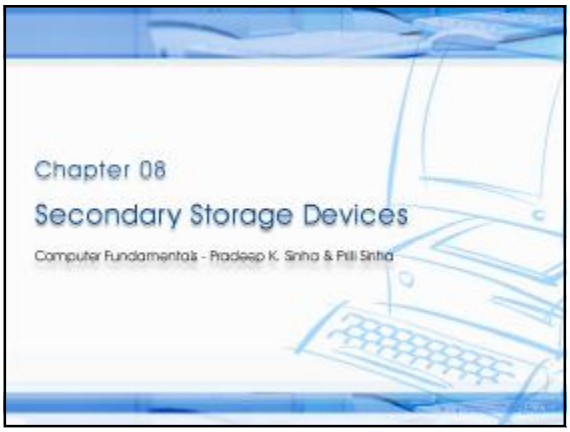

Learning Objectives

In this chapter you will learn about:

- Secondary storage devices and their need
- Classification of commonly used secondary storage devices
- Difference between sequential and direct access storage devices
- Basic principles of operation, types, and uses of popular secondary storage devices such as magnetic tape, magnetic disk, and optical disk

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Learning Objectives

(Continued from previous slide..)

- Commonly used mass storage devices
- Introduction to other related concepts such as RAID, Jukebox, storage hierarchy, etc.

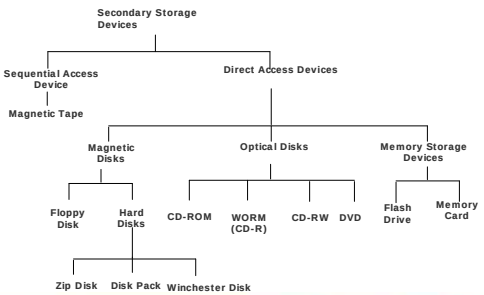
Limitations of Primary Storage

- Limited capacity because the cost per bit of storage is high
- Volatile - data stored in it is lost when the electric power is turned off or interrupted

Secondary Storage

- Used in a computer system to overcome the limitations of primary storage
- Has virtually unlimited capacity because the cost per bit of storage is very low
- Has an operating speed far slower than that of the primary storage
- Used to store large volumes of data on a permanent basis
- Also known as *auxiliary memory*

Classification of Commonly Used Secondary Storage Devices



Sequential-access Storage Devices

- Arrival at the desired storage location may be preceded by sequencing through other locations
- Data can only be retrieved in the same sequence in which it is stored
- Access time varies according to the storage location of the information being accessed
- Suitable for sequential processing applications where most, if not all, of the data records need to be processed one after another
- Magnetic tape is a typical example of such a storage device

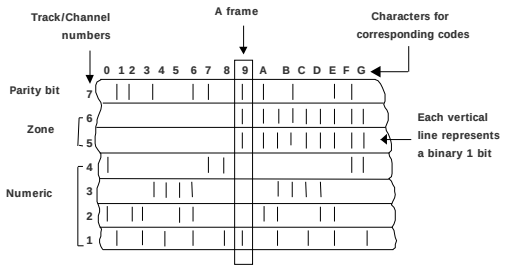
Direct-access Storage Devices

- Devices where any storage location may be selected and accessed at random
- Permits access to individual information in a more direct or immediate manner
- Approximately equal access time is required for accessing information from any storage location
- Suitable for direct processing applications such as on-line ticket booking systems, on-line banking systems
- Magnetic, optical, and magneto-optical disks are typical examples of such a storage device

Magnetic Tape Basics

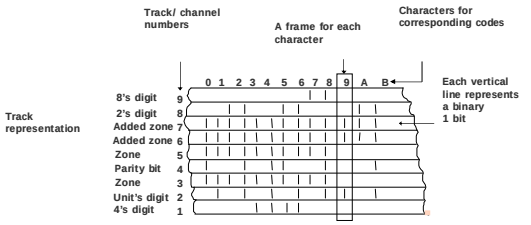
- Commonly used sequential-access secondary storage device
- Physically, the tape medium is a plastic ribbon, which is usually ½ inch or ¼ inch wide and 50 to 2400 feet long
- Plastic ribbon is coated with a magnetizable recording material such as iron-oxide or chromium dioxide
- Data are recorded on the tape in the form of tiny invisible magnetized and non-magnetized spots (representing 1s and 0s) on its coated surface
- Tape ribbon is stored in reels or a small cartridge or cassette

Magnetic Tape - Storage Organization (Example 1)



