Recording Techniques: FM, MFM , RLL, perpendicular recording

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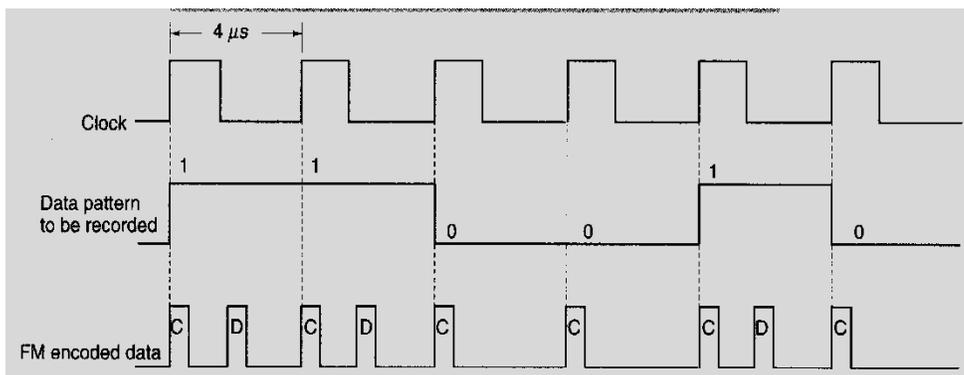
2. MFM Encoding Scheme:

- 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 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.
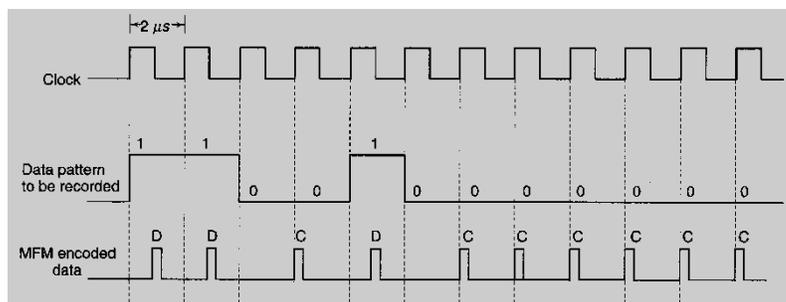
3. RLL Encoding Scheme

- The RLL is encoding or the run length limited encoding is the most common encoding scheme used in the hard disk storage.
- This encoding scheme can be more accurately called as 2,7 RLL encoding because in this scheme in a series or in a running length the minimum number of 0s next to each other is two, and the maximum number of 0s together can not be more than seven.
- The RLL encoding scheme can store 50 percent more information than MFM encoding scheme on a given surface and it can store three times as much information as the FM encoding scheme. 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.

- For the RLL encoding, an encoder/decoder (Endec) table is used to find the pulse signal to be used for different data bit groups. Endec table used by the IBM to convert bit information to the pulse signal is shown below

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 Construction
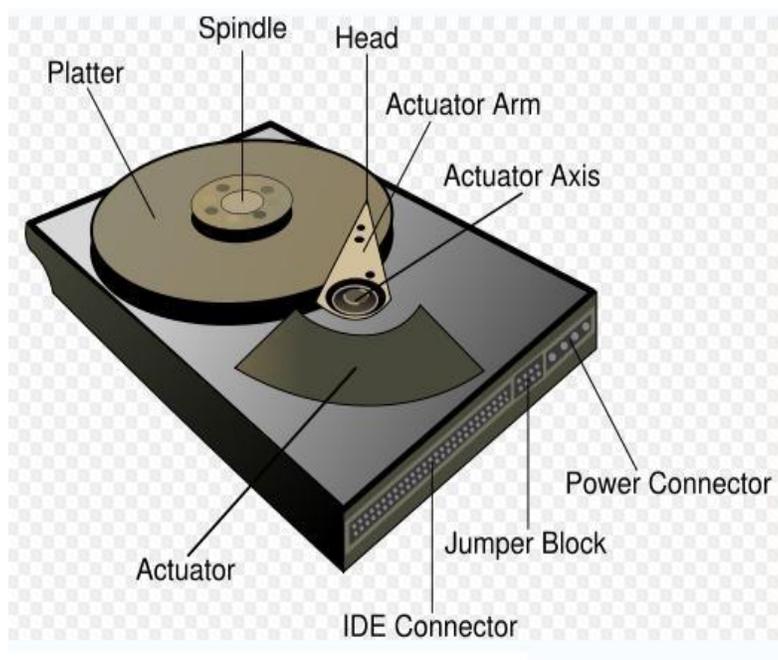
Hard Disk Drive

