Chapter No. 2 Storage Device & interfacing

Primary Memory: RAM and ROM

- **RAM (Random Access Memory)** is volatile (temporary). Programs and data can be written to and erased from RAM as needed. This means that RAM does not retain its bit configuration when the power is turned off, but ROM does
- **ROM (Read Only Memory)** is nonvolatile (permanent). The contents in locations in ROM cannot be changed

Secondary Storage Devices:-

- Storage devices hold data, even when the computer is turned off.
- The physical material that actually holds data is called a storage medium. The surface of a floppy disk is a storage medium.
- **The two primary storage technologies are magnetic and optical.**
- **Magnetic Storage Devices**
  - Diskettes (floppy disks) (FDD)
  - Hard disks (HD)
  - USB flash drive
  - Magnetic tape
- **Optical Storage Devices**
  - Compact Disk Read-Only Memory (CD-ROM)
  - Digital Video Disk Read-Only Memory (DVD-ROM)
  - CD-Recordable (CD-R)
  - CD-Rewritable (CD-RW)

Recording Techniques: FM, MFM, RLL, perpendicular recording

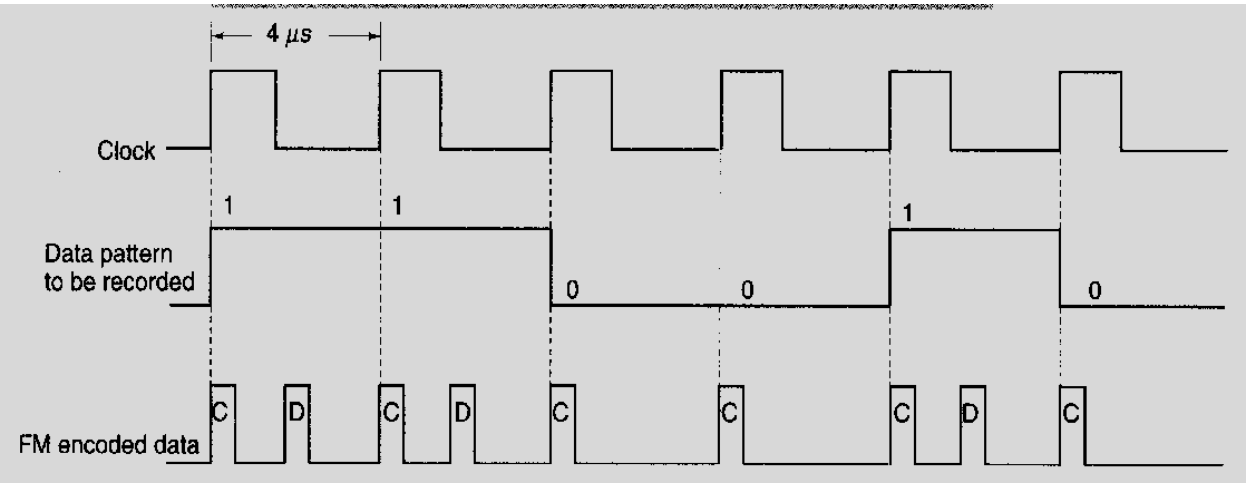
Q. Describe Modified Frequency Modulation (MFM) and Run Length limited (RLL) techniques of recording with suitable example. (For explanation 2 marks, Waveform or coding 2 marks)

Three most common encoding methods are:

- 1. FM encoding method
- 2. MFM encoding method
- 3. RLL encoding method

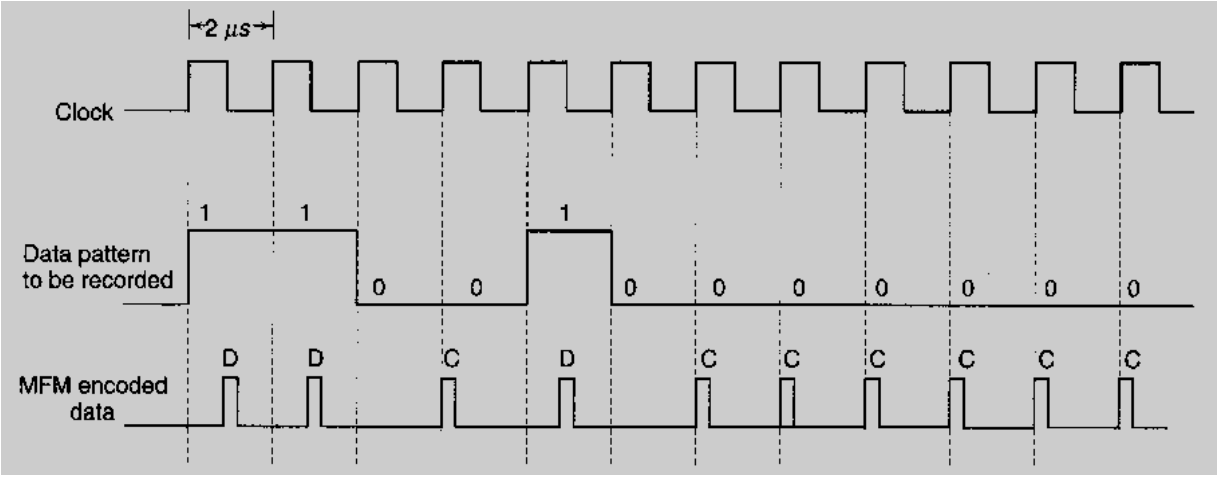
1. FM Encoding Scheme:

- FM or Frequency Modulation was the original data-encoding scheme used for storing the data on the magnetic recording surface.
- This method of data encoding is also known as the "Single density recording".
- In this method, a clock signal is put with every data signal on the recording surface. This clock signal is used for synchronizing the read operation, as there will always be a clock signal, whether the data signal is there or not.
- In this FM method of data recording a 1 bit is stored as two pulses(one clock pulse and one data pulse), and a o bit is stored as a one pulse and one gap or no pulse.
- For example, a binary number 1011 will be stored as PP PN PP PP



2. MFM Encoding Scheme:

- More data can be stored on the same surface or the data storage density can be increased, if the number of pulses required to store the data can be minimized.
- When minimizing the pulses, one should be careful that the number of no pulses together should not be very long; otherwise the disk controller may go out of synchronization with the data.
- The MFM (modified frequency modulation) method of data storage, by reducing the number of pulses, is able to store more data without any data and synchronization loss. In MFM recording the 0s and 1s are encoded as given below
- **1 is always stored as no pulse, and a pulse(NP)**
- **0, when preceded by another 0, is stored as a pulse, and no pulse(PN)**
- **0, when preceded by a 1, is stored as two no pulses(NN)**
- If you store 1001 on the disk surface using the MFM storage method, it would be stored as NP NN PN NP.



