UNIT 3 MEMORY SYSTEM

Structure **Page No.**

3.0 INTRODUCTION

To understand how data is processed, by a computer, we can draw a simple analogy between computers and humans.

Suppose a student asks a teacher "what happens when 15 is multiplied by 8". S/He receives the answer 120 from teacher. In the case of a computer, this process can be described as follows:

The teacher's brain receives the question through his/her ears (analogous to a computer's input device), processes the question with the help of his brain's information processing and analytical ability (analogous to computer's CPU) and gives the answer through the mouth (analogous to a computer's output device). Further, just as the teacher can write down the answer on a sheet of paper or blackboard, the computer can also print the answer on a paper through a printer attached to it.

Every modern computer system consists of three basic sections:

1. **Input device** (i.e. Keyboard, mouse or scanner etc.)
2. **Processor** (or CPU):
   - Control unit (CU)
   - Arithmetic and Logic Unit (ALU)
   - Memory unit
3. **Output device** (Visual Display Unit (Monitor/screen) or printer etc.)

The basic parts of a computers are shown in Figure 3.1

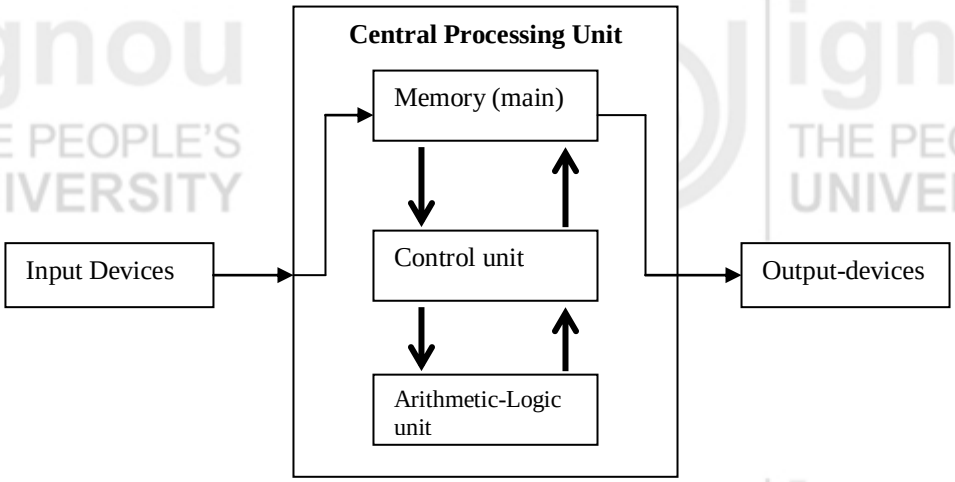

Figure 3.1: Basic Parts of a Computer

- Input devices such as a keyboard, mouse or scanner are used to enter input (data and/or instructions), directly into the computer.
- The **CPU** is like the human brain; it has a memory and just like there is a faculty in the brain that regulates the functioning of all parts of the body, a computer has a control-unit **(CU),** which controls its entire operation including its input and output devices.
- Processing of data is done in the arithmetic and logic unit (**ALU**). It performs Arithmetic and logic operations such as addition, subtraction, multiplication and division. Here the word "Logic" is used because a computer (unlike a calculator) has the capacity to do logical operations also, such as compare two numbers, and find out which of the two numbers is greater.

The Memory unit is an important component of a computer where all the data and information are stored in the form of binary digits (combination of 0's and 1's) and retrieved whenever necessary. Computer systems use a variety of devices for storing instructions and data. The computer memory is the place where the computer holds data and programs that are in use. Computer memory refers to the physical devices in a computer. If our computer's CPU had to constantly access the hard drive to retrieve every piece of data it requires, the operation will be very slow. On the other hand, when the data or information is kept in memory the CPU can access it much more quickly. From the time the computer is turned on until the time it is shut down, the CPU is constantly using the memory system. The act of entering data into a storage location is called a memory write operation, and the act of retrieving data from a storage location is called a memory read operation. Data and instructions are moved, to and from memory, in bunches of word length. These memory devices are categorised according to access time, storage capacity and cost-per-bit of storage.

The Memory unit is an important component of a computer where all the data and information are stored in the form of binary digits

Based on these criteria memory is broadly categorised into two types:

- Primary or main memory (also called semiconductor memory).
- Secondary or auxiliary memory (magnetic memory/Optical memory).

The Table 3.1 summarizes the difference between Primary (or main) memory and secondary (or auxiliary) memory.

Table: 3.1 : Difference between Memories

	Access Time	Storage capacity	Cost/bit of storage
Primary memory	Faster	Smaller	High
Secondary memory	Slower	higher	Low

That is, Primary memory (i.e. RAM, ROM etc.) have *faster access time*, *smaller storage capacity*, and *higher cost per bit of storage*, as compared to secondary memory.

Based on *access time*, *storage capacity* and *cost/bit storage*, the memory devices (such as RAM, ROM, Hard-disk, Floppy disk, Magnetic disk, Magnetic Tape, CD-ROM, and DVD etc.) can be categorized into three kinds of memory systems:

- Semiconductor memory such as RAM, ROM etc
- Magnetic memory such as Hard-disk, Floppy disk, and Magnetic tapes
- Optical memory such as CD-ROM, DVD etc

A Central Processing Unit (CPU) in a computer system is an extremely fast device as compared to the main memory, but it can not work on its own. It depends on the main memory that sends data and instruction when required for processing.

In other words, we can say that even memories with smaller size (i.e. primary memory) have very high access time (time taken by CPU to access a location in memory), which reduces the overall speed of a computer.

To reduce the cost of a large sized memory, a special type of high speed memory, known as ***cache memory*** can be used in between the CPU and the main memory

Computer memory can also be categorized on the basis of **Volatile** and **Non-Volatile** characteristics. Non-volatile Memory is a type of computer memory which can retain the stored information even if the power is shut down. Examples of Non-Volatile Memory are Read-only memory (ROM), flash memory, optical discs etc. On the other hand, a Volatile memory loses its content when the power goes off. Random Access Memory (RAM), which is the most common form of Primary Storage, is a type of volatile memory. When the computer is shut down, everything contained in RAM is lost.

To reduce the idle time of the CPU and increase the speed of processing, a fast memory can be used. This can be done by using a large size of main memory. But the cost of main memories of relatively large size is still very high. To reduce the cost of a large sized memory, a special type of high speed memory, known as ***cache memory*** can be used in between the CPU and the main memory (as shown in Figure 3.2). Thus the cost versus access time leads to a hierarchy of computer memory, where the memory is organized into a hierarchy, known as the **memory hierarchy**. This includes CPU registers, Cache memory, main memory and various secondary storage devices. Although the memory hierarchy is organized in such a way to minimize the cost, without compromising the overall speed of access.

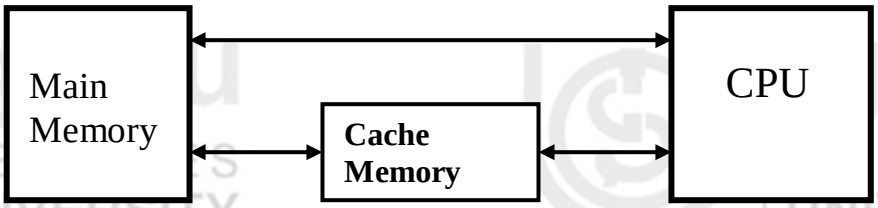

Figure 3.2: Memory Organization

In this unit we will mainly focus on storage organization and storage devices such as disk/tape, CD/DVD and ROM/PROM etc. We also discuss the memory hierarchy which includes main memory and high speed memory such as cache memory.

3.1 OBJECTIVES

After going through this unit, you should be able to:

- differentiate between types of memory and needs of the memory system;
- differentiate between various types of memories such as semiconductor, magnetic and Optical memory;
- describe the various secondary storage devices such as Hard-disk, floppy disk, CD-ROM, DVD-ROM etc; and
- describe the importance of the memory hierarchy.

3.2 MEMORY AND STORAGE DEVICES

Memory is an important component of a computer where all the data and information are stored in the form of binary digits (combination of 0's and 1's) and retrieved whenever necessary.

There are two main functions of the memory:

- To store programs, data and information into the computer.
- To store the results of computation.

A computer system uses a variety of devices for storing the instructions and data. When you want to execute a computer program, the program has to be in memory. Any input data needed for processing by that program should also be in memory. All the intermediate results and outputs from the program are stored in the memory until the machine is turned off.

The storage devices of a computer system are ranked according to the following criteria:

1. **Access time:** This is the time required to locate and retrieve stored data from the storage unit in response to a program instruction. That is the time interval between the read/write request and the availability of the data. A fast access time is always preferred.

2. **Storage capacity:** It is the amount of data that can be stored in the storage unit. A large capacity is preferred.
3. **Cost per bit of storage:** It is the cost of a storage unit for a given storage capacity. Low cost per bit of storage is always preferred. The final goal is to minimize this cost.

