

# 1 Basic Computing Concepts (5) Storage Devices

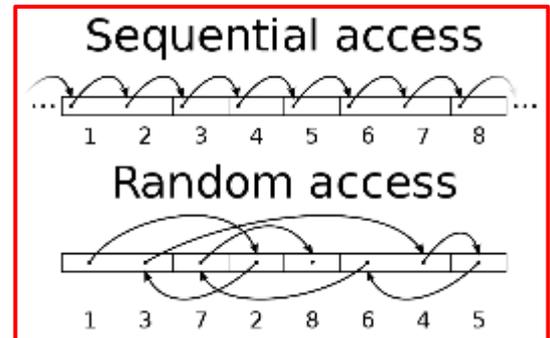
## 5 Secondary Storage

**Secondary Storage** refers to all media that retains digital data or programs. It is therefore non-volatile. This media's storage has to be loaded in the RAM to be executed and worked-upon by the processor. In contemporary usage 'memory' usually refers to RAM and 'storage' to secondary storage.

### 5.1 Storage Access Methods

How data files are stored in secondary storage varies with the types of media and devices you are using. Data files may be stored on:

- sequential-access storage,
- direct-access (random-access) storage



#### 5.1.1 Sequential-Access Storage

Tape is an example of **sequential-access** storage media. When operating in a sequential environment, a particular record can be read only by first reading all the records that come before it in the file. When you store a file on tape, the 125th record cannot be read until the 124 records in front of it are read. The records are read in sequence. You cannot read just any record at random. This is also true when reading punched cards or paper tape.

#### 5.1.2 Direct-Access Storage

**Direct-access (random-access)** storage allows you to access the 125th record without first having to read the 124 records in front of it. Magnetic disks are examples of direct-access storage media. Data can be obtained quickly from anywhere on the media.

## 5.2 Fundamental Storage Technologies

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

- **Semiconductor** (a semiconductor is somewhere between a conductor and an insulator of electricity)
  - Flash memory
- **Magnetic**
  - Magnetic disk

- Floppy disk
  - Hard disk
- Magnetic tape
- **Optical**
  - CD, CD-ROM, DVD, BD-ROM (Read only storage, off-line storage)
  - CD-R, DVD-R, DVD+R, BD-R (Write once storage, off-line storage)
  - CD-RW, DVD-RW, DVD+RW, DVD-RAM, BD-RE (Slow write, fast read storage, off-line storage)
  - Ultra Density Optical or UDO (similar in capacity to BD-R or BD-RE, slow write, fast read, off-line storage)
- **Magneto-optical** disc storage
- **3D** optical data storage
- **Paper**
  - Paper tape
  - Punched cards
  - OCR
  - OMR
  - Barcode
- Others (uncommon)

### 5.3 Flash Memory



Flash memory is a very popular **non-volatile, rewritable** memory chip used for storage. Extremely durable, flash memory is used in myriad portable devices, including digital cameras, digital music players, smartphones and tablet computers. USB drives (pen drives) are flash memory chips, and the solid state drives (SSDs), which are increasingly replacing hard disks in laptops, are also flash memory chips.

Years ago, flash replaced the permanent read-only-memory (ROM) chip on a PC motherboard that held the BIOS. Instead of having to open the case and physically replace the ROM BIOS chip, updated BIOS code could be downloaded into the flash chip



Evolving from the EEPROM, flash was invented by Toshiba and named after its ability to erase a block of a data "in a flash."