3. RLL Encoding Scheme

- The RLL is encoding or the run length limited encoding is the most common encoding scheme used in the hard disk storage.

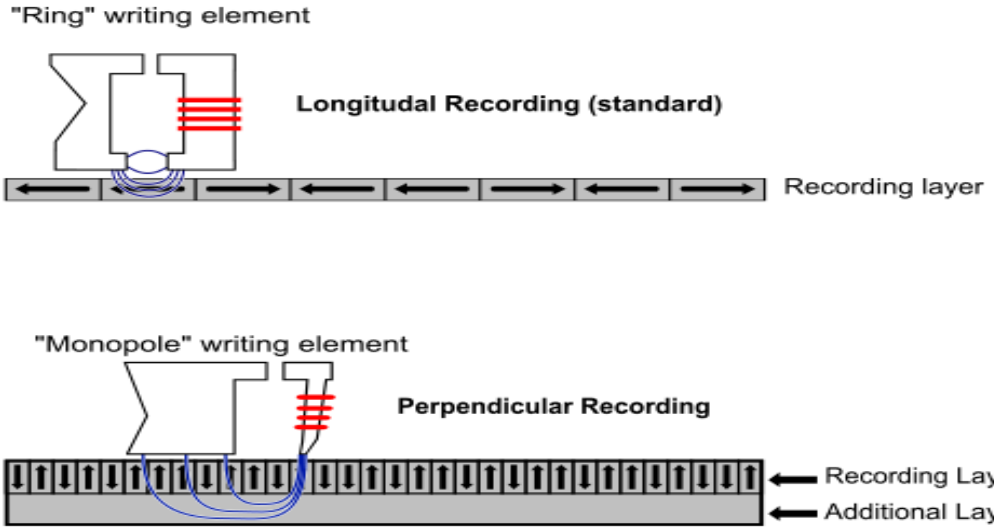
- It records the information on given disk twice than MFM & three times as much information of FM.
- It provides much faster data transfer rate compared to the other encoding technique.
- The Run length Limited name comes from the minimum number (run Length) and maximum number (run Limit) of "no pulse" values allowed between two pulses.
- RLL encoding is work based on group of bits the group of 2, 3, or 4 bits generate the pattern these patterns are mapped with the combination of clock & data pulses.
- **Below table is used by IBM to convert bit information to pulse signal.**
- **There are thousands of different translation tables possible for the RLL encoder.**

Example of RLL Encoding Scheme:

Data Bit	Pulse Encoding
10	NPNN
11	PNNN
000	NNNPNN
010	PNNPNN
011	NNPNNN
0010	NNPNNPNN
0011	NNNNPNNN

- For example, if you want to encode a byte 100011 to proper RLL pulse signal then the
- Bit 10 can be encoded as NPNN
- Bit 0011can be encoded as NNNNPNNN

4. Perpendicular Encoding



- Virtually all hard drives record data using longitudinal recording which stores magnetic bits horizontally across the surface of the media.
- However perpendicular recording which aligns magnetic signals vertically on the media surface has the potential to achieve higher data intensities because vertically oriented magnetic bits use less space than longitudinally stored bits.

Hard Disk Drive (HDD) Construction & Working

- It is secondary storage device.
- It is non-volatile storage device.
- It stores huge data on magnetic rotating platters.
- Types of HDD available in market
  1. IDE (PATA) _integrated drive electronics
  2. SATA (serial advanced technology attachment)
  3. SCSI (small computer system interface)

Q. State differences between IDE, SATA & SCSI.

IDE(PATA)	SATA	SCSI
Device level interface supported	Device level interface supported	System level interface
Speed is low	Speed is high compared to IDE	Speed is high compared to IDE & SATA
Used in desktop PC	Used in desktop PC	Used in Server System
40/80 wire cable	4 wire Cable	50 wire cable
Easy to install	Easy to install	Complex to install
Adapter not required	Adapter not required	Adapter required

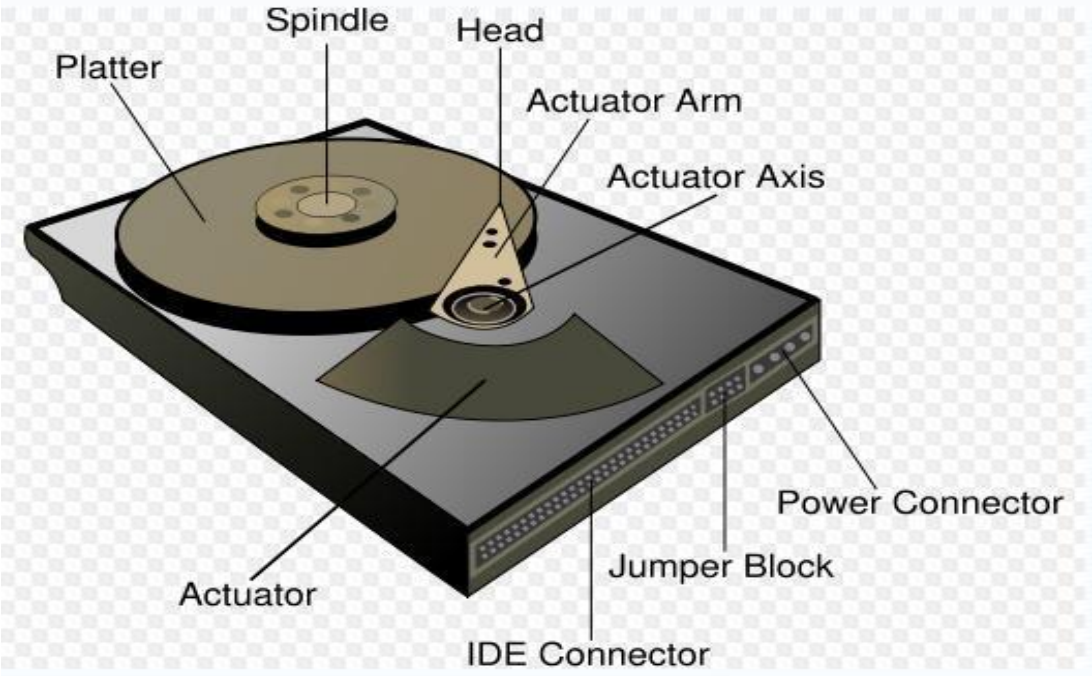
Hard Disk Construction

Q. Explain working principle of HD with neat diagram. OR

Q. Explain the working of HD with the help of its construction.

- A hard disk drive is made up of several physical components

1. Disk platter
2. Read/Write head
3. Head arm/Head slider
4. Head actuator mechanism
5. Spindle motor
6. Logic board
7. Air filter
8. Bezel
9. Cables & Connectors



Hard Disk Drive

1. **Platters:-**
   - The data's are stored in this media.
   - Store information on one or more flat circular disc called platter.
   - Platter are mounted on a spindle.
   - Platter size (i.e. diameter) is called form factor of HDD.
   - Platter size are 5.12 inch, 3.74 inch etc.
   - The 5.25" platter were used in earlier days
   - The 2.5", 1 1/8", 1 1/3" & 1" platters are using in the laptop computers.
2. **Read / Write heads**
   - A hard disk drive usually has one read/write head for each platter surface(meaning that each platter has two sets of read/write heads- one for top side and one for bottom side
   - These heads are connected on a single movement mechanism so heads across the platters in unison.
   - The HDD uses various types of heads for read/write purpose.
     - ✓ Ferrite head
     - ✓ Metal-In-Gap Head, Thin Film Head
     - ✓ Magneto Resistive Head
     - ✓ Giant Magneto Resistive Head
3. **Head Arm/Head Slider**
   - The arm on which the Read/Write head is located.
   - Slider of this size is called "Nano Slider".