Based on above mentioned criteria, at present the following three kinds of memory system are commonly used in modern computers:

Table 3.2 : Memory and its Purposes

Sl.No.	Types of Memory	Purpose
1	**Processor's internal (CPU) memories**	• These are the small set of high speed registers which are internal to a processor and are used as temporary locations where actual processing is done.
2	**Primary (main) memory**	• It is a fast and large memory but is slower than processor memory. Primary memory has faster access time, smaller storage capacity and higher cost per bit storage. • This memory is accessed directly by the processor. It stores programs and data which are currently needed by the CPU. The CPU communicates directly with the main memory. The size of the main memory is kept small because of its high cost. It is a volatile type of memory.
3	**Secondary (or auxiliary) memory**	• Secondary memory is mainly used for bulk storage (mass storage) of programs, data and other information. It has much larger capacity than main memory but is slower. • It is non-volatile type of memory. It stores system software, compiler, assembler and useful packages,, large data files etc.

Thus from above discussions, we can summarize the following points:

- Secondary memory cannot be accessed directly by the CPU. First the information of these memories (which is needed by the CPU for current processing) is transferred to the main memory and then the information can be accessed as the information of main memory. Hard-disk and floppy disks are the most common secondary memories used in computers.
- Secondary storage systems must offer large storage capacities, low cost per bit and medium access times. Magnetic media (such as *floppy disks* and *hard disks*) have been used for such purposes for a long time. But audio and video media, either in compressed form or uncompressed form, require higher storage capacity than the other media forms and the storage cost for such media is significantly higher.
- Optical storage devices offer a higher storage density at a lower cost. A CD-ROM can be used as an optical storage device. Many software companies offer both operating system and application software on CD-ROMs today. This technology has

been the main catalyst for the development of multimedia in computing because it is used in multimedia external devices such as video recorders and digital recorders (Digital Audio Tape) which can be used for multimedia systems.

- Removable disk, tape cartridges are other forms of secondary storage devices used for back-up purposes having higher storage density and higher transfer rate.

There is another type of high speed memory, known as **Cache memory**, which is used to increase the speed of processing by making current programs and data available to the CPU at a rapid rate. Cache memory is a relatively small, high speed memory that stores the most recent used instructions or data. It acts as a high-speed buffer between main memory and the CPU.The cache memory is placed in between CPU and main memory. Access time is the time it takes a device or program to locate information and make it available to the computer for further processing. Cache memory access time is about 0.5 to 2.5 ns which is much less than that of the main memory. The access time of main memory is about 50-70 ns. Because of its very high cost, the capacity of the cache memory deployed is 2 to 3 percent of that of the main memory. The access time of mass storage devices such as hard disks are measured in milliseconds (ms).

The most common memory hierarchy is shown in Figure 3.3 :

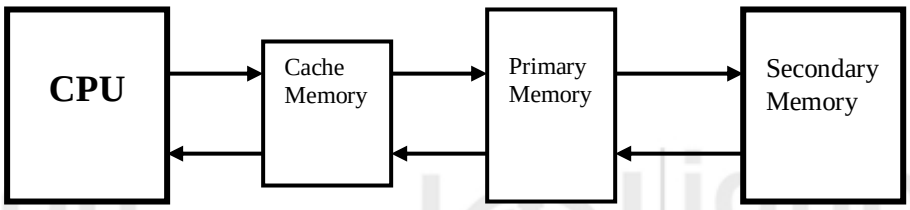

Figure 3.3 : Memory Hierarchies

Now let us start with the memory organization of primary storage. A primary or internal storage section is basic to all computers. Figure 3.4 compares the different types of memory in terms of capacity, access speed, cost per bit of storage as follows:

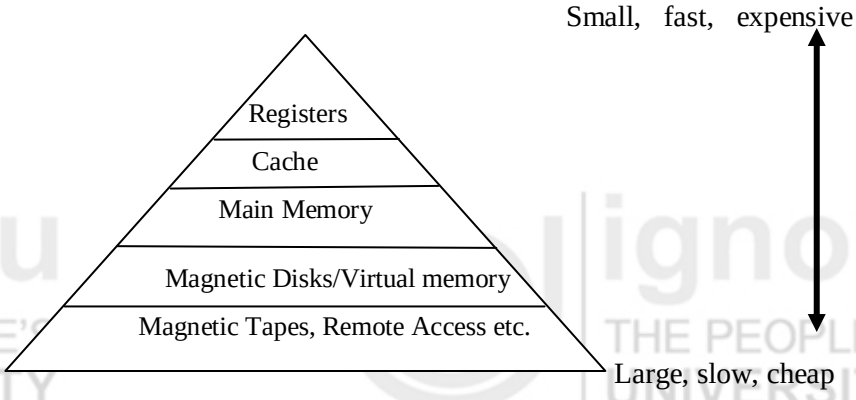

Figure 3.4 : Storage media in terms of cost, Speed and capacity trade-offs

All the memory devices can be categorized into three main categories:

- Semiconductor (or Main) memory
- Magnetic memory
- Optical memory

The Figure 3.5 illustrates the storage cost, speed and capacity of these memories. Note that cost increases with faster access speeds but decreases with access capacity.

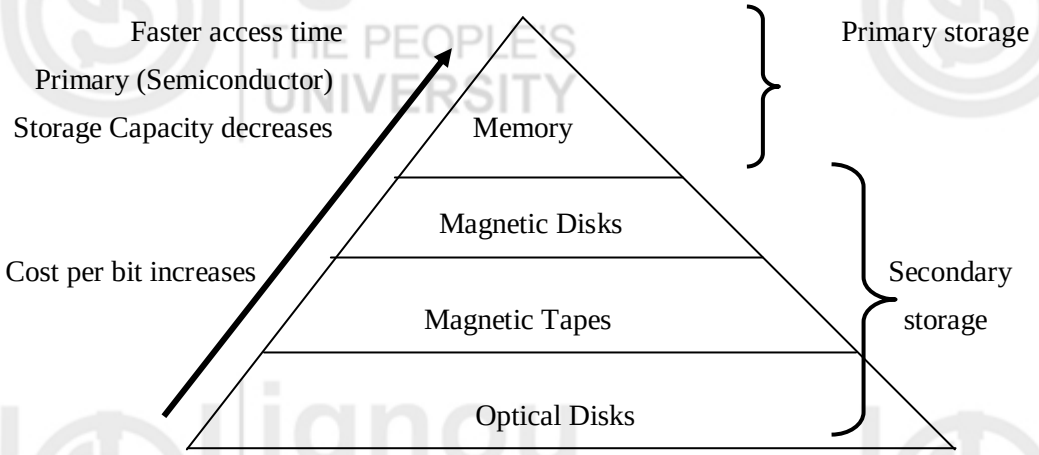

Figure 3.5: Storage media cost, Speed and capacity trade-offs

You can note down the following points from the Figure 3.5

- Semiconductor memories are used mainly for primary storage. It stores programs and data which are currently needed by the CPU.
- The semiconductor memory is an electronic, static device. There are no moving parts in it. Some examples of semiconductor memory are RAM, ROM etc.
- The semiconductor memory is faster, compact and lighter. It consumes less power.
- The magnetic and optical memories are slow compared to semiconductor memory.

But they are cheaper than semiconductor memory. They are not static devices. They are either in the form of a rotating disk or tape. All computers contain both semiconductor as well as magnetic memory.
The examples of magnetic memory are Hard-disk, floppy disk, magnetic disk and tapes.

The Figure 3.6 shows a relationship between the access-time and capacity of various types of memory.

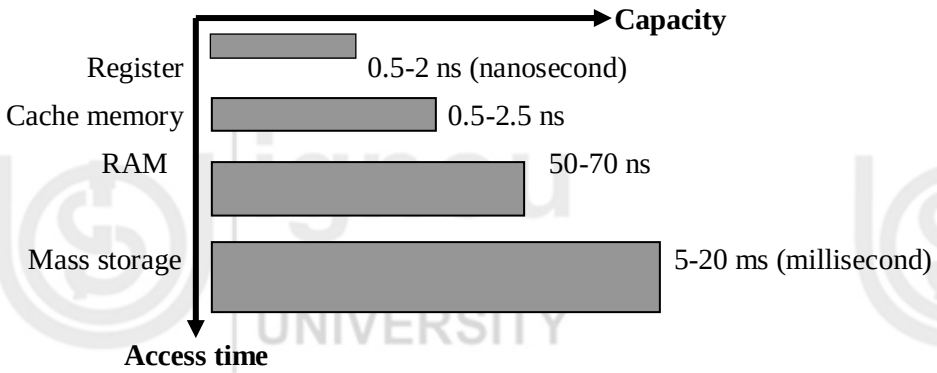

Figure 3.6 : Capacity vs. access-time

Optical recording techniques have been recently used to store data on the surface of a coated disk. Information is written to or read from an optical disk using a laser beam. An example of this kind of serial access memory is a CDROM (Compact Disk Read-Only Memory). Only one surface of an optical disk is used to stored data. An optical disk has very high storage capacity, up to 20 GB. It is relatively inexpensive and has a long life of

at least 15-20 years. Better optical recording methods which records data on multiple layers on a disk surface have been recently introduced. This storage device is known as DVD-ROM (Digital Versatile Disk Read-Only Memory). The main drawback of the optical disk system is its slow average access time. Table 3.3 shows the some characteristics of the discussed various memory technologies.

