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Memory System Organization and Architectures

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External Memory

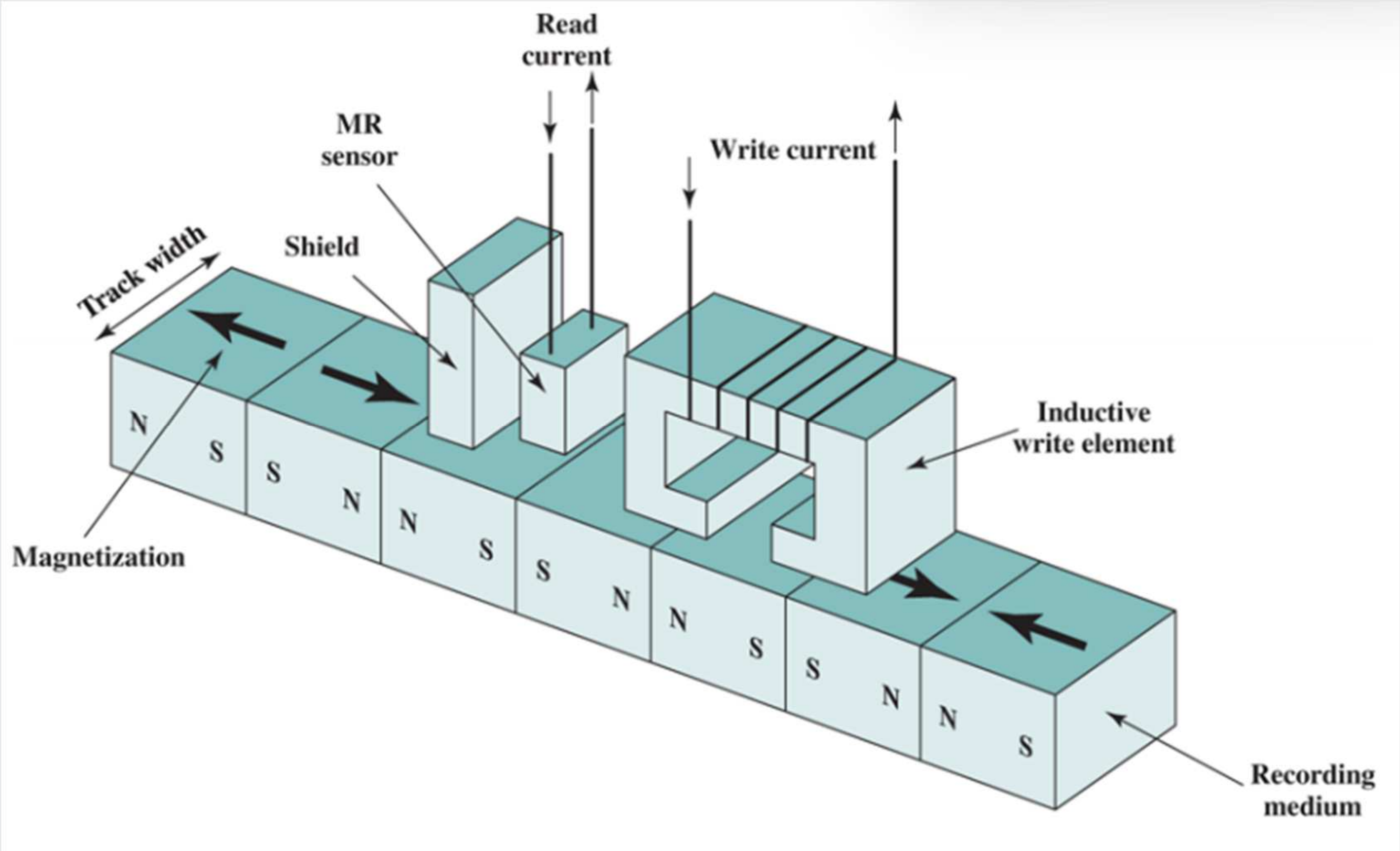
Magnetic Disk

A disk is a circular **platter constructed** of nonmagnetic **material**, called the **substrate**, coated with a magnetizable **material**. **Traditionally**, the **substrate** has been an aluminum or aluminum alloy material. **More recently**, **glass substrates** have been introduced. The glass substrate has a number of **benefits**, including the following:

- Improvement in the uniformity of the magnetic film surface to **increase disk reliability**.
- A significant reduction in overall surface defects to help **reduce** read-write errors.
- **Ability** to **support lower** fly heights.
- **Better stiffness** to **reduce** disk dynamics.
- **Greater** ability to withstand shock and damage.

Magnetic Read and Write Mechanisms

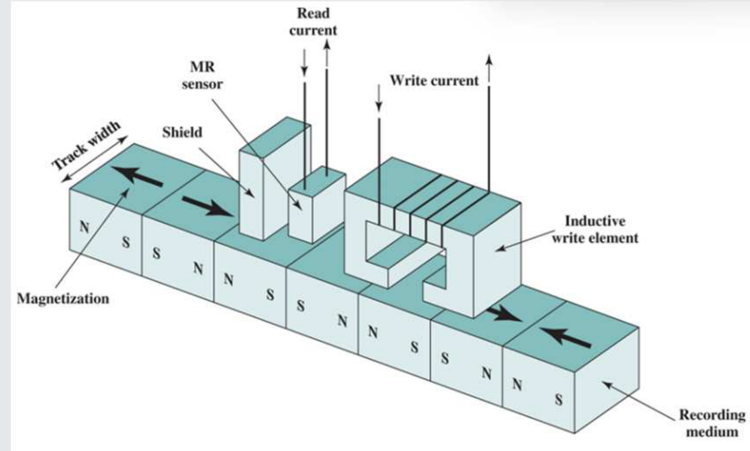
Data are recorded on (write) and later retrieved from (read) the **disk** via a conducting coil named the **head**; in many systems, there are **two** heads, a **read** head and a **write** head. During a **read** or **write operation**, the **head** is **stationary** while the **platter rotates beneath it**.



Inductive Write/Magnetoresistive Read Head

Computer Organization and Architecture 11th Ed William Stallings Pearson Education Inc 2019

The **write** mechanism exploits the fact that **electricity flowing** through a **coil** produces a **magnetic field**. **Electric pulses** are **sent** to the **write head**, and the resulting **magnetic patterns** are **recorded** on the **surface below**,



The **structure** of the **head** for reading is in this case essentially the same as for writing, and therefore the same head can be used for both. Such single heads are used in **floppy disk systems** and in **older** rigid disk systems.

Contemporary rigid disk systems use a different read mechanism, requiring a separate read head, positioned for convenience close to the write head. The read head consists of a partially shielded **magnetoresistive (MR)** sensor.

The MR material has an electrical resistance that depends on the direction of the magnetization of the medium moving under it.

