Ministry of Secondary Education
Progressive Comprehensive High School
PCHS Mankon – Bamenda
Department of **Computer Studies**

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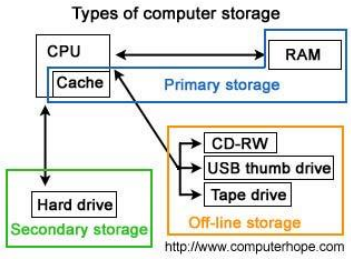
COMPUTER STORAGE DEVICES

Class: Comp. Sc A/L **By:** DZEUGANG PLACIDE

Computer data storage, often called **storage** or **memory**, refers to computer components and recording media that retain digital data used for computing for some interval of time. Computer data storage provides one of the core functions of the modern computer, that of information retention. Many different forms of storage, based on various natural phenomena, have been invented. So far, no practical universal storage medium exists, and all forms of storage have some drawbacks. Therefore a computer system usually contains several kinds of storage, each with an individual purpose. This chapter discusses the computer storage devices and their various facets such as their types, how they work, what purpose do they solve, and so on.



After studying this topic students will be able to:

- Learn the various units of storage device
- Understand the memory types- Primary memory and Secondary memory and their functionning

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I. GENERALITIES ON COMPUTER MEMORY

I.1 What is a computer memory?

Computer **memory** is any physical device capable of storing information temporarily or permanently.

I.2 Memory representation

For measuring computer memory, a standard unit is required. Although the smallest unit of data that a computer can deal with is a bit, the computers generally do not deal with a single bit. Instead, they deal with a group of eight bits, which is referred as 'byte'. Various units used to measure computer memory are as follows:

- **Bit:** It is the smallest unit of data on a machine and a single bit can hold only one of two values: 0 or 1. Bit is represented by lower case b.
- **A nibble** is a collection of 4 bits.
- **Byte:** A unit of eight bits is known as a byte. Hence, a byte is able to contain any binary number between 00000000 and 11111111. It is represented by upper case B.
- **Kilobyte:** In a decimal system, kilo stands for 1000, but in a binary system, kilo refers to 1024. Therefore, a kilobyte is equal to 1024 bytes. It is usually represented as KB.
- **Megabyte:** It comprises 1024 kilobytes or 10,48,576 bytes. However, since this number is hard to remember, a megabyte can be thought of as million bytes. Megabyte is the standard unit of measurement of RAM and is represented as MB.
- **Gigabyte:** It consists of 1024 megabytes (10,73,741,824 bytes). It is the standard unit of measurement for hard disks and is often represented as GB.
- **Terabyte:** It refers to 1024 gigabytes and is often represented as TB. Terabyte memory is usually associated with only super computers

Unit	Symbol	Bytes
Byte	B	2^0 = 1 byte
Kilobyte	KB	2^{10} = 1024 bytes
Megabyte	MB	2^{20} = 1024 KB
Gigabyte	GB	2^{30} = 1024 MB
Terabyte	TB	2^{40} = 1024 GB

NOTE: *In modern computers, groupings of bytes (usually 2 or 4) called computer **words** can represent larger 'chunks' of information.*

I.3 Memory characteristics

Computer memories can be differentiated by evaluating certain core characteristics. These core characteristics are ***volatility, mutability, accessibility***, and ***addressability***.

I.3.1. Volatility

→ **Non-volatile mem**ory will retain the stored information even if it is not constantly supplied with electric power. It is suitable for long-term storage of information.

→ **Volatile memory r**equires constant power to maintain the stored information. The fastest memory technologies of today are volatile ones.

I.3.2. Mutability

→ **Read/write storage or mutable storage a**llows information to be overwritten at any time.
→ **Read only storage** retains the information stored at the time of manufacture
→ **Write once storage** (Write Once Read Many) allows the information to be written only once at some point after manufacture. These are called **immutable storage**. Examples include CD-ROM and CD-R
→ **Slow write, fast read storage** : Read/write storage, which allows information to be overwritten multiple times, but with the write operation being much slower than the read operation. Examples include CD-RW and flash memory.

I.3.3. Accessibility

Access Mode: Access mode refers to the way the data are accessed from the memory.

→ **Random access:** Any location in storage can be accessed at any moment in approximately the same amount of time. Such characteristic is well suited for primary and secondary storage.
→ **Sequential access:** The accessing of pieces of information will be in a serial order, one after the other; therefore the time to access a particular piece of information depends upon which piece of information was last accessed. Such characteristic is typical of off-line storage.
→ **Direct access**: In some cases, the data are accessed neither in a random nor in a sequential fashion, but using a combination of both the modes.This type of semi-random mode exists in the magnetic disk.

I.3.5. Addressability

→ **Location-addressable:** Each individually accessible unit of information in storage is selected with its numerical memory address.
→ **File addressable:** Information is divided into *files* of variable length, and a particular file is selected with human-readable directory and file names. In modern computers, secondary, tertiary and off-line storage use file systems.
→ **Content-addressable:** Each individually accessible unit of information is selected based on the basis of (part of) the contents stored there. Content-addressable storage can be implemented using software (computer program) or hardware (computer device), with hardware being faster but more expensive option. Hardware content addressable memory is often used in a computer's CPU cache.

