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## UNIT – III

**Building blocks of Computer: Anatomy of Digital Computer : Functions of CPU , ALU and Control Units.**

**Data Storage: Introduction – Memory Units : RAM, ROM, EPROM,EEPROM.**

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### *Building blocks of Computer:*

#### **Main Memory**

Memory enables a computer to store, at least temporarily, data and programs

#### **Output Device**

The results that are stored in the memory can be transformed into a form that can be understood by users of a computer system by means of an output device. Some common output devices are monitor, printer, speaker etc.

#### **Mass storage Device**

These devices allow computer to permanently retain large amounts of data. Common mass storage device include disk drives and tape drives.

#### **Central Processing Unit (CPU)**

The CPU or processor is the brain of computer. It is the component that actually executes the instructions. The CPU itself has three components, namely, arithmetic logic unit (ALU), control unit (CU), and memory unit (MU).

#### **Arithmetic Logic Unit:-**

Arithmetic logic unit (ALU) performs two types of operations- arithmetic and logical. Fundamental arithmetic operations include addition, subtraction, multiplication, and division. Logical operations include comparisons like equal to, less than, greater than etc.

#### **Control Unit:-**

Control unit (CU) coordinates and controls the operations of a computer system. It controls the activities between memory and ALU and between CPU and input/output devices.

#### **Memory Unit:**

A memory unit (MU) is also called primary memory or main memory or RAM (random access memory). It holds data for processing, instructions for processing data (program), and information (processed data). The contents of main memory are lost when the computer is turned off.

### *Anatomy of Digital Computer :*

The two main characteristics of a computer are: (i) it responds to a specific set of instructions in a well-defined manner. (ii) It can execute a pre-recorded list of

instructions (a program). Modern computers are electronic and digital. The actual machinery - wires, transistors and circuits is called hardware; the instructions and data are called software.

All general purpose computers require the following hardware components:

(i) **Central Processing Unit (CPU):** The 'brain' of the computer, the component that actually executes instructions.

(ii) **Memory :** It enables a computer to store, at least temporarily, data and programs.

(iii) **Input device :** Usually a keyboard or mouse is used to read data and programs into the computer.

(iv) **Output device:** A display screen, printer, etc. that lets you see what the computer has accomplished.

(v) **Mass storage device:** It allows a computer to permanently store large amounts of data. Common mass storage devices include disk drive and tape drive.

vi) **Memory -** also known as the primary storage or main memory - is a part of the microcomputer that holds data and instructions. Part of the contents of the memory is held only temporarily, that is, it is stored only as long as the microcomputer is turned on. When you turn the machine off, the contents are lost. The capacity of the memory to hold data and program instructions varies in different computers. The original IBM PC could hold approximately several thousand characters of data or instructions only. But modern microcomputers can hold millions or even billions of characters in their memory.

vii) **Registers:** Computers also have several additional storage locations called registers. These appear in the Control Unit and ALU and make processing more efficient. Registers are a sort of special hi-speed storage areas that hold data and instructions temporarily during processing. They are parts of the Control Unit and ALU rather than the memory. Their contents can, therefore be handled much faster than the contents of the memory.

viii) **Addresses:** To locate the characters of data or instructions in the main memory, the computer stores them in locations known as addresses. A unique number designates each address. Addresses can be compared to post office mailboxes. Their numbers remain the same, but contents continuously change.

### *Functions of CPU , ALU and Control Units.*

#### CPU (central processing unit)

#### CPU organization and operation flowchart

#### General concepts

- The primary function of the Central Processing Unit is to execute sequences of instructions representing programs, which are stored in the Main Memory.

- As mentioned before, the CPU consists of the ALU and CU.
- To carry out its role the CPU must be an interpreter of a set of instructions at machine language level.

• Program execution is carried out as follows:

1. The CPU transfers instructions and, when necessary their input data, called operands, from the Main Memory into the registers of the CPU.

2. The CPU executes the instructions in their stored sequence (one after another) except when the execution sequence is explicitly altered by a branch instruction.

