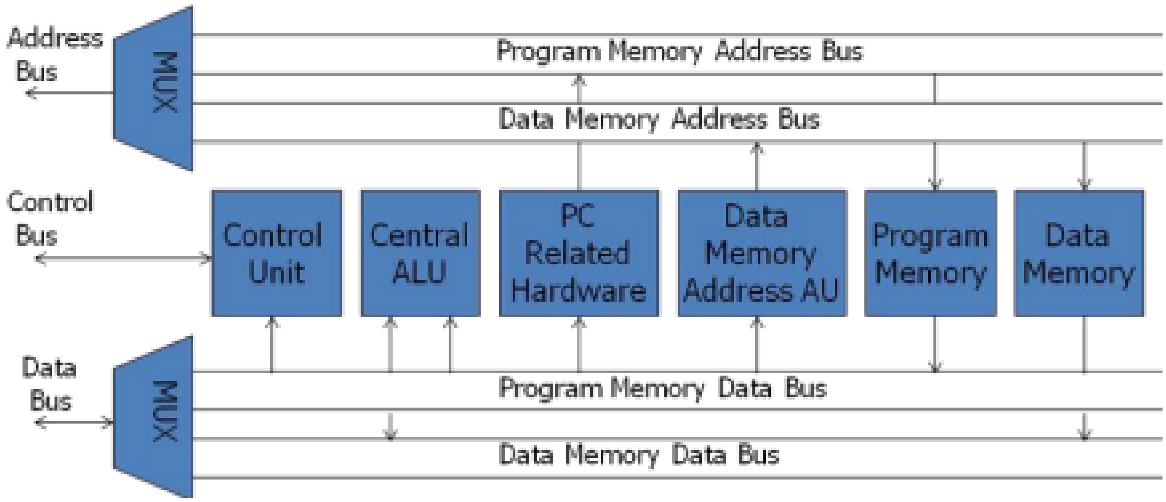

Fig: Harvard Architecture Based Microprocessor

The control unit controls the sequence of operations. Central ALU consists of ALU, multiplier, accumulator and scaling chief register. The PC used to address program memory and always contains the address of next instruction to be executed. Here data and control buses are bidirectional and address bus is unidirectional.

It is important to understand the difference between the microcomputer (μC) and the microprocessor (μP). A microcomputer contains several elements, the most important of which is the microprocessor. The microprocessor is usually a single IC that contains all of the circuitry of the control and arithmetic-logic units-in other words, the CPU. It is common to refer to the microprocessor as the MPU (microprocessor unit), since it is the CPU (central processing unit) of the microcomputer.

The microprocessor unit of the computer consists of various registers to store data, the arithmetic logic unit (ALU) to perform arithmetic and logical operations, instruction decoders, counters, and control lines. The CPU reads instructions from the memory and performs the tasks specified. The CPU communicates with input/ output devices to accept or to send data. The input and output devices are known also as peripherals. The CPU is the primary and central player in communicating with various devices such as memory, input, and output; however, the timing of the communication process is controlled by the group of circuits called the control unit.

Microprocessor

The microprocessor is one component of the microcomputer. A microcomputer is a computer similar to any other computer, except that the CPU functions of the microcomputer are performed by the microprocessor. Similarly, the term peripheral is used for input/ output devices; however, occasionally memory is also included in this term.

The various components of the microcomputer and their function are described in the following paragraphs. The MPU (microprocessor unit) is the heart of every microcomputer. It performs a number of functions, including.

1. Providing timing and control signals for all elements of the µC
2. Fetching instructions and data from memory
3. Transferring data to and from memory and I/O devices
4. Decoding instructions
5. Performing arithmetic and logic operations called for by instructions
6. Responding to I/O generated contro l signals such as RESET and

INTERRUPT

The MPU contains all of the logic circuitry for performing these functions, but its internal logic is generally not externally accessible. Instead, we can control what happens inside the MPU by the program of instructions that we put in memory for the MPU to execute. This is what makes the MPU so versatile and flexible when we want to change its operation, we simply change the programs stored in RAM (software) or ROM (firmware) rather than rewire the electronics (hardware).

The microprocessor is a semiconductor device consisting of electronic logic circuits manufactured by using either a large-scale (LSI) or very-large-scale integration (VLSI) technique. The microprocessor is capable of performing computing functions and making decisions to change the sequence of program execution. In large computers, the CPU performs these computing functions and it is implemented on one or more circuit boards. The microprocessor is in many ways similar to the CPU; however, the microprocessor includes all the logic circuitry (including the control unit) on one chip. For clarity, the microprocessor can be divided into three segments, arithmetic/logic unit (ALU), register unit, and control unit.

- ♦ Arithmetic and Logic Unit: In this area of the microprocessor, computing functions are performed on data. The CPU performs arithmetic operations such as addition and subtraction, and logic operations such as AND, OR, and exclusive OR. Results are stored either in register or in memory or sent to output devices.
- ♦ Register Unit: This area of the microprocessor consists of various registers. The register is used primarily to store data temporarily during the executing of a program. Some of the registers are accessible to the user through instructions.
- ♦ 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

peripherals (including memory).