### 5.4 Floppy Disk

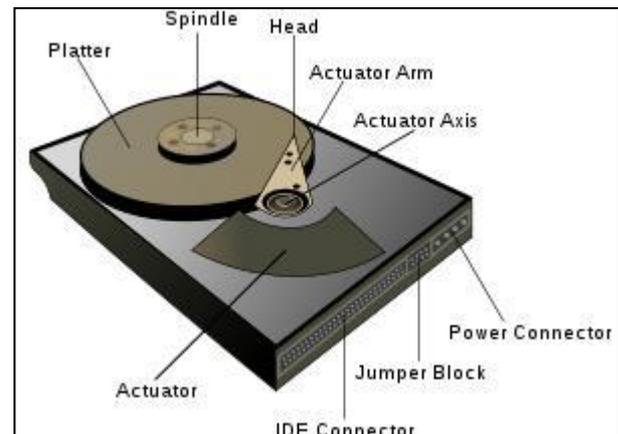
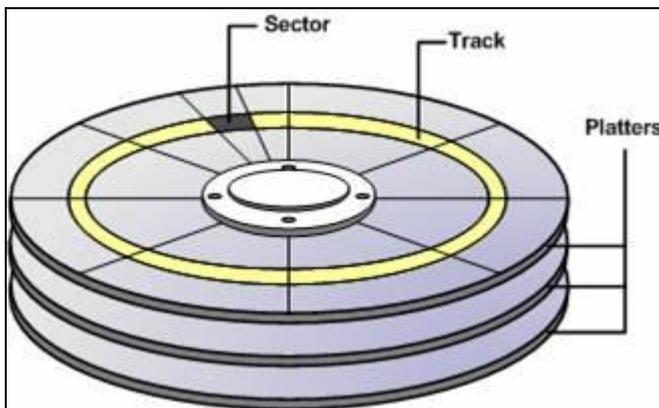
The floppy disk was introduced by IBM in 1971. It was officially called a "diskette," but nicknamed "floppy". Until the early 1990s, the floppy was the primary method for distributing applications, for backup and for

transferring data between machines. By the mid-1990s, the floppy gave way to the CD-ROM for software distribution, while local networks and the Internet became popular for backup and data exchange. The floppies in the drive used to rotate at about 300 RPM. The following table summarises the floppy types and capacities.



Floppy Types (from recent to oldest)			
Jacket	Storage Capacity		Creator
	Highest	Lowest	
3.5" rigid	1.44 MB	400 KB	Sony
5.25" flexible	1.2 MB	100 KB	Shugart
8" flexible	1.2 MB	100 KB	IBM

### 5.5 Hard Disk



A hard-disk is a magnetic disk (or disks) as shown in the diagram. The term '*hard*' is used to distinguish it from a soft, or '*floppy*, disk'. A hard disk can hold gigabytes of data. A single hard disk usually consists of several *platters*. Each platter requires two read/write heads, one for each side. All the read/write heads are attached to a single access arm so that they cannot move independently. Each platter has the same number of *tracks*, and a track location that cuts across all platters is called a cylinder. For example, a typical 84 megabyte hard disk for a PC might have two platters (four sides) and 1,053 cylinders (sector, see diagram).

The primary computer storage medium, which is made of one or more aluminum or glass platters, coated with a ferromagnetic material. Most hard disks are "fixed disks," which have platters that reside permanently in the drive. Almost all computers have an internal hard disk, and external units can be plugged in for additional storage or backup.

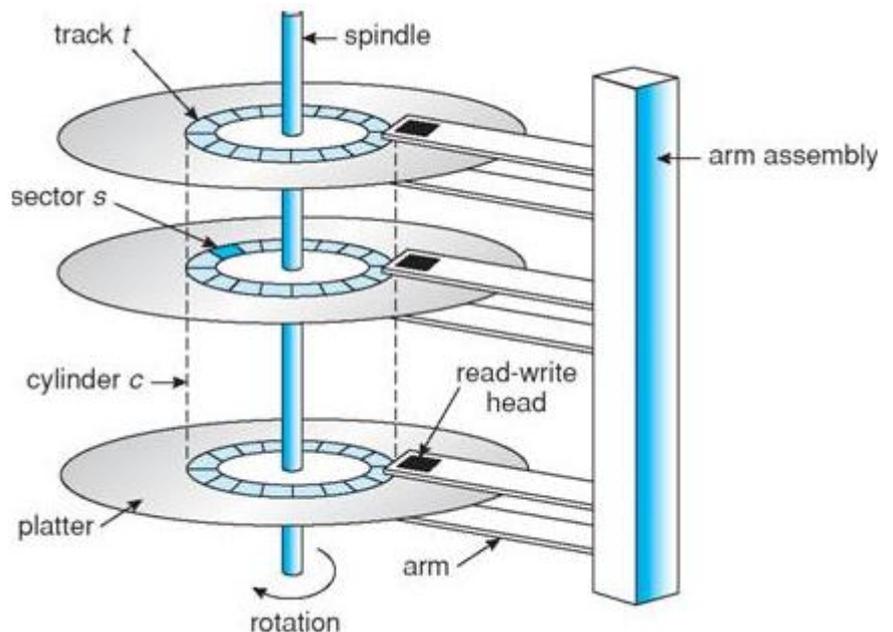
The other type of hard disk is a "removable disk" encased in a cartridge, allowing data to be ejected from the drive for external storage or

transfer to another party. Before high-speed Internet connections, removable SyQuest, Jaz and Zip cartridges were often used.