3. When necessary, the CPU transfers results from the CPU registers into the Main Memory.

• Sometimes CPUs are called simply Processors.

• Consequently, there exist streams of instructions and data between the Main Memory and the set of general registers that forms the CPU' s local memory.

• The CPU is significantly faster than the Main Memory, that is it can read from or write in the CPU's registers 5 to 10 times faster than it can read from or write in the Main Memory (MM). Nowadays, VLSI technology tends to increase the CPU/ Main Memory speeds disparity.

• As mentioned before to remedy this drawback, the memory is organized in a hierarchical way; a new layer of memory, called Superoperative Memory (SOM) is placed between the Main Memory and CPU. At present, the SOM is represented by the CACHE Memory (CM); this CM is smaller and faster than MM and can be placed wholly or in part on the same chip as CPU (the so called internal Cache Memory).

• The main role of CM is to ensure a memory read or write operation in a single clock cycle, whereas a MM access(bypassing the CM memory) takes several clock cycles.

• The CM and MM are seen by the CPU as forming a single memory space, because the operation of CM is totally transparent to the CPU.

• CPU – memory communication with a cache:

•CPU communicates with I/O devices in much the same way as it communicates with the Main Memory. The I/O devices are associated with addressable registers called I/O PORTS. The CPU can store or extract a word from I/O PORTS (the OUTPUT and INPUT operations).

• The programs executed by the CPU are divided into two broad groups: user programs and supervisor programs.

- A user program, known also as application program, handles a specific application, whereas a supervisor program manages various routine aspects of the entire computer system on behalf of the users and it is part of the system software named the operating system. As examples of supervisor programs there are mentioned the control of transferring data between Secondary Memory and Main Memory, control of a graphic interface etc.
- In a normal operation any CPU switches between user programs and supervisor programs.

#### General structure of a CPU

- CPU is made up of the Control Unit ( CU ) and of the Arithmetic and Logic Unit (ALU); it is also called the processor.

CPU = ALU + CU

- CPU must communicate with the other units of a digital computer: Memory Unit, Input Units and Output Units. CPU is issuing addresses, data, control signals and is receiving instructions, data, status signals, interrupt requests. This communication is carried out through a System Bus.
- The System Bus is formed of several subbuses each with its particular tasks. Most important are: Address Bus, Data Bus, Control Bus. Address Bus is unidirectional emanating from the CPU and reaching the Memory Unit and Input / Output Units. Data Bus is bidirectional carrying both instructions and data. Control Bus is a mixed Bus containing the Control Lines, representing commands to different units to perform actions, as well as Status lines, representing condition bits supplied by the external units to CPU

#### The operation or task that must perform by CPU is:

**Fetch Instruction:** The CPU reads an instruction from memory.

**Interprete Instruction:** The instruction is decoded to determine what action is required.

**Fetch Data:** The execution of an instruction may require reading data from memory or I/O module.

**Process data:** The execution of an instruction may require performing some arithmetic or logical operation on data.

**Write data:** The result of an execution may require writing data to memory or an I/O module.

To do these tasks, it should be clear that the CPU needs to store some data temporarily. It must remember the location of the last instruction so that it can know where to get the next instruction. It needs to store instructions and data temporarily while an instruction is being executed. In other words, the CPU needs a small internal memory. These storage location are generally referred as registers.

The major components of the CPU are an arithmetic and logic unit (ALU) and a control unit (CU). The ALU does the actual computation or processing of

data. The CU controls the movement of data and instruction into and out of the CPU and controls the operation of the ALU.

The CPU is connected to the rest of the system through system bus. Through system bus, data or information gets transferred between the CPU and the other component of the system. The system bus may have three components:

**Data Bus:** Data bus is used to transfer the data between main memory and CPU.

**Address Bus:** Address bus is used to access a particular memory location by putting the address of the memory location.

**Control Bus:** Control bus is used to provide the different control signal generated by CPU to different part of the system. As for example, memory read is a signal generated by CPU to indicate that a memory read operation has to be performed. Through control bus this signal is transferred to memory module to indicate the required operation.