Input

The input section transfers data and instructions in binary from the outside world to the microprocessor. It includes devices such as keyboards, teletypes, and analog-to-digital converters. Typically, a microcomputer includes a keyboard as an input device. The key board has sixteen data keys (0 to 9 and A to F) and some additional function keys to perform operations such as storing data and executing programs.

Output

The output section transfers data from the microprocessor to output devices such as light emitting diodes (LEDs), cathode-ray-tubes (CRTs), printers, magnetic tape, or another computer. Typically, single-board computers include LEDs and seven-segment LEDs as output devices.

Memory

Memory stores binary information such as instructions and data, and provides that information to the microprocessor whenever necessary. To execute programs, the microprocessor reads instructions and data from memory and performs the computing operations in its ALU section. Result are either transferred to the output section for display or stored in memory for later use. The memory block has two sections: Read - Only Memory (ROM) and Read / Write Memory (R/WM), popularly known as Random Access Memory (RAM).

Microprocessor Architecture and its Operations

The microprocessor is a programmable logic device, designed with registers, flip-flops. The microprocessor has a set of instructions designed internally, to manipulate data and communicate with peripherals. This process of data manipulation and communication is determined by the logic design of the microprocessor, called the architecture. The microprocessor can be programmed to perform functions on given data by selecting necessary instructions from its set. These instructions are given to the microprocessor by writing them into its memory. Writing (Or entering) instruction and data is done through an input device such as a keyboard. The microprocessor reads or transfers each instruction one at a time, matches it with its instruction set, and performs the data manipulation indicated by the instruction. The result can be stored in memory or sends to such output devices as LEDs or a CRT terminal. In addition, the microprocessor can respond to external signals. It can be interrupted, reset, or asked to wait to synchronize with slower peripherals. All the various functions performed by the microprocessor can be classified in three general categories:

- ♦ Microprocessor-initiated operations
- ♦ Internal data operations
- ♦ 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. However, early processors do not have the necessary circuitry on one chip; the complete units are made up more than one chip. Therefore, the term Micro Processing Unit (MPU) is defined here as a group of devices that can perform these functions with the necessary set of control signals. This term is similar to the term Central Processing Unit (CPU). However, later microprocessors include most of the necessary circuitry to perform these operations on a single chip. Therefore, the terms MPU and microprocessor often are used

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Microprocessor-Initiated Operations and 8085 Bus Organization

The MPU performs primarily four operations.

1. Memory Read: Reads data from memory.
2. Memory Write: Writes data into memory.
3. I/O read: Accepts data from input devices.
4. I/O Write: Sends data to output devices.

All these operations are part of the communication process between the MPU and peripheral devices (including memory). 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 (with its address).
Step 2: Transfer data
Step 3: Provide timing or synchronization signals.

The 8085 MPU performs these functions using three sets of communication lines called buses: The address bus, the data bus, and the control bus.

Internal Data Operations and the 8085 Registers

The internal architecture of the 8085/8080A microprocessor determines how and what operations can be performed with the data. These operations are

1. Store 8-bits data.
2. Perform arithmetic and logical operations.
3. Test for conditions.
4. Sequence the execution of instructions.
5. Store data temporarily during execution in the defined R/W memory locations called the stack. To perform these operations, the microprocessor requires registers, arithmetic logic unit (ALU) and control logic, and internal buses (path for information flow).

Registers

The 8085 has six general - purpose registers to perform the first operation listed above, that is, to store 8-bit data during a program execution. These registers are identified as B, C, D, E, H, and L. They can be combined as register pairs - BC, DE, and HL - to perform some 16-bit operation. These registers are programmable, meaning that a programmer can use them to load or transfer data from the registers by using instructions. For example, the instruction MOV B, C transfers the data from register C to register B. Conceptually, the registers can be viewed

as memory locations, except they are built inside the microprocessor and identified by specific names. Some microprocessors do not have these types of registers; instead, they use memory space as their registers.

Accumulator

The accumulator is an 8-bit register that is part of the 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 that are set or reset according to data conditions in the accumulator and other registers. The microprocessor uses them to perform the third operation; namely testing for data conditions. For example, after an addition of two numbers, if the sum in the accumulator is larger than eight bits, the flip-flop that is used to indicate a carry, carry the Carry flag (CY), is set to one. When an arithmetic operation results in zero, the flip-flop called the Zero flag (Z) is set to one. The 8085 has five flags to indicate five different types of data conditions. They are called Zero (Z), Carry (CY), Sign (S), Parity (P), and Auxiliary Carry (AC) flags. The most commonly used flags are Zero and Carry; the others will be explained as necessary.

Program Counter (PC)

This 16 bit register deals with the fourth operation, sequencing the execution of instructions. This register is a memory pointer. Memory locations have 16-bit address, and that is why this is a 16-bit register. The microprocessor uses this register to sequence the execution of 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; initially, it will be called the stack pointer register to emphasize that it is a register. It pointers of a memory location in R/W memory, called the stack. The beginning of the stack is defined by loading a 16-bit address in the stack pointer (register).