Table 3.3: Characteristics of Memory Technologies

Technology	Nature of storage medium	Access Mode	Volatile/ Nonvolatile	Access Time (in sec)	Average cost (Rs/bit)
Semiconductor Memories	Electronic	Random (or Direct)	Volatile	10^{-8}	10^{-2}
Magnetic Memories	Magnetic	Sequential/Random	Non-volatile	10^{-1}	10^{-6}
Optical Memories	Optical (laser beam)	Random	Non-volatile	1	10^{-7}

Note that there are two basic methods of accessing information from various memory devices :

- Sequential or serial access, or
- Direct or Random access

- A ***Sequential-access*** memory device reads data in sequence. In other words, information on a serial device can only be retrieved in the same sequence in which it is stored. Data is recorded one after another in a predetermined sequence (such as in numeric order) on a storage medium. Sequential processing is quite suitable for such applications like preparation of monthly pay slips, or monthly electronic bills etc., where each address needs to be accessed in turn. If you are working with a sequential access device and information is stored at the last address, then data stored at the last address cannot be accessed until all preceding locations in the sequence have been traversed. That is locating an individual item of data requires searching the recorded data on the tape until the desired item is located.

- A sequential-access memory such as *magnetic tape* is organized by arranging memory cells in a linear sequence. These do not have unique storage address that can be directly addressed. Instead, data is presented serially for writing and is retrieved serially during a read.

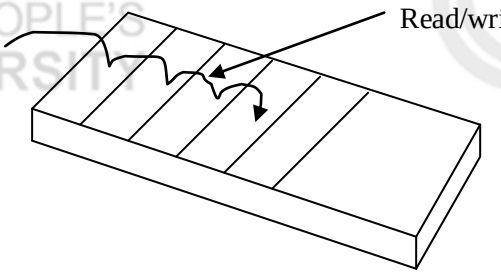

Figure 3.7: Sequential Access Memory

- In case of a ***random access*** device the information is available at random, i.e., any location in the device may be selected at random. So any location in the device can be accessed in approximately equal time in any order. In other words, we can say that each storage position (1) has a unique address and (2) can be individually accessed in approximately equal time without searching through other storage positions. Magnetic disk and CDROM are typical random access storage devices. Any data record stored on a magnetic or optical disk can be accessed directly in approximately the same time period. The Figure 3.8 shows sequential versus direct access storage:

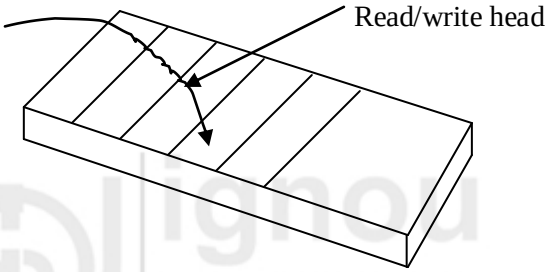

Figure 3.8: Random Access Memory

Basic Storage Fundamentals

Data is processed and stored in a computer system through the presence or absence of electronic or magnetic signals in the computer's circuitry (ie. RAM) or in the media it uses (i.e. magnetic Disk). This is called a "two-state" or **Binary representation** of data. Transistor and other semiconductor circuits are either in conducting or in non-conducting states. For Magnetic media, such as magnetic disk or tapes, these two states are represented by having magnetized spots whose magnetic fields have one of two different directions or polarities.

For any electronic circuits, the conducting (ON) state represents the number 1, while the non-conducting (OFF) state represents the number 0.This is so only for positive logic. One can always have the reverse convention that we call negative logic. For magnetic media, the magnetic field of a magnetized spot in one direction represents a 1 while magnetism in the other direction represents a 0.

For any electronic circuits, the conducting (ON) state represents the number 1, while the non-conducting (OFF) state represents the number 0

The smallest element of data is called a bit, which can have a value of either 0 or 1. The capacity of a memory chip is usually expressed in terms of bits. A group of 8-bits is known as a byte, which represents one character of data in most computer coding schemes. Thus, the capacity of a computer's memory and secondary storage devices is usually expressed in term of bytes. Computer codes such as ASCII (American Standard Code for Information Interchange) use various arrangements of bits to form bytes that represent the numbers 0 to 9, the letters of the alphabet, and many other characters.

☞ Check Your Progress 1

1. State whether **True** or **False**
   a) Primary memory is faster than secondary memory but that has a larger capacity. True ☐ False ☐
   b) Primary memory is mainly used for bulk storage. True ☐ False ☐
   c) CD-ROM is a Random access storage device. True ☐ False ☐

d) When we load software from a floppy, hard disk or CD-ROM, it is stored in main
True ☐ False ☐

e) In Random access memory any memory location can be accessed directly.
True ☐ False ☐

f) Non-volatile memory means the stored data are lost when power goes off.
True ☐ False ☐

2. Differentiate between the following:

a) Primary (main) memory versus secondary memory

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b) Different types of memory (in terms of access speed, storage capacity and cost per bit storage).

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c) A graph showing Capacity versus access time for different types of memory.

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d) Random versus Sequential access.

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3.2.1 Semiconductor (Main) Memory

- All computers except very small computers contain both semiconductor as well as magnetic memory.
- All modern computers use semiconductor memory as its main memory (or primary memory). Semiconductor memory is known as Random access memory (RAM) because any part of the memory can be accessed for reading and writing.
- It stores programs and data which are currently needed by the CPU.
- Another part of main memory is Read Only Memory (ROM). ROMs are those memories on which it is not possible to write the data. They can only be read.
- Thus RAM and ROM memories are used as the main memory of the computer.
- The Main memory holds the programs and data required by the CPU for carrying out its operations.
- The primary (main) storage is a semiconductor device that is built using integrated circuits. The data is stored in binary form in main memory. Numeric as well as non-numeric data can be represented in binary form. With two binary digits, we can represent 4 different characters. With three binary digits, we can represent 8 different

characters. Computers internally use eight binary digits to represent characters and digits (A binary digit is referred to as a bit and 8 bits are called a byte). 256 characters can be represented by a byte.

The capacity of a computer's memory is usually expressed in terms of bytes. Computer codes such as ASCII (American Standard Code for Information Interchange) use various arrangements of bits to form bytes that represent the numbers 0 to 9, the letters of the alphabet, and many other characters.

Storage capacities are frequently measured in **Kilobytes** (KB), **Megabytes** (MB), **Gigabytes** (GB), or **Terabytes** (TB). Table 3.4 summarizes the commonly used names with abbreviations and number of bytes for these storage capacities.

Storage capacities are frequently measured in **Kilobytes** (KB), **Megabytes** (MB), **Gigabytes** (GB), or **Terabytes** (TB)

Table 3.4: Commonly used names, Abbreviations and storage capacity in bytes.

Name (Abbreviations)	Number of Bytes
Byte (B)	1
Kilobytes (KB)	1024
Megabytes (MB)	1024*1024 (about one million)
Gigabytes (GB)	1024*1024*1024
Terabytes (TB)	1024*1024*1024*1024

Types of Main Memory

Memory can be of various types like Random Access Memory (RAM) and Read-Only Memory (ROM). Figure 3.9 summarizes the different types of main memory.

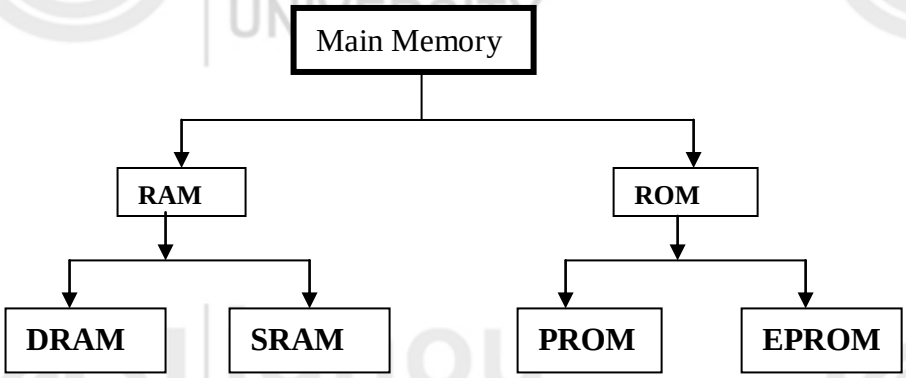


Figure 3.9: Different types of Main Memory

RAM (Random Access Memory)

- The Read and write memory (R/W memory) of a computer is called a RAM. The user can write information into RAM and read information from it. It is called **random access** since any memory location can be accessed in a random manner for reading and writing. The access time is the same for each memory location. It usually refers to "temporary" memory, which means that when the system is shut down, the memory is lost.

- ***Random Access Memory*** (RAM) is really the main store and is the place where the program and software we load gets stored. When the CPU runs a program, it fetches the program instructions from the RAM and carries them out. Similarly, if the CPU needs to store the final results of calculations, it stores them in RAM. Thus, the CPU can both READ data from RAM and WRITE data into the RAM.
- There are two important types of RAMs:
  - Static RAM (or SRAM)
  - Dynamic RAM (or DRAM)
- Static RAMs retain stored information only as long as the power supply is on whereas a Dynamic RAM loses its stored information in a very short time (a few milliseconds) even though the power supply is on.
- Dynamic RAMs are cheaper and consume less power whereas Static RAMs are costlier and consume more power. Static RAMs have a higher speed than dynamic RAMs.
- Dynamic RAM is cheaper and so is used for main memory. Static Ram is faster and so is used in cache memory.
- Dynamic RAM requires the data to be refreshed periodically in order to retain the data while SRAM does not need to be refreshed.