4. Head Actuator Mechanism

- This mechanism moves the heads across the disk and positions them accurately above the desired cylinder.
- Two basic Categories are used
  a. Stepper Motor Mechanism
  b. Voice Coil Actuator

1. Stepper Motor Actuator

- It is a motor which rotates in steps
- Stepper motor turns in a fixed angle
- The smallest fixed angle is called a "detent"
- The stepper motor is connected to the R/W head by using two mechanism.

2. Voice Coil Actuator:-

- In the voice coil actuator head moves in & out in a straight line
- It is more faster and accurate
- Stepper motor is used in the Open loop disk drive and the Voice coil actuator is used in the closed loop disk drive
- All hard disk drives being manufactures today use voice coil actuator.

5. Spindle Motor

- It is the main motor which rotates the hard disk drive platter
- It is called Spindle motor because it is directly connected to the Spindle on which the platters are connected
- Spindle motor rotates at a speed of 3600 to 7200 RPM or more…

6. Logic Board

- A disk drive will have a board containing the electronics that control the drive's spindle and head actuator systems these are called logic boards.
- They present data to the controller in a planned format.
- They may be removed and replaced to rectify a logic board problem.

7. Air filter

- To filter the air.
- Most HDD will have two air filters
- The two air filters are One is called the Recirculating Air filter & the second one is called Breather filter

8. Bezel

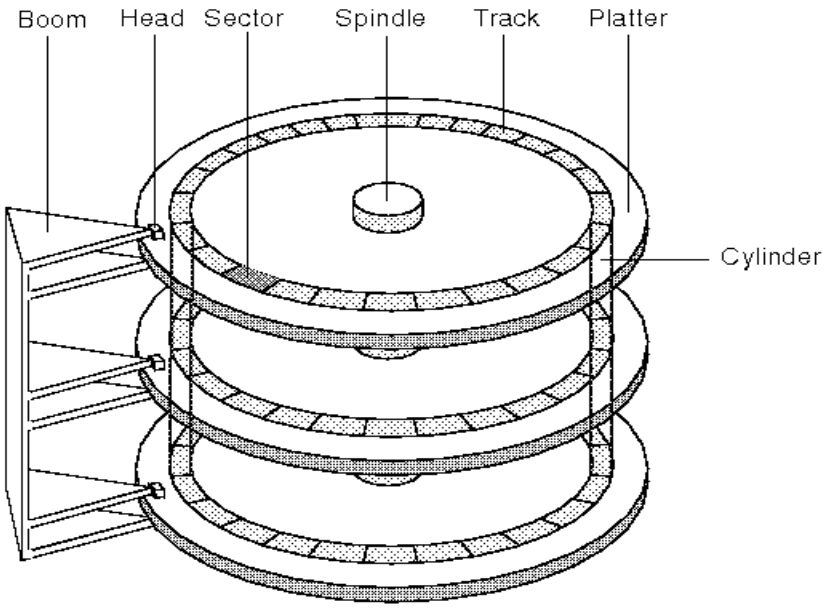
- It is front faceplate provided on most of the HDD
- Connected internally & hidden to user

9. Cables & Connectors

- Cable and connectors are used to connect HDD to the main computer system.
- All hard disk drive contains connections for Data/Control interface connector, Power connector

Terms Related to Hard disk

Q. Explain following terms related to hard disk-cluster, cylinder, sector, landing zone. (Each term – 1M.)



1. Tracks

- Tracks are concentric circles placed on the surface of each platter
- All information stored on a hard disk is recorded in tracks
- A modern hard disk has tens of thousands of tracks on each platter.

2. Sector

- Sector is a basic unit of data storage on hard disk
- Each track is broken into smaller units called sectors.
- Data is stored on a sector
- Each sector holds 512 byte of user data.

3. Cylinders

- Combining of the Same tracks on different platters called cylinder
- In a hard disk the data is stored in a cylinder by cylinder method
- i.e. 1st all the tracks of same cylinder are written, once the cylinder becomes full the read/write head moves to the next cylinder.
- A track & cylinder are two different things, but they are used simultaneously
- Total no of tracks on a side = Total no of cylinders
- The cylinder numbering starts from 0-….
- It starts from the outermost of the platter.

4. Clusters

- A group of sector is called Clusters.
- It is the smallest unit of data storage which can identified by the operating system.

- When OS writes some information on the hard disk, it does not allocate the space sector wise, instead uses a new unit of storage called "Cluster".
- Clusters are the minimum space allocated by DOS when storing any information on the disk
- Even to store only one byte long information on the disk requires minimum one cluster area on the disk surface.
- A cluster can be made up of one or more sectors, it depends on disk type being used.
- This reduces the size of FAT that DOS uses to keep track of the used and the empty disk space.
- Clusters are used to allocate the storage area for data area only, FAT and directory areas are not allocated according to the cluster size.

5. Landing Zone

- It is an area of the platter usually near its inner diameter, where no data is stored
- This area called the contact start/stop.
- Disk are designed to such to park the heads in the case of unexpected power loss
- A special track that is designated to be where the heads will be placed for track offs & landings.
- The process of moving the heads to this designated area is called head parking.