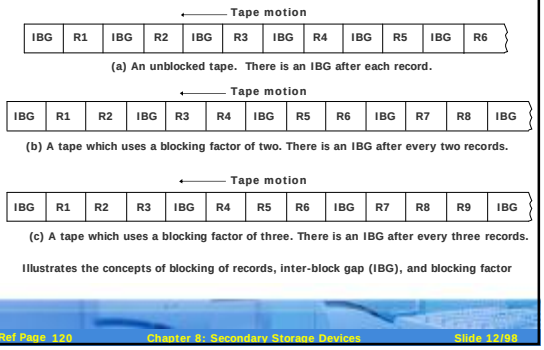
Illustrates the concepts of frames, tracks, parity bit, and character-by-character data storage

Magnetic Tape - Storage Organization (Example 2)



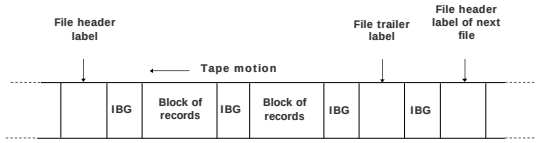
Illustrates the concepts of frames, tracks, parity bit, and character-by-character data storage

Magnetic Tape - Storage Organization (Example 3)



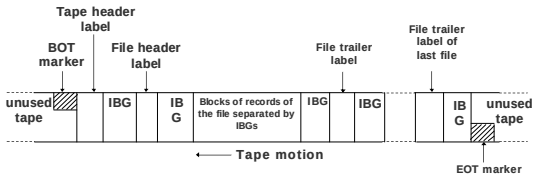
Illustrates the concepts of blocking of records, inter-block gap (IBG), and blocking factor

Magnetic Tape - Storage Organization (Example 4)



Illustrates the concepts of multiple blocks of records forming a file that is separated from other files by a file header label in the beginning and a file trailer label at the end of the file

Magnetic Tape-Storage Organization (Example 5)



Illustrates the concepts of Beginning of Tape (BoT) and End of Tape (EoT) markers, and tape header label

Magnetic Tape Storage Capacity

- Storage capacity of a tape = Data recording density x Length
- Data recording density is the amount of data that can be stored on a given length of tape. It is measured in bytes per inch (bpi)
- Tape density varies from 800 bpi in older systems to 77,000 bpi in some of the modern systems
- Actual storage capacity of a tape may be anywhere from 35% to 70% of its total storage capacity, depending on the storage organization used

Magnetic Tape – Data Transfer Rate

- Refers to characters/second that can be transmitted to the memory from the tape
- Transfer rate measurement unit is bytes/second (bps)
- Value depends on the data recording density and the speed with which the tape travels under the read/write head
- A typical value of data transfer rate is 7.7 MB/second

Magnetic Tape – Tape Drive

- Used for writing/reading of data to/from a magnetic tape ribbon
- Different for tape reels, cartridges, and cassettes
- Has read/write heads for reading/writing of data on tape
- A magnetic tape reel/cartridge/cassette has to be first loaded on a tape drive for reading/writing of data on it
- When processing is complete, the tape is removed from the tape drive for off-line storage

Magnetic Tape – Tape Controller

- Tape drive is connected to and controlled by a tape controller that interprets the commands for operating the tape drive
- A typical set of commands supported by a tape controller are:

Read	reads one block of data
Write	writes one block of data
Write tape header label	used to update the contents of tape header label
Erase tape	erases the data recorded on a tape
Back space one block	rewinds the tape to the beginning of previous block

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Magnetic Tape – Tape Controller

(Continued from previous slide..)

Forward space one block	forwards the tape to the beginning of next block
Forward space one file	forwards the tape to the beginning of next file
Rewind	fully rewinds the tape
Unload	releases the tape drive's grip so that the tape spool can be unmountedfrom the tape drive

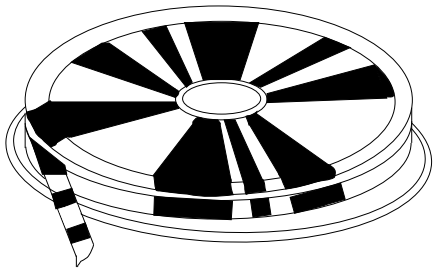
Types of Magnetic Tape

- ½-inch tape reel
- ½-inch tape cartridge
- ¼-inch streamer tape
- 4-mm digital audio tape (DAT)