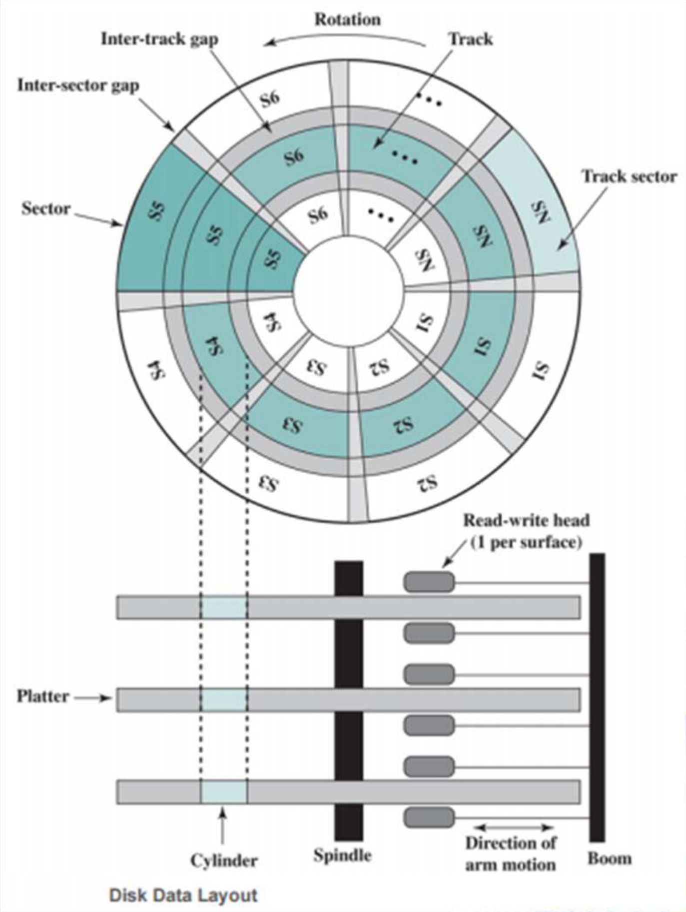
Standard Floppy Disk: **Capacity**: Originally around **360 KB to 1.2 MB. Size: 5.25 inches** in diameter. **Use:** It was the standard in the **1970s** and **1980s.**

Micro Floppy Disk (3.5-inch): Capacity: Ranges from **720 KB** (**Double-Density**) to **1.44 MB (High-Density). Size: 3.5 inches** in diameter. **Use:** more popular in the late 1980s and **1990s**

Data Organization and Formatting

The **head** is a **relatively small device** capable of **reading from** or **writing to** a portion of the platter **rotating beneath it**. This gives rise to the organization of data on the platter in a concentric set of rings, called tracks. Each track is the same width as the head. There are thousands of tracks per surface.

Figure depicts this **data layout**. Adjacent tracks are **separated** by **intertrack gaps**. This prevents, or at least minimizes, **errors due to** misalignment of the head or simply interference of magnetic fields. Data are transferred to and from the disk in **sectors**. There are **typically hundreds** of **sectors per track**, and these may be of either fixed or variable length. In most contemporary systems, fixed-length sectors are used. To **avoid imposing unreasonable precision requirements** on the **system,** adjacent sectors are separated by **intersector gaps**.

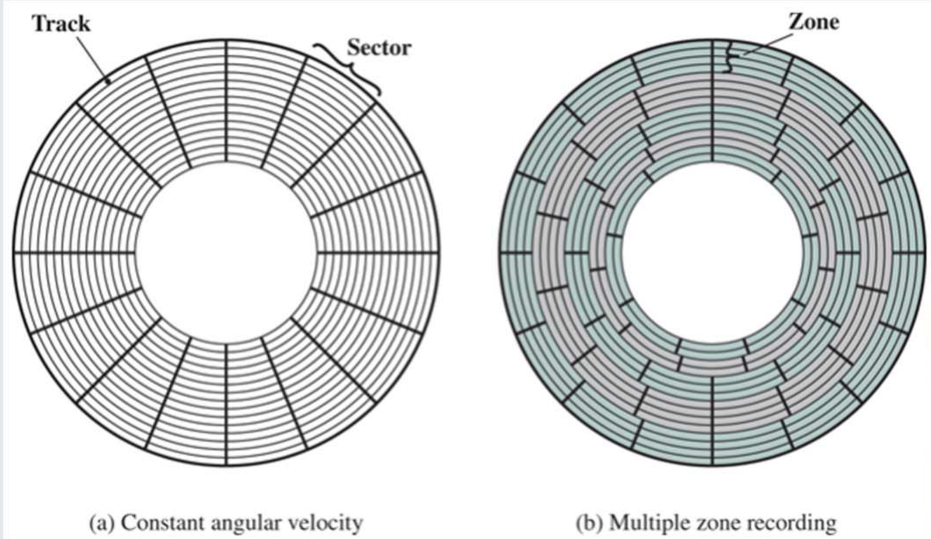


Disk data Layout

The **information** can then be **scanned** at the **same rate** by **rotating** the **disk** at a **fixed speed**, known as the constant angular velocity (CAV).