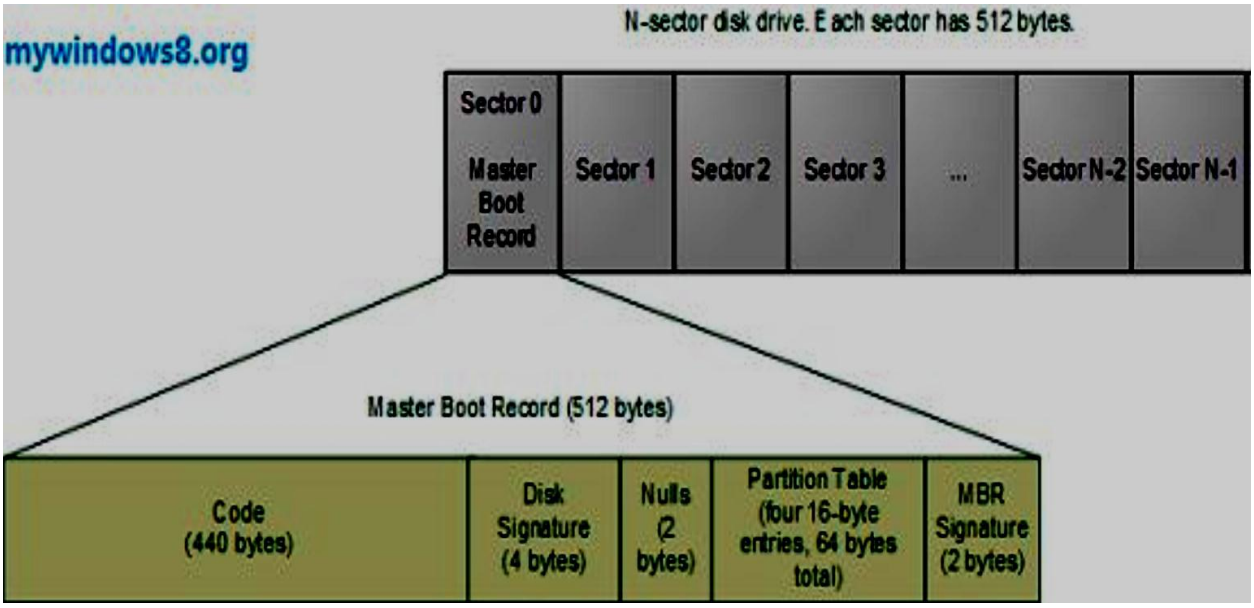
6. Master Boot Record

- Short for **M***aster* **B***oot* **R***ecord,* a small program that is executed when a computer boots up.
- Typically, the MBR resides on the first sector of the hard disk or diskette that identifies how and where an operating system is located so that it can be boot (loaded) into the computer's main storage or random access memory.
- The program begins the boot process by looking up the partition table to determine which partition to use for booting.
- It then transfers program control to the *boot sector* of that partition, which continues the boot process. In DOS and Windows systems, you can create the MBR with the FDISK /MBR command

The MBR contains two elements;

1. Executable code and
2. A partition table,

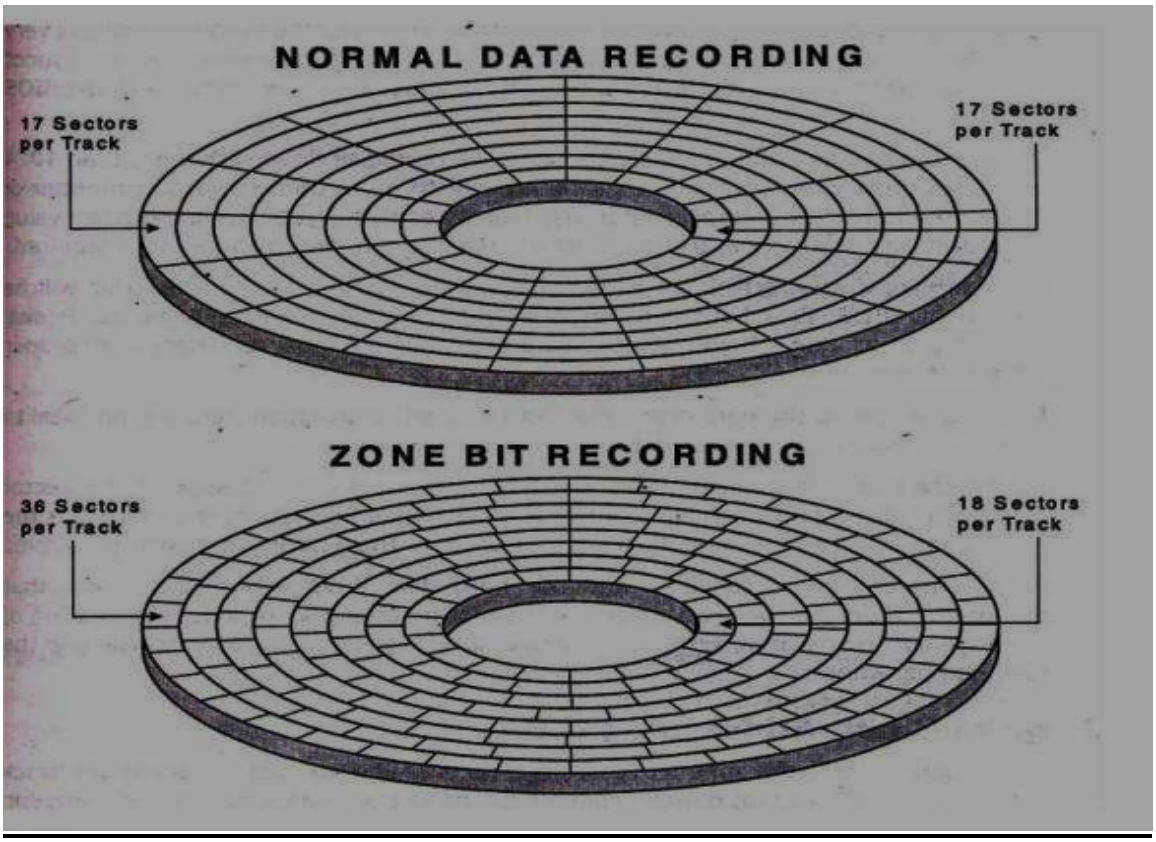
- Which identifies each partition residing on the hard drive. The MBR executable code or program begins the boot process by looking up the partition table to determine what partition holds the operating system.
- This program looks for two hidden program files IO.SYS and MSDOS.SYS for DOS and executes IO.SYS program first. This program in turn loads MSDOS.SYS and COMMAND.COM into RAM to complete the process of booting.
- From the below figure, you can see that a disk drive is composed of N sectors and each sector is of 512 bytes.



- Out of the N sectors, the first sector is assigned to the Master Boot record. The first 512 bytes of the BIOS is the Master Boot Record. MBR is composed of two components: a Bootstrapping program and the partition table. The code can be Windows loader, UNIX loaders, or a virus.
- Next, comes the partition table. The partition table is of 64 bytes and a 16 byte part which tells about the partition of the disk.
- The MBR is very small in size. Its machine code just helps to load that sector which is responsible for booting the associated partition.