A hard disk drive is made up of several physical components

1) Disk platters
2) Read/write heads
3) Head actuator mechanism
4) Spindle motor
5) Logic board
6) Cables and connectors
7) Bezel / Front Plate
8) Air Filter

Hard Disk Platters(Disks)

- The platters stores information. It comes in varying sizes like 5.12", 3.14",0.85" etc. The physical size of a drive is expressed as the size of the platters
- Most hard disk have two or more platters
- Platters were originally made from an aluminium/magnesium alloy which provides bothe strangth and light weight
- All modern drives use glass or glass ceramic plates.

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-oneee for top side and one for bottom side
- These heads are connected on asingle 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

Head Actuator Mechanism

- This mechanism moves the heads across the disk and positions them accurately above the desired cylinder.
- Two basic Categories are used
  - Stepper Motor Mechanism
  - Voice Coil Actuator
- Stepper Motor actuators were commonly used on hard drives made during the 1980s and early 1990s with capacities of 100MB or less
- Floppy disk drives position their head by using a stepper motor actuator
- All hard disk drives being manufactures today use voice coil actuator.

Voice Coil Actuator

- The two main types of voice coil positioner mechanisms are

Linear Voice Coil Actuators

Rotary Voice Actuators

Spindle Motor

- The spindle motor spins the platters connected to spindle. The motor is directly connected to the spindle of platters. These platters revolve at exactly 3600 rpm to 1500 rpm. The speed of motor has to be controlled very precisely.
- Normally a feedback loop is employed in the control electronics to monitor the speed. The speed control is fully automatic.

Logic Boards

- A disk drive will have a board containing the electronics that control the drive's spindle and headactuator systems These are calledlogic boards.
- They present data to the controller in aplanned format.
- They may be removed and replaced to rectify a logic board problem.

Cable and Connectors

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

Bezel/ Front Faceplate

Bezel is the front faceplate provided on most of the hard disk drives.

Air Filters

- Nearly all hard disk drives have two air filter. One is called the recirculating filter and the other is called either a barometric or breather filter.
- These filters are permanently sealed inside the drive and are designed never to be changes for the life of the drive.
- A hard disk on a PC system does not circulate air from inside to outside the HDD or vice versa.
- The recircualting filter permanently installed inside HDA is designed to filter only small particles. Scraped off platters during head takeoffs and landings.

Terms Related to Harddisk

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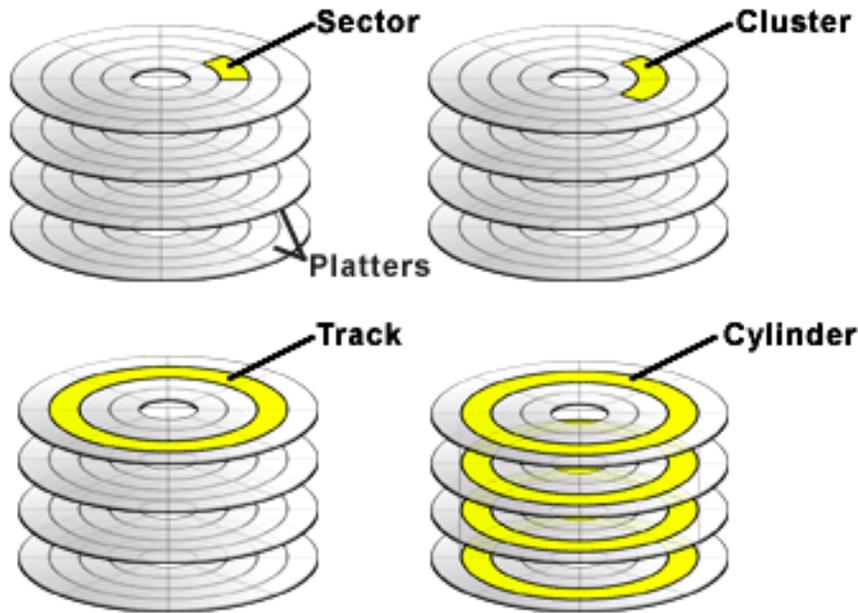
Cluster