Figure (a) shows the **layout** of a **disk using** CAV. The disk is divided into a **number** of pie-shaped sectors and into a series of concentric tracks. The **advantage** of **using CAV** is that individual blocks of data can be directly addressed by track and sector. To **move** the **head from its current location** to a **specific address,** it only takes a short movement of the head to a specific track and a short wait for the proper sector to **spin under the head**. The **disadvantage** of CAV is that the amount of data that can be stored on the long outer tracks is the **same** as what can be stored on the short inner tracks.

Because the density, in bits per linear inch, **increases** in moving from the **outermost track** to the **innermost track**, disk storage capacity in a **straightforward CAV system** is limited by the maximum recording density that can be **achieved** on the innermost track**.**



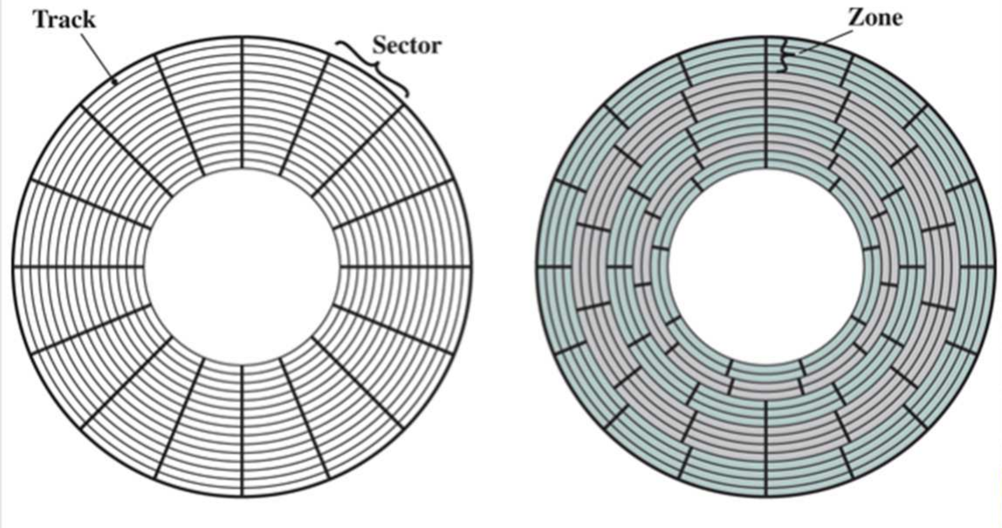
Comparison of Disk Layout Methods

concentric – with common middle point: describes circles and spheres of different sizes with the same middle point

To maximize storage capacity, it would be preferable to have the same linear bit density on each track. This would require unacceptably complex circuitry. **Modern hard disk systems use** a **simpler technique**, which approximates **equal bit density per track**, known as multiple zone recording (MZR), in which the surface is divided into a number of concentric zones (16 is typical).

Each zone contains a **number** of contiguous **tracks**, **typically** in the **thousands**. Within a **zone**, the **number** of **bits per track** is **constant**.

Figure (b) is a **simplified** MZR layout, with 15 tracks **organized** into 5 zones. The innermost two zones have two tracks each, with each track having nine sectors; the next zone has 3 tracks, each with 12 sectors; and the outermost 2 zones have 4 tracks each, with each track having 16 sectors.