Hard disks provide fast retrieval, because they rotate constantly at high speed from 4,000 to 15,000 RPM. Either to preserve battery life in laptops or to promote longevity, hard disks can be configured to turn off after a defined period of inactivity.

Hard disk access times range from 3 ms to about 15 ms, whereas CDs and DVDs range from 80 ms to 120 ms.

The platters in a drive are separated by disk spacers and are clamped to a rotating spindle that turns all the platters in unison. The spindle motor is built right into the spindle or mounted directly below it and spins the platters at a constant set rate.



The space between the platter and the head is so minute that even one dust particle or a fingerprint could disable the spin.

All the heads are attached to a single head actuator, or actuator arm, that moves the heads around the platters.

The time taken to access a given byte of information stored on a hard disk is typically a few thousandths of a second, or milliseconds. By contrast, the time taken to access a given byte of information stored in random access memory is measured in billionths of a second, or nanoseconds. Rotating optical storage devices, such as CD and DVD drives, have even longer access times.

## 5.6 Magnetic Tape

The magnetic tape is a sequential storage medium used for data collection, backup and archiving. Like videotape, computer tape is made of flexible plastic with one side coated with a ferromagnetic material. Tapes were originally open reels, but were superseded by cartridges and cassettes of many sizes and shapes.





Tape has been more economical than disks for archival data, but that is changing as disk capacities have increased enormously. If tapes are stored for the duration, they must be periodically recopied or the tightly coiled magnetic surfaces may contaminate each other.

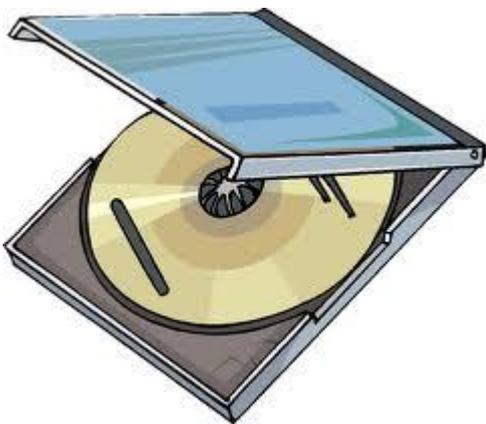
Although most tapes are used for archiving rather than routine updating, some drives allow rewriting in place if the byte count does not change. Otherwise, updating requires copying files from the original tape to a blank tape (scratch tape) and adding the new data in between.

Legacy open reel tapes used nine linear tracks (8 bits plus parity), while modern cartridges use 128 or more tracks. Data are recorded in blocks of contiguous bytes, separated by a space called an "interrecord gap" or "interblock gap." Tape drive speed is measured in inches per second (ips). Over the years, storage density has increased from 200 to 38,000 bpi.



## 5.7 The CD as a Medium of Data Storage

**CD ROM (Compact Disc Read Only Memory)** is similar to an audio CD and works in much the same way, but stores data instead of music. A typical data CD can store up to 700Mb, 486 times more information than a standard 1.44Mb 3.5" floppy disk.



A CD Writer (CD burner) can save data or audio to a special type of recordable CD (CD-R or CD-RW).

You will often see CD Writers advertised as 48X-12X-50X, this means it will burn (write) at 48X, ReWrite (write again over an existing rewritable CD) at 12X, and read at 50X the normal CD speed. For instance, a 48X CD Writer will write a CD 48 times faster than a 1X CD. 1X CD-ROM takes about 70 minutes to be read completely.

CD-R (Compact Disc-Recordable) refers to a recordable CD ideal for backing up data.