- 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

- First cluster no. is taken as 2

- Clusters are used to allocate the storage area for data area only, FAT and directory areas are not allocated according to the cluster size

Cylinder: (Diagram optional); If given, Diagram- ½M.

Cylinder

- Same tracks of different platters form an imaginary cylinder like structure

- Data is stored cylinder by cylinder

- All tracks on a cylinder are written and then the R/W head moves to the next cylinder. This reduces movement of R/W head and increases the speed of read and write operation
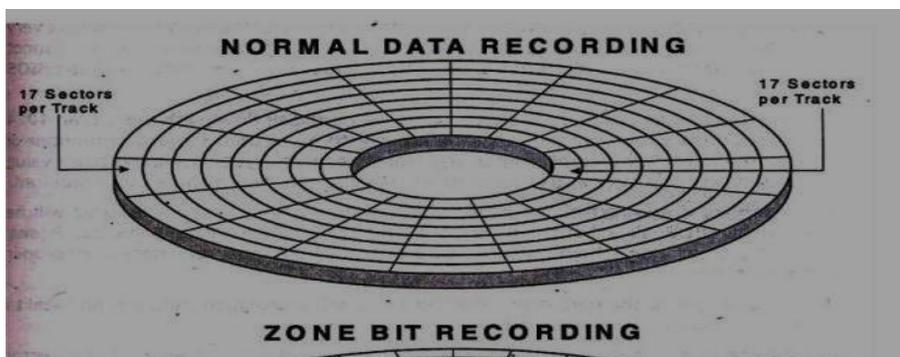
Sector

- A track is a big area to store data(5000 bytes). Hence tracks are divided into sectors

- The formatting program divides disk surface into sectors by writing magnetic pattern on disk surface

- Different HDD capacities have different number of tracks

- 512 byte data can be stored in each sector. Sector no. starts from 1

Landing zone:

- This setting specifies the cylinder to which the BIOS should send the heads of the hard disk when the machine is to be turned off. This is where the heads will "land" when they spin down. Modern drives automatically park the heads in a special area that contains no data when the power is turned off. Therefore this setting is meaningless and is typically ignored.

- Most BIOSes set this value to be the largest cylinder number of the logical geometry specified for the disk when auto detection takes place. So if the drive has 6,136 logical cylinders, the landing zone will be set to 6,135. In any event a modern IDE drive will ignore this setting and auto-park by itself.
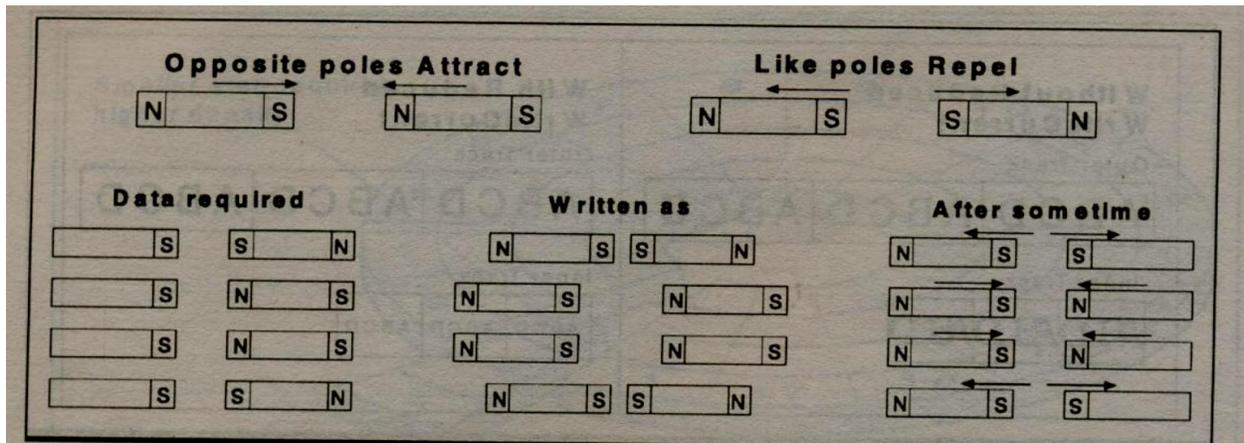
Zone Recording