(a) Constant angular velocity

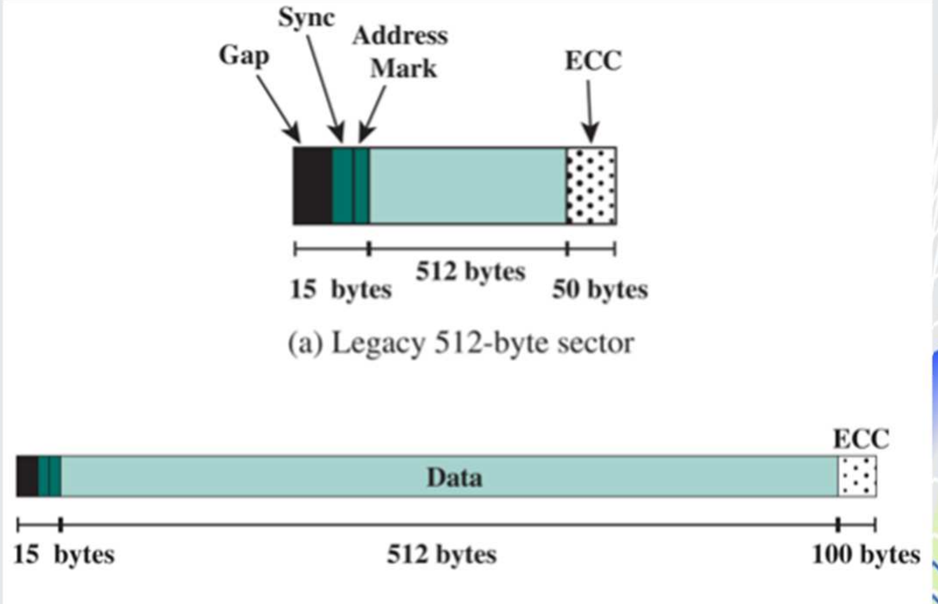
(b) Multiple zone recording

Comparison of Disk Layout Methods

contiguous – adjoining: sharing a boundary or touching each other physically

Figure shows two common sector formats **used** in **contemporary** hard disk drives. The **standard format** used for many years divided the track into sectors, each containing 512 bytes of data. Each sector also **includes** control information **useful** to the disk controller. The **structure** of the **sector layout** for this format consists of the following:

- Gap: **Separates** sectors.
- Sync: **Indicates** the **beginning** of the sector and provides **timing alignment**.
- Address mark: Contains **data** to **identify** the **sector's number** and **location**. It also provides **status** about the **sector** itself.
- Data: The **512 bytes** of **user data**
- Error correction code (ECC): **Used** to **correct data** that might be damaged in the **reading** and **writing process.**



(a) Legacy 512-byte sector

(b) Advanced Format 4k-byte sector

Legacy and Advanced Sector Formats

Although this format has served the industry well for many years, it has **become** increasingly inadequate for two reasons:

1. **Applications common** in **modern computing systems use** much **greater amounts** of **data** and **manage** the **data** in **large blocks**. Compared to these requirements, the small blocks of traditional sector formatting devote a considerable fraction of each sector to **control information**. The overhead consists of 65 bytes, yielding a format efficiency of $\frac{\mathbf{512}}{\mathbf{512+65}} = \mathbf{0.887}$

2. Bit density on **disks** has **increased** substantially, so that each **sector** consumes **less physical space**. Accordingly, a **media defect** or **other error source** can **damage** a **higher percentage** of the **total payload**, requiring **more error correction strength**.

Accordingly, the **industry** has **responded** by standardizing a **new** Advanced Format for a 4096-byte block, illustrated in **Figure 7 (b)**. The leading overhead remains at 15 bytes and the ECC is expanded to 100 bytes, yielding a format efficiency of $\frac{\mathbf{4096}}{\mathbf{4096+115}} = \mathbf{0.973}$ almost a 10% improvement in **efficiency**. More significantly, doubling the ECC to 100 bytes **enables** the **correction** of **longer sequences** of **error bits**.

Physical Characteristics of Disk Systems

Table lists the major characteristics that differentiate the various types of magnetic disks. First, the head may either be fixed or movable with **respect** to the **radial direction** of the **platter**. In a **fixed-head disk**, there is **one read-write** head per track. All of the heads are mounted on a rigid arm that extends across all tracks; such systems are rare today.

