Unit 3 Memory System and I/O Devices

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3.0 Introduction

In this unit, you will learn about the basic concept of computer memory and its significance. It is not enough to just know how data is processed in a computer system. Even before data can be processed, the system needs the data to be available to it at all times. In this unit, we will discuss how data is stored in a computer. You will learn about the different types of storage devices available, such as SRAM, DRAM, ROM and cache memory. Further, the unit will explain certain types of magnetic storage devices, such as magnetic tapes and magnetic disks; as well as disk devices like floppy disks and hard disks. You will also learn how data is organized on a magnetic disk.

Finally, in this unit, you will learn about optical and solid storage devices. The Compact Disk (CD) was invented by James Russell. A CD is a small, portable and easy to use device made of moulded polymer. It is used record, store, play back audio, video, text, graphics, etc. in a digital form. You will also learn about devices like zip drives, USBs, iPAD, set-top-box, etc.

3.1 Unit Objectives

After going through this unit you will be able to:

- Explain the significance of memory hierarchy
- Identify the several types of storage devices
- Explain the significance of magnetic storage devices
- Describe the organization of data on a magnetic disk
- Discuss the various types of disk devices
- Understand the use of tape drives
- Measure the performance of drives
- Explain various optical and solid storage devices

3.2 Computer Memory

An electronic circuitry that allows data to be stored and retrieved when required is known as memory. The memory unit is known as the main memory. It directly interacts with the CPU. Storage devices are called auxiliary memory and these devices provide backup storage.

The memory is an integral part of any computer system. It is a storage device. It stores sets of instructions, i.e., programs, data and the intermediate results of computations. It is classified into two categories called main (or primary) memory and auxiliary (or secondary) memory. As already explained, the memory unit is known as the main or primary memory.

The computer memory is classified according to the following key characteristics:

(i) Location

- CPU
- Internal memory (main memory)
- External memory (secondary memory)

(ii) Access Method

- Sequential access
- Direct access
- Random access

(iii) Performance

- Access time
- Cycle time
- Transfer rate

(iv) Physical Type

- Semiconductor
- Magnetic surface

(v) Physical Characteristics

- Volatile/non-volatile
- Erasable/non-erasable

(vi) Capacity

- Internal
- External
- Addressable unit

(vii) Unit of transfer

- Word
- Block

3.2.1 Memory Hierarchy

Memory hierarchy consists of the total memory system of any computer. Memory components range from the higher capacity, slow auxiliary memory to a relatively fast main memory and to cache memory that can be accessed by the high speed processing logic.

Figure 3.1 illustrates the memory hierarchy. Memory hierarchy starts with a small, expensive and relatively fast unit called the cache, followed by a larger, less expensive and relatively slow main memory unit. Cache and main memory are built using solid state semiconductor material, Complementary Metal Oxide Semiconductor (CMOS) transistors. The solid state memory is followed by larger, less expensive and far slower magnetic memories that consist of the (hard) disk and the tape. The objective behind designing a memory hierarchy is to have a memory system that performs as if it consists entirely of the fastest unit and whose cost is determined by the cost of the slowest unit.

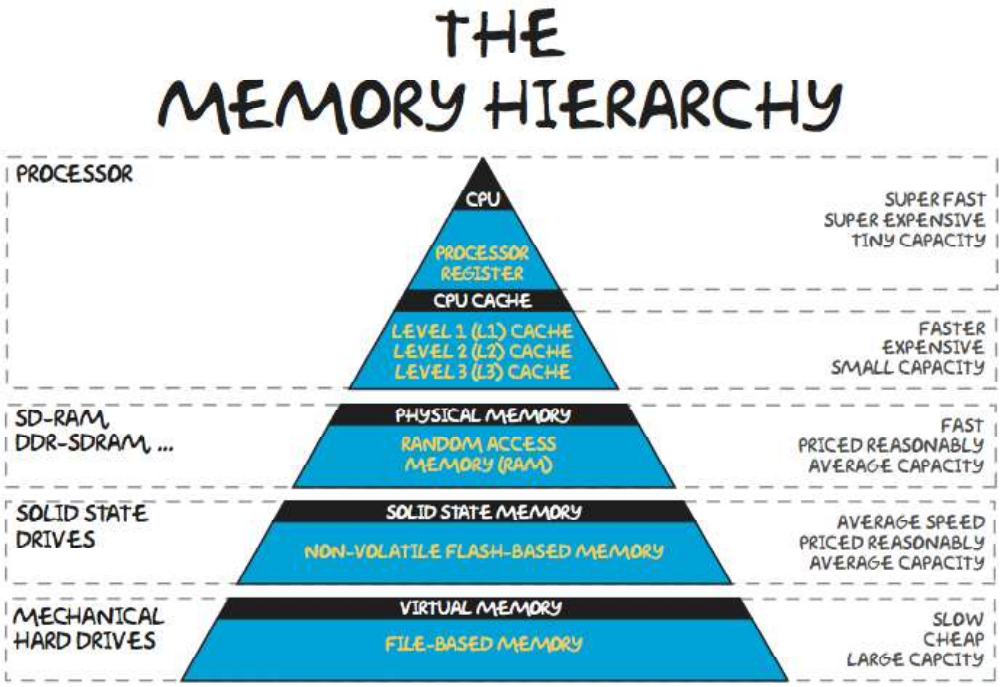

Fig. 3.1 *Structure of Memory Hierarchy*

Table 3.1 summarizes the access type, capacity, latency and bandwidth of registers and different types of memory. The term random access refers to the fact that any access to any memory location takes the same fixed amount of time regardless of the actual memory location and the sequence of accesses that take place. For example, if a write operation to memory location 100 takes 15 ns and if this read is followed by a write operation to memory location 3000, then the write operation will take 15 ns. This is to be compared to sequential access in which if access to location 100 takes 15 ns and if a consecutive access to location 101 takes 20 ns, then it is expected that an access to location 300 may take 1000 ns. This is because the memory has to cycle through locations 100 to 300 with each location requiring 5ns.

Registers and Memory	Access Type	Capacity	Latency	Bandwidth
CPU Register	Random	64-1024 Bytes	1-10ns	System Clock Rate
Cache Memory	Random	8-512 KB	15-20ns	10-20 MB/s
Main Memory	Random	16-512 MB	30-50ns	1-2 MB/s
Disk Memory	Direct	1-20 GB	10-30ns	1-2 MB/s
Tape Memory	Sequential	1-20 GB	30-10000ns	1-2 MB/s

Table 3.1 *Access Type, Capacity, Latency and Bandwidth for Registers and Memory*

The efficiency of a memory hierarchy depends on the principle of moving information into the fast memory and accessing it many times before replacing it with new information. This principle is useful due to a well known phenomenon known as the 'locality of reference', i.e., within a given period of time programs tend to reference relatively confined area of memory repeatedly. The two forms of locality are known as spatial locality and temporal locality. Spatial locality refers to the phenomenon that when a given address has been referenced, it is most likely that addresses near it will be referenced within a short period of time, for example consecutive instruction in a straight line program. Temporal locality, on the other hand, refers to the phenomenon that once a particular memory item has been referenced, it is most likely that it will be referenced again within a short period of time, for example an instruction in a program loop. The sequence of events that takes place when the processor makes a request for an item is as follows:

- First, the item is processed in the first memory level of the memory hierarchy. The probability of finding the requested item in the first level is called the hit ratio and generally represented as h_1.
- Second, the probability of not finding (missing) the requested item in the first level of the memory hierarchy is called the miss ratio and represented as $1–h_1$.

At the top of this hierarchy is a CPU register which is accessed at full CPU speed. This provides local memory to the CPU. Next comes cache memory which is currently in the range of 32 KB to few MB. Next is the main memory with sizes currently ranging from 16 MB for entry level systems to few gigabytes at the higher end. Next come the magnetic disks, and finally we have magnetic and optical tapes. The memory, as we move down the hierarchy, mainly depends on the following three key parameters:

- Access time
- Storage capacity
- Cost

Access Time

CPU registers are the CPU's local memory and are accessed in nanoseconds. The access time of the cache memory is a multiple of that of CPU registers. The main memory's access time is typically a few tens of nanoseconds.