- One way to increase the capacity of a hard drive during the low level format is to create more sectors on the disks Outer cylinders than on the inner ones.
- Because they have a larger circumference the outer cylinders can hold more data. Drives that use zoned recording split the cylinders into groups called zones, with each successive zone having more sectors per track as you move outward from the center of disk.

With suitable diagram explain write precompensation. (Diagram 2 M, explanation -2M)

Write Pre-compensation

- 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.

Interleave and Interleave factor

- Although traditionally interleaving was more a controller performance issue than drive issue modern hard disk drives with built-in controllers are fully capable of processing the data as fast as the drive can send it All modern drives are formatted with no interleave sometimes expressed as 1:1 interleave ratio.

- Interleave factor- the number of sectors that pass beneath the read/write heads before the next numbered sector arrives eg 1:3
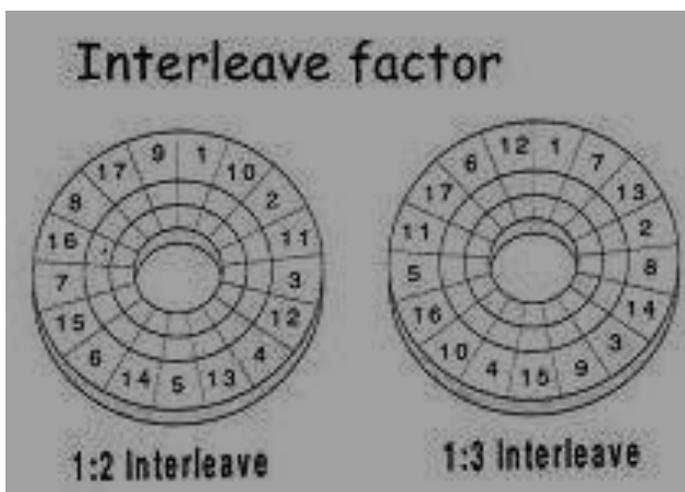
Master Boot Record (MBR)
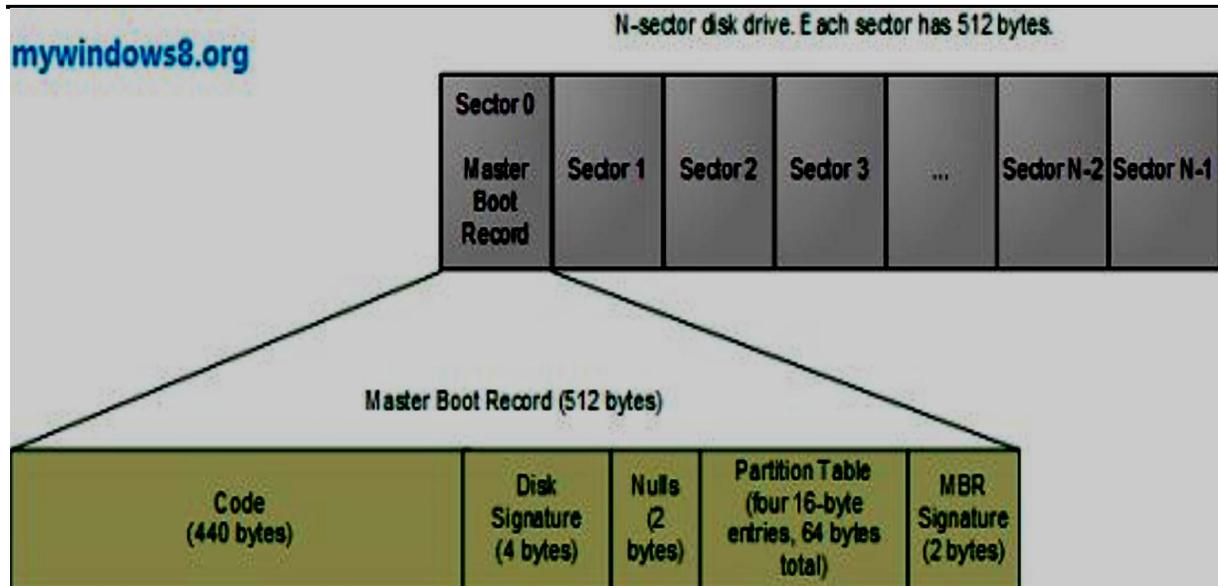
- Short for **M**aster **B**oot **R**ecord, a small program that is executed when a computer boots up.
- Typically, the MBR resides on the first sector of the hard disk or diskette that identifies how and where an operating system is located so that it can be boot (loaded) into the computer's main storage 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 above 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 Bootsrapping 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.