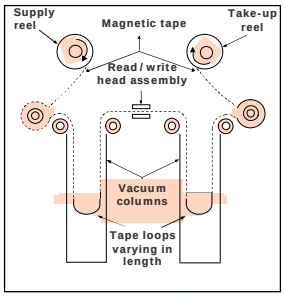
Half-inch Tape Reel

- Uses ½ inch wide tape ribbon stored on a tape reel
- Uses parallel representation method of storing data, in which data are read/written a byte at a time
- Uses a read/write head assembly that has one read/write head for each track
- Commonly used as archival storage for off-line storage of data and for exchange of data and programs between organizations
- Fast getting replaced by tape cartridge, streamer tape, and digital audio tape they are more compact, cheaper and easier to handle

Half-inch Tape Reel



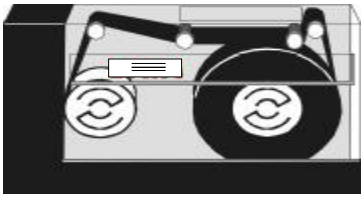
Tape Drive of Half-inch Tape Reel



Half-inch Tape Cartridge

- Uses ½ inch wide tape ribbon sealed in a cartridge
- Has 36 tracks, as opposed to 9 tracks for most half-inch tape reels
- Stores data using parallel representation. Hence, 4 bytes of data are stored across the width of the tape. This enables more bytes of data to be stored on the same length of tape
- Tape drive reads/writes on the top half of the tape in one direction and on the bottom half in the other direction

Half-inch Tape Cartridge



Quarter-inch Streamer Tape

- Uses ¼ inch wide tape ribbon sealed in a cartridge
- Uses serial representation of data recording (data bits are aligned in a row one after another in tracks)
- Can have from 4 to 30 tracks, depending on the tape drive
- Depending on the tape drive, the read/write head reads/writes data on one/two/four tracks at a time
- Eliminates the need for the start/stop operation of traditional tape drives

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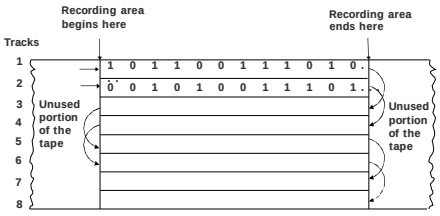
Quarter-inch Streamer Tape

(Continued from previous slide...)

- Can read/write data more efficiently than the traditional tape drives because there is no start/stop mechanism
- Make more efficient utilization of tape storage area than traditional tape drives because IBGs are not needed
- The standard data formats used in these tapes is known as the QIC standard

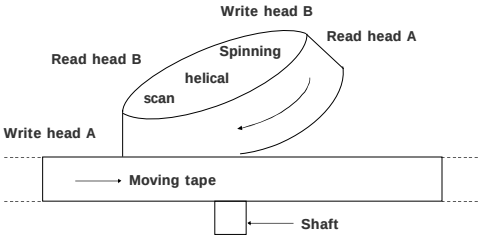
Quarter-inch Streamer Tape (Example)



4mm Digital Audio Tape (DAT)

- Uses 4mm wide tape ribbon sealed in a cartridge
- Has very high data recording density
- Uses a tape drive that uses helical scan technique for data recording, in which two read heads and two write heads are built into a small wheel
- DAT drives use a data recording format called Digital Data Storage (DDS), which provides three levels of error-correcting code
- Typical capacity of DAT cartridges varies from 4 GB to 14 GB

The Helical Scan Techniques Used in DAT Drives



Advantages of Magnetic Tapes

- Storage capacity is virtually unlimited because as many tapes as required can be used for storing very large data sets
- Cost per bit of storage is very low for magnetic tapes.
- Tapes can be erased and reused many times
- Tape reels and cartridges are compact and light in weight
- Easy to handle and store.
- Very large amount of data can be stored in a small storage space

(Continued on next slide)

Advantages of Magnetic Tapes

(Continued from previous slide..)

- Compact size and light weight
- Magnetic tape reels and cartridges are also easily portable from one place to another
- Often used for transferring data and programs from one computer to another that are not linked together

Limitations of Magnetic Tapes

- Due to their sequential access nature, they are not suitable for storage of those data that frequently require to be accessed randomly
- Must be stored in a dust-free environment because specks of dust can cause tape-reading errors
- Must be stored in an environment with properly controlled temperature and humidity levels
- Tape ribbon may get twisted due to warping, resulting in loss of stored data
- Should be properly labeled so that some useful data stored on a particular tape is not erased by mistake

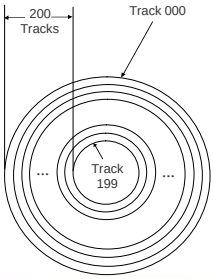
Uses of Magnetic Tapes

- For applications that are based on sequential data processing
- Backing up of data for off-line storage
- Archiving of infrequently used data
- Transferring of data from one computer to another that are not linked together
- As a distribution media for software by vendors