Then there is a big gap as the disk access time is at least 10 msec, and tapes and optical disks' access time may be measured in seconds if the media is to be fetched and inserted into a drive.

Storage Capacity

The storage capacity increases as we go down the hierarchy. CPU registers are good for 128 bytes. Cache memories are a few MB. The main memory is about 10 to 1000 MB. Magnetic disk capacities range from a few GB to tens of GB. The capacity of tapes and optical disks is limited as they are usually kept offline.

Another way of viewing the memory hierarchy in computer system is illustrated in Figure 3.2. The main memory is at the centre as it can communicate directly with the CPU and through the I/O processor with the auxiliary devices. The cache memory is located between the main memory and the CPU. Figure 3.2 also illustrates an interconnection between CPU and I/O processor.

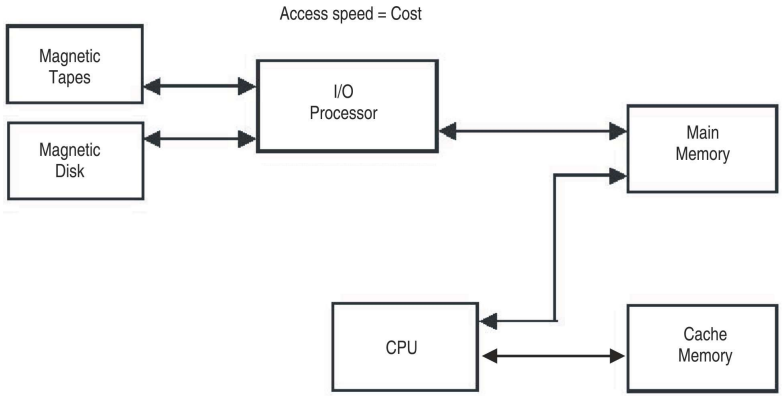

Fig. 1.23 *Memory Hierarchy System*

Cost

The cache usually stores the program segments currently being executed in the CPU and temporary data frequently asked by the CPU in the current calculations. The I/processor manages data transfer between the auxiliary memory and the main memory. The auxiliary memory usually has a large storing capacity but low access rate as compared to the main memory and, hence, is relatively inexpensive. The cache is very small but has a very high access speed and is relatively expensive.

The main objective of using a memory hierarchy is two fold; first, to achieve the highest possible average speed and, second, to bring down the total cost of the memory system.

3.3 Types of Storage Devices

The most common properties used for characterizing and evaluating the storage unit of the computer system are expressed below:

1. **Storage Capacity:** Represents the size of the memory. It is the amount of data that can be stored in the storage unit. Primary storage units have less storage capacity as compared to secondary storage units. The capacity of internal memory and main memory can be expressed in terms of the number of words or bytes. The capacity of external or secondary storage, on the other hand, is measured in terms of bytes.
2. **Storage Cost:** Cost is another key factor that is of prime concern in a memory system. It is usually expressed per bit. It is obvious that lower costs are desirable. It is worth noting that with the increase in the access time for memories, the cost decreases.
3. **Access Time:** The time required to locate and retrieve the data from the storage unit. It is dependant on the physical characteristics and access mode used for that device.

   Primary storage units have faster access time as compared to secondary storage units.
4. **Access Mode:** Memory comprises various locations. Access mode is the mode in which information is accessed from the memory. The user can access memory devices in any of the following ways:

   (a) Random Access Memory (RAM): This refers to the mode in which any memory location can be accessed in any order in the same amount of time. Ferrite and semiconductor memories, which usually constitute the primary storage or main memory are of this nature.

   (b) Sequential Access: Memories that can be accessed only in a pre-defined sequence are sequential access memories. Here, since sequencing through other locations precedes the arrival at a desired location, the access time varies according to the location. Information on a sequential device can be retrieved in the same sequence in which it was stored. Songs stored on a cassette, that can be accessed only one by one, are an example of sequential access. Typically, magnetic tapes are sequential access memory.

   (c) Direct Access: Sometimes, the information is neither accessed randomly nor in sequence but something in between. In this type of access, a separate read/write head exists for each track, and on a track, you can access the information serially. This semi-random mode of access exists in magnetic disks.

5. **Permanence of Storage:** If the storage unit can retain the data even after the power is turned off or interrupted, it is termed as non-volatile storage. And, if the data is lost once the power is turned off or interrupted, it is called volatile storage. It is obvious from these properties that the primary storage units of the computer systems are volatile, while the secondary storage units are non-volatile. A non-volatile storage is definitely more desirable and feasible for storage of large volumes of data.

Static and Dynamic RAM

The main memory is the central storage unit in a computer system. It is a relatively large and fast memory. It is used to store programs and data during computer operations. The principal technology used for the main memory is based on semiconductor-integrated circuits. There are two possible modes in which the integrated circuit RAM chips are available. These modes are: static and dynamic.

The Static RAM (SRAM) stores binary information using clocked sequential circuits. The stored information remains valid only as long as power is applied to the unit. On the other hand, Dynamic RAM (DRAM) stores binary information in the form of electric charges that are applied to capacitors inside the chip. The stored charge on the capacitors tends to discharge with time and so must be periodically recharged by refreshing the dynamic memory. The dynamic RAM offers larger storage capacity and reduced power consumption. Therefore, large memories use dynamic RAM, while static RAM is mainly used for specialized applications.

The different types of memory discussed above are both of the read/ write type. What about a memory where only one of the operations is possible, e.g., if we allow only reading from the memory (cannot change the information in the memory)? The memory might have some major importance; like an important bit of the computer's operating system which normally does not change can be stored in this kind of memory. Such a memory is called ROM (Read Only Memory).

Read Only Memory (ROM)

Most of the memory in a general-purpose computer is made of RAM integrated circuit chips, but a portion of the memory may be constructed using ROM chips. Originally, RAM was used to refer to random-access memory, but now we use the term read/ write memory to distinguish it from read-only memory (since, ROM is also random access). RAM is used for storing the bulk of the programs and data that are subject to change, while ROM is used to store programs that are permanently resident in the computer and do not change once the production of the computer is completed.

Among other things, the ROM portion of the main memory is used for storing an initial program called the bootstrap loader, whose function is to get the computer software operating when power is turned on. Since, RAM is volatile, its contents are destroyed when power is turned off. The contents of ROM remain unchanged even after the power is turned off and on again.

Read only memories can be manufacturer-programmed or user-programmed. When the data is burnt into the circuitry of the computer by the manufacturer, it is called manufacturer-programmed ROM. For example, a personal computer manufacturer may store the boot program permanently in the ROM chip of the computers manufactured by it. Such chips are supplied by the manufacturer and are not modifiable by users. This is an inflexible process and requires mass production. Thus, a new kind of ROM , known as Programmable Read-only Memory (PROM), was designed. This is also non-volatile in nature. It can be written only once using some special equipment. The supplier or the customer can electrically perform the writing process in PROM.

In both ROM and PROM, you can perform write operations only once and you cannot change whatever you have written. But what about the cases where you mostly read but also write a few times? Another type of memory chip called EPROM (Erasable Programmable Read Only Memory) was developed to take care of such situations. EPROMs are typically used by R&D personnel who experiment by changing micro-programs on the computer system to test their efficiency.

Further, EPROM chips are of two types: EEPROMs (Electrically EPROM) in which high voltage electric pulses are used to erase stored information and UVEPROM (Ultra Violet EPROM) in which stored information is erased by exposing the chip for a while to ultraviolet light.

Figure 3.3 summarizes the various types of Random Access Memories.