Other characteristics of computer memory involve

- **Access time**: Access time is the time required between the request made for read/write operation and the time it takes for the completion of the request. Generally,

the access time is measured for read operations only. Disk access time depends on the following three parameters:

→ **Seek Time:** It is the time required to position the read/write head over the desired track, as soon as a read/write command is received by the disk unit

→ **Latency:** It is the time required to spin the desired sector under the read/write head, once the read/write head is positioned on the desired track

→ **Transfer Rate:** the transfer rate is the number of characters or words that a device can transfer per second after it has been positioned at the beginning of the record. As the transfer rate is negligible as compared to seek time and latency,

Average access time = Average seek time + Average latency

- **Storage capacity**: Storage capacity refers to the size of the memory, that is, the amount of data that can be stored in the memory.
- **Cost:** The cost of memory is valued by estimating the cost per bit of storage, that is, the cost of a storage unit for a given storage capacity.

I.4 Types of Memory

These are the fundamental types of memory in a computer system:

a) Primary storage device: The primary memory allows the computer to store data for immediate manipulation and to keep track of what is currently being processed. There are two main types of primary storage:
- **Main memory** (***RAM*** and ***ROM***) and
- **Internal processor memories** (***Cache memory*** and ***registers***).

b) Secondary Memory: This is also known as **auxiliary memory**. It differs from primary storage in that it is not directly accessible by the CPU.

c) Tertiary Storage: Tertiary storage is very large storage which is separate from the computer. The most obvious example of tertiary storage is an automated storage facility where mechanical arms retrieve media and load it into large computers. Other tertiary storage may simply be off-grounds locations which allow vital data in various mediums to be safe-guarded for security purposes- fire, theft, etc.

d) Off-line Storage: Offline storage is storage media which can be inserted into the computer and used but which can then be removed from the computer and stored elsewhere. ***Floppy drives, CD drives***, and ***DVD drives*** might also alternately be considered secondary storage because their drives are usually installed in the computer but the key here is the media the data is stored on.

I.5 Storage technologies

Most commonly used data storage technologies are **semiconductor**, **magnetic**, and **optical**, while paper still sees some limited usage. Some other fundamental storage technologies have also been used in the past or are proposed for development.

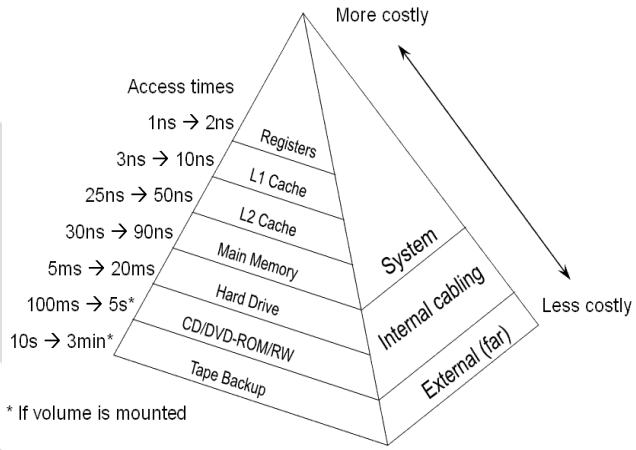
- **Magnetic storage media**: Magnetic storage uses different patterns of magnetization on a magnetically coated surface to store information. In modern computers, magnetic

storage will take these forms: **Magnetic disk** (Floppy disk, Hard disk drive) and **Magnetic tape** data storage.

- **Optical storage media**: The typical optical disc, stores information in deformities on the surface of a circular disc and reads this information by illuminating the surface with a laser diode and observing the reflection.
- **Semiconductor storage media**: Semiconductor memory uses semiconductor-based integrated circuits to store information. A semiconductor memory chip may contain millions of tiny transistors or capacitors. Both volatile and non-volatile forms of semiconductor memory exist.
- **Magneto-optical disc storage media**: Magneto-optical disc storage is optical disc storage where the magnetic state on a ferromagnetic surface stores information. The information is read optically and written by combining magnetic and optical methods.

I.6 Memory hierachy

A "memory hierarchy" in computer storage distinguishes each level in the "hierarchy" by response time. Since response time, complexity, and capacity are related, the levels may also be distinguished by the controlling technology. The figure below illustrates the memory hierarchy.



II. PRIMARY STORAGE DEVICE

The primary memory allows the computer to store data for immediate manipulation and to keep track of what is currently being processed. There exist two main types of primary storage device**: Main memories** and **internal processor memories**

II.1 Main memory

Broadly primary memory can be of two types RAM (Random Access Memory) and ROM (Read only memory***).*** Every computer comes with a small amount of ROM, which contains the boot firmware called **BIOS (*Basic Input Output System)***.

II.1.1 Random Access Memory (RAM)

1. **What is RAM?**

RAM is the place where the computer temporarily stores its operating system, application programs and current data so that the computer's processor can reach them quickly and easily. RAM allows the computer to store data for immediate manipulation and to keep track of what is currently being processed. RAM is much faster to read from and write to than the other

kinds of storage in a computer (like hard disk or floppy disk). The major limitation of this type of memory is that it is **volatile**. It means that when the power is turned off, the contents of the primary memory are lost forever.

