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CHAPTER 3: COMPUTER SYSTEM ARCHITECTURE AND COMPONENTS: STRUCTURE, MEMORY, AND STORAGE TECHNOLOGIES

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Abstract
This chapter provides a detailed understanding of the architecture and components of a computer system, focusing on its fundamental units such as the input unit, central processing unit (CPU), and output unit. It explains how these components interact to perform data processing tasks efficiently. Special emphasis is given to the structure and functions of the CPU, including the Arithmetic Logic Unit (ALU), Control Unit (CU), and memory unit.
The chapter further explores different types of computer architectures, namely Von Neumann and Harvard architectures, highlighting their design principles and operational differences. In addition, it presents an in-depth discussion of computer memory systems, including primary memory, secondary memory, and cache memory, along with their characteristics and classifications.
The role of input and output devices is also examined, along with various storage technologies such as magnetic and optical storage devices. The chapter concludes with a comprehensive overview of storage media, including hard disks, magnetic tapes, and floppy disks, emphasizing their structure, working mechanisms, and performance considerations. Overall, this chapter builds a strong foundation for understanding how computer systems are organized and how they manage data and instructions.

Keywords
Computer Architecture, CPU, ALU, Control Unit, Memory, Primary Memory, Secondary Memory, Cache Memory, Input Devices, Output Devices, Storage Devices, Von Neumann Architecture, Harvard Architecture, Magnetic Storage, Optical Storage

Elements/components of A Computer System(Architecture):

A computer system mainly has three components viz. Input Unit, Central Processing Unit and Output Unit. These components are the building blocks of a computer and define its architecture.

The relationship among these components is well established by the following diagram:

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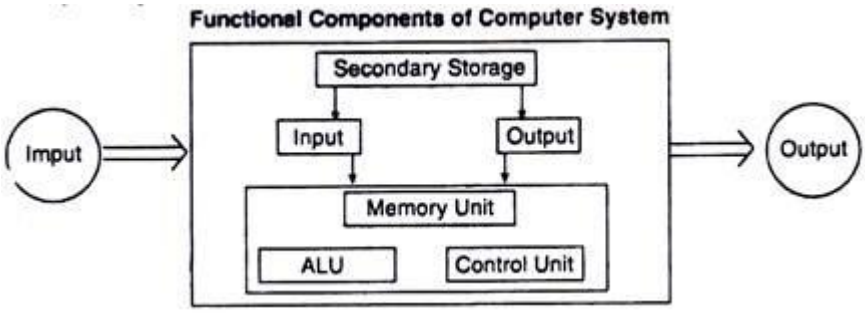


(i) Input Unit:

Input unit is responsible for controlling the various input devices that are used to enter data into the computer. The commonly used input devices are mouse, keyboard, light pen, optical scanner etc. While some input devices are designed for special purposes such as Optical Character Recognition (OCR), Magnetic Ink Character Recognition (MICR) and Bar Code Reader etc, there are other devices that accept input by responding to physical touch and voice such as ATMs.

(ii) Central Processing Unit (CPU):

The CPU ensures the flow of data into the system by directing the data to enter the system, storing it into the memory and retrieving it when needed to produce the output.

It has three parts:

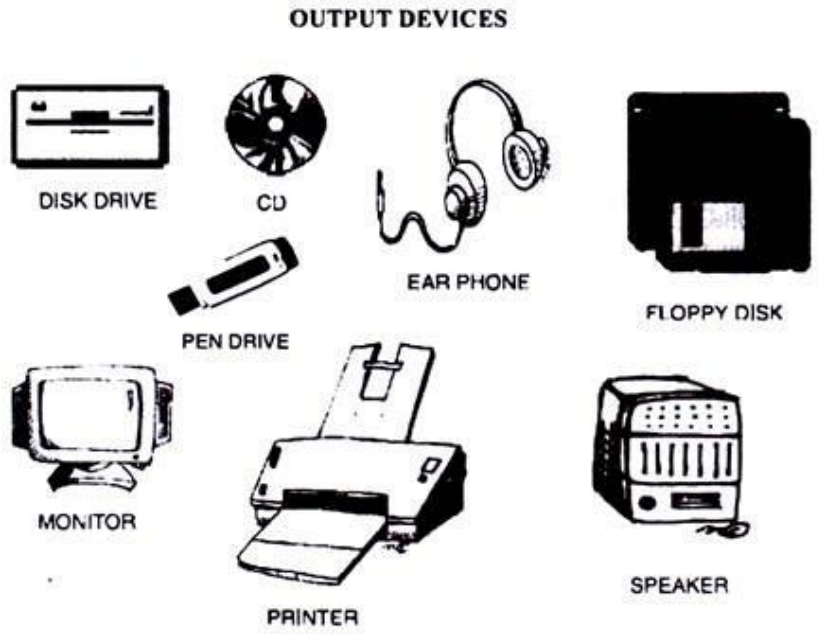
Arithmetic and Logic Unit (ALU): It performs all the arithmetical calculations and computations like addition, subtraction, multiplication and division. It is also responsible for logical calculations like comparisons among data items.