Magnetic Disk - Basics

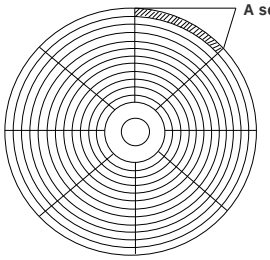
- Commonly used direct-access secondary storage device.
- Physically, a magnetic disk is a thin, circular plate/platter made of metal or plastic that is usually coated on both sides with a magnetizable recording material such as iron-oxide
- Data are recorded on the disk in the form of tiny invisible magnetized and non-magnetized spots (representing 1s and 0s) on the coated surfaces of the disk
- The disk is stored in a specially designed protective envelope or cartridge, or several of them are stacked together in a sealed, contamination-free container

Magnetic Disk – Storage Organization Illustrates the Concept of Tracks



- 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

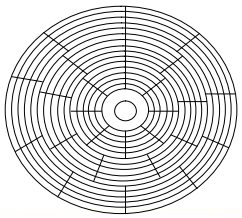
Magnetic Disk – Storage Organization Illustrates the Concept of Sectors



- 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

Magnetic Disk – Storage Organization

Illustrates Grouping of Tracks and Use of Different Number of Sectors in Tracks of Different Groups for Increased Storage Capacity

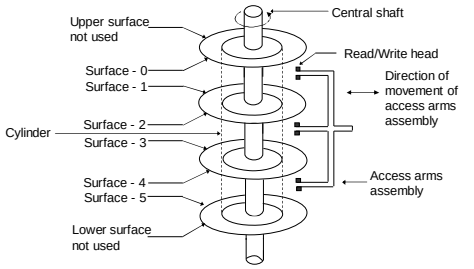


- Innermost group of tracks has 8 sectors/track
- Next groups of tracks has 9 sectors/track
- Outermost group of tracks has 10 sectors/track

Magnetic Disk – Disk Address or Address of a Record on a Disk

- Disk address represents the physical location of the record on the disk
- It is comprised of the sector number, track number, and surface number (when double-sided disks are used)
- This scheme is called the *CHS addressing* or *Cylinder-Head-Sector* addressing. The same is also referred to as *disk geometry*

Magnetic Disk – Storage Organization (Illustrates the Concept of Cylinder)

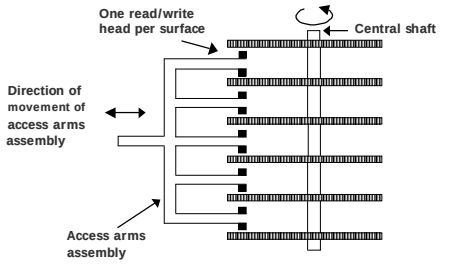


No. of disk platters = 4, No. of usable surfaces = 6. A set of corresponding tracks on all the 6 surfaces is called a cylinder.

Magnetic Disk – Storage Capacity

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

Magnetic Disk Pack – Access Mechanism



Vertical cross section of a disk system. There is one read/write head per recording surface

Magnetic Disk – Access Time

- *Disk access time* is the interval between the instant a computer makes a request for transfer of data from a disk system to the primary storage and the instant this operation is completed
- 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

Magnetic Disk – Access Time

  - *Transfer Rate*: It is the rate at which data are read/written to the disk, once the read/write head is positioned over the desired sector
- As the transfer rate is negligible as compared to seek time and latency,

  Average access time

  = Average seek time + Average latency

Disk Formatting

- Process of preparing a new disk by the computer system in which the disk is to be used.
- For this, a new (unformatted) disk is inserted in the disk drive of the computer system and the disk formatting command is initiated
- 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

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Disk Formatting

(Continued from previous slide..)

- 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
- One of the basic tasks handled by the computer's operating system
- Enables the use of disks manufactured by third party vendors into one's own computer system

Magnetic Disk – Disk Drive

- Unit used for reading/writing of data on/from a magnetic disk
- Contains all the mechanical, electrical and electronic components for holding one or more disks and for reading or writing of information on to it

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Magnetic Disk – Disk Drive

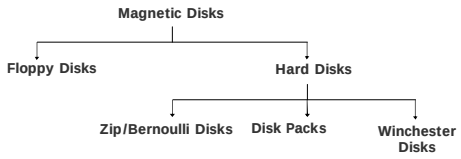
(Continued from previous slide..)