Physical Characteristics of Disk Systems

Head Motion Fixed head (one per track) Movable head (one per surface)	**Platters** Single platter Multiple platter
Disk Portability Nonremovable disk Removable disk	**Head Mechanism** Contact (floppy) Fixed gap
Sides Single sided Double sided	Aerodynamic gap (Winchester)

blest

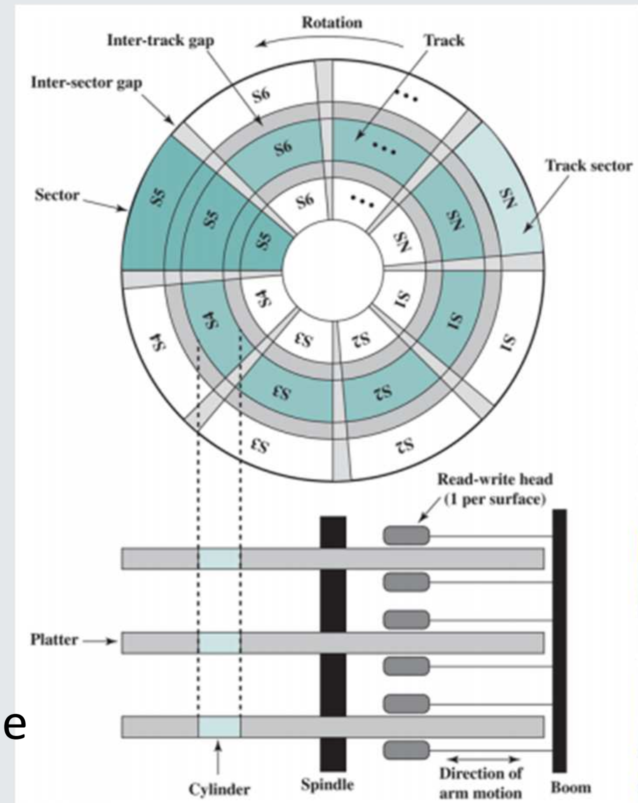
The **disk** itself is **mounted** in a disk drive, which consists of the arm, a spindle that **rotates** the **disk**, and the **electronics** needed for **input** and **output** of **binary data**. A **nonremovable disk** is permanently mounted in the **disk drive**; the hard disk in a **personal computer** is a **nonremovable disk**.

A **removable disk** can be removed and replaced with **another disk**. The **advantage** of the **latter type** is that unlimited amounts of data are **available** with a **limited number** of **disk systems**. Furthermore, such a disk may be **moved** from **one computer system** to **another.** Floppy disks and ZIP cartridge disks are examples of **removable disks**.

For **most disks**, the magnetizable coating is **applied** to both sides of the **platter**, which is then referred to as **double sided**. Some less expensive disk systems use **single-sided disks**.

Some disk drives accommodate multiple platters **stacked vertically** a **fraction** of an **inch apart**. **Multiple arms** are provided (**Figure**). **Multiple–platter disks** employ a movable head, with **one read-write** head per platter **surface**.

All of the **heads** are **mechanically fixed** so that all are at the **same distance** from the **center** of the **disk** and **move together**. Thus, at any time, **all** of the **heads** are **positioned** over **tracks** that are of **equal distance** from the **center** of the **disk**. The **set** of **all** the **tracks** in the **same relative position** on the **platter** is referred to as a **cylinder**.