CD-RW (Compact Disc Re-Writable) refers to a recordable CD which allows the data to be overwritten numerous times (handy for daily backups).

The CD Writer (also Reader) has been superseded in technology by the DVD/CD Writer/Reader.

## 5.8 The DVD as a Medium of Data Storage

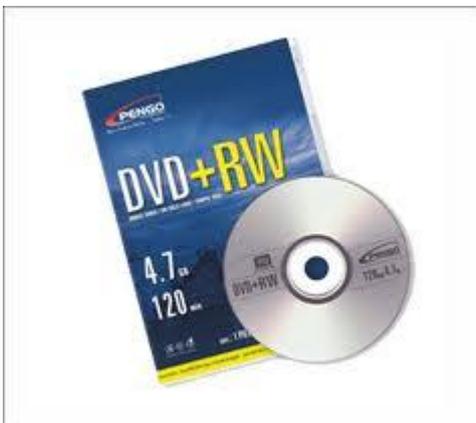
The different variations on the term DVD (e.g. +R, -R, -ROM, and so on) describe the way data is stored on or written to the disc itself. These are called physical formats.

DVD+R and DVD+RW formats are supported by Philips, Sony, Hewlett-Packard, Dell, Ricoh, Yamaha and others. DVD+R is a recordable DVD format similar to CD-R. A DVD+R can record data only once and then the data becomes permanent on the disc. The disc cannot be recorded onto a second time. DVD+RW is a re-recordable format similar to CD-RW. The data on a DVD+RW disc can be erased and recorded over numerous times without damaging the medium.



DVDs that have been made using a +R/+RW device can be read by most commercial DVD-ROM players.

The DVD-R, DVD-RW and DVD-RAM formats are supported by Panasonic, Toshiba, Apple Computer, Hitachi, NEC, Pioneer, Samsung and Sharp. These formats are also supported by the DVD Forum (The DVD Forum is an international organization composed of hardware, software, media and content companies that use and develop the DVD and formerly HD DVD formats. It was initially known as the DVD Consortium when it was founded in 1995).



DVD-R is a recordable DVD format similar to CD-R and DVD+R. A DVD-R can record data only once and then the data becomes permanent on the disc. The disc cannot be recorded onto a second time.

DVD-RW is a re-recordable format similar to CD-RW or DVD+RW. The data on a DVD-RW disc can be erased and recorded over numerous times without damaging the medium. DVDs created by a -R/-RW device can be read by most commercial DVD-ROM players.

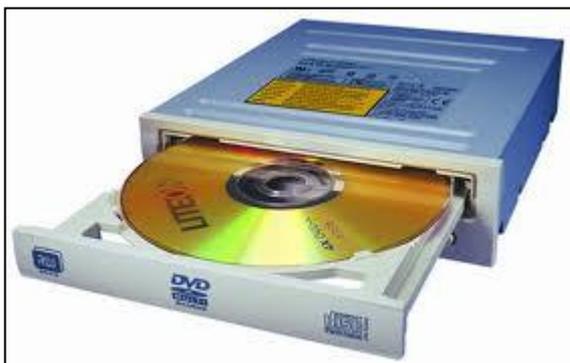
DVD-RAM discs can be recorded and erased repeatedly but are compatible only with devices manufactured by the companies that support the DVD-RAM format. DVD-RAM discs are typically housed in cartridges.

DVD-ROM was the first DVD standard to hit the market and is a read-only format. The video or game content is burned onto the DVD once and the DVD will run on any DVD-ROM-equipped device. DVD-ROMs are similar to CDs.

The DL in DVD+R DL and DVD-R DL stands for Dual Layer. This technology is supported by a range of manufacturers. As the name suggests, dual layer technology provides two individual recordable layers on a single-sided DVD disc. Dual Layer is more commonly called Double Layer in the consumer market, and can be seen written as DVD+R DL or DVD-R DL (also called DVD+R9 and DVD-R9).



The dual layered discs (DVD+R9 and DVD-R9) can hold 7.95GB and double sided dual layer (called DVD-18) can hold 15.9GB.



A Note on DVD Burners: Until 2003 consumers would have to choose a preferred DVD format and purchase the DVD media that was compatible with the specific DVD burner. In 2003 Sony introduced a multi-format DVD burner (also called a combo drive or DVD-Multi) and today many manufacturers offer multi-format DVD burners that are compatible with multiple DVD formats.