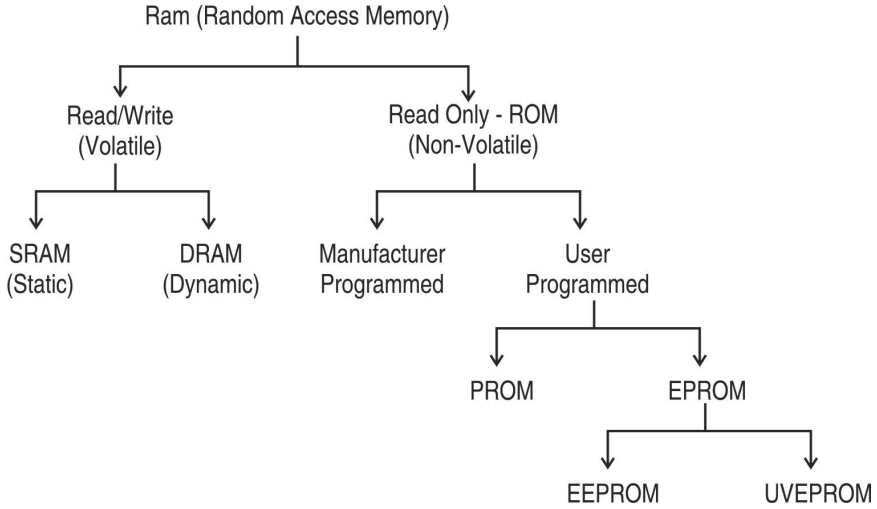

Fig. 3.3 *Types of Random Access Memories*

Cache Memory

Cache memories are small, fast memories placed between the CPU and the main memory. They are faster than the main memory with access times closer to the speed of the CPU. Caches are fast, but very expensive. So, they are used only in small quantities. As an example, caches of size 64K, 128K are normally used in PC-386 and PC-486, which can have 1 to 8 MB of RAM or even more. Cache memories provide fast speed memory retrieval without compromising the size of the memory.

If the memory is so small, would it be advantageous to increase the overall speed of memory? This can be answered with the help of a phenomenon known as locality of reference. Let us examine what this means.

Locality of Reference: If we analyse a large number of typical programs, we would find that memory references at any given interval of time tend to be confined to a few localized areas in the memory. This phenomenon is called the property of locality of reference. This is true because most of the programs typically contain iterative loops (like 'for' or 'while' loops). During the execution of such programs, the same set of instructions (within the loop) are executed many times. The CPU repeatedly refers to the set of instructions in the memory that constitute the loop. Every time a specific subroutine is called, its set of instructions is fetched from the memory. Thus loops and subroutines tend to localize the references to memory for fetching instructions.

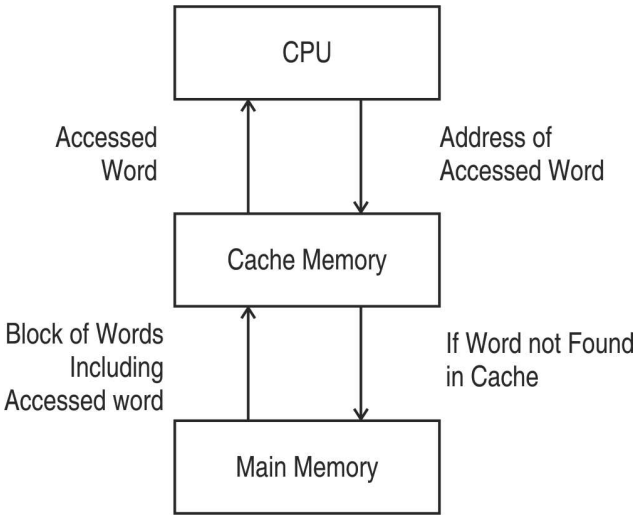

Fig. 3.4 *Functioning of the Cache Memory*

Figure 3.4 explains the functioning of the cache memory.

Based on the locality of reference, we understand that the cache has a copy of certain portions of main memory. First, the memory read or write operation is checked with the cache, and in case of availability of desired data in the cache, it is used directly by the CPU. Otherwise, a block of words is read from main memory to cache and the word is then used by the CPU from cache.

Secondary Storage Devices

As discussed earlier, RAM is a volatile memory with limited storage capacity. The cost of RAM is also relatively higher as compared to secondary memory. Logic dictated that a relatively cheaper media, showing some sort of permanence of storage, be used. As a result, additional memory called *external* or *auxiliary memory* or *secondary storage* is used in most computers.

The magnetic medium was found to be long lasting and fairly inexpensive, and, therefore, became an ideal choice for large storage requirements. The use of magnetic tapes and disks as storage media is very common. As optical technology is advancing, optical disks are turning out to be one of the major secondary storage devices.

3.4 Magnetic Storage Devices

Magnetic tapes are used for storing files of data that are sequentially accessed or not used very often and are stored off line. They are typically used as backup storage for archiving of data.

In case of magnetic tapes, a tape (plastic ribbon usually 1/2 inch or 1/4 inch wide and 50 to 2400 feet long) is wound on a spool and its other end is threaded manually on a take-up spool. The Beginning Of Tape (BOT) is indicated by a metal foil called a *marker*. When a write command is given, a block of data (records are usually grouped in blocks of two or more) is written on the tape. The next block is then written after a gap (called Inter Block Gap or IBG). A series of blocks are written in this manner. The End of Tape (EOT) is indicated by an end-of-tape marker which is a metal foil stuck in the tape. After the data is written, the tape is rewound and kept ready for reading.

The tape is read sequentially, i.e., data can be read in the order in which the data has been written. This implies that if the desired record is at the end of the tape, all the earlier records have to be read before it is reached. A typical example of a tape can be seen in a music cassette, where, to listen to the fifth song one must listen to, or traverse, the earlier four songs. The access time of information stored on tape is therefore very high as compared to that stored on a disk.

The storage capacity of the tape depends on its data recording density and the length of the tape. The data recording density is the amount of data that can be stored or the number of bytes that can be stored per linear inch of tape. The data recording density is measured in BPI (Bytes Per Inch).

Thus,

Storage capacity of a tape = Data recording density × Length of tape

It is worth noting that the actual storage capacity for storing user data,

is much less owing to the file header labels, file trailer labels, BOT and EOT markers, and the use of IBGs.

Some commonly used magnetic tapes are:

- 1/2 inch tape reel.
- 1/2 inch tape cartridge.
- 1/4 inch streamer tape.
- 4 mm DAT (Digital Audio Tape) – typical capacity of 4GB to 14 GB.

Magnetic Disks

Magnetic disks are direct-access medium, and so are the most popular online secondary storage devices. Direct-access devices are also called random-access devices because information is literally available at random or in any order. There is direct access to any location on the device. Thus, approximately equal access time is required for each location. An example of this is a music CD where if you wish to listen to the fifth song, you can directly select the fifth track without having to fast forward the previous four.

A magnetic disk refers to a circular plate made of metal or plastic and coated with magnetized material. Often both sides of the disk are used. Data is recorded on the disk in the form of magnetized and non-magnetized spots (not visible to the naked eye) representing 1s and 0s.

3.5 Organization of Data on a Magnetic Disk

Data is stored in concentric rings or *tracks*. *Inter-track gaps* are used to separate the adjacent tracks so that the interference of magnetic fields is minimized. Tracks are commonly divided into sections called sectors. In most systems, the minimum quantity of information that can be transferred is a sector. Usually 8 or more sectors per track are found.

A track in a given sector near the circumference is longer than the track near the centre of the disk. If bits are recorded with equal density, some tracks would contain more bits than other tracks. To ensure that each sector can store equal amounts of data, some disks use variable recording density with higher density on tracks near the centre than on tracks near the circumference.

Multiple disks are usually stacked and used together to create disk storage systems having large capacities. In this case, multiple disks are fixed on a central shaft, one below the other, to form a *disk pack*. This is then mounted on a disk drive that has a motor to rotate this disk pack about its axis. The disk drive also has an access arm assembly with a separate read/ write head for each surface of the disk pack. The access arms for all the disks surfaces move together. A disk system, is thus addressed by the disk number, the disk surface, the sector number and the track within the sector.