Disk Data Layout

Disk data Layout

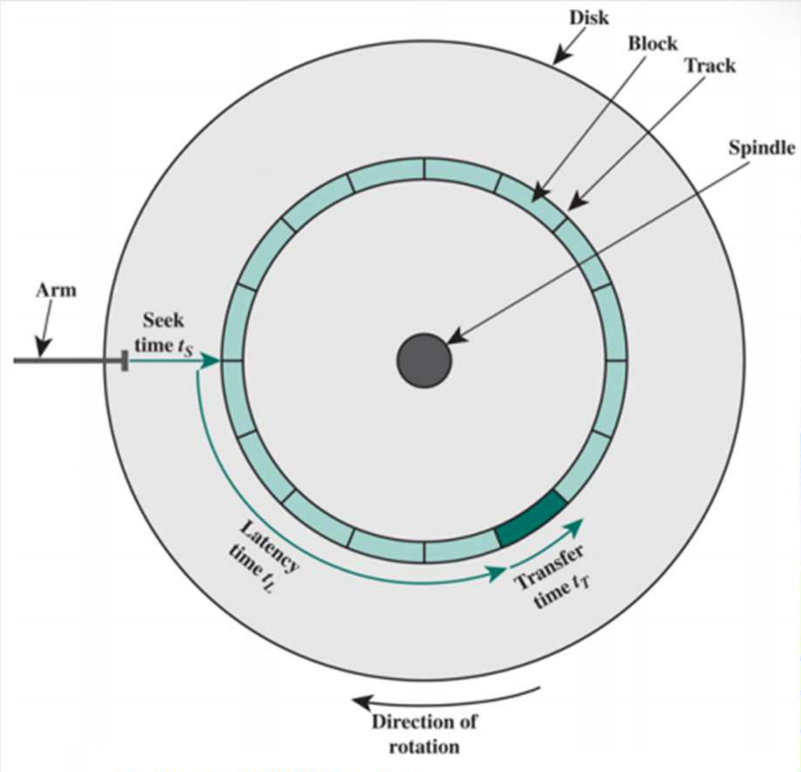
Disk Performance Parameters

On a movable-head system, the time it takes to position the head at the track is known as **seek time t_S**. Once the track is selected, the disk controller waits until the appropriate sector rotates to line up with the head. The time it takes for the beginning of the sector to reach the head is known as **rotational latency,** or **latency time t_L**.

Once the head is in position, the read or write operation is then **performed** as the sector moves under the head; this is the data transfer portion of the operation; the time required for the **transfer** is the **transfer time t_T**.

The **sum** of the seek time t_T, if any, the latency time t_L, and the transfer time t_S **equals** the **bloc access time t_B**, or **access time**:

$$t_B = t_S + t_L + t_T$$



Timing of a Disk I/O Transfer

Seek Time t_S

Seek time t_S is the time required to move the disk arm to the required track. The **seek time** consists of **two key components**: the initial startup time, **and** the time taken to traverse the tracks that have to be crossed once the access arm is up to speed.

The **traversal time** is not a **linear function** of the **number** of **tracks**, but includes a **settling time** (time after positioning the head over the target track **until** track identification is confirmed). A **mean value** of is typically provided by the manufacturer.

Much **improvement** comes from **smaller** and **lighter disk components**. Some years ago, a typical disk was 14 inches (36 cm) in diameter, whereas the **most common size today** is 3.5 inches (8.9 cm), **reducing the distance** that the **arm** has to **travel**. A typical average seek time on **contemporary hard disks** is under **10 ms**.

Latency Time t_L

Disks, other than floppy disks, rotate at speeds **ranging from** 3600 rpm (for handheld devices such as digital cameras) up to 20,000 rpm (year 2019); at this latter speed, there is one revolution per 3ms. On the average, the latency time will be 1.5 ms.

Transfer Time t_T

The transfer time to or from the **disk depends** on the rotation speed of the **disk**:

$$t_T = \frac{b}{rN}$$

b = number of bytes to be transferred

N = number of bytes on a track

r = rotation speed, in revolutions per second

HGST Ultrastar HE, HGST Ultrastar C15K600, and **Toshiba L200** are **hard drives** designed for **different use cases**.

Table gives **disk parameters** for **typical contemporary internal high-performance disks**. The **HGST Ultrastar HE** is intended for enterprise applications, such as use in servers and workstations. The **HGST Ultrastar C15K600** is **designed** for **use** in high-performance computing and mission critical data center installations. The **Toshiba L200** is an internal laptop hard disk drive.