Memory Unit: The data has to be stored in the memory blocks of the computer before it is retrieved for actual processing.

Control Unit: As the name suggests, control unit controls and coordinates the activities of all the components of the computer system. It reads data from the memory, decodes the instructions, looks after its execution, and fetches the next instruction and so on.

(iii) Output Unit:

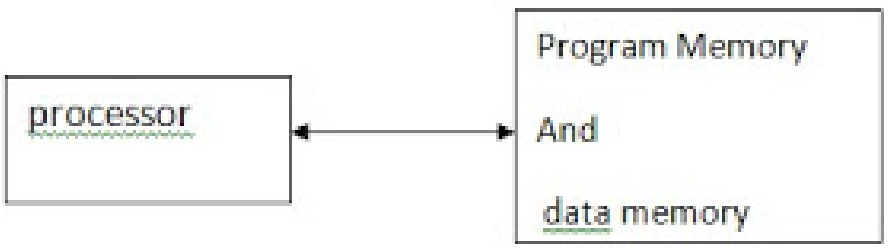
It controls various output devices like printer, graphic plotter, speech synthesizer, monitor (also known as Visual Display Unit or VDU) to produce the desired output and present it to the user. It ensures the convertibility of output into human readable form that is understandable by the user.



computer architectures:

There are basically two types of digital computer architectures. The first one is called Von Neumann architecture and later Harvard architecture was adopted for designing digital computers.

1.Von Neumann Architecture:

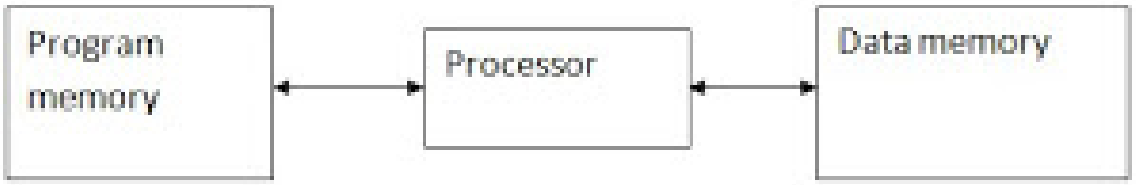


It is named after the mathematician and early computer scientist John Von Neumann. In this the computer has single storage system (memory) for storing data as well as program to be executed. Processor needs two clock cycles to complete an instruction. Pipelining the instructions is not possible with this architecture. In the first clock cycle the processor gets the instruction from memory and decodes it. In the next clock cycle the required data is taken from memory. For each instruction this cycle repeats and hence needs two cycles to complete an instruction. This is a relatively older architecture and was replaced by Harvard architecture.

2.Harvard Architecture:

The Harvard architecture is computer architecture with physically separate storage and signal pathways for

instructions and data. The term originated from the Harvard Mark I relay-based computer, which stored instructions on punched tape (24 bits wide) and data in electro-mechanical counters. These early machines had data storage entirely contained within the central processing unit, and provided no access to the instruction storage as data. Programs needed to be loaded by an operator; the processor could not boot itself.