NOTE: *Random access memory is also called **read/write memory** because, unlike read-only memory (ROM) that does not allow any write operation, random access memory allows CPU to read as well as write data and instructions into it.*

2. Types of RAM

There are two types of random access memory, which are as follows:

a) **Dynamic RAM** (DRAM):

This RAM must be continually refreshed (*pulse of current through all the memory cells*) to maintain the data. This is done by placing the memory on a refresh circuit that rewrites the data several hundred times per second. DRAM is used for most system memory because it is cheap and small. Some of the most popular DRAM technologies are briefed as follows:

- **Fast Page Mode DRAM** (FPM DRAM): It is also called as ***page mode DRAM***. It is the original form of DRAM. FPM DRAM is slow and has an access time of 60–120 ns. Due to its slow speed, FPM DRAM is replaced by EDO RAM.
- **EDO (Extended Data Output) RAM :** In an EDO RAMs, any memory location can be accessed. It is 10–15 per cent faster than FPM DRAM and is usually found on 66 MHz motherboards. EDO memory further enhances the method of access.
- **Burst Extended Data Output DRAM** (BEDO DRAM): Original EDO RAM was too slow for the newer systems being developed at that time. Therefore, a new method of memory access, known as bursting, had to be developed to speed up the memory access.
- **SDRAM (Synchronous DRAMS)**, It is the most common type of RAM used in systems today. This implies that the data stored in the memory is refreshed at system speed. Also, the data are accessed in memory at system speed. SDRAM employs the bursting technology to improve the performance.
- **DDR-SDRAM (Double Data Rate – SDRAM) :** This DRAM is similar to SDRAM except that it has higher bandwidth, which means greater speed. Therefore the transfer rate of the data becomes doubles.
- **Rambus DRAM** (RDRAM): It was developed by Rambus, Inc. and endorsed by Intel as the successor to SDRAM.

b) **Static RAM** (SRAM):

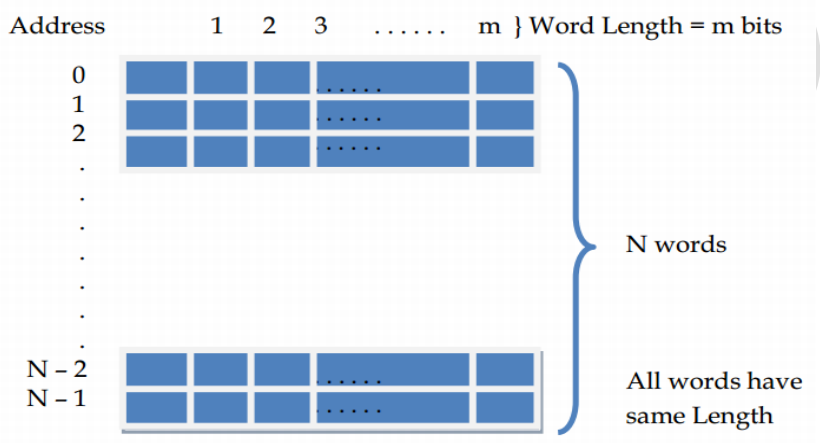
This RAM retains the data as long as power is provided to the memory chip. It need not be 'refreshed' periodically. It is very fast but much more expensive than DRAM. SRAM is often used as **cache memory** due to its high speed. SRAM comes in following types:

- **Asynchronous SRAM** (ASRAM): It is an older type of SRAM used in many PCs for L2 cache, which works independently of the system clock. Thus, the CPU must wait for data requested.

- **Burst SRAM** (BSRAM): Burst SRAM (also known as SynchBurst SRAM or synchronous SRAM) is synchronized with the system clock. This allows it to be more easily synchronized with any device that accesses it and the access time is also less. However, it is expensive.
- **Pipeline Burst SRAM** (PB SRAM): PB SRAM requests are pipelined; larger packets of data are sent to the memory at once and acted on very quickly. This type of SRAM is often used because it can operate at speeds higher than 66 MHz.

3. Main memory organisation

The main memory of computer system is organized into an array of small storage areas known as **cells**, which are serially linked together. Each cell is indexed by a unique number, called the **address** of the cell and is capable of storing a fixed number of bits, called the **word length** of the memory.



The word length is an important architectural factor, which typically relates to the CPU and is usually the size of its registers in bits. The word lengths typically range from 8, 16, 32 bits to 64 bits and accordingly the computers are termed as 8-bit, 16-bit, 32-bit and 64-bit computers. The higher the word length, the more powerful a computer is.

The total number of memory cells that can be uniquely addressed by CPU depends on the total number of address lines in an address bus. If there are n lines in the address bus then there are 2^n addressable locations in the memory.

4. Fixed and Variable Word Length Memory

The main memory of a computer can be designed in two ways: ***fixed word length*** and ***variable word length***.

→ In fixed word length memory system, each memory location stores a fixed number of characters, which are equal to the word length of the computer. The computers that employ fixed word length memory approach are called word-addressable computers. In such computers, the storage space is always allocated in multiples of word length.