**There are three basic components of CPU:** register bank, ALU and Control Unit. There are several data movements between these units and for that an internal CPU bus is used. Internal CPU bus is needed to transfer data between the various registers and the ALU, because the ALU in fact operates only on data in the internal CPU memory.

### **ALU (Arithmetic Logic Unit)**

An arithmetic logic unit (ALU) is a digital circuit used to perform arithmetic and logic operations. It represents the fundamental building block of the central processing unit (CPU) of a computer. Modern CPUs contain very powerful and complex ALUs. In addition to ALUs, modern CPUs contain a control unit (CU).

Most of the operations of a CPU are performed by one or more ALUs, which load data from input registers. A register is a small amount of storage available as part of a CPU. The control unit tells the ALU what operation to perform on that data, and the ALU stores the result in an output register. The control unit moves the data between these registers, the ALU, and memory. The heart of every computer is an Arithmetic Logic Unit (ALU).

This unit consists of two subsections namely,

- ◆ Arithmetic Section
- ◆ Logic Section

Consider an ALU having 4 arithmetic operations and 4 logical operation.

To identify any one of these four logical operations or four arithmetic operations, two control lines are needed. Also to identify the any one of these two groups- arithmetic or logical, another control line is needed. So, with the help of three control lines, any one of these eight operations can be identified.

Consider an ALU is having four arithmetic operations. Addition, subtraction, multiplication and division. Also consider that the ALU is having four logical operations: OR, AND, NOT & EX-OR.

### **Arithmetic Section**

**Function of arithmetic section is to perform arithmetic operations like addition, subtraction, multiplication, and division. All complex operations are done by making repetitive use of the above operations.**

### **Logic Section**

**Function of logic section is to perform logic operations such as comparing, selecting, matching, and merging of data.**

### **How an ALU Works**

**An ALU performs basic arithmetic and logic operations. Examples of arithmetic operations are addition, subtraction, multiplication, and division. Examples of logic operations are comparisons of values such as NOT, AND, and OR.**

**All information in a computer is stored and manipulated in the form of binary numbers, i.e. 0 and 1. Transistor switches are used to manipulate binary numbers since there are only two possible states of a switch: open or closed. An open transistor, through which there is no current, represents a 0. A closed transistor, through which there is a current, represents a 1.**

**Operations can be accomplished by connecting multiple transistors. One transistor can be used to control a second one - in effect, turning the transistor switch on or off depending on the state of the second transistor. This is referred to as a gate because the arrangement can be used to allow or stop a current.**

### **Flags set in the Status Register by the ALU**

**An important function of the ALU is to set up bits or flags which give information to the control unit about the result of an operation. The flags are grouped together in the status word. As the ALU has only an adder, to subtract numbers one has to use 2s-complement arithmetic. The ALU has no knowledge of this at all — it simply adds two binary inputs and sets the flags. It is up to control unit (or really the programmer's instructions executed by the control unit) to interpret the results.**

**Z Zero flag: This is set to 1 whenever the output from the ALU is zero.**

**N Negative flag: This is set to 1 whenever the most significant bit of the output is 1.**

**Note that it is not correct to say that it is set when the output of the ALU is negative: the ALU doesn't know or care whether you are working in 2's complement. However, this flag is used by the controller for just such interpretations.**

**C Carry flag: Set to 1 when there is a carry from the adder.**

### **Control Units.**

- ◆ **CPU is partitioned into Arithmetic Logic Unit (ALU) and Control Unit (CU).**
- ◆ **The function of control unit is to generate relevant timing and control signals to all operations in the computer.**
- ◆ **It controls the flow of data between the processor and memory and peripherals**

## **FUNCTIONS OF CONTROL UNIT**

The control unit directs the entire computer system to carry out stored program instructions.

The control unit must communicate with both the arithmetic logic unit (ALU) and main memory.

The control unit instructs the arithmetic logic unit that which logical or arithmetic operation is to be performed.