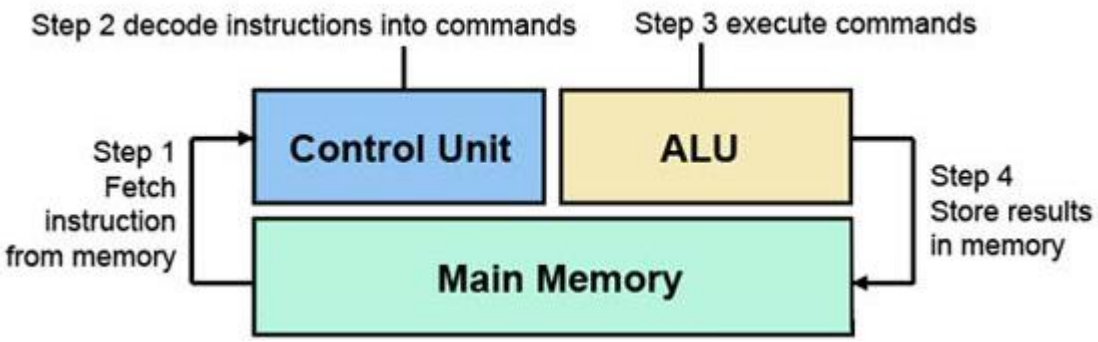
The name is originated from "Harvard Mark I" a relay based old computer. The computer has two separate memories for storing data and program. Processor can complete an instruction in one cycle if appropriate pipelining strategies are implemented. In the first stage of pipeline the instruction to be executed can be taken from program memory. In the second stage of pipeline data is taken from the data memory using the decoded instruction or address. Most of the modern computing architectures are based on Harvard architecture. But the number of stages in the pipeline varies from system to system.

CPU:

Alternately referred to as a processor, central processor, or microprocessor, the CPU is the Central Processing Unit of the computer. A computer's CPU handles all instructions it receives from hardware and software running on the computer.

Components of the CPU

In the CPU, the primary components are the ALU (Arithmetic Logic Unit) that performs mathematical, logical, and decision operations and the CU (Control Unit) that directs all of the processors operations. Following diagram gives working of CPU step by step.



ALU:

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.

How an ALU Works:

It performs both bitwise and mathematical operations on binary numbers and is the last component to perform calculations in the processor. The ALU uses, to operands and code that tells it which operations to perform for

input data. After the information has been processed by the ALU, it is sent to the computer's memory.

Multiple Arithmetic Logic Units can be found in CPUs, GPUs and FPUs. In some computer processors, the ALU is divided into an AU and LU. The AU performs the arithmetic operations, and the LU performs the logical operations.

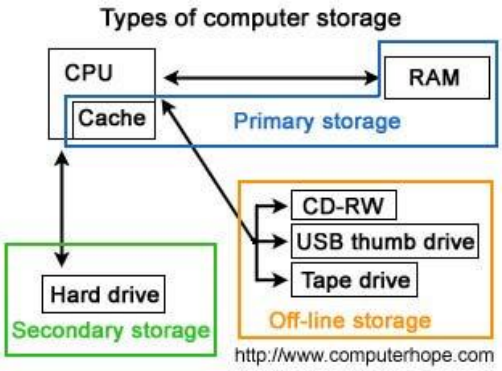
An ALU performs basic arithmetic and logic operations. Examples of arithmetic operations are addition, subtraction, multiplication, and division. Examples of logic operations are comparisons of values such as NOT, AND, and OR.

Control unit(CU):

A control unit is circuitry that directs operations within a computer's processor. It lets the computer's logic unit, memory, as well as both input and output devices know how to respond to instructions received from a program. Examples of devices that utilize control units include CPUs and GPUs.

A control unit works by receiving input information that it converts into control signals, which are then sent to the central processor. The computer's processor then tells the attached hardware what operations carry out. The functions a control unit performs depend on the type of CPU, due to the variance of architecture between different manufacturers. The following diagram illustrates how instructions from a program are processed.