→ In **variable word length memory** system, the memory is designed in such a way that each memory location can store only one character. Hence, the word 'HI' will occupy only 2 bytes, 'MIKE' will occupy 4 bytes, and 'COMPUTER' will occupy 8 bytes of memory. The computers that employ variable word length memory approach are called ***character-addressable computers***

II.1.2 Read Only Memory

1. What is ROM?

Short for **Read-Only Memory, ROM** is a type of "built-in" memory that is capable of holding data and having that data read from the chip, but not written to. Unlike Random Access Memory (RAM), ROM is non-volatile which means it keeps its contents regardless if it has power or not.

NB: The term ROM is used to describe any type of memory or media that is read only. For example, a CD-ROM

2. Types of ROM

Memories in the ROM family are distinguished by the methods used to write data on them and the number of times they can be rewritten. There are different types of ROMs, which are as follows:

- **Masked ROM:** The very first ROMs, known as masked ROMs, were hard-wired devices that contained a preprogrammed set of data or instructions.
- **Programmable ROM** (***PROM***): This form of ROM is initially blank. The user or manufacturer can write data/program on it by using special devices. However, once the program or data is written in PROM chip, it cannot be changed.
- **Erasable Programmable ROM** (***EPROM***): An EPROM is programmed in exactly the same manner as a PROM. However, unlike PROMs, an EPROM can be erased and reprogrammed repeatedly. It can be erased by simply exposing it to a strong source of ultraviolet (UV) light for a certain amount of time.
- **Electrically Erasable Programmable ROM** (***EEPROM***): This type of ROM can be erased by an electrical charge and then written to by using slightly higher-than-normal voltage. EEPROM can be erased one byte at a time, rather than erasing the entire chip with UV light. Hence, the process of re-programming is flexible, but slow.
- **Flash ROM**: flash ROM, also called flash BIOS or flash memory, is a type of ROM that can be erased and re-programmed in blocks.

Type	Writable	Erase Size	Cost Per Byte	Speed
Masked ROM	No	N/A	Inexpensive	Fast
PROM	Only once	N/A	Moderate	Fast
EPROM	Yes	Entire chip	Moderate	Fast
EEPROM	Yes	Byte	Expensive	Fast to read, slow to erase/write
Flash ROM	Yes	Block	Moderate	Fast to read, slow to erase/write

II.2 Internal Processor Memories

These memories are placed within the CPU (processor) or is attached to a special fast bus. Internal memory usually includes **cache memory** and **special registers**, both of which can be directly accessed by the processor. This memory is used for *temporary storage* of data and instructions on which the CPU is currently working. Processor memory is the fastest among all the memories, but is most expensive also.

II.2.1 Cache Memory

Cache memory is used by the central processing unit of a computer to reduce the average time to access memory. The cache is a smaller, faster memory which stores copies of the data from the most frequently used main memory locations. As long as most memory accesses are to cached memory locations, the average latency of memory accesses will be closer to the cache latency than to the latency of main memory.

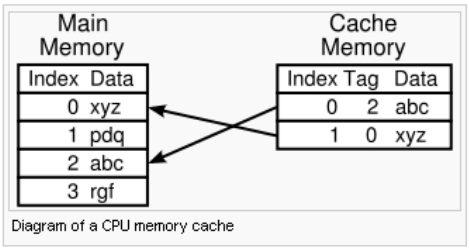


Diagram of a CPU memory cache

The **advantage of cache memory** is that the CPU does not have to use the motherboard's system bus for data transfer. Whenever data must be passed through the system bus, the data transfer speed slows to the motherboard's capability. The CPU can process data much faster by avoiding the bottleneck created by the system bus.

Cache memory is sometimes described in levels of closeness and accessibility to the microprocessor. There are three main types of cache memory:

→ **L1 cache**: It is small and is built inside the CPU. It is fast as compared to L2 cache
→ **L2 cache**: It is large but slower and is mounted on the motherboard
→ Most computers today come with **L3 cache** which is built out of the CPU

II.2.2 Registers

The central processing unit (CPU) contains a number of memory locations which are individually addressable and reserved for specific purpose. These memory locations are called **registers**. CPU instructions operate on these values directly. Registers are at the top of the memory hierarchy, and provide the fastest way for a CPU to access data. On **RISC processors**, all data must be moved into a register before it can be operated. **On CISC (Intel) chips**, there are a few operations that can load data from RAM, process it, and save the result back out, but the fastest operations work directly with registers.

The number of registers that a CPU has and the size of each (number of bits) help determine the power and speed of a CPU. For example a 32-bit CPU is one in which each register is 32 bits wide. Therefore, each CPU instruction can manipulate 32 bits of data.