Formatting

What is formatting? Explain low level and high level formatting. Formatting (1 M)

1. It prepares a blank hard disk for a particular OS.

2. It puts magnetic marks of tracks and sectors on the platter surface.

3. The storage capacity of formatted hard disk is always less than the capacity of unformatted disk.

4. 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

Low Level Formatting (Physical or true formatting) (1 ½ M)
1. It is done at the factory level. (In low level formatting all the data stored on the disk is lost as the disk is physically formatted)

2. It magnetically divides the disk into tracks and sector.

3. Basic addressing information is written to each sector of each cylinder.

3. It checks for bad sectors and maps them out.

High Level Formatting (1 ½ M)

1. It is done with the help of OS.

2. High level Format program scans the disk for tracks and sectors marked bad during low level formatting. The scanning program performs five retries to read the tracks or sectors. If the tracks are still unreadable, the area is noted as bad cluster in FAT.

3. After scanning the entire disk, the drive heads return to the first sector of the partition and write MBR. Immediately in the next sector 1st copy of FAT is written and after that 2nd copy of FAT is written. Initially FATS are blank except for the bad cluster marks found in the initial scan.

4. After the 2nd copy of FAT blank root directory is created.

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

The file system in storage devices starts with **FAT (File allocation Table).**

1. FAT refers to a data table that holds information about how and where files are stored in any partition

2. It is a kind of index used by operating system to keep track of information stored on the hard disk

FAT 32 (Any Two)

1. Introduced with Microsoft windows 95, supports drives up to 2 TB

2. Since it can space more efficiently, it uses smaller clusters(4 KB clusters for drives up to 8 GB) fetch

3. No compression or encryption available on FAT 32 file system

Partitioning

Creating a partition on a hard disk drive enables it to support file systems each in its own partition. Three common file systems are used by PC operating today:/

FAT (File Allocation Table)

1. Developed by Microsoft for MS-DOS, MS-Windows 95,98,Me
2. FAT located in MBR sector of bootable disk
3. 2 Important Functions of FAT;
4. contains allocation information (in the form of linked list)
5. Indicate which allocation units are free.
6. It is simple and reliable. Two identical copies of FAT are used.

Structure of FAT

Partition	FAT 1	FAT 2	Root Folder	Other
Boot Sector		(Duplicate)		Folders and All Files

NTFS (New Technology File System)

Structure

Partition Boot Sector	Master File Table	System File	File Area

1. Used by Windows NT, XP, 2000 , Server 2003, Server 2008, Windows Vista
2. NTFS provides better performance, security compatibility and extendibility than FAT
3. Read, Search, Write, Recovery are done fast.