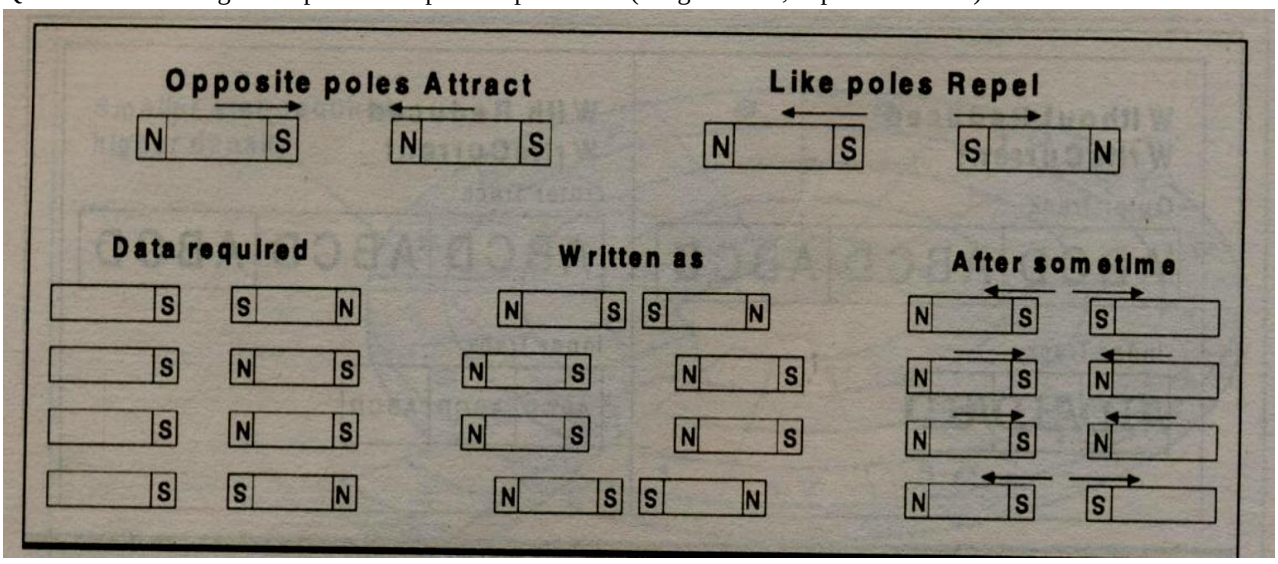
7. Zone Bit Recording

- One way that capacity & speed have been improved over time.
- Used outer track for larger utilization.
- The standard for first hard disk was 17 sectors per track.
- Outside tracks larger than inside tracks.
- To eliminate this wastage space modern HD employ technique Zone bit recording.
- Also called zone recording or multiple recording.
- With ZR tracks are grouped into zones based on their center of the disk.
- Each zone assigned a number of sectors per track.



8. Write Pre-compensation

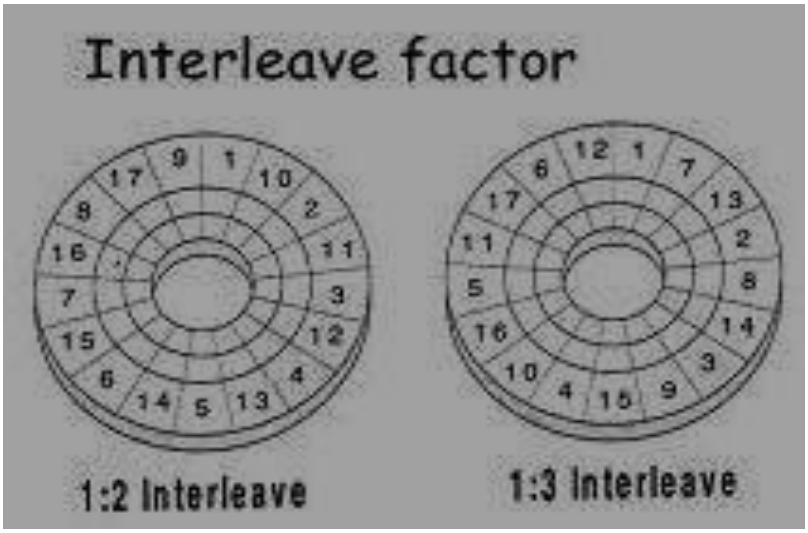
Q. With suitable diagram explain write pre-compensation. (Diagram 2 M, explanation -2M)



- It is useful for drives using standard track, sector format
- Drives using zone bit recording do not require any write pre- compensation
- The magnetic particles used to write on the disk surface have north and south poles
- Like poles repel and unlike poles attract

- In outer surface of hard disk platter, magnetic particles are far apart to be affected by the attraction and repulsion of magnetic particles.
- In the inner tracks of the disk drive, the density of the magnetic are very high and adjacent particles start to attract and repel.
- This will force to change the information written on the disk.
- To compensate for this shift of data particles due to attraction and repulsion, the drive can write the data apart or closer than the required position.
- The particles will slowly shift to the required position because of attraction and repulsion
- This process of writing the data closer or farther to compensate for attraction or repulsion of magnetic particles is called Write pre-compensation.
- The cylinder from which this pre-compensation is started is called pre-compensation cylinder. This value will be used by all the cylinders that are towards the centre of the drive.

9. Interleave and Interleave factor



- Reading on HD sectors is sequentially than disk read operation will very slow
- Numbering the sectors out of order with leaving a gap of one or more sectors in the sector numbering is called interleaving
- Interleave factor- the number of sectors that pass beneath the read/write heads before the next numbered sector arrives e.g. 1:3
- 17 revolution required before interleaving now only 2 revolution required for it.

Formatting

- **What is formatting? Explain low level and high level formatting. Formatting (1 M)**
  - It prepares a blank hard disk for a particular OS.
  - It puts magnetic marks of tracks and sectors on the platter surface.
  - The storage capacity of formatted hard disk is always less than the capacity of unformatted disk.

- A typical sector has 3 standard components.

- **a. Identification field** which contains the address of the sector i.e. the track head and the sector number.
- **b. Data field** which contains data recorded at a particular location. It also contains error detection and correction codes.
- **c. Number of gaps.**
  FAT and root directory are also put on the platter at the time of formatting. Hard Disk requires a low level formatting and a high level formatting to make it useful for data storage.

Two types of formatting:-

1. Low level formatting (physical formatting)
2. High level formatting (logical formatting)

1. Low level formatting (physical formatting):-

- FDD- require only one formatting.
- HDD- require two formatting.(i.e. low & high level)
- Low level formatting does the job of magnetically dividing disk into tracks & sectors.
- It is also known as physical formatting or true formatting.
- After low level format next step to prepare the HDD for partitioning.
- Single HDD can have minimum 1 partition & maximum 24 partition(C to Z).
- Nowadays, Low level formatting is done from factory itself.
- Functions performed during LLF:
  1. Dividing disk surface into track & sectors.
  2. Establishing interleave factor
  3. Marking identification information on each track & sector.
  4. Marking defective sector.