Some characteristics of CPU registers are:

- **Very fast** (access times of a few nanoseconds)
- **Low capacity** (usually less than 200 bytes)
- **Very limited expansion capabilities** (*a change in CPU architecture would be required*)
- **Expensive** (more than one dollar/byte)

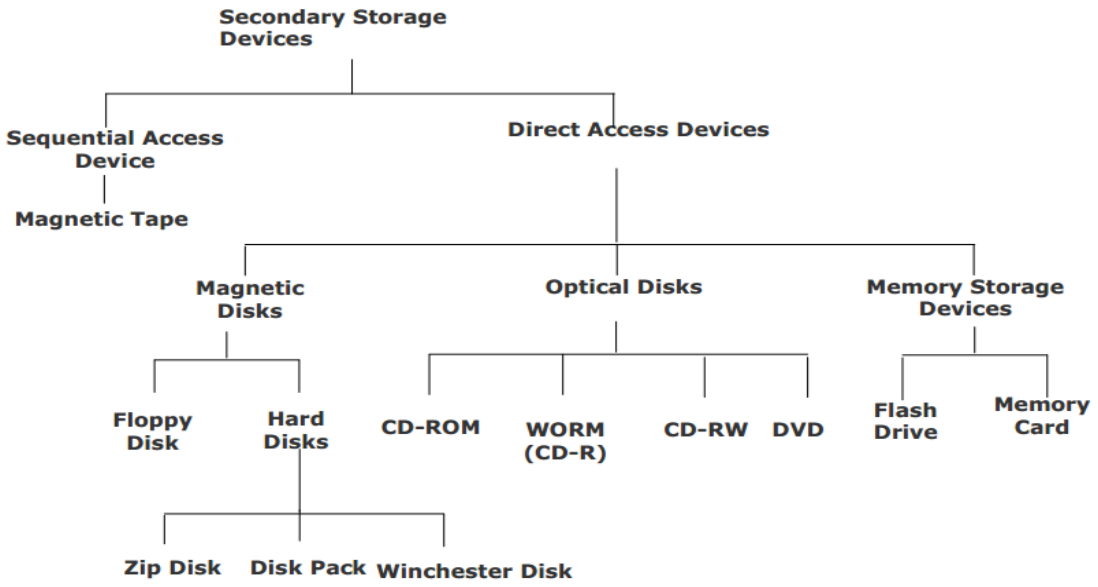
Types of register

Types of Registers are as Followings

→ ***Memory Address Register(***MAR) : This register holds the memory addresses of data and instructions. This register is used to access data and instructions from memory during the execution phase of an instruction.
→ **Program Counter (PC)**: It holds the address of the memory location of the next instruction when the current instruction is executed by the microprocessor.
→ **Accumulator Register**: This Register is used for storing the Results those are produced by the System. When the CPU will generate Some Results after the Processing then all the Results will be Stored into the AC Register.
→ **Memory Data Register** (MDR) : MDR is the register of a computer's control unit that contains the data to be stored in the computer storage (e.g. RAM), or the data after a fetch from the computer storage.
→ **Index Register** (IR) : Also known as base register. An index register in a computer's CPU is a processor register used for modifying operand addresses during the run of a program.
→ ***Memory Buffer Register*** (MBR): This register holds the contents of data or instruction read from, or written in memory. It means that this register is used to store data/instruction coming from the memory or going to the memory.
→ **Data Register**: A register used in microcomputers to temporarily store data being transmitted to or from a peripheral device.

III. SECONDARY STORAGE DEVICES

This is also known as **auxiliary memory**. It differs from primary storage in that it is not directly accessible by the CPU. The secondary memory provides backup storage for instructions (computer programs) and data. The instructions and data stored on secondary storage devices are permanent in nature. They can only be removed if the user wants it so or the device is destroyed.



III.1 Magnetic Tape

Magnetic tape is a recording medium consisting of a thin tape with a coating of a fine magnetic material, used for recording analogue or digital data. Data is stored in frames across the width of the tape. The frames are grouped into blocks or records which are separated from other blocks by gaps. Magnetic tape is a serial access medium, similar to an audio cassette, and so data (like the songs on a music tape) cannot be quickly located. However large amounts of information can be stored within magnetic tape. This characteristic has prompted its use in the regular backing up of hard disks.

Advantages and disadvantage of Magnetic Tapes

The following are advantages and disadvantages of magnetic tape

Advantages of magnetic tape	**Disadvantages of magnetic tape**
Probably the cheapest form of storage per megabyte of storage	Serial access so can be quite slow to access data
Can store large amounts of data - up to 1 Terabyte per tape cartridge	Need a special piece of equipment to record and read the data on the tape
Can be set up to do the back up overnight or over the weekend	The data may be corrupted if the tape is placed near a strong magnetic field e.g. a large speaker or magnet
They are portable because they are compact in size, lightweight and removable.	the data on such devices are difficult to recover even if a minor bit error occurs.
	They are not flexible as compared to other media types when file updating requires record insertion or deletion.

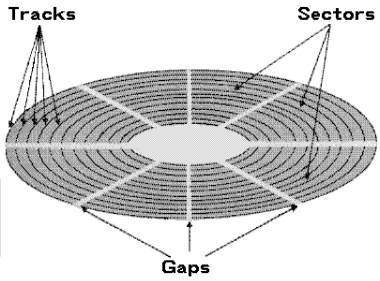
III.2 Magnetic Disk

III.2.1 What is a Magnetic Disk?