Usually, the upper surface of the topmost disk and the lower surface of the bottom-most disk are not used since these are prone to getting scratched easily. For faster access of data from disk packs, a concept called cylinders is used. A set of corresponding tracks on all recording surfaces of the disk pack together form a cylinder. Thus, if there are 100 tracks on each disk surface, there are 100 cylinders in the disk pack.

Cylinder-based organization provides for faster data access. The related records of the file can be stored on the same cylinder (on multiple disks of a disk pack) and subsequently with one movement of the access arm, all records on, say, cylinder 5 (fifth track of every recording surface) can be simultaneously read. The storage capacity of a disk system can be determined as follows:

Storage capacity = Number of recording surfaces × Number of tracks per surface × Number of sectors per track × Number of bytes per sector

Example: If a disk pack consists of 4 plates each having 2655 tracks having 125 sectors per track. Also, each sector can store 512 bytes, then,

Storage capacity = 6 × 2655 × 125 × 512 = 1,01,95,20,000 bytes = 1×10^9 bytes approximately, or 1 GB or 1 Gigabyte

Note: We have 6 recording surfaces since there are 4 disk plates.

Access Time on Disks: As detailed earlier, the disk address is specified in terms of the surface number, track or cylinder number and the sector number. The read/write heads need to be first positioned on the track on which the data are to be recorded or from which data needs to be read. Information is always written from the beginning of a sector and can be read only from the beginning of the desired track. Thus, the disk access time depends on the following factors:

- ***Seek Time:*** The time taken for positioning the head on a specific track. The seek time would vary depending on the position of the access arms at the time the read/write command was received, i.e., if the access arm was positioned on the outermost track and the current read operation required it to be positioned on the fifth track, then the time taken to position the access arm on track 5 is the seek time. It is obvious from this example that moving from the outermost to the innermost track or vice versa would result in the maximum seek time. The average seek time in most systems is 10–100 milliseconds.
- ***Latency Time:*** The time required by the desired sector to be positioned under the read/write head, i.e. the time required to spin the desired sector under the head is called latency. Latency is also known as rotational delay and varies depending on the distance of the desired sector from the initial position of the head on the specified

track. The rotational speed of a disk is measured in rotations per minute (rpm) and can be anywhere between 300 to 7,200 rpm. On an average, latency equals half the time required for a rotation by the disk.

Besides these two times, the time taken to read a block of words (transfer rate) can also be taken into consideration. But this is usually very small as compared to seek and latency times, and disk access time is generally considered to be a sum of seek time and latency times. Further, since access times to disk are large, a sizeable portion of the data is read in a single go. This is the reason why disks are referenced in blocks.

3.6 Disk Devices

A **disk drive** is a peripheral device used to store and collect information. It can be removable or fixed, high capacity or low capacity, fast or slow speed, and magnetic or optical.

Structurally, a drive is the object inside which a disk(s) is either permanently or temporarily stored. While a disk contains the media on which the data is stored, a drive contains the machinery and circuitry required for implementing the read / write operations on the disk.

The disk looks literally like a flat circular disk. The computer writes information onto the disk, where it is stored in the same form as it is stored on a cassette tape. Disks, as such, are just magnetically coated rolls or circular disks which are divided into sectors and tracks. The data is accordingly stored and numbered with respect to the track and sector number on the disk. Only the structure of the media is different from one to another. Examples of removable disk drives are DVD, CD-ROM, floppy disk drive, etc. The examples of non-removable disk drives include hard disk.

The method of accessing data could be sequential access (magnetic tape drives) or random access (HDD, DVD), where the read/write head can directly go to any location on the disk and perform action.

3.6.1 Diskettes

Based on the size and packaging of the disks, they can be classified into two types – floppy disks and hard disks. Further, disks that are permanently attached to the unit assembly and cannot be removed by the occasional user are called hard disks. A drive using removable disks is called a floppy disk drive.

Floppy Disks

The disks used with a floppy disk drive are small removable disks made of plastic, and coated with magnetic recording material. There are two sizes commonly used, with diameters of 5.25 and 3.5 inches.

- The 5.25 inch disk is a 5.25 inch diameter floppy disk. Earlier, such disks recorded data only on one side and were called Single Sided (SS) disks. Today both the surfaces are used for recording and are called Double Sided (DS) disks. These are available in two capacities – Double Density (DD), and High Density (HD), where density refers to the number of bits that can be stored per square inch area.
- The 3.5 inch floppy disk is a disk of 3½ inch diameter. These record data on both sides and are therefore double sided disks. These disks come in three different capacities – double density, high density and very high density. These are smaller and can store more data than can the 5.25 inch disks. The storage capacity for any disk can be calculated as:

  Storage capacity = Number of recording surfaces × Number of tracks per surface × Number of sectors per track × Number of bytes per sector

Thus, for a 3.5 inch high density disk which has 80 tracks, 18 sectors/track, and 512 bytes/sector, the disk storage capacity can be calculated as follows:

2 × 80 × 18 × 512 = 14,74,560 bytes or 1.4 MB (approximately)

Table 3.2 provides the necessary details and associated storage capacities of various kinds of floppy disks.

Floppy disks were extensively used in personal computers as a medium for distributing software to computer users. Nowadays, CDs or DVDs are used for that purpose.

Table 3.2 *Storage Capacities of Floppy Disks*

Size (diameter in inches)	No. of Recording Surfaces	No. of Tracks	No. of Sectors/ Tracks	No. of Bytes/ Sector	Storage Capacity (approx)
5.25	2	40	9	512	3,68,640 bytes or 360kB
5.25	2	80	15	512	12,28,800 bytes or 1.2 MB
3.5	2	40	18	512	7,37,280 bytes or 720 kB
3.5	2	80	18	512	14,74,560 bytes or 1.4 MB
3.5	2	80	36	512	29,49,120 or 2.8 MB

3.6.2 Hard Disks

Unlike floppy disks, hard disks are made up of rigid metal. The sizes for the disk platters range between 1 to 14 inches in diameter. Depending on the way they are packaged, hard disks can be categorised as disk packs or Winchester disks.

- ***Disk Packs*** consist of two or more hard disks mounted on a single central shaft. Because of this, all disks in a disk pack rotate at the same speed. It consists of separate read/write heads for each surface (excluding the upper surface of the topmost disk platter and the lower surface of the bottommost disk platter, as mentioned earlier). Disk packs are removable in the sense that they can be removed and kept offline when not in use (typically stored away in plastic cases). They have to be mounted on the disk drive before they can be used. Thus different disk packs can be mounted on the same disk drive at different instances, thereby providing virtually unlimited (modular) storage capacity.
- ***Winchester Disks*** also consist of two or more hard disk platters mounted on a single central shaft but are of the fixed type. The disk platters are sealed in a contamination-free container. Due to this fact, all the disk platters, including the upper surface of the topmost disk platter and the lower surface of the bottommost platter, are used for storing data. So, even though Winchester disks have limited storage capacity as opposed to disk packs, they can store larger amounts of data as compared to the same number of disk platters.

Another kind of disk called the zip disk is very common today. This consists of a single hard disk platter encased in a plastic cartridge. Such a disk typically has a capacity of about 100 MB. The zip drive can further be fixed or portable. The fixed zip drive is permanently connected to the computer system while the portable ones can be carried around and connected to any computer system for the duration of its use. In both cases, however, the zip cartridge (the actual storage medium) is portable just like a floppy, albeit with a nearly 100 times larger storage capacity.

3.7 Tape Drives

A **tape drive** is a data storage device that reads and writes data on a magnetic tape. Magnetic tape data storage is typically used for offline, archival data storage. A tape drive provides sequential access storage, unlike a disk drive, which provides random access storage. A tape drive physically winds tape between reels to read any one particular piece of data. As a result, tape drives have very slow average seek times. For sequential access once the tape is positioned, however, tape drives can stream data very fast. Typically, it is a device, like a tape recorder, that reads data from and writes it onto a tape. Tape drives can range in capacity from a few megabytes to hundreds of gigabytes of uncompressed data.