2. High level formatting (logical formatting)

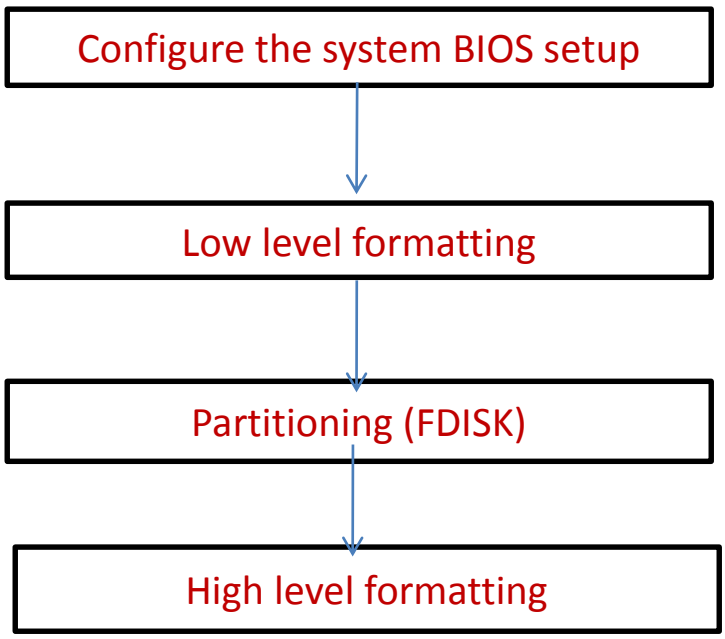
- Once LLF & partition is over HDD is ready high level formatting.
- During HLF the format program, verifies all the track & sectors in the particular partition.
- Functions of HLF:
  1. Scan the disk for tracks & sector marked badly during the LLF.
  2. After scanning the entire disk, it return to 1st sector of partition & write volume boot record.
  3. The write of next sector file allocation table (FAT). Immediately after 1st copy of FAT & 2nd copy of FAT is written.
  4. Next writes a blank root directory on the sector.
  5. If the parameter is specified then copy the system files (IBMDOS.com or IO.sys & MSDOS.sys) & COMMAND.com file on HDD,
  6. Then it copies another hidden system file called DBSPACE.BIN to the root directory.
  7. ACK volume label to the user.

Q. Difference between LLF & HLF

Sr No.	Low level	High level
1.	It is a process of outlining the track & sectors on HD platters. And then writing the control structure.	It is the process of writing file system structure and this can be used to store programs & data & boot sectors. It is that you create the file system (NTFS, FAT etc.)
2.	It is the middle step in HDD formatting & partitioning.	It is done after a low level format because without LLF the disk wouldn't know where to write data to in 1st place.
3.	It is performed at the time of manufacturing.	It is performed after installation of HD or after partitioning of HDD.
4.	It is performed through 3rd party utility s/w or BIOS.	It is performed through the format DOS command.
5.	It is difficult to perform.	It is easy to perform.

Partitioning:-

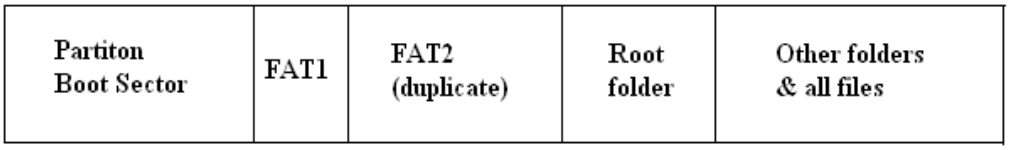
- It is new concept introduced by IBM when they are launch 10 MB HDD.
- It means diving the drives into 2 or more logical parts or volumes.
- DOS command FDISK.exe is used to partition a HDD.



FAT (File Allocation Table)

Q. What is FAT? List two features of FAT 32. (1 M each)

- File system developed by Microsoft for MS-DOS(1977)
- Primary file system for windows OS
- Located at master boot sector of bootable disk
- It has 2 important functions:
  1. It contains the allocation information for each file on the volume in the form of link lists of allocation unit
  2. It indicates which allocation units are free for assignment to a file that is being created or extended.
- FAT file system is simple & reliable.
- It does not loose data.
- It does not use lot of memory.
- It is simple array of 12 bit, 16 bit or 32 bit data elements.
- Comes in three different types: FAT12, FAT16 & FAT32.
- Structure of FAT volume



FAT12

- Initial version FAT
- FAT uses 12-bit binary number to hold the cluster number
- A volume formatted using FAT12 can hold a maximum of 4086 clusters
- FAT stores information about the clusters on the disk in a table.
- It is supported upto 32 MB floppy disk or HD size.

FAT16

- It was introduced in 1988 as the 2nd version of FAT file system.
- 16-bit binary number to hold cluster numbers
- FAT 16 hold a maximum 65536 clusters
- It supports drive size up to 2GB.
- Volumes ranging in size from 16MB to 2GB

FAT32

- Supported by newer versions of windows (95, 98, ME & 2000)
- It uses 28-bit binary cluster number not 32 because 4 of the 32 bits are “reserved”
- 28 bits are still enough to permit huge volumes.
- It can handle volumes with over 268 million clusters
- Support drives up to 2TB in size

NTFS (New Technology file system)

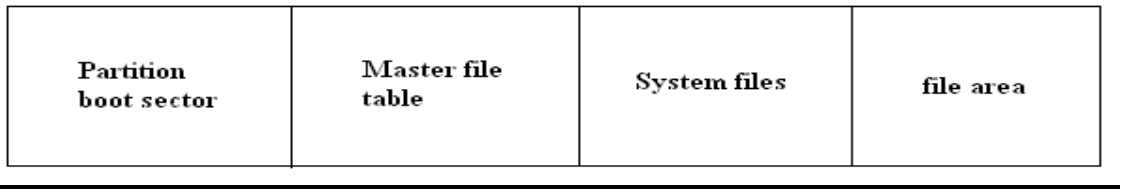


Fig. Format of NTFS volume

- Standard file system that was introduces of Microsoft in 1993 with Windows NT 3.1
- Also include Windows (2000, XP, 2003S, 2008S & Vista)
- Improvement of FAT in terms of performance, extendibility & security.
- Perform faster operations like read, write, search & file system recovery on very large hard disks
- It Support HDD sizes up to 256TB.
- Integrated file compression
- NTFS was primary file system used in Microsoft win7, win vista, win XP, win 2000, win NT operating systems.
- **NTFS disk is symbolically divided into two parts**
- The first 12% is assigned to MFT(master file table) area
- The rest 88% represents usual space for files storage

Goal of NTFS:-

- Reliability,
- security & access control,
- storage efficiency,
- Long file name.