The control unit co-ordinates the activities of the other two units as well as all peripherals and auxiliary storage devices linked to the computer.

## **DESIGN OF CONTROL UNIT**

Control unit generates control signals using one of the two organizations:

**Hardwired Control Unit**

**Microprogrammed Control Unit**

## **HARDWIRED CONTROL UNIT**

It is implemented as logic circuits (gates, flip-flops, decoders etc.) in the hardware.

This organization is very complicated if we have a large control unit.

In this organization, if the design has to be modified or changed, requires changes in the wiring among the various components. Thus the modification of all the combinational circuits may be very difficult.

### **♦ ADVANTAGES**

Hardwired Control Unit is fast because control signals are generated by combinational circuits.

The delay in generation of control signals depends upon the number of gates.

### **♦ DISADVANTAGES**

More is the control signals required by CPU; more complex will be the design of control unit.

Modifications in control signal are very difficult. That means it requires rearranging of wires in the hardware circuit.

It is difficult to correct mistake in original design or adding new feature in existing design of control unit.

Control unit consist of a:

**Instruction Register**

**Number of Control Logic Gates,**

**Two Decoders**

**4bit Sequence Counter**

An instruction read from memory is placed in the instruction register (IR).

The instruction register is divided into three parts: the I bit, operation code, and address part.

First 12bits (0-11) to specify an address, next 3-bits specify the operation code (opcode) field of the instruction and last left most bit specify the addressing mode I.

**I = 0 for direct address**

**I = 1 for indirect address**

## Data Storage: Introduction

Data storage has expanded from text and numeric files to include digital music files, photographic files, video files, and much more. These new types of files require secondary storage devices with much greater capacity than floppy disks.

There are four type of storage:

- ◆ Primary Storage
- ◆ Secondary Storage
- ◆ Tertiary Storage
- ◆ Off-line Storage

### Primary Storage

- ◆ Also known as main memory.
- ◆ Main memory is directly or indirectly connected to the central processing unit via a memory bus.
- ◆ The CPU continuously reads instructions stored there and executes them as required.

• Example:

- RAM
- ROM
- Cache

### Secondary Storage

- ◆ It is not directly accessible by the CPU.
- ◆ Computer usually uses its input/output channels to access secondary storage and transfers the desired data using intermediate area in primary storage.

• Example:

- Hard disk
- Magnetic Tape
- Optical Disc

## Memory Units : RAM, ROM, EPROM,EEPROM.

### Memory Unit

Memory is an essential element of a computer. Without its memory, a computer is of hardly any use. Memory plays an important role in saving and retrieving data. The performance of the computer system depends upon the size of the memory.

There are two kinds of computer memory: primary and secondary. Primary memory is accessible directly by the processing unit. RAM is an example of primary memory. As soon as the computer is switched off, the contents of the primary memory is lost. You can store and retrieve data much faster with primary memory compared to secondary memory. Secondary memory such as floppy disk, magnetic disk, etc., is located outside the computer. Primary memory is more expensive than secondary memory.

Computer memory is used to store two things:



i) instructions to execute a program and ii) data.

In computer's memory both programs and data are stored in the binary form. You have already been introduced with decimal number system, that is the numbers 1 to 9 and 0. The binary system has only two values 0 and 1. These are called bits.

As program or the set of instructions is kept in primary memory, the computer is able to follow instantly the set of instructions. For example, when you book ticket from railway reservation counter, the computer has to follow the same steps : take the request, check the availability of seats, calculate fare, wait for money to be paid, store the reservation and get the ticket printed out. The program containing these steps is kept in memory of the computer and is followed for each request.

### Capacity of Primary Memory

You know that each cell of memory contains one character or 1 byte of data. So the capacity is defined in terms of byte or words. Thus 64 kilobyte (KB) memory is capable of storing  $64 \times 1024 = 32,768$  bytes. (1 kilobyte is equal to 1024 bytes). A memory size ranges from few kilobytes in small systems to several thousand kilobytes in large mainframe and super computer. In your personal computer you will find memory capacity in the range of 8 MB, 16 MB and even 128 MB (MB = Million bytes).