Tape drives can be connected to a computer with SCSI (most common), Fibre Channel, SATA, USB, FireWire or other interfaces. Tape drives are used with autoloaders and tape libraries which automatically load, unload and

store multiple tapes, increasing the volume of data which can be stored without manual intervention. Computer Output Microfilm or COM is a process for copying and printing data onto microfilm from electronic media found on personal, mini or mainframe computers. Characteristically, COM is a unique tape drive that is mostly used by organizations to store payroll, accounting, insurance, inventory or employee data. COM provides a sophisticated electronic records management tool that ensures proper retention of archival records, by decreasing any unauthorized destruction of records and increasing public access.

Computer Output Microfilm (COM)

COM refers to a process characterized by copying/printing data from media located on personal computers, mini or mainframe computers onto a microfilm. It comprises a high-speed recorder, which transfers digital data onto a microfilm applying laser technology, and a processor which develops the microfilm once exposed to the light source.

A computer output microfilm device translates information normally held on magnetic tape into miniature images on a microfilm (also called microfiche– 'fiche' pronounced as 'fish'). The device displays information as characters on a CRT screen and then using photographic methods, records the display onto the film. Drawings and images can also be displayed along with narrative text.

A special reader/printer can be subsequently used to view the processed film. The reader operates on a 'back projection' principle displaying one frame at a time on a translucent screen, typically about A4 size. The printer can then be used selectively to produce a hard copy of what is presented on screen.

3.8 Measuring Drive Performance

The performance of a disk is measured in terms of how fast it can read or write data. Over the years there have been changes in disk drive interface, rotation speeds, number of heads and cylinders and storage format, all of which have led to a decrease in data access time.

The various types of disks currently available in the market are:

1. IDE – Integrated Drive Electronics.
2. EIDE – Enhanced Integrated Drive Electronics.
3. SCSI – Small Computer System Interface.
4. SATA I & II – Serial Advanced Technology Attachment.

There are two standard methods for accessing and writing data on a disk – sequential access and random access.

Sequential Access is when you read or write to the disk blocks in sequential or continuous order, that is, one block after another. Examples of where Sequential Access is used in computing or data storage would be the backing up of data onto tape drives or the process of writing data onto CDs and DVDs. Any storage medium based on magnetic tape, VHS, audio cassette etc., are read and written by Sequential Access.

Random Access, as the name suggests, is performed when the hard drive head needs to read/write data from/at various locations on the disk. In this case, the disk heads move rapidly from one place to another and the seek time to access data is increased because it involves mechanical operations. Most of the disk operations performed during routine computer work are random access. This is also the reason why random access time is more important while measuring disk performance than sequential access time. While data is written onto optical media sequentially, data on CDs and DVDs can be read randomly.

For Random Access, the *average seek time* and *average latency time* are added to come up with the total time it takes for the disk to read and write data on it.

The average seek time is the time it takes to move the head arm from one position to another, and average latency time is the time it takes for the required data block to come under the head for the read/write operations. The average latency time depends on the Rotations Per Minute (RPM) of the disk, which is the speed at which the magnetic or optical disk rotates.

CHECK YOUR PROGRESS

1. How is the storage unit of a computer system evaluated?
2. Why was the concept of auxiliary memory introduced?
3. What are floppy disk drives?
4. What do you mean by COM?
5. On what factors does average latency time depends?

3.9 Optical and Solid State Storage Devices

The following sub-sections discuss about optical and solid state storage devices:

3.9.1 Compact Disk (CD)

The Compact Disk (CD) was invented by James Russell. A CD is a small, portable and easy to use device made of moulded polymer. It is used record, store, play back audio, video, text, graphics, etc. in a digital form. It comes in the shape of circle. No other shape for CD is available in the market. The main feature of CD is that it is portable and hence it can be used in any

type of portable and CD player devices. The other types of CD are popularly used as CD-ROM, CD-I, CD-RW, CD-RW XA, photo CD, video CD etc.

CD is an optical storage medium that reads the recorded data by the arrangement of optical beams. For example, the process of storing audio data (having large amount of data) in digital formats is known as audio encoding because one second of audio information can store one million bits of data. Therefore, CD is quite capable to store one millions of data and it takes area as tiny as pinhead. A CD is 4.75" diameter and made up of polycarbonate plastic disc. It can contain approximately 74 minutes of audio information. The information is encoded into the CD in terms of lands and pits and is represented by binary highs and lows that are read as laser '*reads*'. The future of this disk is that it would be common medium of exchanging the data for audio, video and other applications.

Compact Disk Interactive (CD-I)

CD-I represents the name of interactive multimedia CD player, which is developed by Royal Philips Electronics (RPE) N.V. It is mainly useful for creating movies, game videos. A CD-I movie disk is also known as video CD holds approximately 70 minutes Video Home System (VHS) quality video. In 1990, Sony company launched a portable CD-I device with the 4" LCD monitor.

3.9.2 CD-ROM

This is an optical medium of data storage. The current maximum capacity of a CD-ROM is 900MB with a maximum read/write access speed of 52X, (which means 10,350 Rotations Per Minute (RPM) and transfer rate of 7.62 Megabits per second (Mbps). The data is written with the help of a red infrared laser beam from an optical lens and the same laser of lower intensity is used to read data from the CD-ROM.

3.9.3 Compact Disk-Recordable (CD-R)

Write Once Read Many (WORM) storage has been working around since 1980s and is considered as a type of optical drive that can be written to and read from. When data is written to a WORM drive, physical marks are made on the media surface by a low-powered laser and since, these marks are permanent. They can not be erased, hence write once. The CD-R media manufacturers use media longevity to define tests and mathematical modeling techniques. The colour of the CD-R disc is related to the colour of the specific dye that was used in the recording layer. This base dye colour is modified when the reflective coating is recognized by either will be in gold colour or silver colour.

The CD-R has a spiral track, which is preformed during manufacture,

onto which data is written during the recording process. This ensures that the recorder follows the same spiral pattern as a conventional CD. It has also the same width of 0.6 microns and pitch of 1.6 microns as a conventional disc. Discs are written from the inside of the disc outward. The spiral track makes 22,188 revolutions around the CD, with roughly 600 track revolutions per millimetre. CD-R writes data to a disc by using its laser to physically burn pits into the organic dye. The CD-R is not strictly WORM. By mid-1998, drives were capable of writing at quad-speed and reading at twelve-speed, which is denoted as *4X/12X* and were bundled with much improved CD mastering software. The CD-R format has not been free of compatibility issues. The surface of a CD-R is made to exactly match the 780nm laser of an ordinary CD-ROM drive. However, CD-R's real disadvantage is that the writing process is permanent. The media can not be erased and written to again in CD-R.

3.9.4 The CD-Rewritable (CD-RW)

CD-RW disk looks like CD-ROM and hence distinguishable from CD-R discs by their metallic gray color. It acts as CD-ROM in the time of reading data. It also allows data recording for thousands of times.

The structure of the CD-RW disk is similar to CD-R. It has the similar polycarbonate substrate layer, protective layer and reflective metal layer. It has two dielectric layers and a layer of phase-changing metal alloy. The dielectric layers prevent overheating of the phase-changing layer during data recording process. The data marks called pits are formed inside the light-adsorbing phase-changing film and have different optical properties and different light reflectance.

To simplify the head positioning mechanism on a blank CD-RW, the laser beam of the servo mechanism can follow this groove during both data reading and writing. The CD-RW drive is different from the regular CD-ROM drive since its laser can operate on the different power levels. The highest level causes phase transitions in the recording material and is used for data recording. The medium level is used for annealing or erasuring. And, the lowest level of laser power is used for data reading that scans the pits and lands without damaging the disk surface. CD-RW uses Direct Over-Write (DOW) method when the new data are just written on top of the old data. The design of CD-RW itself makes them a perfect-writable storage, which is inexpensive and mobile. On the other hand, the distant future of CD-RW technology is not fair enough since new technology DVD-RAM gains momentum in the market.