- Although disk drives vary greatly in their shape, size and disk formatting pattern, they can be broadly classified into two types:
  - *Those with interchangeable magnetic disks*, which allow the loading and unloading of magnetic disks as and when they are needed for reading/writing of data on to them
  - *Those with fixed magnetic disks*, which come along with a set of permanently fixed disks. The disks are not removable from their disk drives

Magnetic Disk – Disk Controller

- Disk drive is connected to and controlled by a disk controller, which interprets the commands for operating the disk drive
- Typically supports only *read* and *write* commands, which need disk address (surface number, cylinder/track number, and sector number) as parameters
- Connected to and controls more than one disk drive, in which case the disk drive number is also needed as a parameters of *read* and *write* commands

Types of Magnetic Disks



Floppy Disks

- Round, flat piece of flexible plastic disks coated with magnetic oxide
- So called because they are made of flexible plastic plates which can bend
- Also known as floppies or diskettes
- Plastic disk is encased in a square plastic or vinyl jacket cover that gives handling protection to the disk surface

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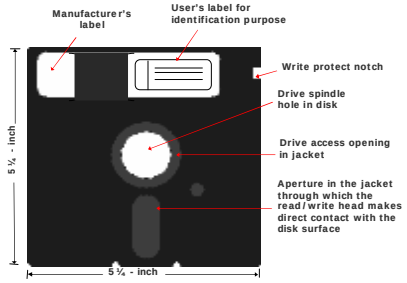
Floppy Disks

(Continued from previous slide..)

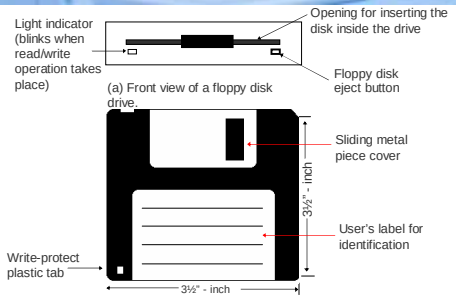
- The two types of floppy disks in use today are:
  - 5¼-inch diskette, whose diameter is 5¼-inch. It is encased in a square, flexible vinyl jacket
  - 3½-inch diskette, whose diameter is 3½-inch. It is encased in a square, hard plastic jacket
- Most popular and inexpensive secondary storage medium used in small computers

A 5¼-inch Floppy Disk



A 5¼-inch floppy disk enclosed within jacket. The drive mechanism clamps on to a portion of the disk exposed by the drive access opening in the jacket

A 3½-inch Floppy Disk



(b) A 3½ - inch floppy disk.

Storage Capacities of Various Types of Floppy Disks

Size (Diameter in inches)	No. of surfaces	No. of tracks	No. of sectors/track	No. of bytes/sector	Capacity in bytes	Approximate capacity
5¼	2	40	9	512	3,68,640	360 KB
5¼	2	80	15	512	12,28,800	1.2 MB
3½	2	40	18	512	7,37,280	720 KB
3½	2	80	18	512	14,74,560	1.4 MB
3½	2	80	36	512	29,49,120	2.88 MB

Hard Disks

- Round, flat piece of rigid metal (frequently aluminium) disks coated with magnetic oxide
- Come in many sizes, ranging from 1 to 14-inch diameter.
- Depending on how they are packaged, hard disks are of three types:
  - Zip/Bernoulli disks
  - Disk packs
  - Winchester disks
- Primary on-line secondary storage device for most computer systems today

Zip/Bernoulli Disks

- Uses a single hard disk platter encased in a plastic cartridge
- Disk drives may be portable or fixed type
- Fixed type is part of the computer system, permanently connected to it
- Portable type can be carried to a computer system, connected to it for the duration of use, and then can be disconnected and taken away when the work is done
- Zip disks can be easily inserted/removed from a zip drive just as we insert/remove floppy disks in a floppy disk drive

Disk Packs

- Uses multiple (two or more) hard disk platters mounted on a single central shaft
- Disk drives have a separate read/write head for each usable disk surface (the upper surface of the top-most disk and the lower surface of the bottom most disk is not used)
- Disks are of removable/interchangeable type in the sense that they have to be mounted on the disk drive before they can be used, and can be removed and kept off-line when not in use

Winchester Disks

- Uses multiple (two or more) hard disk platters mounted on a single central shaft
- Hard disk platters and the disk drive are sealed together in a contamination-free container and cannot be separated from each other

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Winchester Disks

(Continued from previous slide...)

- For the same number of disks, Winchester disks have larger storage capacity than disk packs because:
  - All the surfaces of all disks are used for data recording

  They employ much greater precision of data recording, resulting in greater data recording density
- Named after the .30-30 Winchester rifle because the early Winchester disk systems had two 30-MB disks sealed together with the disk drive

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. A tape is not suitable for such type of usage due to its sequential-access property
- Suitable for both on-line and off-line storage of data

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Advantages of Magnetic Disks

(Continued from previous slide..)