### RAM

**Random Access Memory (RAM) :** The primary storage is referred to as Random Access Memory (RAM) because it is possible to randomly select and use any location of the memory directly to store and retrieve data. It takes same time to any address of the memory as the first address. It is also called read/write memory. The storage of data and instructions inside the primary storage is temporary. It disappears from RAM as soon as the power to the computer is switched off. The memories, which lose their content on failure of power supply, are known as volatile memories. So now we can say that RAM is volatile memory.

A RAM constitutes the internal memory of the CPU for storing data, program and program result. It is read/write memory. It is called random access memory (RAM). Since access time in RAM is independent of the address to the word that is, each storage location inside the memory is as easy to reach as other location & takes the same amount of time. We can reach into the memory at random & extremely fast but can also be quite expensive.

RAM is volatile, i.e. data stored in it is lost when we switch off the computer or if there is a power failure. Hence a backup uninterruptible power system(UPS) is often used with computers. RAM is small , both in terms of its physical size and in the amount of data it can hold.

RAM is of two types

- Static RAM (SRAM)
- Dynamic RAM (DRAM)

#### ◆ Static RAM (SRAM)

The word static indicates that the memory retains its contents as long as power remains applied. However, data is lost when the power gets down due to volatile nature. SRAM chips use a matrix of 6-transistors and no capacitors. Transistors do not require power to prevent leakage, so SRAM need not have to be refreshed on a regular basis.

Because of the extra space in the matrix, SRAM uses more chips than DRAM for the same amount of storage space, thus making the manufacturing costs higher. Static RAM is used as cache memory needs to be very fast and small.

#### ◆ Dynamic RAM (DRAM)

DRAM, unlike SRAM, must be continually refreshed in order for it to maintain the data. This is done by placing the memory on a refresh circuit that rewrites the data several hundred times per second. DRAM is used for most system memory because it is cheap and small. All DRAMs are made up of memory cells. These cells are composed of one capacitor and one transistor

#### Types of DRAM

- ◆ Asynchronous DRAM
- ◆ Fast Page Mode (FPM) DRAM or FPRAM
- ◆ Extended Data Out (EDO) DRAM
- ◆ Burst EDO (BEDO) DRAM
- ◆ Synchronous Dynamic RAM (SDRAM)
- ◆ Direct Rambus DRAM (DRDRAM)
- ◆ Double Data Rate (DDR) SDRAM

#### ROM

- ◆ Read Only Memory (ROM) : There is another memory in computer, which is called Read Only Memory (ROM). Again it is the ICs inside the PC that form the ROM. The storage of program and data in the ROM is permanent.
- ◆ The ROM stores some standard processing programs supplied by the manufacturers to operate the personal computer. The ROM can only be read by the CPU but it cannot be changed.
- ◆ The basic input/output program is stored in the ROM that examines and initializes various equipment attached to the PC when the switch is turned ON. The memories, which do not lose their content on failure of power supply, are known as non-volatile memories. ROM is non-volatile memory.
- ◆ Read-only memory (usually known by its acronym, ROM) is a class of storage media used in computers and other electronic devices.
- ◆ Because data stored in ROM cannot be modified (at least not very quickly or easily), it is mainly used to distribute firmware
- ◆ Firmware is software that is very closely tied to specific hardware, and unlikely to require frequent updates.
- ◆ The memory from which we can only read but cannot write on it. This type of memory is non-volatile. The information is stored permanently in such memories during manufacture.

- ✦ A ROM, stores such instruction as are required to start computer when electricity is first turned on, this operation is referred to as bootstrap. ROM chip are not only used in the computer but also in other electronic items like washing machine and microwave oven.

Following are the various types of ROM:

- ✦ **MROM (Masked ROM):**

The very first ROMs were hard-wired devices that contained a pre-programmed set of data or instructions. These kind of ROMs are known as masked ROMs. It is inexpensive ROM.