Memory:

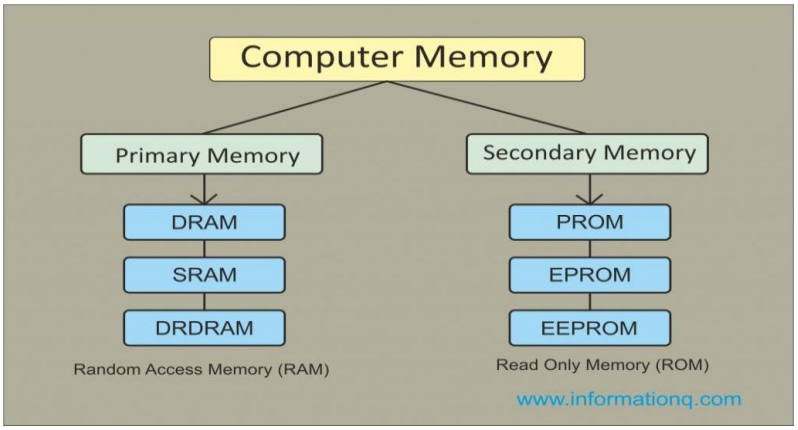


A memory is just like a human brain. It is used to store data and instructions. Computer memory is the storage space in computer where data is to be processed and instructions required for processing are stored. The memory is divided into large number of small parts called cells. Each location or cell has a unique address which varies from zero to memory size minus one. For example if computer has 64k words, then this memory unit has 64 * 1024=65536 memory locations. The address of these locations varies from 0 to 65535.

Memory is major part of computers that categories into several types. The computer memory offers several kinds of storage media some of them can store data temporarily and some them can store permanently. Memory consists of instructions and the data saved into computer through Central Processing Unit (CPU).

Memory is primarily of three types

- Cache Memory
- Primary Memory/Main Memory
- Secondary Memory



Types of Computer Memory:-Memory is the best essential element of a computer because computer can't perform simple tasks. The performance of computer mainly based on memory and CPU. Memory is internal storage media of computer that has several names such as majorly categorized into two types, Main memory and Secondary memory.

1. Primary Memory / Volatile Memory.
2. Secondary Memory / Non Volatile Memory.
3.Cache Memory

1. Primary Memory / Volatile Memory/ Main memory:- Primary Memory also called as volatile memory because the memory can't store the data permanently. Primary memory select any part of memory when user want to save the data in memory but that may not be store permanently on that location. It also has another name i.e. RAM.

Random Access Memory (RAM):- The primary storage is referred to as random access memory (RAM) due to the random selection of memory locations. It performs both read and write operations on memory. If power failures happened in systems during memory access then you will lose your data permanently. So, RAM is volatile memory.

RAM categorized into following types.

- DRAM
- SRAM
- DRDRAM

Characteristics of Main Memory

- These are semiconductor memories
- It is known as main memory.
- Usually volatile memory.
- Data is lost in case power is switched off.
- It is working memory of the computer.
- Faster than secondary memories.
- A computer cannot run without primary memory.

2. Secondary Memory / Non Volatile Memory:- Secondary memory is external and permanent memory that is useful to store the external storage media such as floppy disk, magnetic disks, magnetic tapes and etc cache devices. Secondary memory deals with following types of components.

Read Only Memory (ROM) :- ROM is permanent memory location that offer huge types of standards to save data. But it work with read only operation. No data lose happen whenever power failure occurs during the ROM memory work in computers.

ROM memory has several models such names are following.

1. PROM: Programmable Read Only Memory (PROM) maintains large storage media but can't offer the erase features in ROM. This type of RO maintains PROM chips to write data once and read many. The programs or instructions designed in PROM can't be erased by other programs.

2. EPROM : Erasable Programmable Read Only Memory designed for recover the problems of PROM and ROM. Users can delete the data of EPROM thorough pass on ultraviolet light and it erases chip is reprogrammed.

3. EEPROM: Electrically Erasable Programmable Read Only Memory similar to the EPROM but it uses electrical beam for erase the data of ROM.

Characteristic of Secondary Memory

- These are magnetic and optical memories
- It is known as backup memory.
- It is non-volatile memory.
- Data is permanently stored even if power is switched off.
- It is used for storage of data in a computer.
- Computer may run without secondary memory.
- Slower than primary memories.