4. Master File Table (MFT) contain information about all files and folders. First file on NTFS volume.
5. Partition Boot Sector Start at Sector 0 to 16. First Info on an NTFS volume.

Features
1. It allows you to encrypt files and automatically decrypt them as they are read.
2. Supports long file names upto 255 characters
3. Supports File Size upto 2 TB
4. For keeping track of clusters it uses a B- tree directory
5. Reliable File System as compared to FAT
6. Allows Large partition sizes i.e more than 4 GB
7. Built-in file compression facility
8. Improved Security And access control deciding who can perform what sorts of operations on various data within the file system

Compare FAT 16, FAT 32, NTFS (Any four points – 1 mark each)

Criteria	NTFS	FAT 32	FAT16
OS	**Windows 2000, XP, 2003 server**	**DOS V7, Win 2000,98,XP**	**Dos , All version of Windows**
Maximum Vol Size	2TB	32GB	2GB
Max. Files on Vol	Unlimited	**4194304**	65536
Max file size	**Limited by vol size**	4GB	2 GB
Max Cluster number	Unlimited	**4177918**	65524
Boot sector location	**1st and last**	**First sector and copy in sector No 6**	**First sector**
Compression	Yes	NO	NO
Built in security	Yes	NO	NO
Recoverability	Yes	NO	NO
performance	**High on large vol Low on small vol**	**Good on small vol, Low on large**	**Good on small vol, Low on large**
Security	**Folder and fie access can be controlled individually**	**Very little**	**Very little**

HDD Interface Types

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

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

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

1. This interface is not a drive level interface but it a system level interface. SCSI is not a controller for a single device.
2. SCSI interface is used in high end configurations   IDE is used in low end configuration

Features

1. Fast and wide Data Path
2. Supports upto 7 peripheral Devices such as CD-Rom, scanner that can attach to a single SCSI port
3. Faster than the average parallel interface
4. It will allow data transfer upto 100 MB/s to 160 MB/s
5. SCSI is now plug and play in nature such as automatic SCSI ID assigning and termination

## 2) SATA (Serial Advanced Technology Attachment)

- Is a computer bus primarily designed for transfer of data between a computer and mass storage devices such as hard disk drives and optical drives.

Features

1. SATA is better more efficient interface than the dated PATA standard.
2. It supports hot swapping
3. Serial ATA uses only 7 conductors while PATA uses 40.
4. Data Transfers at the rate of 1.5 Gbit/s, 3 Gbit/s and 6 Gbit/s

CD ROM Recording

Explain working of CD-ROM drive with block diagram. (2 Diagram; 2 M working)
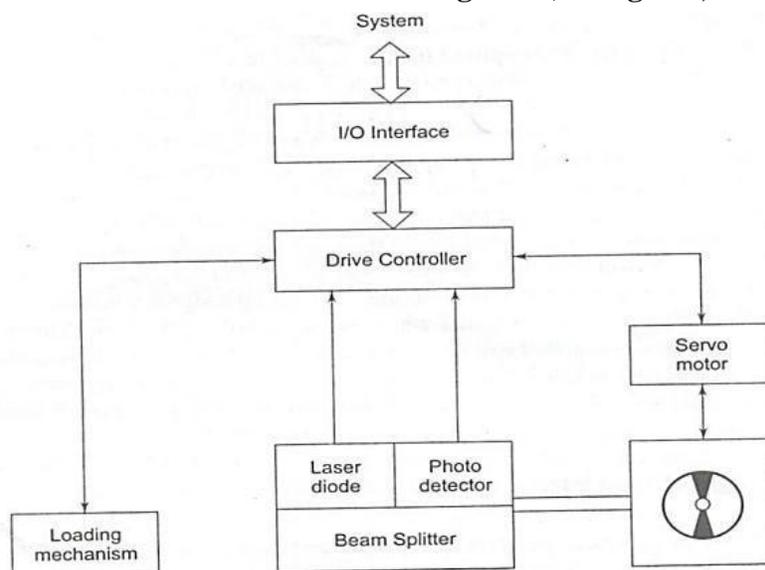
Fig: Block Diagram of CDROM drive