The magnetic disks are the most widely used and popular medium for direct access secondary storage. They offer high storage capacity and reliability and have capability to access the stored data directly. A magnetic disk comprises a thin piece of plastic/metal circular plate/platter, which is coated with a magnetic oxide layer. The data are represented as magnetized spots on the disk. Data are recorded on the disk in the form of tiny invisible magnetized and non-magnetized spots (representing 1s and 0s) on the coated surfaces of the disk

III.2.2 Storage Organization of a Magnetic Disk

A disk's surface is divided into a number of invisible concentric circles called **tracks** The tracks are numbered consecutively from outermost to innermost starting from zero. The number of tracks on a disk may be as few as 40 on small, low-capacity disks, to several thousand on large, high-capacity disks. Each track of a disk is subdivided into **sectors**



There are 8 or more sectors per track. A sector typically contains 512 bytes. Disk drives are designed to read/write only whole sectors at a time.The track sectors are grouped into a collection known as **cluster**. It refers to the basic allocation unit for storage on a disk, consisting of one or more track sectors. The number of track sectors that make up one cluster depends on the type and size of the media. The term 'cluster' also refers to the minimum amount of disk space used by a single file. Even if the file occupies only part of a cluster, the entire cluster is allocated to the file and marked as used space.

III.2.3 Disk formatting

Disk formatting is the process of preparing a new disk by the computer system in which the disk is to be used. There exist two type of formatting:

a) Low-level disk formatting

- Disk drive's read/write head lays down a magnetic pattern on the disk's surface
- Enables the disk drive to organize and store the data in the data organization defined for the disk drive of the computer

b) OS-level disk formatting

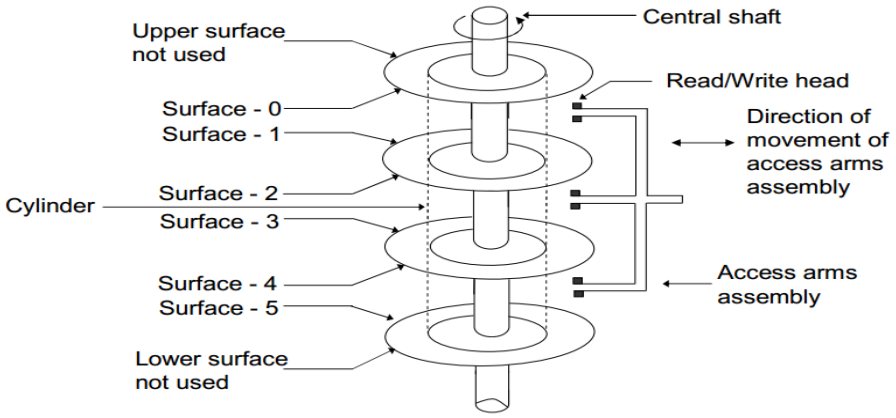
- Creates the File Allocation Table (FAT) that is a table with the sector and track locations of data
- Leaves sufficient space for FAT to grow
- Scans and marks bad sectors

III.2.4 **Master Boot Record (MBR)**

The **Master Boot Record**, created when you create the first partition on the hard disk, is probably the most important data structure on the disk. It is the first sector on every disk. The location is always track (cylinder) 0, side (head) 0, and sector 1.The **Master Boot Record** contains the Partition Table for the disk and a small amount of executable code. The **Master Boot Record** then finds the system partition's starting location on the disk, and loads a copy of its Partition Boot Sector into memory. The Master Boot Record then transfers execution to executable code in the Partition Boot Sector.

III.2.5 Storage Capacity of a Magnetic Disk

Several parameters must be considered while finding out the capacity of a magnetic disk. These parameters include number of recording surfaces, number of tracks per surface, number of sectors per track and number of bytes per sector. Therefore, one can define storage capacity of a disk as a multiple of all the above parameters.



No. of disk platters = 4, No. of usable surfaces = 6. A set of corresponding tracks on all the 6 surfaces is called a **cylinder**.

Storage capacity of a disk system = Number of recording surfaces x Number of tracks per surface x Number of sectors per track x Number of bytes per sector

III.2.6 Advantages of Magnetic Disks

→ More suitable than magnetic tapes for a wider range of applications because they support direct access of data
→ Random access property enables them to be used simultaneously by multiple users as a shared device.
→ Suitable for both on-line and off-line storage of data
→ the cost per bit of storage is low for magnetic disks.
→ An additional cost benefit is that magnetic disks can be erased and reused many times

→ Floppy disks and zip disks are compact and light in weight. Hence they are easy to handle and store.
→ Very large amount of data can be stored in a small storage space
→ Data transfer rate for a magnetic disk system is normally higher than a tape system

III.2.7 Limitations of Magnetic Disks

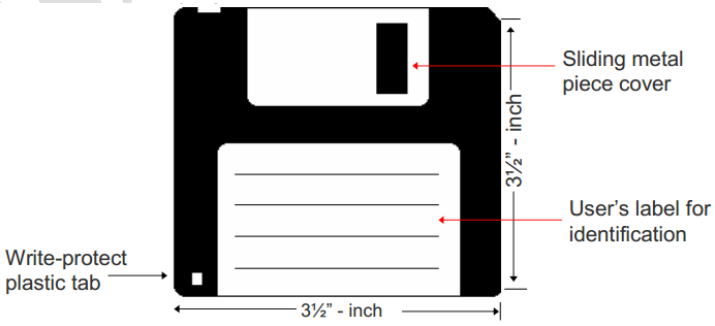
→ A disk crash or drive failure often results in loss of entire stored data. It is not easy to recover the lost data.
→ Some types of magnetic disks are not so easily portable like magnetic tapes
→ the cost of magnetic disks is low, but the cost of magnetic tapes is even lower
→ Must be stored in a dust-free environment
→ They possess slow data access speed as compared to the magnetic disks.