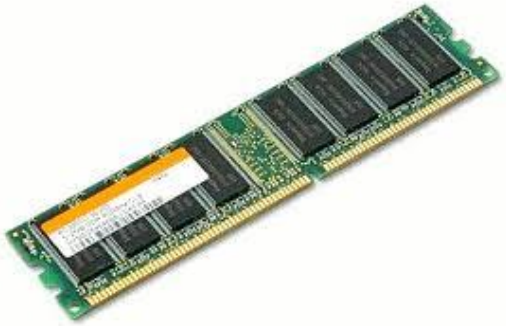


Figure 3.10 : Random Access Memory

Both static and dynamic RAMs use CMOS technology. CMOS devices consume less power. Static RAMs hold information in a flip-flop circuit consisting of two cross coupled inverters. In a RAM the memory cell must be associated with a read and write facility. Six (6) transistors are needed per memory cell in a static RAM. Dynamic RAMs required fewer transistors per memory cell. The following are commonly used RAM chips:

- **EDO (Extended Data Output RAM):** In an EDO RAM any memory access stores 256 bytes of data into latches. The latches hold next 256 bytes of information, so that in most programs which are sequentially executed, the data are available without wait states.
- **SDRAM (Synchronous DRAM) and SGRAM (Synchronous Graphics RAM):** These RAM chips use the same clock rate as the CPU uses. As a result the memory chips remain ready to transfer data when the CPU expects them to be busy. SDRAM is often used as mass storage whereas SGRAM is used as a high end graphics memory.
- **Dual-Ported DRAM:** These types of RAM allow one to access two memory locations simultaneously. Sometimes it is also called video RAM (or VRAM). WRAM (Window RAM) is a special version of VRAM, which is commonly used in PCs running WINDOWS and WINDOWS applications.

- **SIMM and DIMM:** These stand for single-Inline and Double Inline Memory Modules. These are small printed circuit cards, on which several DRAM memory chips are placed. Such cards are plugged into the system board of the computer.

ROM (Read Only Memory)

- A ***Read-Only memory*** (ROM) is a **non-volatile** memory, i.e., the information stored in it is not lost even if the power supply goes off. Thus a Read Only Memory (ROM) is one in which information is stored permanently.
- Unlike RAM, the information from ROM can only be READ and it is not possible to WRITE fresh information to it. That is, the CPU can only fetch or READ instructions from ROM. This is the reason why it is called ROM. Computers almost always contain a small amount of ***Read-Only memory*** (ROM). It is much cheaper compared to RAMs when produced in large volumes.
- ROM is used for storing a special set of instruction, which the computer needs when it starts up (boots up).
- The contents of ROMs are decided by the manufacturers. The contents are permanently stored in a ROM at the time of manufacture.
- From the programming mode point of view, we have
  - Masked-programmed
  - User-programmed
- ROMs in which contents are written at the time of IC manufacture are called *mask-programmed* ROMs. PROM, EPROM and EEPROM or any other kind of PROM are *user programmable* ROMs. If we simply write (or say) ROM it means masked programmed.
- An example of a ROM is the Toshiba mask ROM, TCS 534000.

PROM (Programmable ROM)

- A variation of ROM chip is programmable read only memory (PROM). A PROM is a memory chip on which data can be written only once.
- ROM chips are supplied by computer manufacturer and it is not possible for a user to modify the programs stored inside the ROM chip. However, in case of PROM, it is possible for a user to customize a system by storing own program in a PROM chip.
- Once a program has been written on to a PROM chip, the recorded information cannot be changed i.e., the PROM becomes a ROM and it is only possible to read the stored information.
- PROM is also a **non-volatile** memory i.e. the stored information remains even if power is switched off.
- The basic difference between PROM and a ROM is that a PROM is manufactured as blank memory, whereas a ROM is programmed during the manufacturing process.

To write data on a PROM chip, you need a special device called a PROM programmer or a PROM burner. The process of programming a PROM is sometimes called burning the PROM.

Table: 3.5: Memory and its Features

Memory	Category	Volatility	Writing Mechanism	Erasure
RAM	Read-write memory	Volatile	Electrically	Electrically
ROM	Read-only memory	Non-volatile	Mask	Not-possible
PROM	Read-only memory	Non-volatile	Electrically	Not-possible
EPROM	Read-only memory	Non-volatile	Electrically	Using UV light
EEPROM	Read-only memory	Non-volatile	Electrically	Electrically

3.2.2 Magnetic Memory

In the above section we have seen various types of semiconductor RAMs. These high speed semiconductor storage devices (i.e. RAMs) are expensive. So we need some inexpensive media for storage. Also semiconductor memory has the following limitations:

1) **Limited Capacity**: Semiconductor (primary) memory of today's computers is not sufficient, since most of the data processing organizations deal with a large volume of data.
2) **Volatile Memory**: Semiconductor memory is volatile in nature. But there is always a need to store data on a permanent basis.

Thus there is a need of additional memory, that is inexpensive, non-volatile in nature and has large capacity. Magnetic material is inexpensive and long lasting, so it is an ideal choice for us. Magnetic memory is a permanent non-volatile, type of memory. Now-a-days, we are not using floppy disk.

A modern computer uses the following two types of magnetic memory:

(i) **Magnetic Disks**: Hard disks and Floppy disks.

(ii) **Magnetic Tapes** : Magnetic disks are the most common form of secondary storage because they provide fast access and high storage capacities at a reasonable cost.

Storage Mechanism: Magnetic disk drives contain metal disks that are coated on both sides with an iron oxide recording material. Several disks are mounted together on a vertical shaft which typically rotates the disks at speeds of 3600 to 7600 revolutions per minute (rpm). Electromagnetic read/write heads are positioned by access arms between the slightly separated disks to read and write data on concentric, circular tracks. Data are recorded on tracks in the form of tiny magnetized spots to form the binary digits of common computer codes. Thousands of bytes can be recorded on each track, and there are several hundred data tracks on each disk surface, which provides billions of storage positions for your software and data.

There are basically **two types** of magnetic disk arrangements, one having a removable disk cartridge and other having a fixed disk unit. Removable disk devices are popular because they are transportable and can be used as backup copies of your data.

Data Organizations: A magnetic disk is a surface device, which stores data on its surface. Its surface is divided into circular concentric tracks. The number of tracks on a disk range up to 800. Each track is divided into sectors (normally 10-100). These sectors can be either fixed or variable length sectors. The division of track into equal sized blocks or pages is set by the Operating system during disk formatting. The number of bytes stored in each sector is kept the same.

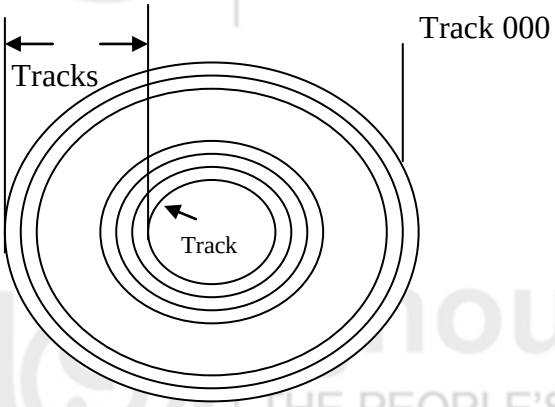


Figure 3.11 (a): tracks on disks. The no. of tracks

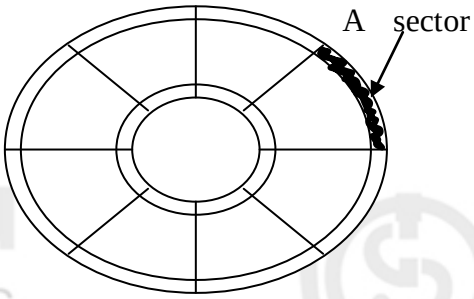


Figure 3.11 (b): Sectors of a disk.

The numbers vary but there are often 200 or more ranging up to 800 is sectors per track. Magnetic disks are semi-random devices. A track on a disk is selected in a random fashion, but data is written to or read from a sector in serial fashion.

Hard-Disk Drives (HDD)

- Hard disks are on-line storage devices.
- The term online means that the device (hard-disk) is permanently connected to the computer system and when the computer is on, the device (hard-disk) is available to store information or to retrieve information.
- HDD stores programs, data, operating system, compiler, assemblers, application programs etc.

Storage Organization in HDD

- HDD contains magnetic disks, access arms and read/write heads into a sealed, air filtered enclosure. This technique is known as **Winchester technique**.
- Winchester disk is another name for "hard disk drive". There are two stories behind the name Winchester disks; one is that the disk was developed at IBM's facility at *Winchester*, New York State; that had 30MB of fixed storage and 30MB of removable storage; the other is that the first model number was given as 3030, which is also the model number of the well-known *Winchester* Rifle popular in the Wild West. Although modern disk drives are faster and hold more data, the basic technology is the same, so *Winchester* has become synonymous with *hard disk*.
- Thus Winchester disk is a sealed "hard disk" having rotation speed typically 7200 rpm. A disk has 5000 to 10,000 concentric tracks per centimeter and about 100,000 bits per centimeter around circumference. Figure 3.12 illustrates a portion of Winchester disk.