- Except for the fixed type Winchester disks, the storage capacity of other magnetic disks is virtually unlimited as many disks can be used for storing very large data sets
- Due to their low cost and high data recording densities, 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

(Continued on next slide)

Advantages of Magnetic Disks

- Due to their compact size and light weight, floppy disks and zip disks are also easily portable from one place to another
- They are often used for transferring data and programs from one computer to another, which are not linked together
- Any information desired from a disk storage can be accessed in a few milliseconds because it is a direct access storage device

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Advantages of Magnetic Disks

(Continued from previous slide..)

- Data transfer rate for a magnetic disk system is normally higher than a tape system
- Magnetic disks are less vulnerable to data corruption due to careless handling or unfavorable temperature and humidity conditions than magnetic tapes

Limitations of Magnetic Disks

- Although used for both random processing and sequential processing of data, for applications of the latter type, it may be less efficient than magnetic tapes
- More difficult to maintain the security of information stored on shared, on-line secondary storage devices, as compared to magnetic tapes or other types of magnetic disks

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Limitations of Magnetic Disks

(Continued from previous slide..)

- For Winchester disks, a disk crash or drive failure often results in loss of entire stored data. It is not easy to recover the lost data. Suitable backup procedures are suggested for data stored on Winchester disks
- Some types of magnetic disks, such as disk packs and Winchester disks, are not so easily portable like magnetic tapes
- On a cost-per-bit basis, the cost of magnetic disks is low, but the cost of magnetic tapes is even lower

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Limitations of Magnetic Disks

(Continued from previous slide..)

- Must be stored in a dust-free environment
- Floppy disks, zip disks and disk packs should be labeled properly to prevent erasure of useful data by mistake

Uses of Magnetic Disks

- For applications that are based on random data processing
- As a shared on-line secondary storage device. Winchester disks and disk packs are often used for this purpose
- As a backup device for off-line storage of data. Floppy disks, zip disks, and disk packs are often used for this purpose

(Continued on next slide)

Uses of Magnetic Disks

(Continued from previous slide..)

- Archiving of data not used frequently, but may be used once in a while. Floppy disks, zip disks, and disk packs are often used for this purpose
- Transferring of data and programs from one computer to another that are not linked together. Floppy disks and zip disks are often used for this purpose
- Distribution of software by vendors. Originally sold software or software updates are often distributed by vendors on floppy disks and zip disks

Optical Disk – Basics

- Consists of a circular disk, which is coated with a thin metal or some other material that is highly reflective
- Laser beam technology is used for recording/reading of data on the disk
- Also known as laser disk / optical laser disk, due to the use of laser beam technology
- Proved to be a promising random access medium for high capacity secondary storage because it can store extremely large amounts of data in a limited space

Optical Disk – Storage Organization

- Has one long spiral track, which starts at the outer edge and spirals inward to the center
- Track is divided into equal size sectors

(a) Track pattern on an optical disk

(b) Track pattern on a magnetic disk

Difference in track patterns on optical and magnetic disks.

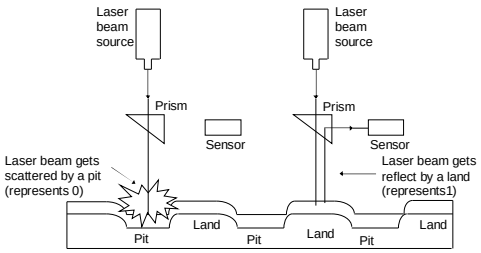
Optical Disk – Storage Capacity

Storage capacity of an optical disk

= Number of sectors
´ Number of bytes per sector

The most popular optical disk uses a disk of 5.25 inch diameter with storage capacity of around 650 Megabytes

Optical Disk – Access Mechanism



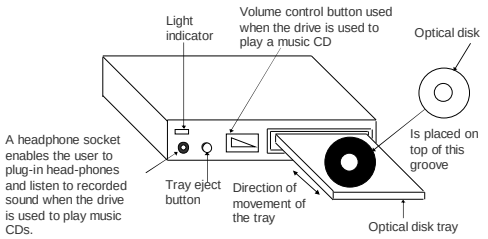
Optical Disk – Access Time

- With optical disks, each sector has the same length regardless of whether it is located near or away from the disk's center
- Rotation speed of the disk must vary inversely with the radius. Hence, optical disk drives use a constant linear velocity (CLV) encoding scheme
- Leads to slower data access time (larger access time) for optical disks than magnetic disks
- Access times for optical disks are typically in the range of 100 to 300 milliseconds and that of hard disks are in the range of 10 to 30 milliseconds