There are other DVD formats such as DVD-VCD, DVD-SVCD and DVD-MP3.

## 5.9 Magneto-Optic Disk

This is a rewritable optical disk that is used in combination with magnetic technology. Employed in a variety of storage and archival applications, including large disk libraries, magneto-optic (MO) disks are housed in removable cartridges that have a 30-year shelf life. Capable of up to a million rewrites, MO access times are in the sub-25ms range and are faster than pure optical CD-RWs and DVD-RAMs.



MO discs come in 3.5" and 5.25" cartridges. The latter are double sided, but must be removed and flipped over. Capacities of 3.5" cartridges vary but can hold up to 1.3GB. 5.25" disks can hold up to 9.1GB.

Data are written on an MO disk by a laser and a magnet. Reading is accomplished by means of reflection of light on bits.

### 5.10 UDO

An UDO (Ultra Density Optical) disk is a 5.25" rewritable optical disc technology from Plasmon, Broomfield, CO. It also supports write-once (WORM) media. UDO disks can support up to 240GB.



Although conceptually similar to the rewritable CD/DVD drives used by consumers, UDO was designed with more hardy engineering for commercial applications and long-term storage. For example, rewritable UDO uses eight layers in the disk compared to four, which is typical for rewritable consumer media.

Designed to supersede magneto-optic (MO) disks in capacity, UDO's first blue laser 30GB drives offered a big storage jump over 9.1GB, the final format for 5.25" MO drives. UDO's phase change technology provides a stable recording layer that is expected to last 50+ years compared to 25 for MO.

### 5.11 Blu-ray

A Blue-ray disk (BD) is a high-capacity optical disc for high-definition (HD) movies. Developed primarily by Sony, Blu-ray and DVD discs have the same diameter and look similar, but Blu-ray's blue-violet laser reads pits a third the size of a DVD on tracks packed much tighter together. Blu-ray players support DVDs and CDs.



A BD comes in ROM (read-only memory), R (recordable) and RE (rewritable) formats. Blu-ray disks can hold up to 50GB.

### 5.12 Comparison Tables

Below are two tables that compare the main secondary storage media. The tables may not show the latest technologies but are still valid in comparing technologies.

Drive	Capacity	Transfer Speed	Portable	Drive Cost	Media Cost
<b>Floppy Disk</b>	Low	Slow	Yes	Very low	Very low
<b>Hard Disk</b>	Very High	Very Fast	No	Low/Medium	N/A
<b>Tape</b>	Very High	Fast	Yes	High	Low
<b>CD</b>	High	Fast	Yes	Low	<ul style="list-style-type: none"> <li>• CD -R Very Low</li> <li>• CD -RW Low</li> </ul>
<b>DVD</b>	Very High	Fast	Yes	Low/medium	<ul style="list-style-type: none"> <li>• DVD R Low</li> <li>• DVD RW Low</li> </ul>
<b>USB Flash</b>	High	Fast	Yes	Low/medium	

Drive	Capacity	Transfer Speed	Drive Cost	Media Cost
<b>Floppy Disk</b>	1.44 MB	0.04 Mbps	£5	10p per disk
<b>Hard Disk</b>	100GB Approx 6,000 FD's	100 Mbps	£50	N/A
<b>Tape</b>	30GB Approx 2,000 FD's	10 Mbps	£370	£50
<b>CD</b>	700 MB Approx 500 FD's	30 Mbps	£25	<ul style="list-style-type: none"> <li>• CD -R 13p</li> <li>• CD -RW 40p</li> </ul>
<b>DVD</b>	9 GB Approx 6,300 FD's	30 Mbps	£70	<ul style="list-style-type: none"> <li>• DVD R £1.50</li> <li>• DVD RW £2.50</li> </ul>
<b>USB Flash</b>	256 MB Approx 200 FD's	1 Mbps	£45	N/A

(Acronyms: MB = Megabytes, GB = Gigabytes, Mbps= Megabits per second, R = Recordable, RW = Rewriteable, FD = Floppy disks, FDD = Floppy disk drive)