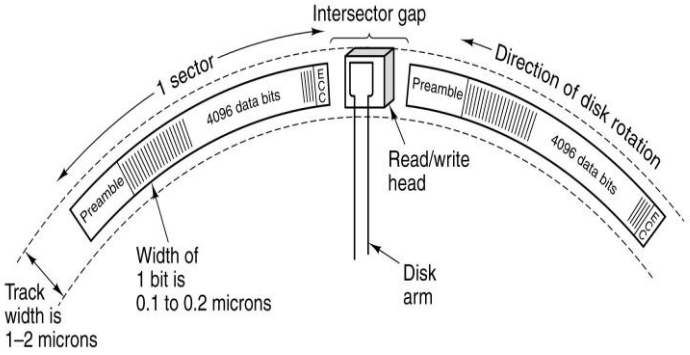


Figure 3.12: Winchester disk- a portion of disk track

- The read/write head reads data from the disk and writes data to the disk. A disk is mounted (or stacked) on the disk drive, which has the motor that rotates it. Hard-disks together with read/write heads, access mechanism and driving motor constitute a unit called **hard-disk-drive (HDD) unit**. The whole unit is fixed.
- Hard disk is also known as **platter**. It can not be removed or inserted into a HDD unit. Some disks have a single platter e.g. floppy disk.
- To increase the storage capacity several hard-disks (platters) are mounted (stacked) vertically, normally at a distance of an inch. This is known as **disk pack** or **multi-platter configuration**.
- A set of corresponding tracks in all surfaces of a disk pack (i.e. the tracks with the same diameter on the various surfaces) is called a **cylinder** (see Figure 3.13). Here the concept of cylinder is very important because data stored on the same cylinder can be retrieved much faster than if it were distributed among different cylinders.

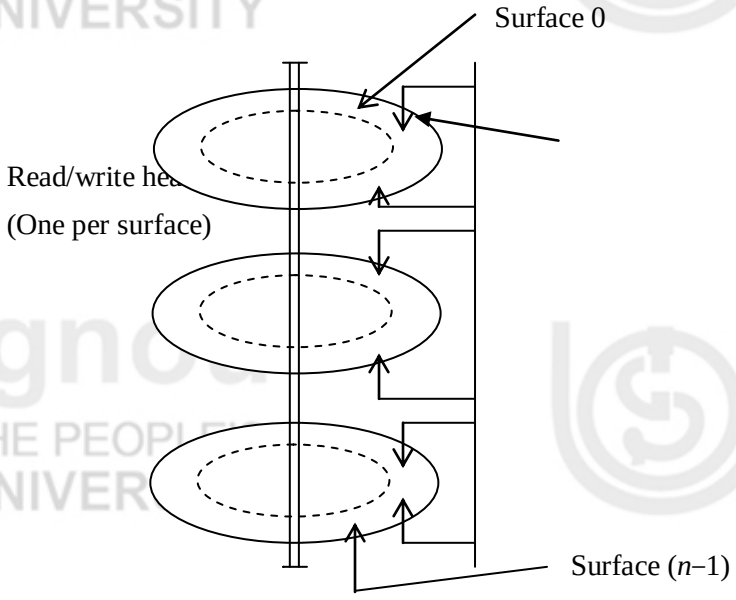


Figure 3.13: A disk having n platters (0 to n-1 plates). A set of corresponding tracks on all the (n-1) Surfaces, at a given radial distance, is called a cylinder

Relationship among Capacity, density and speed

Suppose a HDD (or disk pack) having n plates, has:
m=2n= total number of recording surfaces
t= tracks per surface
p= Sectors per track
s=bytes per sector,
π=3.14 then

- Storage capacity of the disk=(m*t*p*s) bytes
- If d is the diameter of the disk, the density of the recording is:
  Density=(s*p)/(π*d) byte/inches

Example 1: A 2.5 inch diameter disk pack has 6 plates (12 recording surfaces), 256 sectors per track, 5250 tracks per surface, 512 byes per sector. Thus disk capacity = 12×5250×256×512=8,257,536,000 bytes = 7.69 GB and recording density= (512×256)/(3.14×2.5)=16697 bytes/inch.

Example 2: What will be the storage capacity of a 2.5 inch diameter disk pack having 8 plates, 400 sectors per track, 2820 tracks per surface where 512 bytes of data can be stored per sector.

Solution: Total number of recording surface (m) = 2n = 2*8=16
Storage Capacity=16*2820*400*512 = 9240576000 bytes = 8.6 GB

There are several disk drives (C,D,F etc.) in a computer, which are connected to a **disk controller**. The controller converts instructions received form the computer (software) to electrical signals to operate disks. The Disk controller accepts commands from the computer and positions the read/write head of the specified disk for reading or writing.

For reading or writing operations on a disk pack, the computer must specify the drive number, cylinder number, surface number, and sector number. The drive number must be specified, because a controller normally controls more than one drive. Table 3.6 shows a disk address format for a disk controller of 8 drives, each disk pack having 250 cylinders, 12 surface and 256 sectors.

Table 3.6: Disk address format

Drive number	Cylinder number	Surface number	Sector number
3-bits	13 bits	4 bits	8-bits

Access time on a magnetic disk

The time required to position the read/write head over proper track is called the **seek time**

Magnetic disks are semi-random devices. A track on a disk is selected in random fashion, but data is written to or read from a sector in serial fashion. In order to access information from a disk, the disk address of the desired data has to be specified. The disk address is specified in terms of track number, surface number and the sector number. Information is always written from the beginning of a sector and can be read only from the track beginning.

As soon as the read/write command is received by the disk controller, the read/write heads are first positioned onto the specified track number (or cylinder) by moving the arm assembly in the proper direction. The time required to position the read/write head over proper track is called the **seek time.**

Seek time (Ts): The time required to move the read/write head on a specific (address) track.

- Seek time varies depending on the position of the arm assembly when a read/write command is received.
- Seek time will be maximum, if the arm assembly is positioned on the outer most track and the track to be reached is the inner most one and it will be zero if the arm assembly is already on the desired track.
- The average seek time is thus specified for most systems which is generally between few milliseconds to fractions of a second.

Note that seek time is associated only with movable-head system. For a fixed-head system, it is always 0 because there is a head for each track and no head movement is required for accessing a particular track.

Time required to bring the needed data (i.e. starting position of the addressed sector) under the read/write head is called the **latency time**

Once the heads are positioned on the desired track, the head on the specified surface is activated. Since the disk is continuously rotating, this head should wait for the desired data (specified sector) to come under this head. This rotational waiting time i.e. time required to bring the needed data (i.e. starting position of the addressed sector) under the read/write head is called the **latency time**.

Latency Time (t_L) or **Search time:** Time required to bring the needed data under the R/W head. Latency time is also a variable and depends on the following two parameters:

- Distance of the desired data from the initial position of the head on the specified track.
- Rotational speed of the disk.

The average seek time is thus normally specified for most systems which is generally of the order of 10 to 15 milliseconds.

The total access time for a disk is equal to the seek time plus the latency time.

Access time = Seek time + Latency time

The average access time for most disk systems is usually between 10 to 100 milliseconds.

Pen Drive

Now-a-days a Pen Drive is available as a very convenient and flexible data storage medium which can store up to 256 GB data. It can be used for the same purposes as floppy-disks or CD-ROMs. Pen Drives are a smaller, faster, durable and more reliable storage medium. Compared to floppy disks or CD-ROMs it has thousands of times more

data storage capacity. It is a portable USB flash memory device. It is integrated with a USB (Universal Serial Bus) interface. It can be used to quickly transfer data from one system to another. The pen drive derives its name from the fact that many of these devices resemble a small pen or pencil in shape and size. Flash drives implement the USB mass storage device class so it is possible for modern operating systems to read and write from them without installing the device driver software. Some computers can even boot up from flash drives.

Figure 3.14: Pen Drive

Magnetic Tapes

A Magnetic tape is a sequential access type secondary storage device. It is used for backups in servers, workstations, and large computers. The main advantages of magnetic tapes are that they are cheaper and since these are removable from the drive, they provide unlimited storage capacity (20 GB to 150 GB).

The read/write heads of magnetic tape drives record data in the form of magnetized spots on the iron oxide coating of the plastic tape. Magnetic tape devices include tape reels and cartridges in mainframes and midrange systems, and small cassettes or cartridges for PCs.

The main drawback of magnetic tapes is that they store information sequentially. A file or some particular information stored on a magnetic tape cannot be accessed directly on a random basis as is possible in the case of hard-disks or floppy disks. These devices are slower, but due to their low cost, they are still widely used for massive data warehouse and other business storage requirements.

The storage capacity of a tape is measured by multiplying its length and data recording density

The storage capacity of a tape is measured by multiplying its length and data recording density. Data recording density is the amount of data that can be stored on a given length of tape. That is,

Storage Capacity = data recording density * length

Example 1 : If a tape length is 3400 feet long and has a data recording density of 900 bpi (bytes per inch) its storage capacity will be 3400*12 inches *900 bpi =36720000 bytes.