3.10 Current Trends in Memory

Various storage devices, such as input storage devices and output storage devices are used in computer peripherals. The input storage devices allow information on a computer to be retrieved anytime. Depending on the computer manufacturer, different internal storage devices are made with computers. Magnetic disks use a read-write head that give direct access to storage and the information can be skipped to get to the correct data. Redundant Array of Independent/Inexpensive Disks (RAID) uses a stripping method where data is stored on individual physical disks and information lost is retrieved by the individual disks. Magneto-optical disks use a laser beam to record information. Magnetic tape can be used on a computer internally or externally. Information from a magnetic tape is saved sequentially, so data is lost while the time of accessing certain files or records. The external storage output external hardware devices are used to save information from a computer. Optical disks use laser beams to record information on a CD or DVD. For example, Iomega zip drives compress data onto a disk. Virtual tape stores information on a tape cartridge. PCMCIA cards are used in digital camera or cellular phones. These cards can also be used to save or upload files to a computer. Songs and music files are also be stored on an iPod or MP3 music device. The latest storage devices, such as DVD-RW, zip disk, Blu-ray disk, HVD, USB, external HDD, pen drives and memory sticks, iPod, MPEG audio layer III**,** Set-Top-Box, etc. frequently used in networking era as follows:

Digital Versatile Disc-Rewriteable (DVD-RW)

DVD-RW is like a DVD-R but can be erased and written to again. It can be erased so that new data can be added. DVD-RWs can hold 4.7GB of data and do not come in double-layered or double-sided versions like DVD-R does. Because of their large capacity and ability to be used multiple times, DVD-RW discs are a great solution for frequent backups. To record data onto a DVD-RW disc, you will need a DVD burner that supports the DVD-RW format. DVD-RW disc brings increased functionality to the DVD-R format. These discs are rewritable up to 1,000 times. With this built-in versatility, you can store a combination of both digital video and digital audio files on the same disc. Some of the examples of rewritable media are 17344 DVD-RW 4×1pk w/Standard Jewel Cases, 17345 DVD-RW 4x5pk w/Standard Jewel Cases and 17346 DVD-RW 4x25pk Spindle. The features of DVD-RW are as follows:

- It has 4.7GB capacity that is equal to 2 hours of video.

- It has high-storage density, which is compatible with existing DVD video players and DVD-ROM drives.
- It holds seven times more data than a full size CD-R.
- It has outstanding picture quality and long archival life.
- It is capable in 2x and 4x recording speeds.
- It transfers data easily and useful for video recording or authoring.

DVD-RW and DVD+RW formats are known as re-writable formats. The sister format of DVD-RW is known as DVD-R, which is essentially a record-once version of DVD-RW. DVD+RW's sister format is called DVD+R. DVD-RW discs can be read with virtually any PC DVD-ROM drive and with most of the regular, stand-alone DVD players.

ZIP Drives

These are similar to disk drives but with thicker magnetic disks and a larger number of heads in the drive to read/write. The Zip drive was introduced mainly to overcome the limitations of the floppy drive and replace it with a higher capacity and faster medium. They are better than floppy disks but still slow in performance and with a high cost-to-storage ratio. The disk size ranges from 100MB to 750MB. Zip drives were popular for several years until the introduction of CD-ROMs and CD-Writers, which have now come to be widely accepted due to their cost, convenience and speed.

Blu-Ray Disk

Another high-density optical storage media format is gaining popularity these days. It is mainly used for high-definition video and storing data. The storage capacity of a dual layer Blue-ray disc is 50 GB, almost equal to storing data in six double-dual layer DVD or more than 10 single-layer DVD. With high storage capacity, Blu-ray disks can hold and play back large quantities of high-definition video and audio, as well as photos, data and other digital content.

Holographic Versatile Disk (HVD)

A high density, mostly single sided, double layered optical disc which can hold up to 15GB on a single layer and 30GB on a dual layer disc. The read/ write speed on an HD-DVD varies between 36 Mbps and 72 Mbps. These were primarily designed for the storage of high-definition videos and large volumes of data. The basic look and feel of an HD-DVD drive and disk is the same as that of a CD-ROM and DVD except that it uses a laser of different wavelength and the microscopic structure of storage on a disk is different. HVD uses a technology called *collinear technology* in which two laser rays (one blue-green and one red) are collimated into a single beam. The role of blue-green laser

is to read the data encoded in the form of laser interference fringes from the holographic layer on the tap, while the red laser serves the purpose of a reference beam and read the servo information from the aluminium laser.

Universal Serial Bus (USB)

USB is considered as high speed serial bus. Its data transfer rate is higher than that of a serial port. It supports interfaces such as monitors, keyboard, mouse, speaker, microphones, scanner, printer and modems. It allows interfacing several devices to a single port in a daisy-chain. USB provides power lines along with data-lines. USB cable contains four wires collectively. Two of them are used to supply electrical power to peripherals, eliminating bulky power supply. The other two wires are used to send data and commands. USB uses three types of data transfer and they are isochronous or real time, interrupt driver and bulk-data transfer. USB is a set of connectivity which is developed by Intel. It is easily connected with other peripherals to the system unit. The configuration process takes place after plugging in the Integrated Drive Electronics (IDE) cables to the socket. USB is to be considered as most successful interconnection technology in the world of system unit. It can easily migrate to the mobile gadgets and other consumer electronics too. It avoids special types of interface cards and easily movable to the laptop. In the year of 1995, the USB was released. It operates at the speed of 480 Mbps and portable. The various types of portable devices, such as handhelds, digital cameras, mobiles are connected to the system unit. For example, the images and pictures, music files, multimedia files are transferred from digital camera to a printer with the help of USB or wireless USB. The wired technology is enabled to the mobile lifestyle. It connects the power telephonic conversation and videoconferencing technique. In USB, four-wire cable is interfaced. Two of the wires are set for differential mode. The function of this mode is to transit and receive the information/data. The rest two wires are set for power supply. The source of power comes from the host. Hub is self-powered. Two different connectors are used with USB cable in which one end connector is attached for upstream communication, whereas other end connector is used for downstream communication. The USB cable length is available as 5 meters.

Features of USB

The following features are provided by USB:

- Once USB is connected with the computer system, it acts as a host in temporary basis.
- The host is connected with up to 127 devices by USB hubs.

- The USB cables run at least 5 meters and are connected with hub. The devices are connected in that way so that 6 cables (up to 30 meters) can work with the host.
- The USB 2.0 allows the maximum data speed at the rate of 480 MB/s.
- A USB cable is connected with two wires for power supply (+5 Volts) and the twisted pair of wires is connected with it to carry the data.
- The system unit supplies 500 milliamps of power supply (5 Volts).
- Mouse, known as low power device, gets the power supply directly from USB. But, hubs use own power supply that connects to the USB devices.
- The USB devices are to be considered as hot-swappable device in which it is plugged into the bus and can be unplugged if you do not want to work with it.
- The USB devices maintain 'sleep' or 'hibernate' status by the host while system unit enters into the power-saving mode.
- The USB cables are USB port connected with because they carry data and continuous power supply.

Printers, joysticks, mouse, scanners, flight yokes, Webcams, digital cameras, data acquisition devices, speakers, telephones, video phones, modems, speakers, zip drives, etc. are considered to be as important USB devices. The USB host controller holds own specifications. They are known as Universal Host Controller Interface (UHCI), Open Host Controller Interface (OHCI – used by USB 1.1), Enhanced Host Controller Interface (EHCI – used by used by USB 2.0).

The USB serial bus supports four-shielded wires in which two are used for power supply and other two are used for data signals (differential), i.e., D+ and D-pinout. The Data+ and Data- signals are transmitted for twisted pair cable. The D+ and D- are operated together for line high for 3.3 volts and hence not required for simplex connections. The USB 3.0 is recently installed 4.8 GB/s.