III.2.8 Types of Magnetic Disk

All magnetic disks come in the form of round platters. These disks are available in different sizes, shapes and designs. Some are attached to the read/write head assembly, whereas some are available in the form of removable disks. Broadly, magnetic disks can be classified into three types: ***floppy disk, hard disk*** and ***zip disk***.

1) Floppy disks

A **floppy disk**, or **diskette**, is a disk storage medium composed of a disk of thin and flexible magnetic storage medium, sealed in a rectangular plastic carrier lined with fabric that removes dust particles. Floppy disks are read and written by a **floppy disk drive** (FDD). Floppy diskettes are small, inexpensive, readily available, easy to store and have a good shelf life, if stored properly.



The two types of floppy disks in use today are:

→ **5¼-inch diskette**, whose diameter is 5¼-inch.It is encased in a square, flexible vinyl jacket
→ **3½-inch diskette**, whose diameter is 3½-inch.It is encased in a square, hard plastic jacket

Size (Diameter in inches)	N° of surfaces	N° of tracks	N° of sectors/tracks	N° of bytes/sector	Capacity in bytes	Approximate capacity
5 ¼	2	40	9	512	368640	360 KB
3 ½	2	80	36	512	2949120	2.88 MB
3 ½	2	80	18	512	1474560	1.44 MB

2) Hard disk

A **hard disk drive** (**HDD**) is a data storage device used for storing and retrieving digital information using rapidly rotating disks (platters) coated with magnetic material. An HDD retains its data even when powered off. Data is read in a random-access manner, meaning individual blocks of data can be stored or retrieved in any order rather than sequentially. An HDD consists of one or more rigid ("hard") rapidly rotating disks (platters) with magnetic heads arranged on a moving actuator arm to read and write data to the surfaces. Depending on how they are packaged, hard disks are of three types: ***Zip/Bernoulli disks, Disk packs, Winchester disks***

3) Zip disk

A Zip drive is a small, portable disk drive used primarily for backing up and archiving personal computer files. Zip drives and disks come in two sizes. The 100 megabyte size actually holds 100,431,872 bytes of data or the equivalent of 70 floppy diskettes. There is also a 250 megabyte drive and disk.

III.3 Optical Disk

III.3.1 What is an Optical Disk?

An optical disk is a storage medium from which data is read and to which it is written by lasers. The typical optical disc, stores information in deformities on the surface of a circular disc and reads this information by illuminating the surface with a laser diode and observing the reflection. The optical disk storage system consists of a rotating disk coated with a thin layer of metal (aluminum, gold or silver) that acts as a reflective surface and a laser beam, which is used as a read/write head for recording the data onto the disk. There are three basic types of optical disks:

- **CD-ROM :** Like audio CDs, CD-ROMs come with data already encoded onto them. The data is permanent and can be read any number of times, but CD-ROMs cannot be modified.
- **WORM :** Stands for *write-once, read -many*. With a WORM disk drive, you can write data onto a WORM disk, but only once. After that, the WORM disk behaves just like a CD-ROM.
- **Erasable:** Optical disks that can be erased and loaded with new data, just like magnetic disks. These are often referred to as *EO* (**e**rasable **o**ptical) disks.

III.3.1 Types of Optical Disks

a) Compact Disk

Compact disk is the most popular and the least expensive type of optical disk. It was originally intended only for storing music (in the form of digital audio) and can record about 80 minutes of uninterrupted playing time. A **CD** is capable of being used as a data storage device along with storing of digital audio. Compact disks are available in various formats: **CD-ROM** (*compact disk-read-only memory*), **CD-R** (compact disk-recordable) and **CD-RW** (compact disk-rewritable) disks.

- A **CD-ROM** disk comes with pre-recorded data by the manufactures and can be read but cannot be altered.
- **CD-R** is a type of WORM (write once-read many) disk that allows you to record your own data. Once written, the data on the CD-R can be read but cannot be altered.
- **A CD-RW** disk is rewritable version of CD-R, which means, it allows writing, erasing and rewriting of the data several times.

The data recorded on all CD formats can be read using the CD-ROM drive; however, to write data on CD-R and CD-RW disks, one needs a special peripheral device known as CD-writer (or CD-burner)

b) Digital Versatile Disk

DVD, initially called digital video disk, is a high-capacity data storage medium.
NOTE: *Like CDs, DVDs are also available in different formats: DVD-ROM, DVD-R and DVD-RW.*

c) Blu-ray Disk

A Blu-ray Disc is a high density optical disc storage medium, which is used for the storage of all high-definition digital formats like audio, video, and play-station games and so on. They have the same physical appearance as a DVD. The name "BLU-RAY" is actually a combination of the colour "blue" and "ray". Here blue refers to the blue colour of the laser that is used for its reading and ray refers to the optical ray.