☞ Check Your Progress 2

1. State **True** or **False :**
   a) ROM is a volatile type of memory. True ☐ False ☐
   b) 1 Terabyte (1 TB) equals 2^{30} bytes. True ☐ False ☐
   c) Magnetic disk has higher storage capacity than Magnetic tape. True ☐ False ☐
   d) The basic difference between PROM and a ROM is manufactured as blank that a PROM is memor, whereas a ROM is programmed during the manufacturing process. True ☐ False ☐
   e) When we load software from a floppy disk, hard disk or CD-ROM, it is stored in the main memory. True ☐ False ☐
   f) Tracks with the same diameter on the various surfaces are known as a cylinder. True ☐ False ☐
   g) Time required to bring the needed data under R/W. head is known as seek time. True ☐ False ☐
   h) Access time is the sum of seek time and latency time. True ☐ False ☐

Multiple Choice Questions

2) The different types of memory units are:
   a) RAM
   b) ROM
   c) PROM
   d) All of the above
3) Which of the following memory loses it contents when the computer is turned off?
   a) RAM
   b) ROM
   c) PROM
   d) All of the above
4) Which of the following memory chips is programmed during the manufacturing process?
   a) RAM
   b) ROM
   c) PROM
   d) EEPROM
5) An EEPROM can be erased by exposing it to:
   a) Sunlight
   b) Ultraviolet Radiation
   c) Magnetic field
   d) Electric Charge

6. Match the following:

i) Semiconductor memory	a) Hard-disk
ii) Magnetic memory	b) CD-ROM
iii) Optical memory	c) Floppy disk
iv) Double side double density	d) RAM

7. Suppose in your library the following types of memory are present:
   RAM, ROM, PROM, EPROM, and EEPROM.
   Differentiate between these memories on the basis of their volatility.
8. A 2.5 inch diameter disk pack has 6 plates (12 recording surfaces), 256 sectors per track, 5268 tracks per surface, and 512 byes per sector. Find the capacity and recording density of the disk pack.
9. Explain the following terms with respect to. magnetic memory:
   a) Seek time and Latency time
   b) Track, sectors and cylinder

……

……

……

3.2.3 Optical Memories

Optical memories or Optical disks are alternate mass storage devices with huge capacity (up to 20 GB). Information is written to or read from an optical disk using a laser beam. Only one surface of an optical disk is used to stored data. An optical disk is relatively inexpensive, and has a long life of at least 15 years. Since the read/write head does not touch the disk surface, there is no problem of disk wear or head crash. The main draw back of the optical disk system is its slow average access time. Here, we will discuss 3 types of optical disks:

1. CD-ROM (Compact-Disk Read Only Memory)
2. WORM (Write Once Read many) or CD-R (CD-Recordable).
3. Erasable Optical Disk
4. DVD-ROM, DVD-R and DVD-RAM

(1) **CD-ROM**

CD-ROM technology uses 12-centimeter (4.7-inch) compact disks (CDs) similar to those used in stereo music systems. Each disk can store more than 600 MB. That is approximately equivalent to 400 1.44 MB floppy disks or 300,000 double-spaced pages of text.

First of all a master disk is prepared. On a master disk, a laser records data by burning permanent microscopic pits in a spiral track to represent 1. From a master disk, CD-ROMs are produced on mass scale. Then CD-ROM disk drives use a laser device to read the binary codes formed by those pits.

For reading the data a laser beam of lower intensity is employed. A laser system needs 25mW for writing whereas only 5mW are needed for reading.

CD-ROMs use long spiral tracks to store data serially, as shown in Figure 3.15. The track is divided into blocks of same size as shown in the figure. A CD-ROM disk rotates at a variable speed so that the pits are read by the laser at a constant linear speed. The speed of the disk is adjusted in such a way that the track passes under the read/write head at a constant linear velocity.

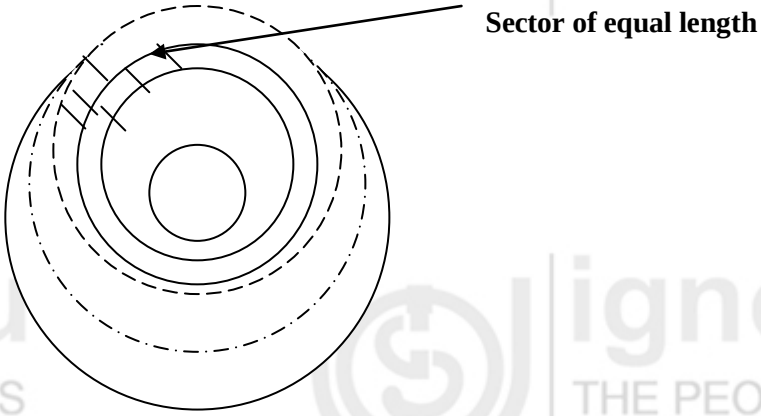


Figure 3.15: A CD-ROM disk layout

Advantages

- High storage capacity.
- Cost per bit of storage is cheaper than the other types of memory devices.
- Removable from the computer, so suitable for archival storage. 5.25 inch disks store 650 MB data.

Disadvantages

- Longer access time as compared to that of a magnetic hard disk (because locating a desired address involves first moving the head to the specific area then adjusting the rotating speed and then reading the address, and then to find and access the specific sector).
- Information can not be updated because it is a read-only (permanent) memory.

(2) **WORM or CD-R (CD-Recordable)**

CD-R (compact-disk recordable) is another optical disk technology. The user can record (write) their own data once on a CD with a CD-R disk drive unit. After this recording user can read the data as many times as desired.

CD-R is suitable for data and files which are not to be changed. The user can store permanent data, information, and files for maintaining records.

Advantages and Limitations

- High storage capacity.
- Better reliability and long life.
- Greater access time as compared to a hard-disk.

(3) **Erasable Optical disk or CD-RW (CD-rewritable)**

The major limitation of CD-ROM and CD-R disks is that recorded data can not be erased. However, CD-RW (CD-rewritable) optical disk systems have now become available which record and erase data by using a laser to heat a microscopic point on the disk's surface.

Advantages and limitations

- Very high storage capacity. A 5.25 inch optical disk can store about 650 MB data
- It is more reliable and has a long life.
- Longer access time as compared to that of a hard-disk.

(4) **DVD-ROM, DVD-R and DVD-RAM**

DVD stands for **Digital Video Disks** or **Digital Versatile Disks**. A DVD stores much more data than a CD-ROM. Its capacities are 4.7GB, 8.5GB, and 20GB etc. The capacity depends on whether it is a single layer, double layer; single sided or double sided disk. DVD uses laser beam of shorter wavelength than CD-ROM uses and therefore more tracks are available. Working principles of DVD disks are same as those of a CD-ROM, CD-R or CD-RW.

The Speed of CD-ROM or DVD-ROM is given in terms of nX, where n is an integer. For example 32X. In case of CD, X=150 KB/s, so 32X=32x150=4.8 MB/s. In case of DVD, X=1.38 MB/s.

DVD-R: It is a recordable DVD, same as a CD-R disk. The user can write data once on a DVD-R, then read the data as many times as required.

DVD-RAM: It is a rewritable DVD, same as a CD-RW disk. DVD-RAM uses a phase change technology to write, read and erase data.

Table 3.7 summarizes the different types of secondary (auxiliary) memory devices

Table: 3.7: Different types of Secondary Memories and its Features

Medium	Capacity	Advantages	Disadvantages	Primary Uses	Storage mechanism
Hard Disk	Variable	Usually integrated into the PC • very robust	• Slower computer performance when disk is full	• To store data and files • To store software	Magnetic
Pen Drive	1 GB-256 GB	Portable Large storage capacity Smaller, faster and reliable	Most USB flash drives do not include a write-protect mechanism. Due to its small size they can easily be misplaced or lost.	• To store data and files. For transferring data and files between computers	
CD-ROM/ CD-R/CD-RW	650-700 MB	Portable & Medium storage capacity • Inexpensive • Some types (CD-RW) can be reused i.e. rewritable disk. • Can be used in certain models of DVD players	Some older computers cannot read CD-RW media • CD-R discs are 'write once', which means once data is copied to it, new or additional data cannot be added	To store files and software • To store archive material from hard disks • To store scanned files such as exam papers • To store applications from the Internet	Optical
DVD-ROM DVD±R DVD±RW	4.7GB to 8.5GB	• Large storage capacity • Some types (DVD±RW) can be reused or rewritable. • Can be used in certain models of DVD players.	• Not all computers can read DVD±R or DVD±RW disks. DVD±R discs are 'write once', which means once data is copied to it, new or additional data cannot be added	Same as.. CD-ROM/ CD-R/CD-RW	Optical
Magnetic tape	20GB to 2TB +	• Very Large storage capacity • Disks are durable, robust and rewriteable • Inexpensive	• Data cannot be accessed immediately • Requires tape drive and third party software • Tape drives for large capacity tapes can be very expensive	• To store files • Ideal for large scale daily and weekly backup operations, particularly for servers.	Magnetic

3.3 MEMORY HIERARCHY AND THEIR NEEDS

Every programmer wishes to have a large and fast memory. However, the two requirements are conflicting. Fast memories are expensive and small; and slow memories are cheaper and large. To give a user the illusion of both fast and large, the memory system of modern computers is organized in a hierarchical way. The very top of the hierarchy is CPU registers, between the CPU and main memory, a fast cache memory is added. The hard disk is used by the technique of virtual memory to expand the capacity of main memory. Most computer systems make use of a hierarchy of memory technologies as a single type of memory is not sufficient. This hierarchy is known as the memory hierarchy.

Most computer systems make use of a hierarchy of memory technologies, this hierarchy is known as the memory hierarchy

In the previous section, we have discussed the various types of memory systems such as semiconductor (main) memory, Magnetic memory and Optical memory. In this section, we will discuss the hierarchy of these memory systems.