Optical Disk Drive

- Uses laser beam technology for reading/writing of data
- Has no mechanical read/write access arm
- Uses a constant linear velocity (CLV) encoding scheme, in which the rotational speed of the disk varies inversely with the radius

Optical Disk Drive



Types of Optical Disks

The types of optical disks in use today are:

CD-ROM

- **Stands for Compact Disk-Read Only Memory**
- **Packaged as shiny, silver color metal disk of 5¼ inch (12cm) diameter, having a storage capacity of about 650 Megabytes**
- **Disks come pre-recorded and the information stored on them cannot be altered**
- **Pre-stamped (pre-recorded) by their suppliers, by a process called *mastering***

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Types of Optical Disks

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- **Provide an excellent medium to distribute large amounts of data in electronic dorm at low cost.**
- **A single CD-ROM disk can hold a complete encyclopedia, or a dictionary, or a world atlas, or biographies of great people, etc**
- **Used for distribution of electronic version of conference proceedings, journals, magazines, books, and multimedia applications such as video games**
- **Used by software vendors for distribution of software to their customers**

Types of Optical Disks

WORM Disk / CD-Recordable (CD-R)

- Stands for Write Once Read Many. Data can be written only once on them, but can be read many times
- Same as CD-ROM and has same storage capacity
- Allow users to create their own CD-ROM disks by using a CD-recordable (CD-R) drive that can be attached to a computer as a regular peripheral device
- Data to be recorded can be written on its surface in multiple recording sessions

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Types of Optical Disks

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- Sessions after the first one are always additive and cannot alter the etched/burned information of earlier sessions
- Information recorded on them can be read by any ordinary CD-ROM drive
- They are used for data archiving and for making a permanent record of data. For example, many banks use them for storing their daily transactions

Types of Optical Disks

CD-Read/Write (CD-RW)

- Same as CD-R and has same storage capacity
- Allow users to create their own CD-ROM disks by using a CD-recordable (CD-R) drive that can be attached to a computer as a regular peripheral device
- Data to be recorded can be written on its surface in multiple recording sessions
- Made of metallic alloy layer whose chemical properties are changed during burn and erase
- Can be erased and written afresh

Types of Optical Disks

Digital Video / Versatile Disk (DVD)

- Looks same as CD-ROM but has capacity of 4.7 GB or 8.5 GB
- Designed primarily to store and distribute movies
- Can be used for storage of large data
- Allows storage of video in 4:3 or 16:9 aspect-ratios in MPEG-2 video format using NTSC or PAL resolution
- Audio is usually Dolby® Digital (AC-3) or Digital Theater System (DTS) and can be either monaural or 5.1 Surround Sound

Advantages of Optical Disks

- The cost-per-bit of storage for optical disks is very low because of their low cost and enormous storage density.
- The use of a single spiral track makes optical disks an ideal storage medium for reading large blocks of sequential data, such as music.
- Optical disk drives do not have any mechanical read/write heads to rub against or crash into the disk surface. This makes optical disks a more reliable storage medium than magnetic tapes or magnetic disks.
- Optical disks have a data storage life in excess of 30 years. This makes them a better storage medium for data archiving as compared to magnetic tapes or magnetic disks.

Advantages of Optical Disks

- As data once stored on an optical disk becomes permanent, danger of stored data getting inadvertently erased/overwritten is removed
- Due to their compact size and light weight, optical disks are easy to handle, store, and port from one place to another
- Music CDs can be played on a computer having a CD-ROM drive along with a sound board and speakers. This allows computer systems to be also used as music systems

Limitations of Optical Disks

- It is largely read-only (permanent) storage medium. Data once recorded, cannot be erased and hence the optical disks cannot be reused
- The data access speed for optical disks is slower than magnetic disks
- Optical disks require a complicated drive mechanism

Uses of Optical Disks

- For distributing large amounts of data at low cost
- For distribution of electronic version of conference proceedings, journals, magazines, books, product catalogs, etc
- For distribution of new or upgraded versions of software products by software vendors

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Uses of Optical Disks

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- For storage and distribution of a wide variety of multimedia applications
- For archiving of data, which are not used frequently, but which may be used once in a while
- WORM disks are often used by end-user companies to make permanent storage of their own proprietary information

Memory Storage Devices

Flash Drive (Pen Drive)