Pen Drives and Memory Sticks

"*A flash drive is a small, portable storage device which, unlike a hard drive or optical drive, has no moving parts. Most connect to the PC via a built-in USB port. Storage capacity ranges from as small as 16MB to as much as 64GB and more .Flash drives can be written and rewritten to an almost unlimited number of times, much like a standard hard drive.*" —pcsupport.about.com

A USB pen drives is normally removable and has lesser storage capacity than any other external storage device since it is much smaller than even a

floppy disk and is more durable than other external storage device. It usually connects to the USB1.1 or USB2.0 ports. The common uses of Pen drive are described below:

- Pen drives are normally used to transport personal files, such as documents, pictures, video's, music files, presentation etc.
- Secure storage of data, application and software files. With Pen drives being used in various secured and insecure environments, data security becomes an upmost issue. Data is encrypted with biometrics and encryption systems like On-The-Fly Encryption (OTFE) systems particularly *FreeOTFE* and *Truecrypt* are also used to encrypt large amounts of data. Secure USB drives are also used as hardware based encryption mechanism instead of software for encrypting data.
- Pen drives are used by system and network administrators, who utilize them for configuring software used for system maintenance, troubleshooting and for data recovery.
- Computer technicians happily use pen drives for data transfer and antivirus software to infected PC's while PC maintenance. With the increasing size of the pen drives, they have also replaced driver and installer CD ROMS which were required after formatting of the PC.
- Pen drives are also used to transport and run applications that run on computer without installation. The U3 company works with pen drive manufacturers to develop customized window based applications which auto load a menu when plugged into a computer running Windows.
- Bootable pen drives also known as *Live drives* are used for booting PC's and can be used at the time of system crash or virus cleaning.
- Pen drives can also be used for storing digital music files, which can be played on a compatible media player, home music system, car audio system or any other compatible device.
- Since pen drives are getting cheaper they are used for promotional and marketing purposes. At times they are given away for free or sold at less than manufacturing cost with company names and logos printed on them for promotional purposes.

Memory Sticks

"Memory Stick is a removable flash memory card format, launched by Sony in October 1998, and is also used in general to describe the whole family of Memory Sticks. In addition to the original memory stick, this family includes

the *Memory Stick PRO*, a revision that allows greater maximum storage capacity and faster file transfer speeds; *Memory Stick Duo,* a small-form-factor version of the memory stick (including the *PRO Duo*); and the even smaller *Memory Stick Micro (M2)*. In December 2006 Sony added the *Memory Stick PRO-HG,* a high speed variant of the PRO, to be used for high definition still and video cameras." – Wikipedia.

Normally memory sticks are used for data storage & transportation of portable devices such a digital camera, PDA's, Cell phones, Play Station Portable (PSP), which can be later accessed by a personal computer for retrieval and permanent storage of data. For example, with a memory stick a user can transfer photographs clicked on a digital camera to its computer through a memory stick reader.

iPod

An iPod is a portable device used for storing and playing audio files encoded by MP3 or Advance Audio Coding (AAC) compression algorithms. The original iPod came with a body of white Lucite and chrome in 2001. Later, Apple released the iPod Mini, approximately one-third the size of the original iPod and encased in a variety of shiny metallic colors. All iPods came with distinctive white headphones. The larger iPod and the iPod Mini use an extremely small hard disk for storage. The Shuffle uses a flash memory. Unlike the memory found in computers, flash memory does not lose its contents when the power is turned off. As the prices and capacities of both hard disks and flash memory continue to fall, the storage capacity of all three models has increased over time. When connected to a Personal Computer (PC), Windows or Macintosh, the iPod communicates with a piece of Apple software called iTunes. The iPod and iTunes work together to synchronize the songs available on the iPod to those available on the PC. This happens automatically, without any intervention being required from the user. This is the reason why iPods grabbed the portable MP3 player market. In addition to playing MP3 audio files, the iPod plays AAC. AAC was developed by Dolby Labs as part of the MPEG-4 audio or video standard. While technically advanced as a compression algorithm, AAC's principle is different from MP3 is its ability to support Digital Rights Management (DRM). DRM is a response to the type of song sharing first enabled by Websites like Napster. By encoding legally purchased songs with digital signatures, it increases the difficulty of sharing them inappropriately. Here, you get a new concept of digital signature. You must know what digital signature is. Digital Signature (DS) follows authentication mechanism. A code is attached with messages in DS. Primarily, the signature is generated by hashing the message and then later

this message is encrypted with the sender's private key. DS is based on public key encryption. A signature confirms that integrity and source of message is correct. National Institute of Standards and Technology (NIST) standard recognized the DSS standard that basically uses the Secure Hash Algorithm (SHA). Message authentication protects digital signature because in that mechanism messages are exchanged by the third-party. DS is analogous to manual signature. The characteristics of DS are as follows:

- It attaches date and time along with author of the signature.
- It authenticates the contents when signature was being completed.
- It solves the disputes using third-party.
- It ensures that message is not altered. The message can be electronic documents, such as e-mail, text file, spreadsheet, etc.

Inserting signatures immediately work with into working documents, for example autograph for iPhone also lets you email signatures or save them directly to your photo library for future use. You can change your signature color or line width using style options with the help of app and even include the date with the signature to save time. People using only the one computer can enable the auto-send feature. This will select the computer in the network used most often, eliminating the need to select from detected computers every time you wish to send a signature. To create and insert a digital signature, launch Autograph Helper on your Mac or PC, launch Autograph on iPhone or iPod touch and make sure the iPhone/iPod touch or computer receiving signature are on the same network. The iPods are designed by Apple computer and have distinctive styling and can hold anywhere from a few hundred to ten thousand songs.

Apple has continued to develop the iPod, giving it a slimmer, sleeker exterior and also expanding its capacity and capabilities. The user interface has also evolved as Apple seeks to find the most intuitive, user-friendly design.

MPEG Audio Layer III (MP3) Music Device

This storage device is especially used for storing the songs and music. If you want to listen to your favourite tunes while commuting to work, trekking across campus or working out, then MP3 player is essential for the user. A player that uses flash memory can store music on flash devices because it has distinct advantages the users can take it along with them when they are away from home. Many portable music players can do more than play music. Some players have a built-in voice recorder, Frequency Modulation (FM) recorder, etc. And some of the extra accessories, for example high-quality

headphones, a belt clip or an armband can also be used with it. When you have hundreds of songs on your player, you really need an easy way to select your music by artist, album or genre. It is little bit critical if you want to find that one song or artist you really want to hear. A display also comes in handy when you look for your favourite radio station. FM radio lets you put your player on autopilot as you mountain bike, cycle or rollerblade. The price of a player will depend on its storage capacity, i.e., the More Megabytes (MB) of storage, it has the more music it can hold and the more it will cost. If you rip your own CDs, using a player with Windows Media Audio (WMA), it supports MP3 support too that gives you the most music per megabyte.

An MP3 is a digital audio file compressed using a standard defined by the Motion Pictures Experts Group (MPEG). It is also known as *MPEG-1, Layer 3* device. MP3s can use as little as 10 per cent of the storage required by the CD format. An MP3 player is a device for playing MP3 files. MP3 players come in many sizes and capacities. The smallest MP3 players use a type of memory known as flash. Unlike conventional memory, flash memory does not lose stored information when the power is turned off. Flash is very compact and uses very little power, allowing for extremely small designs with long battery life. The limitation of flash-based MP3 players is that they do not have a great deal of storage capacity. For larger storage needs, hard disk-based MP3 players were developed and this storage device can have storage capacities in the tens of thousands of songs, but controlled by the ultra compactness of flash-based players. Hard disk-based MP3 players are also generally more expensive than flash-based players. While not invented by Apple, it was Apple's line of iPod MP3 players that popularized the devices. With their distinctive white headphones and Lucite and chrome styling, coupled with extreme ease of use, iPods soon dominated the portable MP3 player market. With the rise in popularity of MP3s as a format for storing music, a number of non-portable MP3 players appeared for the home market. Sometimes, it is referred to as *digital hubs* or 'media centers, these devices are a cross between a stereo component and a computer. With network connections, often wireless, they are able to access MP3s and other digital content stored on computers on the home network. With a full array of standard audio/visual connections, they are able to integrate with home entertainment systems. These devices come with remote controls and may use a television as a display screen for menus and playback information. A major advantage of these devices when used as MP3 players is that more than one device can access your MP3 files at the same time. All the music can be stored in one place.