As you have seen in the previous section faster memory technology (such as semiconductor memory) is more expensive. In addition fast memory requires power supply till the information needs to be stored. Furthermore, the memory with less cost (such as Optical memory) have very high access time, that is the time taken by CPU to access the memory location is high, which result in a slower operation of CPU. Thus the cost versus access time leads to a memory hierarchy. The overall goal of Memory Hierarchy is to obtain the highest possible access speed while minimizing the total cost of the memory system. Figure 3.16 (a) illustrates the components of a typical memory system.

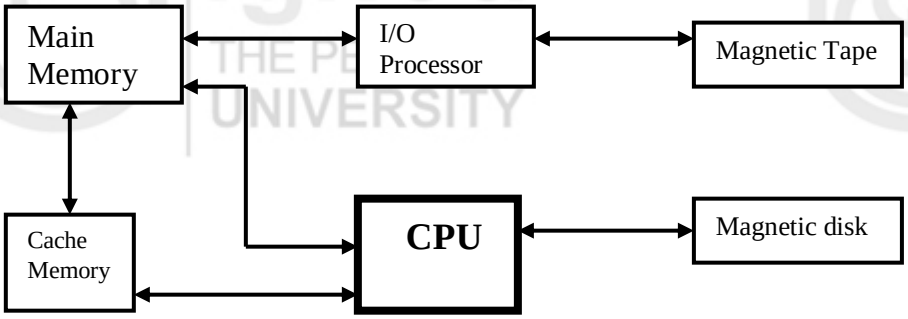


Figure 3.16 (a): Components of Memory System

A computer system uses a variety of devices for storing the instructions and data. A storage devices (or units) may vary according to the *access time*, *storage capacity*, and *cost-per-bit of storage*, as discussed in the previous section. Based on these criteria, a memory system can be considered to consist of three groups of memories.

1. **Processor's internal (CPU) memories:** consisting of the small set of high speed registers which are internal to a processor and are used as temporary locations where actual processing is done.
2. **Primary (main) memory:** It is a fast and large memory but slower than processor memory. Primary memory has faster access time, smaller storage capacity and higher cost per bit storage. This memory is accessed directly by the processor. It stores programs and data which are currently needed by the CPU. The size of the main memory is kept small because of its high cost.

3. **Secondary (or auxiliary) memory:** The secondary memory is mainly used for bulk storage (mass storage) of programs, data and other information. It has much larger capacity than main memory but slower than main memory. It basically stores system software, compiler, assembler and useful packages, large data files etc.

A typical storage hierarchy is shown in Figure 3.16(b).

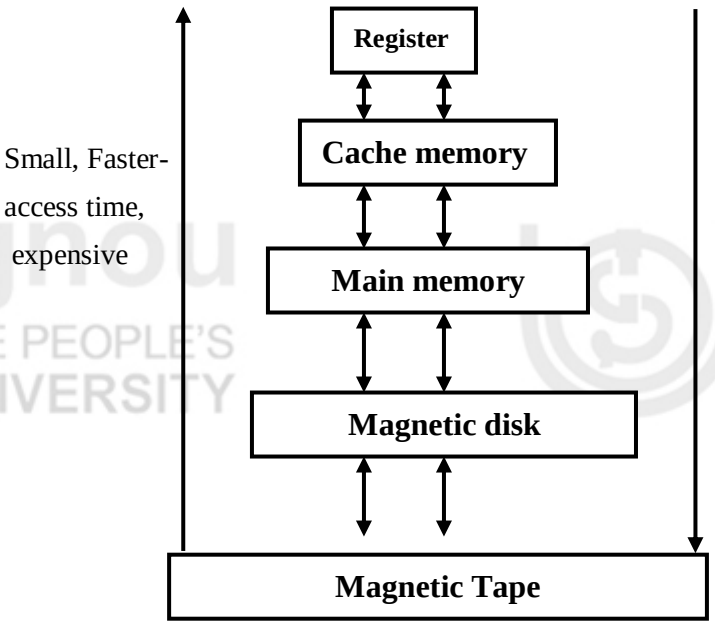


Figure 3.16 (b): The Memory Hierarchy

A block diagram of storage hierarchy, as shown in Figure-3.16(b) includes:

- CPU (register)
- Cache memory
- Main memory
- Secondary storage, and
- Mass storage

As we move up the storage hierarchy, we encountered memory elements having faster access time, less capacity and higher cost per bit stored. When we move down, we have a larger storage capacity, slower access time and lower cost per bit stored. Thus, CPU storage components generally have the fastest access time, the smallest storage capacity and the highest cost per bit stored. The cache memory which is placed in between the CPU and the main memory is a very high speed semiconductor memory used to enhance the speed of main memory. The main (primary) memory falls next in the memory hierarchy list. Secondary storage media such as hard-disk/magnetic disk memories make up the level of hierarchy just below the main memory. Secondary storage devices are at the bottom of the memory hierarchy. Secondary storage devices such as magnetic tapes are used for archival storage. They are very cost effective and so are used for mass storage of data, when fast access time is not required.

☞ **Check Your Progress 3**

1. State **True** or **False :**
   a) Cache memory is faster than the Register (CPU) memory. True ☐ False ☐
   b) Cache memory has a smaller capacity than the main memory. True ☐ False ☐
   c) Secondary memory has a faster access-time than primary memory True ☐ False ☐
   d) The main draw back of the optical disk system is its slow average access time. True ☐ False ☐
   e) CD-ROM has longer access time as compared to that of a magnetic hard disk. True ☐ False ☐
   f) In CD-R data can be read once and write indefinitely True ☐ False ☐
   g) The overall goal of Memory Hierarchy is to obtain the highest possible access speed while minimizing the total cost of the memory system. True ☐ False ☐
   h) Magnetic tape has a higher capacity than magnetic disk but slow access time than magnetic disk. True ☐ False ☐

2. Match the following:

1)	CD-ROM	a)	Write once read many times
2)	CD-R	b)	Read and write indefinitely
3)	CD-RW	c)	Read only
4)	DVD-ROM	d)	Write once, read indefinitely and having capacity up to 20GB

3. Differentiate between the following:
   a) CD-ROM, CD-R and CD-RW
   ……
   ……
   b) DVD-ROM versus DVD-RW
   ……
   ……

4. What is the overall purpose of the memory hierarchy? Name the general classes of storage media that might make up a memory hierarchy.
   ……
   ……

3.4 SUMMARY

This unit basically outlines the storage organization, storage devices of different types of memory systems and the importance of the memory hierarchy.

The memory system is categorized according to access time, storage capacity and cost-per-bit of storage.

Based on these criteria memory is broadly categorised into two types:

- Primary memory
- Secondary memory.

All modern computers use semiconductor memory as its main memory (or primary memory). Semiconductor memory is known as Random access memory (RAM). Although it is a very fast memory but it is very expensive. Thus semiconductor (primary) memory of today's computers is not sufficient, since it has very limited capacity. Thus there is a need of an additional memory, which should be inexpensive, non-volatile in nature and having large capacity. Magnetic (secondary) memory is a permanent, non-volatile type memory. In this unit we have discussed the two types of magnetic memory namely magnetic disks (i.e. ,Hard-disk and floppy disk) and magnetic tapes. Magnetic disks are the most common form of secondary storage because they provide fast access and high storage capacities at a reasonable cost.

Another type of secondary storage is Optical memories or Optical disks. These devices provide a huge storage capacity (up to 20 GB), at a lower cost. Information is written to or read from an optical disk using a laser beam. An optical disk is relatively inexpensive, and has a long life of at least 15 years. Since the read/write head does not touch the disk surface, there is no problem of head crashes. The main draw back of the optical disk system is its slow average access time. Many software companies offer both operating system and application software on CD-ROM today. This technology has been the main catalyst for the development of multimedia in computing because it is used in multimedia external devices such as video recorders and digital recorders (Digital Audio Tape) which can be used for multimedia systems.

In this unit, we have discussed the various types of storage devices used by the computer system. A cost effective technique for the design of large computer systems is the use of a hierarchy of memory technologies. The overall goal of Memory Hierarchy is to obtain the highest possible access speed while minimizing the total cost of the memory system.

3.5 ANSWERS TO CHECK YOUR PROGRESS

Check Your Progress 1

1. (a) False (b) False (c) True (d) True (e) True (f) False
2. (a)

Primary (semiconductor) memory	Secondary memory
• It is fast and large memory but slower than processor memory. Primary memory has faster access time, smaller storage capacity and higher cost per bit storage. • This memory is accessed directly by the processor. It stores programs and data which are currently needed by the CPU. The CPU communicates directly with the CPU. The size of the main memory is kept small because of its high cost. • It is made of **semiconductors** and uses VLSI technique. Mainly these are in the form of **Chips.**	• The secondary memory is mainly used for bulk storage (mass storage) of programs, data and other information. It has much larger capacity than main memory but slower than main memory. • It basically stores system software, compiler, assembler and useful packages, large data files etc. • These are magnetic and **optical devices.** Mainly these are in the form of **Floppy, Hard Disk and CD.**

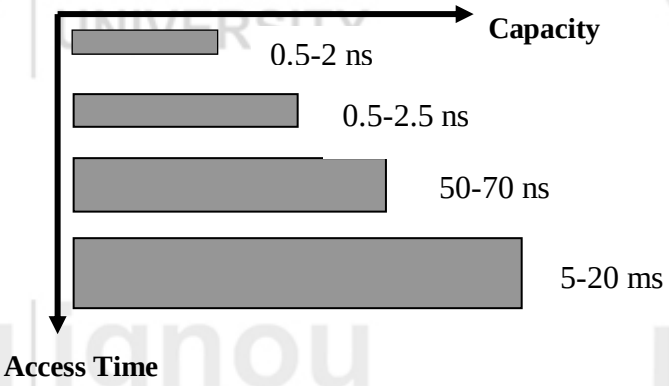
b) Different types of memory (in terms of access speed, storage capacity and cost per bit storage).