3.Cache Memory:- Cache memory is a very high speed semiconductor memory which can speed up CPU. It acts as a buffer between the CPU and main memory. It is used to hold those parts of data and program which are most frequently used by CPU. The parts of data and programs are transferred from disk to cache memory by operating system, from where CPU can access them.

Advantages:- The advantages of cache memory are as follows:

- Cache memory is faster than main memory.
- It consumes less access time as compared to main memory.
- It stores the program that can be executed within a short period of time.
- It stores data for temporary use.

Disadvantages:- The disadvantages of cache memory are as follows:

- Cache memory has limited capacity.
- It is very expensive.

Input device

An input device is a piece of hardware that is used to enter data into a computer or a similar processing device such as a smart phone.

Input devices are usually categorized as either manual or automatic.

Examples of manual input devices are:

- Keyboard
- Mouse
- Touchpad
- Joystick
- Touchscreen
- Concept keyboard
- Scanner
- Graphics tablet
- Microphone
- Digital camera
- Examples of automatic input devices are:
- Barcode readers
- Optical mark reader (OMR)
- Magnetic Ink Character Recognition (MICR)
- Optical Character Recognition (OCR)
- Magnetic stripe readers
- Sensors

- Biometric devices

Output device

An output device is a piece of hardware that is used to output data that has been previously entered into a computer or similar processing device.

In computing terms, an output device is a piece of hardware that obeys a computer command to do something in the real world. For example a printer is an output device that will produce a page of information when the correct commands are sent to it from a computer

Here are some examples of output devices:

- Monitor
- Printer
- Plotter
- Projector
- Speaker
- Headphones
- Light / LED

Storage device:- Physical components or materials on which data is stored are called storage media. Hardware components that read/write to storage media are called storage devices. Two main categories of storage technology used today are magnetic storage and optical storage.

Primary magnetic storage:-

- Diskettes
- Hard disks (both fixed and removable)
- High capacity floppy disks
- Disk cartridges
- Magnetic tape

Primary optical storage

- Compact Disk Read Only Memory (CD ROM)
- Digital Video Disk Read Only Memory (DVD ROM)
- CD Recordable (CD R)
- CD Rewritable (CD RW)
- Photo CD

1) Magnetic Tapes: The Magnetic Tapes is the Type of Secondary Storage Device and this Device is used for taking back up of data and this Tape contains some magnetic fields and the Magnetic Tapes are used Accessing the data into the Sequential Form and the Tape Also Contains a Ribbon which is coated on the Single Side of the Tape and also contains a head which reads the data which is Recorded on to the Tape. And when we are reading the information from the disk then we can also read backward information means we can also back the Tape for Reading the Previous information. And For inserting the Tape into the System we also Requires Some Tape Drives Which Contains Tape and which is Responsible for Reading the contents from the Tapes.

They can Store huge Amount of data into the Tape Drive , But the Main Limitation of the Tape Drive is that we can't Access the Data from the Disks directly means if we want to 100th Record from the Tape then we must have to move all the Previous i.e. 99th Records first. And the Tapes are also easily damaged due to the Human Errors.

2.Magnetic Disks:- This is also called as the hard disk and this is made from the thin metal platter which is coated on the both sides of the magnetic Disks. And the there are Many Plates or Platters into a single Hard Disk and all the Plates are Made from the Magnetic Materials and all the Disks are Rotate from the 700 to 3600 rpm means Rotation per Minute and the Hard Disk also Contains a head which is used for both Reading and Writing the Data from the Hard Disks. The disk surface is divided into concentric tracks (circles within circles). The thinner the tracks, the more storage. The data bits are recorded as tiny magnetic spots on the tracks. The smaller the spot, the more bits per inch and the greater the storage.

The Plate of Disk is Divided into the Tracks and sectors and the collection of Tracks makes a Cylinder means all

the Tracks of the Disk which a Consecutive Areas makes a Cylinder.

The Disk is first divided into the Number of Tracks and the Tracks are further divided into the sectors and the Number of Tracks Makes a Cylinder. All the data is Stored into the disk by using Some Sectors and each sectors belongs to a Tracks. The Data is accessed from the Disk by using the heads, all the heads have Some Arm those are used for Reading the Data from the Particular Tracks and sector. When the Disk Rotates very high Speed then the Head also Moves, For Reading the data from the Disk the ARM touches with the Particular Track and read the data from that Location.