Set-Top-Box

Set-Top-Box (STB) is fully integrated STB and considered as latest storage device in computer era. They have good processors, memory and optional large hard drives and hence retain good storage capacity. They are often used with high-speed connections. Features could include high-speed Internet access, iTV, digital video recording and gaming. These boxes provide an additional transport stream of data from the network operator to compliment the original stream that is being received by the subscriber via their original STB. These are capable of Video-on-Demand (VoD), E-commerce, Internet browsing, e-mail communications, chatting, etc. The VoD technology is used in many applications, for example, entertainment, e-commerce based applications, distance learning etc. It refers to a system in which users are allowed to choose and watch the audio or video content on demand. The video is delivered by the transmission of unicast stream as request sent by clients. The throughput and bandwidth factors make VoD scalable. Using VoD mechanism it is always considered to check the files with VoD servers which are needed to deliver the data, open streams as per client requests. The client get listen two streams at a time in which one stream is used to deliver the data and other stream is used to send the data. VoD provides a broadband interactive service in which users can avail the various services, such as selecting and choosing remote, delivering the ordered content, such as TV program, multimedia applications, movies, sport event, music etc. It completely replaces the VCRs because it works as same as video player works, for example it provides *STOP, PAUSE, FORWARD* and *REWIND* services. For this, it frequently requires STB. The services collectively represent the virtual multimedia/video content shop. The characteristics of VoD can be considered as follows:

- Obtain more profit and revenue by registering more viewers.
- Obtain high broadband data network operator by offering the advanced multimedia services.
- Watch and order the selcted movie or multimedia content in-house.
- Possibility of remote accessing of all the services in terms of 24×7 timing.

Digital STB converts signals into content and it can be displayed on a television screen. This solution can be easily used to create standalone streaming media products or Digital Video Recorder (DVR) systems. Similarly, this solution can also be used as a sub-system to add streaming media capability to various consumer products. With the addition of a HDD, this

platform can be made to support DVR or Personal Video Recorder (PVR) functionality as well. Added system savings can be achieved by compressing content before storing.

CHECK YOUR PROGRESS

6. What is needed to record a DVD-RW?
7. How much data can you store on Blu-ray disk?
8. What are different communication transfer modes available for USB?
9. What is the need of an external hard disk drive?
10. What do you mean by set-top box?
11. Discuss I/O Devices in details.

3.11 Summary

- The main memory is the central storage unit in a computer system. It is a relatively large and fast memory. It is used to store programs and data during computer operations.
- The Static RAM (SRAM) stores binary information using clocked sequential circuits. The stored information remains valid only as long as power is applied to the unit.
- Dynamic RAM (DRAM) stores binary information in the form of electric charges that are applied to capacitors inside the chip. The stored charge on the capacitors tends to discharge with time and so must be periodically recharged by refreshing the dynamic memory. The dynamic RAM offers larger storage capacity and reduced power consumption.
- Large memories use dynamic RAM, while static RAM is mainly used for specialized applications.
- Most of the memory in a general-purpose computer is made of RAM integrated circuit chips, but a portion of the memory may be constructed using ROM chips.
- RAM is used for storing the bulk of the programs and data that are subject to change, while ROM is used to store programs that are permanently resident in the computer and do not change once the production of the computer is completed.
- Cache memories are small, fast memories placed between the CPU and the main memory. They are faster than the main memory with access times closer to the speed of the CPU. Caches are fast, but very expensive.

- Magnetic tapes are used for storing files of data that are sequentially accessed or not used very often and are stored off line. They are typically used as backup storage for archiving of data.
- Data is stored in concentric rings or tracks. Inter-track gaps are used to separate the adjacent tracks so that the interference of magnetic fields is minimized.
- Tracks are commonly divided into sections called sectors.
- A disk drive is a peripheral device used to store and collect information. It can be removable or fixed, high capacity or low capacity, fast or slow speed, and magnetic or optical.
- Optical disks are storage devices with huge storage capacities. They are a relatively new storage medium and use laser beam technology for writing and reading of data.
- The performance of a disk is measured in terms of how fast it can read or write data. Over the years there have been changes in disk drive interface, rotation speeds, number of heads and cylinders and storage format, all of which have led to a decrease in data access time.
- A CD is a small, portable and easy to use device made of molded polymer. It is used record, store, play back audio, video, text, graphics, etc. in a digital form. It comes in the shape of circle.
- CD-RW disk looks like CD-ROM and hence distinguishable from CD-R discs by their metallic gray color. It acts as CD-ROM in the time of reading data. It also allows data recording for thousands of times.
- DVD-RW is like a DVD-R but can be erased and written to again. It can be erased so that new data can be added. DVD-RWs can hold 4.7GB of data and do not come in double-layered or double-sided versions like DVD-R does.
- ZIP Drives are similar to disk drives but with thicker magnetic disks and a larger number of heads in the drive to read/write.
- USB is considered as high-speed serial bus. Its data transfer rate is higher than that of a serial port. It supports interfaces such as monitors, keyboard, mouse, speaker, microphones, scanner, printer and modems.
- In control mode host uses this mode in which data is transferred in both directions to send and transfer the small amount of data.
- Interrupt Mode is hosted by querying devices in which host is used to transfer the data.
- Bulk Mode is used to get the features of data accuracy, disk drive storage.

- Isochronous Mode guarantees the timing of data delivery, for example USB audio peakers.
- The external hard disk drive is required for computer system if hard disk is not sufficient to store all the important data.
- A USB pen drives is normally removable and has lesser storage capacity than any other external storage device since it is much smaller than even a floppy disk and is more durable than other external storage device.
- An iPod is a portable device used for storing and playing audio files encoded by MP3 or Advance Audio Coding (AAC) compression algorithms.
- Set-Top-Box (STB) is fully integrated STB and considered as latest storage device in computer era. They have good processors, memory and optional large hard drives and hence retain good storage capacity.

3.12 Key Terms

- **RAM:** The mode that facilitates accessing a memory location in any order in the same amount of time
- **SRAM:** Storage of binary information using clocked sequential circuits
- **DRAM:** Storage of binary information in the form of electric charges that are applied to capacitors inside the chip
- **ROM:** Read-only memory, whose information cannot be changed
- **Bootstrap loader:** A program whose function is to get the computer software operating when the power is turned on
- **Cache memory:** Provides fast memory retrieval without loss of memory size
- **Locality of reference:** Memory reference confined to a few localized areas
- **Magnetic storage devices:** Devices that store data on a magnetized medium
- **COM:** A process characterized by copying/printing data from media located on PCs, mini or mainframe computers onto a microfilm

3.13 Questions for Exercise

Short-Answer Questions

1. What is seek time and access time?
2. What are hard disks?
3. What is ROM?

4. What are the different types of CD?
5. What are different types of communication transfer modes in USB?
6. How we will solve the error in hard disk when we get the error "Drive not detected"?

Long-Answer Questions

1. Discuss the functioning of the cache memory with the help of example.
2. Distinguish between static and dynamic RAM.
3. Explain the use of optical storage devices with suitable examples.
4. How is drive performance measured? Describe in brief.
5. What is a pen drive? Explain its various uses.
6. Describe all the technologies used in a Set-top-box.

3.14 Further Readings

ITL Education Solutions Limited. *Introduction to Computer Science*, 2nd edition. United Kingdom: Pearson.

Jaiswal, A. *Fundamentals of Computer and Information Technology*. New Delhi: Dreamtech Press.

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