1. The laser diode emits a low –energy infra red beam towards the reflecting mirror
2. The servo motor positions the beam onto the correct track on the CD ROM by moving the reflecting mirror
3. When the beam hits the disc, its reflected light is gathered and focused through the first lens beneath the platter, bounce off the mirror and sent towards the beam splitter
4. The beam splitter directs the returning laser light towards another focusing lens
5. The last lens direct the light beam to a photo detector and convert the light into electric impulses

These incoming impulses are decoded by the microprocessor and sent along to the host computer as data

Recording of CDROM Drive

- EFM (Eight to Fourteen Modulation) is an encoding technique used by CDs and provides a way of countering errors by encoding a byte into 2 bytes.
- Using EFM data is broken into 8 bit blocks(bytes)
- Each 8 bit block is translated into a corresponding 14 bit codeword using a predefined lookup table.

Digital Versatile Disc
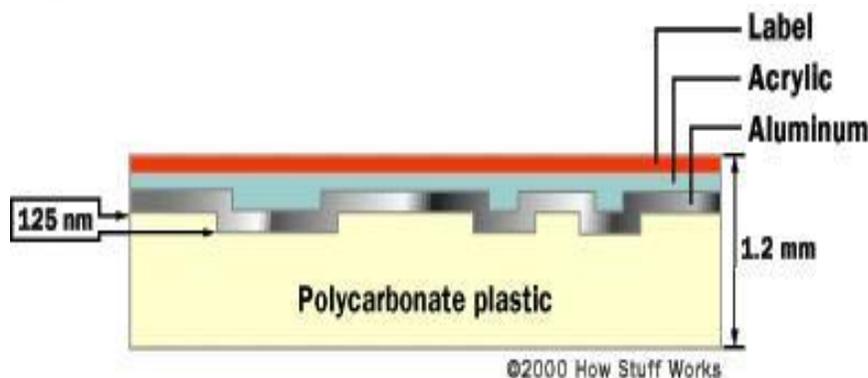
1. Optional storage media for storing data
2. Uses primary for movies softwares and data backup purpose
3. DVD holds about 7 times more data than CD Data
4. DVDs can store more data than CDs for a few reasons:

   Higher-density data storage
   Less overhead, more area
   Multi-layer storage

Comparison of CD and DVD

Parameter	CD	DVD	Remarks
Sides	1	1 or 2	
Layers	1	1 or 2	
Capacity (GB)	0.68 GB	4.7-17 GB	
Track pitch(μ)	1.6	0.74	
Minimum pit length(μ)	0.83	0.4	
Wavelength(nm)	780	650	Of laser diode pickup
Tracks	Yes	No	DVD uses files not tracks

DVD physical disc formats

Sr. No	Format	Capacity	Layers	Sides
1	DVD 5	4.7 GB	1	1
2	DVD 9	8.54 GB	2	1
3	DVD 10	9.4 GB	1	2
4	DVD 18	17.08 GB	2	2

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.

- The format offers more than five times the storage capacity of traditional DVDs and can hold upto 25 GB on a single layer disc and 50 GB on a dual layer disc.

- A blue laser is used to read the media. Blue light has a shorter wavelength than red used by previous technologies. This makes it possible to read data with greater precision.

Blu –Ray Disc Specification

Specification	Value	Specification	Value
Capacity (Single Layer)	23.3 GB/25 GB/27 GB	**Tracking Pitch**	0.32μm
Capacity (Dual Layer)	46.6 GB/50 GB/54 GB	**Shortest pit length**	0.160/0.149/0.138 μm
Laser Wave Length	405 nm (blue-violet)	**Recording Density**	16.8/18.0/19.5 Gb/sq.in
Lens Numerical Aperture	0.85	**Data transfer Rate**	36 Mbps
Disc Diameter	120 mm	**Recording format**	Phase Change Recording
Disc thickness	1.2 mm	**Tracking format**	Groove Recording
Optical Protection Layer	0.1 mm	**Video Format**	MPEG2