Like CDs and DVDs, Blu-ray disks are also available in different formats:

- **BD-ROM**: It comes with prerecorded content that can only be read.
- **BD-R**: It is a WORM type of disk on which you can record data only once.
- **BD-RW**: It is similar to BD-R disk, but the difference is that it is rewritable. This means that the data can be erased and recorded a number of times on the same disk.
- **BD-RE**: It is also a rewritable disk, but is used only for high-definition audio/video and television recording

Blu-Ray Disc (BD) vs DVD

- Both of them have the same physical appearence. [Thickness = 1.2 mm]
- The single layer Blu-ray disc can store up to 27 GB data. A singe layer DVD can hold only 4.7 Gb of data.
- A DVD needs two substrates and they should be bonded. But a Blu-ray disc requires only one substrate.
- The production cost of Blu-ray is lesser than that of a DVD because there is no need for bonding of substrates..
- The Blu-Ray disc uses violet-blu laser with improved lens specifications, while a DVD uses red laser.

III.4 Magneto-Optical Disk

As implied by the name, these disks use a hybrid of magnetic and optical technologies. A magneto-optical disk writes magnetically (with thermal assist) and reads optically using the laser beam. A magneto-optical disk drive is so designed that an inserted disk will be exposed to a magnet on the label side and to the light (laser beam) on the opposite side.

III.5 Memory Stick

Memory Stick also known as '**Memory Card**' is a digital storage device, which is designed to be used with portable electronic devices such as mobile phone, digital camera, PDA, iPod and so on. It was launched in 1998 by Sony and immediately gained popularity due to its support for fast data transfer speed and large storage capacity.

Nowadays, several different standards or formats of Memory Stick are available in the market, which are as follows:

- **Memory Stick PRO (SP)**: It supports marginally higher data transfer speed than the original one and provides theoretical storage capacity of up to 32 GB
- **Memory Stick Duo (SD)**: It is a small size Memory Stick for small, pocket-sized devices such as mobiles, music players, digital cameras, and so on.
- **Memory Stick PRO Duo**: Although Memory Stick Duo fulfils the need of smaller memory card for pocket-sized devices, it is superseded by Memory Stick PRO Duo because of its slow transfer rate and limited storage capacity of 128 MB. Memory Stick PRO Duo provides larger memory space (up to 32 GB) and high speed of data transfer to/from the card.
- **Memory Stick PRO-HG Duo**: Unlike Memory Stick PRO which has a parallel interface of 4 bits, Memory Stick PRO HG Duo has 8-bit parallel interface. In addition, the clock frequency has increased from 40 to 60 MHz in the Memory Stick Pro-HG Duo.
- **Memory Stick Micro (M2):** It is a light and compact storage medium, which comes in the dimension of $15 \times 12.5 \times 1.2$ mm^3. It offers large storage capacity ranging from 16 MB to 32 GB and transfer speed of 160 Mb/s.

III.6 Universal Serial Bus

Universal Serial Bus (USB) (developed by Intel) is a set of connectivity specification that establishes communication between personal computers and devices such as ***mouse, keyboard, pen drive*** and ***external hard disk drives***.

a) Pen Drive

The flash drive is a high storage (ranging from 1 to 512 GB) capacity device and is physically small enough to fit into a pocket. In addition, it

is fast, robust and reliable, and requires very less power to operate, which it gets through USB port and hence no battery is required.

b) External Hard Disk Drive

External hard disk drive is a type of hard drive that resides in its own enclosure (called hard drive cage) outside the computer case and is connected to the system through interfaces like USB.

The internal structure and functioning of external hard disk drive is similar to the internal hard disk drive. Hence, external hard disk drive is a reliable and high-capacity storage media. In addition, it is portable and provides plug and play feature.

III.7 Mass Storage Devices

To get a vast amount of storage capacity in a computer system, a different kind of storage system is used. In such type of system, multiple units of similar kinds of storage media are associated together to form a chain of mass storage devices. These storage media may include multiple magnetic tape reels or cartridges, multiple arrays of magnetic disks or multiple CD-ROMs as storage devices.

However, they have huge amount of storage capacity and possess minimum cost per bit storage. Mass storage devices are cost-effective option to the online tapes and disks storage in situations where large storage capacity is required and where prompt data access is not essential. When used as offline storage, they are referred as an archival storage.

Broadly speaking, mass storage devices are categorized into three types:

- **Redundant Array of Inexpensive Disks** (RAID): The basic idea of RAID is to combine multiple hard disks into an array of disk drives to obtain high performance, large capacity and reliability. These arrays of drives appear to the host computer as a single logical drive.

- **Automated Tape Library**: An automated tape library comprises numerous sets of magnetic tapes along with their drives and controllers mounted in a single unit. The unit comprises one or more tape drives to perform read/write operations on the tapes in the tape library.

- **CD-ROM Jukebox**: A CD-ROM jukebox comprises numerous sets of CD-ROM disks along with their drives and controllers mounted in a single unit. The unit comprises one or more CD-ROM drives to perform read/write operations on the CD-ROM in the jukebox. In the multiple CD-ROM drive environment, these CD-ROMs can be simultaneously read or written, resulting in the speedy rate of data transfer.