For Locating a Particular data from the Disk the head Moves Around the Disk very Fastly and data which a user wants to Access must have an Address So that Arm of the head just use that Address Means the Number of Cylinder, Number of Track and Number of Sectors from which user wants to read the data. With the Help of these Read and Write heads we can also Read the Data from the Disk and we can also Stores some data onto the Disk. Some Time Considerations are also used when we are accessing or storing the data onto the hard disk.

1) Seek Time: - The Total Time which is Taken to Move on the Desired track is known as the seek Time. And time is always measured by using the Milliseconds.

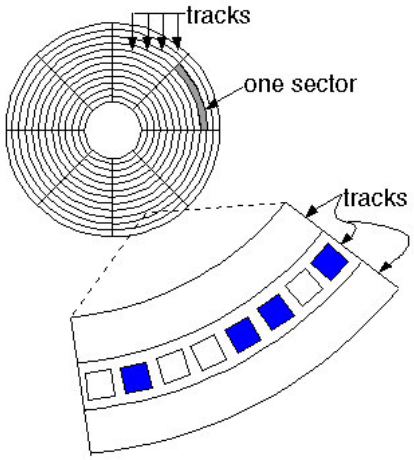
2) Latency Time. : The time required to Bring the Particular Track to the Desired Location Means the Total Time to bring the Correct the Sector for Reading or for the read and Write head. This is also called as the Average Time.

3) Data Transfer Time: The Total Time which is required for Reading and Writing the data into the Disk is known as the Data transfer Time.

When we are Taking About the Magnetic Tapes then we can say that the Storage Capacity of the disk is Measure in the Form of Mega Bytes and when are talking about the Hard Disk then the Measurement will be in the Form of Giga Bytes. Means the Capacity of t the Hard Disk will be Read by using the Giga Bytes. The Magnetic Tapes are Sequential Access Device and the Hard Disk is the Direct Access Device means the data of this Disk will be Read from Any Location and the Data can be Read from the Disk by using the Read Write Heads. But hard Disks are Costlier than the Simple Magnetic Tapes. But the capacity of the Hard Disk is very high in compare to the Tapes.

Tracks and Spots:-The disk surface is divided into concentric tracks (circles within circles). The thinner the tracks, the more storage. The data bits are recorded as tiny magnetic spots on the tracks. The smaller the spot, the more bits per inch and the greater the storage.

Sectors:-Tracks are further divided into sectors, which hold a block of data that is read or written at one time; for example, READ SECTOR 782, WRITE SECTOR 5448. In order to update the disk, one or more sectors are read into the computer, changed and written back to disk. The operating system figures out how to fit data into these fixed spaces. Modern disks have more sectors in the outer tracks than the inner ones because the outer radius of the platter is greater than the inner radius



Block diagram of Magnetic Disk

3. Floppy Diskette: Floppy disk is a kind of storage device that can be used to carried around? The Floppy Disk is also a Secondary Storage device which is used for storing the data in a Permanent Manner. The floppy is made up of Rigid Mylar Plastic and also contains a Magnetic black disk inside the Plastic Cover. The Floppy Disk also Stores all the Data into the Form of Tracks and Sectors and the floppy Disk provides both Reading and Writing the data into the Disk. The Floppy Disk is also called as Reusable Disk means the Floppy Disk Provides us the Facility to Read and Writes the Data into disk as and When Necessary and Also Many Times. We can Read and Write the data from the Disk.

The Main Advantage of the Floppy Disk is that the Data can be Stored many Times but the Main Limitation of the floppy Disk is that floppy Disk have a Small capacity and the Floppy Disk also doesn't have Reliability means the Data Stored into the Disk may not be used for Long Time because the floppy Disk is very Sensitive Thing when we Move the Head of the Disk Again and Again then the floppy disk gets Damaged. So that we can say that Floppy Disk is not a Reliable thing. And I the Other side the Cost of floppy Disk is also high means with the Comparison of the Other Storage Media's Floppy Disk have some more cost.