- ✦ **PROM (Programmable Read only Memory)**

PROM is read-only memory that can be modified only once by a user. The user buys a blank PROM and enters the desired contents using a PROM programmer. Inside the PROM chip there are small fuses which are burnt open during programming. It can be programmed only once and is not erasable.

- ✦ **EPROM(Erasable and Programmable Read Only Memory)**

The EPROM can be erased by exposing it to ultra-violet light for a duration of upto 40 minutes. Usually, a EPROM eraser achieves this function. During programming an electrical charge is trapped in an insulated gate region. The charge is retained for more than ten years because the charge has no leakage path. For erasing this charge, ultra-violet light is passed through a quartz crystal window(lid). This exposure to ultra-violet light dissipates the charge. During normal use the quartz lid is sealed with a sticker.

- ✦ **EEPROM(Electrically Erasable and Programmable Read Only Memory)**

The EEPROM is programmed and erased electrically. It can be erased and reprogrammed about ten thousand times. Both erasing and programming take about 4 to 10 ms (milli second). In EEPROM, any location can be selectively erased and programmed. EEPROMs can be erased one byte at a time, rather than erasing the entire chip. Hence, the process of re- programming is flexible but slow.

## EPROM

**PROM :** There is another type of primary memory in computer, which is called Programmable Read Only Memory (PROM). You know that it is not possible to modify or erase programs stored in ROM, but it is possible for you to store your program in PROM chip. Once the programs are written it cannot be changed and remain intact even if power is switched off. Therefore, programs or instructions written in PROM or ROM cannot be erased or changed.

**EPROM :** This stands for Erasable Programmable Read Only Memory, which overcome the problem of PROM and ROM. EPROM chip can be programmed time and again by erasing the information stored earlier in it. Information stored in EPROM can be erased by exposing it to ultraviolet light. This

memory can be reprogrammed using a special programming facility. When the EPROM is in use, information can only be read.

Erasable programmable read-only memory (EPROM) can be erased by exposure to strong ultraviolet light (typically for 10 minutes or longer), then rewritten with a process that again requires application of higher than usual voltage. Repeated exposure to UV light will eventually wear out an EPROM, but the endurance of most EPROM chips exceeds 1000 cycles of erasing and reprogramming.

The EPROM can be erased by exposing it to ultra-violet light for a duration of upto 40 minutes. Usually, a EPROM eraser achieves this function. During programming an electrical charge is trapped in an insulated gate region. The charge is retained for more than ten years because the charge has no leakage path. For erasing this charge, ultra-violet light is passed through a quartz crystal window(lid). This exposure to ultra-violet light dissipates the charge..

The EPROM device is programmed by forcing an electrical charge on a small piece of polysilicon material (called a floating storage gate) located in the memory cell. When this charge is present on this gate, the cell is “programmed,” usually a logic “0,” and when it is not present, it is a logic “1.”

## **EEPROM**

EEPROM(Electrically Erasable and Programmable Read Only Memory) The EEPROM is programmed and erased electrically. It can be erased and reprogrammed about ten thousand times. Both erasing and programming take about 4 to 10 ms (milli second). In EEPROM, any location can be selectively erased and programmed. EEPROMs can be erased one byte at a time, rather than erasing the entire chip. Hence, the process of re- programming is flexible but slow.

it is based on a similar semiconductor structure to EPROM, but allows its entire contents (or selected banks) to be electrically erased, then rewritten electrically, so that they need not be removed from the computer (or camera, MP3 player, etc.). Writing or flashing an EEPROM is much slower (milliseconds per bit) than reading from a ROM or writing to a RAM (nanoseconds in both cases).

- ◆ Electrically alterable read-only memory (EAROM) is a type of EEPROM that can be modified one bit at a time. Writing is a very slow process and again requires higher voltage (usually around 12 V) than is used for read access. EAROMs are intended for applications that require infrequent and only partial rewriting.EAROM may be used as non-volatile storage for critical system setup information; in many applications, EAROM has been supplanted by CMOS RAM supplied by mains power and backed-up with a lithium battery.