Features of NTFS:-

1. It allows you to encrypt files & automatically decrypt them as they are used.
2. It supports long file name up to 255chacters.
3. It removes security & access control weakness of FAT.
4. It supports file size up to 2TB.
5. it is a reliable file system as compared to FAT.
6. It allows very large partition sizes (i.e. more than 4GB)
7. Built in file compression facility.
8. Multi data streams.
9. General index mechanism

Q. Compare FAT16, FAT32 & NTFS

Sr. No.	criteria	NTFS	FAT32	FAT16
1	OS	Win Nt,2000,XP, win 7,8	Win 98,ME,2000,XP	DOS

2	Max volume size	2TB	2TB	2GB
3	Max file name length	Up to 255(char)	Up to 255(char)	Standard 8.3
4	System records mirror	MFT mirror file	2nd copy of FAT	2nd copy of FAT
5	Boot sector location	1st & last sectors	1st sector	1st sector
6	Compression	Yes	No	No
7	Built in security	Yes	No	No
8	Disk space	Max	Average	Minimal on large volumes
9	Fault tolerance	Max	Minimal	average

Hard Drive Interfaces

Interfacing means connecting the hard disk drive to the main computer system.

- ATA (Advanced Technology Attachment) interfaces dominate today's market
  - Many changes throughout years
  - Parallel ATA (PATA) historically prominent
  - Serial ATA (SATA) since 2003
- Small Computer System Interface (SCSI)
  - Pronounced "Scuzzy"
  - Used in many high-end systems

1) PATA Parallel Advanced Technology Attachment (IDE)

- IDE stands for integrated Drive/Device Electronics in ST-506/412 interfaces the controller card was with the expansion slot and the drive was connected through cables.
- **Features**

1. Proven and reliable technology integration

2. Upto 133 MB/s interface transfer rate

3. PATA allows cable lengths upto 18 inches (46 cms)

4. Designed for desktop PCs and Notebook PCs with usage in entry servers and consumer electronics as well

5. PATA is based on the original IBM PC ISA bus

2) SATA (Serial Advanced Technology Attachment)

- It is an interface used to connect ATA HDD to computer motherboard.
- Serial ATA (SATA) creates a point-to-point connection between the device and the controller
- **Features**
  - Hot-swappable
  - Can have as many as eight SATA devices
  - Thinner cables resulting in better airflow and cable control in the PC
  - Maximum cable length of 39.4 inches compared to 18 inches for PATA cables
  - It provides low cost storage for user.

- Improved speed & bandwidth
- Easy integration due to improved cabling.
- Easily upgrade their storage devices.

Advantages:-

- SATA is better more efficient interface then PATA standard.
- It supports hot swapping.
- SATA uses only 7 conductor, while PATA uses 40.
- Data transfer at the rate of 150 mbps to 6 gbps.

3) SCSI (pronounces as scuzzy) Small Computer System Interface

- Pronounced "Scuzzy"
- Been around since '70s
- Devices can be internal or external
- SATA replacing SCSI in many applications
- It is a set of standards for physically connecting & transferring data between computer & peripheral devices.

Features:

- Fast & wide data path.
- Supports upto 7 peripheral devices (such as HD, CD-ROM, scanner etc.)
- Faster than Parallel interface.
- Plug & play in nature.
- Data transfer upto 100 MBPS to 160 MBPS

CD-ROM Drive (Compact Disc Read Only Memory)

- CD-ROM drive consists of following components.

1. Optical head.
2. Turntable.
3. Computer interface section.
4. Microprocessor based control system.

1. Optical head:

- It contains the circuitry to read the data from the disc.
- It consists 4 main subassemblies:
  - Laser used to generate a light beam.
  - Lens system to focus laser beam on the disc & to direct reflected light to the photo detector.
  - Servo motor that control the position of the laser & lenses to ensure proper tracking & focus.
  - Photo detector: the reflected light & converts light into electrical impulse.

2. Turntable.

- The turntable rotates the disc & is driven by a servo motor.

- Data is written in continues spiral speed of the turntable must be adjustable. So that information passes over the optical head at a constant speed.

3. **Interface section:**
   - It provides for transfer data between computer & CD-ROM drive.
4. **Microprocessor based control:**
   - The information from photo diodes that is received by the controller is still encoded in 8 to 14 modulation (EFM) data.
   - The decoding of EFM data is done by the microprocessor.