- Relatively new secondary storage device based on flash memory, enabling easy transport of data from one computer to another
- Compact device of the size of a pen, comes in various shapes and stylish designs and may have different added features
- Plug-and-play device that simply plugs into a USB (Universal Serial Bus) port of a computer, treated as removable drive
- Available storage capacities are 8MB, 16MB, 64MB, 128MB, 256MB, 512MB, 1GB, 2GB, 4GB, and 8GB

Memory Storage Devices

Memory Card (SD/MMC)

- Similar to Flash Drive but in card shape
- Plug-and-play device that simply plugs into a port of a computer, treated as removable drive
- Useful in electronic devices like Camera, music player
- Available storage capacities are 8MB, 16MB, 64MB, 128MB, 256MB, 512MB, 1GB, 2GB, 4GB, and 8GB

Mass Storage Devices

- As the name implies, these are storage systems having several trillions of bytes of data storage capacity
- They use multiple units of a storage media as a single secondary storage device
- The three commonly used types are:
  1. *Disk array*, which uses a set of magnetic disks
  2. *Automated tape library*, which uses a set of magnetic tapes
  3. *CD-ROM Jukebox*, which uses a set of CD-ROMs
- They are relatively slow having average access times in seconds

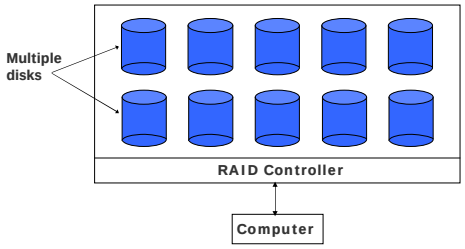
Disk Array

- Set of hard disks and hard disk drives with a controller mounted in a single box, forming a single large storage unit
- It is commonly known as a *RAID (Redundant Array of Inexpensive Disks*)
- As a secondary storage device, provides enhanced storage capacity, enhanced performance, and enhanced reliability

Disk Array

- Enhanced storage capacity is achieved by using multiple disks
- Enhanced performance is achieved by using parallel data transfer technique from multiple disks
- Enhanced reliability is achieved by using techniques such as mirroring or striping
- In *mirroring*, the system makes exact copies of files on two hard disks
- In *striping*, a file is partitioned into smaller parts and different parts of the file are stored on different disks

A RAID Unit



Automated Tape Library

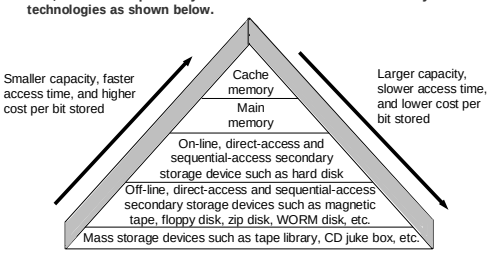
- Set of magnetic tapes and magnetic tape drives with a controller mounted in a single box, forming a single large storage unit
- Large tape library can accommodate up to several hundred high capacity magnetic tapes bringing the storage capacity of the storage unit to several terabytes
- Typically used for data archiving and as on-line data backup devices for automated backup in large computer centers

CD-ROM Jukebox

- Set of CD-ROMs and CD-ROM drives with a controller mounted in a single box, forming a single large storage unit
- Large CD-ROM jukebox can accommodate up to several hundred CD-ROM disks bringing the storage capacity of the storage unit to several terabytes
- Used for archiving read-only data in such applications as on-line museums, on-line digital libraries, on-line encyclopedia, etc

Storage Hierarchy

As a single type of storage is not superior in speed of access, capacity, and cost, most computer systems make use of a hierarchy of storage technologies as shown below.



Key Words/Phrases

- Automated tape library
- Auxiliary memory
- Block
- Blocking
- Blocking factory
- CD-ROM
- CD-ROM jukebox
- Check bit
- Cylinder
- Data transfer rate
- Direct access device
- Disk array
- Disk controller
- Disk drive
- Disk formatting
- Disk pack
- DVD
- Even parity
- File Allocation Tube (FAT)
- Floppy disk
- Hard disk
- Inter-block gap (IBG)
- Inter-record gap (IRG)
- Land
- Latency
- Magnetic disk
- Magnetic tape
- Magnetic tape drive
- Mass storage devices
- Master file
- Odd parity
- Off-line storage
- On-line storage
- Optical disk
- Parallel representation
- Parity bit
- Pit

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Key Words/Phrases

(Continued from previous slide..)

- QIC Standard
- Record
- Redundant Array of Inexpensive Disks (RAID)
- Secondary storage
- Sector
- Seek time
- Sequential access device
- Storage hierarchy
- Tape controller
- Track
- Transaction file
- Winchester disk
- WORM disk
- Zip disk