Primary memory and Secondary memory

	Access Time	Storage capacity	Cost/bit of storage
Primary memory	Faster	Smaller	High
Secondary memory	slower	higher	Low

As the **table indicates**, that the Primary memory (i.e. RAM, ROM etc.) have faster access time, smaller storage capacity, and higher cost per bit of storage, as compared to the secondary memory.

c) The following figure shows the relationship between the access-time and capacity of various types of memory.



Capacity vs. access-time

d) A ***Sequential-access*** memory device reads data in sequence. In other words, information on a serial device can only be retrieved in the same sequence in which it was stored. Data is recorded one after another in a predetermined sequence (such as in numeric order) on a storage medium. Sequential processing is quite suitable for such applications like preparation of monthly pay slips, or monthly electronic bills etc., where each address needs to be accessed in turn. If you are working with a sequential access device and information is stored at the last address, then data stored at the last address cannot be accessed until all preceding locations in the sequence have been traversed. That is locating an individual item of data requires searching much of the recoded data on the tape until the desired item is located. Example *magnetic tape*..

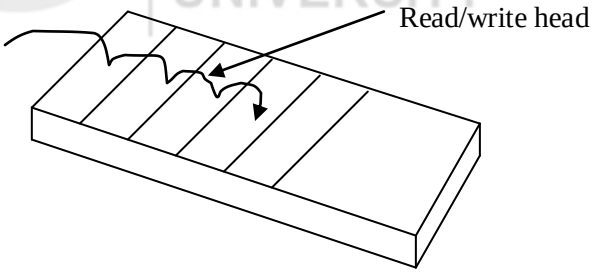


Figure 1: Sequential Access memory

- In case of ***random access*** device the information is available at random, i.e. any location in the device may be selected at random. So any location in the device can be accessed in approximately equal time. In other words we can say that each storage position (1) has a unique address and (2) can be individually accessed in approximately in equal time without searching through other storage positions. Magnetic disk and CDROM are the typical random access storage devices. Any data record stored on a magnetic or optical disk can be accessed directly in approximately the same time period. The following figure-2 shows sequential versus direct access storage.

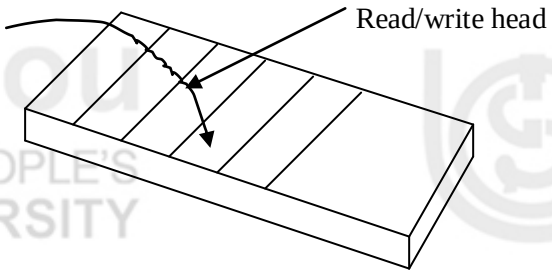


Figure 2: Random Access memory

Check Your Progress 2

1. (a) False (b) False (c) False (d) True (e) True (f) True (g) False (h) True
2. (d)
3. (a)
4. (b)
5. (d)
6. 1-(d), 2-(a), 3-(b), 4-(c)

7. Volatile memory means the stored data are lost, if the power goes off.. For example RAM is a **volatile** memory. A **non-volatile** memory means the information stored in it is not lost even if the power supply goes off. A ***Read-Only memory*** (ROM) is a non-volatile memory.

Memory	Category	Volatility	Writing Mechanism	Erasure
RAM	Read-write memory	Volatile	Electrically	Electrically
ROM	Read-only memory	Non-volatile	Mask	Not-possible
PROM	Read-only memory	Non-volatile	Electrically	Not-possible
EPROM	Read-only memory	Non-volatile	Electrically	Using UV light
EEPROM	Read-only memory	Non-volatile	Electrically	Electrically

8. **Disk capacity**= 12x5268x256x512=7.716 GB and
   Recoding density= (512x256)/(3.14x2.5)=16688 bytes/inch.

9. a) **Seek time and Latency time :** The time required to position the read/write head over proper track is called the **seek time.** The time required to bring the needed data (i.e., starting position of the addressed sector) under the read/write head is called the **latency time**.

Latency Time (t_L) or **Search time**: Time required to bring the needed data under R/W head. Latency time is also a variable and depends on the following two things:

- Distance of the desired data from the initial position of the head on the specified track
- Rotational speed of the disk.

Access time= Seek time + Latency time

b) Track, sectors and cylinder : A magnetic disk is a surface device, which stores data on its surface. Its surface is divided into circular concentric tracks. The number of tracks on a disk range up to 800. **Each track is divided into sectors (normally 10-100).** These sectors should be either fixed or variable length sectors. The division of track into equal sized blocks or pages is set by the Operating system during disk formatting.

A set of corresponding tracks in all surfaces of a disk pack (i.e. the tracks with the same diameter on the various surfaces) is called a **cylinder.**

Check Your Progress 3

1. (a) False (b) True (c) False (d) true (e) True (f) False (g) True (h) False
2. 1-c, 2-a, 3-b, 4-d.

3. **CD-ROM** technology uses 12-centimeter (4.7-inch) **compact disk (CDs)**. CDROM are the typical random access storage devices. Any data record stored on a magnetic or optical disk can be accessed directly in approximately the same time period.

Advantages

- High storing capacity.
- Mass copy of information stored, which is very cheaper.
- Removable disk from the computer, so suitable for archival storage. 5.25 inch disks store **650 MB data.**

CD-R (compact-disk recordable) is optical disk technology. The user can record (write) on it. It follows **write once and read many times** CD-R is suitable for data and files which are not to be changed. The user can store **permanent data**, information, and files for maintaining records.

Advantages

- High storing capacity.
- Better reliability and long life.

Erasable Optical disk or CD-RW (CD-rewritable)- As the name indicates the data written on it can be erased by using a laser to heat a microscopic point on the disk's surface.

Advantages

- Very high storing capacity. A 5.25 inch optical disk can store about 650.
- It is more reliable and having long life.

4. A *memory system* is a hierarchy of storage devices with different capacities, costs, and access times. CPU registers hold the most frequently used data. Small, fast *cache memories* nearby the CPU act as staging areas for a subset of the data and instructions stored in the relatively slow main memory. The main memory stages data stored on large, slow disks, which in turn often serve as staging areas for data stored on the disks or tapes of other machines connected by networks.

The overall effect is a large pool of memory that costs as much as the cheap storage near the bottom of the hierarchy, but that serves data to programs at the rate of the fast storage near the top of the hierarchy.

The overall purpose of Memory Hierarchy is to obtain the highest possible access speed while minimizing the total cost of the memory system.

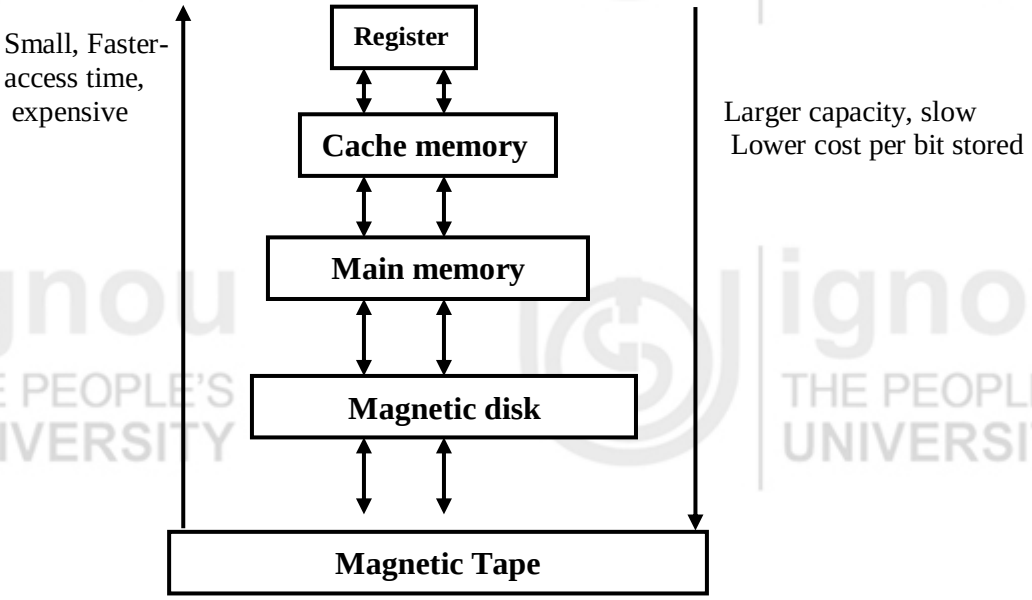


Figure 3: The Memory hierarchy

3.6 FURTHER READINGS

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P. Sudharsan & J. Jeyabalan, *Computers-systems and applications*, JAICO Books.
V.Rajaraman, *Fundamentals of computers*, PHI.
T.N. Srivastava, *An introduction to computers& their application to banking*, Macmillan, Macmillan India limited.

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