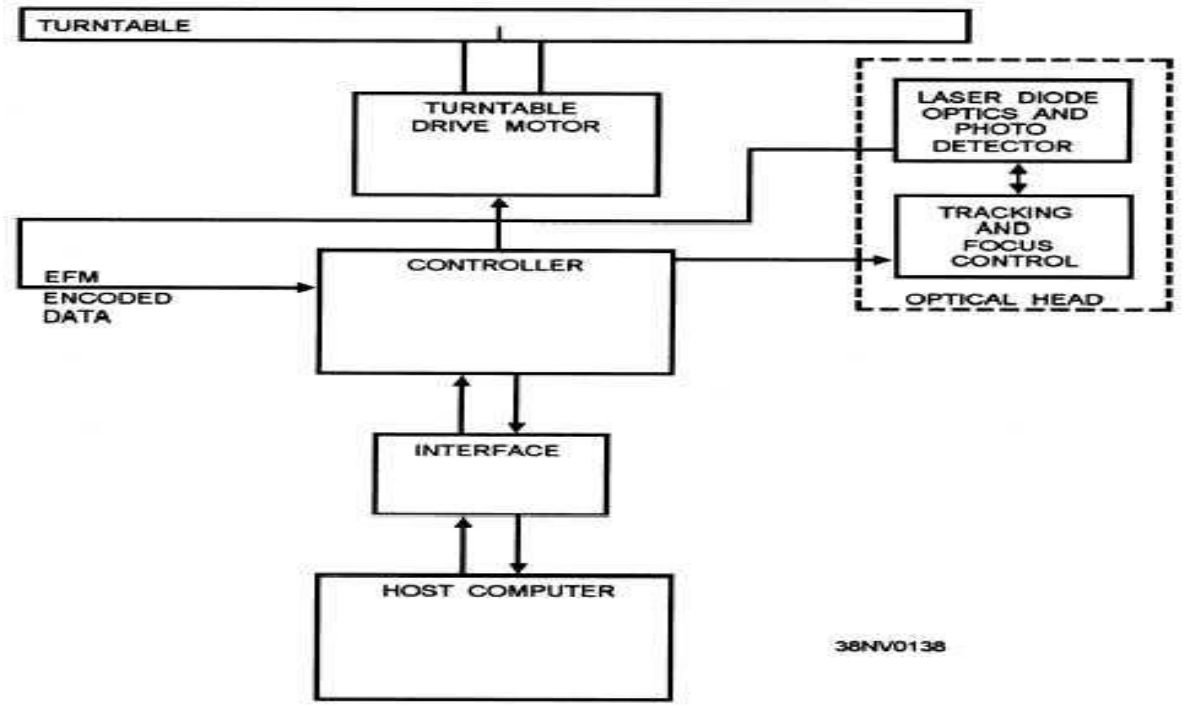


Fig. Block diagram of CD-ROM drive

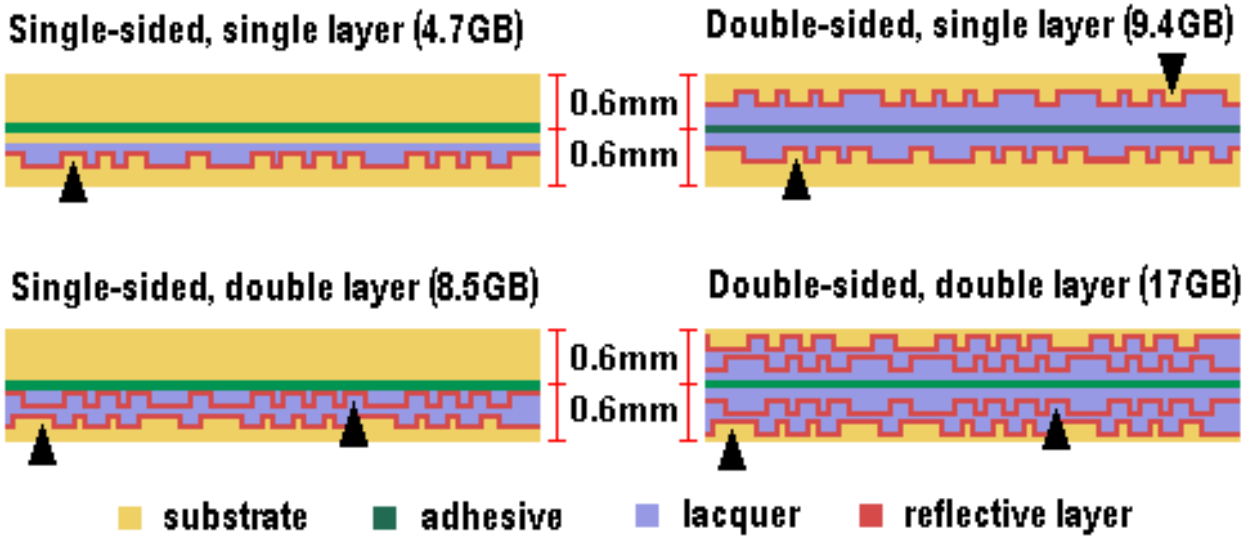
Working of CD-ROM Drive:-

- CD-ROM drive uses a laser beam to read the data.
- Laser reflects light, reflected light read by the photo detector.
- Detail working of CD-ROM Drive:-
  1. Laser diode emits on a reflecting mirror.
  2. Microprocessor controls the servo motor, so that reflecting mirror takes the position of the beam on the correct track on the CD-ROM.
  3. When beam strikes the disk, light is gathered & focused through the 1st lens & sent to beam splitter.
  4. Beam splitter directs the returning laser light toward another focusing lens.
  5. Light beam to a photo detector that converts the light into electric pulses.
  6. Microprocessor decodes these incoming pulses & then sent to the host computer as data.

Construction of DVD (Digital Versatile Disc) Drive:-

- It is very similar to CD-ROM drive.
- It has laser assembly that shines the laser beam onto the surface of the disc to read pattern of bumps.
- DVD drive has the job of finding & recording the data stored as bumps on DVD.
- It consists of 3 fundamental components:-(internal mechanism of CDROM & DVD drive is same)
  1. A drive motor to spin the disc:-the drive motor is precisely controlled to rotate between 200 & 500 RPM (rotate per minutes).
  2. A laser & Lens system to focus on the bumps & read them.
  3. A tracking Mechanism that can be move the laser assembly so the laser beam can follow the track.
- **Recording of DVD:-**

  Recording of DVD is same as CD only difference is as follows:
  1. Higher density data storage.
  2. Less overhead, more area
  3. Multi-layer storage
- **DVD (Digital Versatile Disk)**
  1. Allows up to 17 gigabytes of storage (from 4.7 GB to 17 GB).
  2. Compatible with older CD-ROM technology.
  3. The four versions of the DVD:



Blu-Ray Disc:-

- **Blu ray also known as Blu-ray Disc(**BD is a next generation optical disc format jointly developed by members of the **Blu-ray Disc Association(BDA)** – a group of the world's leading consumer electronics, personal computer and media manufactures (including

Apple, Dell, Hitachi, HP, JVC, LG, Mitsubishi, Panasonic, Pioneer, Philips, Samsung, Sharp, Sony, TDK and Thomson)

- The format was developed to enable recording, rewriting and playback of High Definition Video (HD) as well as storing large amounts of data.
- New optical disc format that is rapidly replacing DVD.
- More than 5 times the storage capacity of traditional DVDs & can hold up to 25GB on a single layer disc & 50GB on dual layer disc.

Blu- Ray specification with DVD & HD-DVD

Parameters	Blu-ray	DVD	HD-DVD
Storage capacity	25 GB(single layer) 50GB(dual layer)	4.7GB (single) 8.5GB (dual)	15GB(single) 30GB(dual)
Laser wavelength	405nm(blue laser)	650nm(red laser)	405nm(blue laser)
Numerical aperture	0.85	0.60	0.65
Disc diameter Disc thickness	120mm 1.2mm	120mm 1.2mm	120mm 1.2mm
Protection layer	0.1mm	0.6mm	0.6mm
Hard coating	Yes	No	No
Track pitch	0.32 micrometers	0.74 micrometers	0.40 micrometers
Data transfer rate(data)	36.0 Mbps(1x)	11.08 Mbps(1x)	36.55 Mbps(1x)
Data transfer rate (video/audio)	54.0 Mbps(1.5x)	10.08 Mbps(<1x)	36.55 Mbps(1x)
Video resolution(Max)	1920*1080(1080p)	720*480(1080p)	1920*1080(1080p)
Video bit rate (Max)	40 Mbps	9.8 Mbps	28.0 Mbps

Video codecs	MPEG-2 MPEG-4 AVC	MPEG-2	MPEG-2 MPEG-4 AVC
Audio codecs	Linear PCM Dolby Digital Dolby Digital plus Dolby TrueHD	Linear PCM Dolby Digital	Linear PCM Dolby Digital Dolby Digital plus Dolby TrueHD
Interactivity	BD-J	DVD-Video	HDi