But the Main Advantage of the Floppy Disk is that floppy Disk is used for Moving the data from one Computer to Another With the Advent of the Floppy Disk we can Store the Data Into the Floppy Disk and after that we can Easily Remove that Disk from the System and Also Put the Disk into the Another System for Taking the Data.

But we cannot Start or Run the System without the Hard Disk So that floppy Disk is used to Transfer the Files from one System into the. There are Two Types of floppy Disk Available first is the 3.5 and second is the 5.2. But for inserting the Floppy Disk into the System we must have to use the Floppy Disk Drive in the System.

For Reading the data from the Disk there are also Some Read and Write heads those are too used. And the Head will touch the Surface of the floppy Disk So that this will lead to the Damage of the Disk So Quickly because when the Head Directly Touch the Surface of the Disk, then this will lead to the Scratches on the Disk and also cause Damage of the Disk. And the Drive can take only one Disk Means we can insert only one Floppy Disk at a Time into the Floppy Drive. The capacity of the floppy Disk is 1.44 MB. So that we can Floppy Disks as rare as Possible.

Floppy Disk Contains a Notch which Specify Whether the data will be Read or Write Means to Say if we wants to protect our data then we can set the Notch of the Floppy Disk as a Read Only.

4.Hard disk:- A hard disk drive also called hard drive, hard disk or disk drive is a device used for storing and retrieving digital data or information. A hard disk is a stack of disk known as the platter. A single hard disk usually consists of several platters and each platter requires two read/write heads, one for each side and is attached to a single access arm. Data are recorded electromagnetically in a concentric circle such as the track on a disk.

Hard disk is still the most common storage device for all computers. Like diskettes hard drives store data in tracks divided into sectors. Physically however they look quite different to diskettes. Includes one or more metal platters mounted on a central spindle, like a stack of rigid diskettes. Each platter is covered with a metal coating and the entire unit is contained in a sealed chamber. The hard disk and drive is a single unit which includes the hard disk, the motor that spins the platters and a set of read/write heads. Because you cannot remove the disk from the drive the terms hard disk and hard drive are used interchangeably. Hard drives have become the primary storage devices for PCs because they are convenient and cost effective. They outperform diskettes in both speed and capacity. Hard disks offer capacities from several hundred MB and more. Most entry level PCs now come with hard disks of at least 6.8MB.

Two important physical differences between hard disks and diskettes account for the differences in performance.

1. Hard disks are sealed in a chamber
2. Hard disk consists of a rigid metal platter (usually aluminum) rather than flexible Mylar.

Hard disk spin between 3600 rpm and 7200 rpm compared to a diskette 300 rpm. The speed at which the disk spins is a major factor in overall performance. The rigidity of the disk and the high-speed rotation allows more data to be recorded on the surface. Waving a magnet past an electric coil causes a current to flow. The faster you wave the magnet and the closer the magnet is to the coil, the larger the current generated in the coil. The disk that spins faster can use smaller magnetic charge to make current flow to the read/write head. The drives heads can also use a lower density current to record data on the disk. Not only does hard disks pack the data closer together they also hold more data because they usually include multiple platters stack one on top of each other. This configuration means that the disk has more than 2 sides, in addition to side 0 and 1 there are sides 2, 3, 4, and so on. Larger capacity disks may use 12 platters but both side of every platter are not always used. The number of sides that the disk uses is specified by the number of read/write heads. A particular disk may have 6 disks platters (12 sides) but only 11 heads à one side is not used to store data. Unused side is often the bottom one. The term cylinder is often used to refer to the same track across all the disks. Track 0 (outermost track) on every disk is cylinder 0.

Platter :-A hard disk platter or the disk is a circular disk in which the magnetic data is stored. A hard disk drive can have several platters that are mounted on the same spindle.

spindle / spindle motor :-The spindle motor is responsible for turning the hard disk platters and must provide stable, reliable and consistent turning , to allow the hard disk to function properly.

Head : -Responsible for read - write operation of data from and to the platter.

actuator : - Used to position the head arms to different tracks on the surface of the platter, actuator is used in changing from track to track the only operation on the hard disk that requires active movement. This mechanism of hard disk must works at extreme speed, with precise accuracy for the data to be read and write accurately on the platter.

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