Typical Hard Disk Drive Parameters

Characteristics	HGST Ultrastar HE	HGST Ultrastar C15K600	Toshiba L200
Application	Enterprise	Data Center	Laptop
Capacity	12 TB	600 GB	500 GB
Average seek time	8.0 ms read 8.6 ms write	2.9 ms read 3.1 ms write	11 ms
Spindle speed	7200 rpm	15,030 rpm	5400 rpm
Average latency	4.16	< 2 ms	5.6 ms
Maximum sustained transfer rate	255 MB/s	1.2 GB/s	3 GB/s
Bytes per sector	512/4096	512/4096	4096
Tracks per cylinder (number of platter surfaces)	8	6	4
Cache	256 MB	128 MB	16 MB
Diameter	3.5 in (8.89 cm)s	2.5 in (6.35 cm)	2.5 in (6.35 cm)
Maximum areal density (Gb/cm^2)	134	82	66

RAID (Redundant Array of Independent Disks)

Industry has **agreed** on a **standardized scheme** for **multiple-disk database design**, known as **RAID (Redundant Array of Independent Disks)**. The **RAID scheme consists** of seven levels, zero **through** six. These **levels** do not **imply** a **hierarchical relationshi**p, but **designate different design architectures** that share three common characteristics:

1. RAID is a **set of physical disk drives** viewed by the operating system as a single logical drive.

2. Data are **distributed across the physical drives** of an **array** in **a scheme** known as **striping**.

3. **Redundant disk capacity** is **used** to **store parity information**, which guarantees **data recoverability** in **case** of a **disk failure**.

The term RAID was originally **coined** in a paper by a group of researchers at the University of California at Berkeley. The **paper outlined** various RAID configurations and applications and introduced the **definitions** of the **RAID levels** that are still used. The RAID strategy employs multiple disk drives and distributes data in such a way as to **enable simultaneous access to data from multiple drives**, thereby **improving I/O performance** and allowing **easier incremental increases** in **capacity**.

RAID Levels

RAID Levels

Note: N = number of data disks ; m proportional to log N

Category	Level	Description	Disks Required	Data Availability	Large I/O Data Transfer Capacity	Small I/O Request Rate
Striping	0	Nonredundant	N	Lower than single disk	Very high	Very high for both read and write
Mirroring	1	Mirrored	$2N$	Higher than RAID 2, 3, 4, or 5; lower than RAID 6	Higher than single disk for read; similar to single disk for write	Up to twice that of a single disk for read; similar to single disk for write
Parallel access	2	Redundant via Hamming code	$N+m$	Much higher than single disk; comparable to RAID 3, 4, or 5	Highest of all listed alternatives	Approximately twice that of a single disk
	3	Bit-interleaved parity	$N+1$	Much higher than single disk; comparable to RAID 2, 4, or 5	Highest of all listed alternatives	Approximately twice that of a single disk

RAID Levels

RAID Levels

Note: N = number of data disks; m proportional to log N

Category	Level	Description	Disks Required	Data Availability	Large I/O Data Transfer Capacity	Small I/O Request Rate
Independent access	4	Block-interleaved parity	$N+1$	Much higher than single disk; comparable to RAID 2, 3, or 5	Similar to RAID 0 for read; significantly lower than single disk for write	Similar to RAID 0 for read; significantly lower than single disk for write
	5	Block-interleaved distributed parity	$N+1$	Much higher than single disk; comparable to RAID 2, 3, or 4	Similar to RAID 0 for read; lower than single disk for write	Similar to RAID 0 for read; generally lower than single disk for write
	6	Block-interleaved dual distributed parity	$N+2$	Highest of all listed alternatives	Similar to RAID 0 for read; lower than RAID 5 for write	Similar to RAID 0 for read; significantly lower than RAID 5 for write

RAID Comparison

Level	Advantages	Disadvantages	Applications
0	I/O performance is greatly improved by spreading the I/O load across many channels and drives No parity calculation overhead is involved Very simple design Easy to implement	The failure of just one drive will result in all data in an array being lost	Video production and editing Image Editing Pre-press applications Any application requiring high bandwidth
1	100% redundancy of data means no rebuild is necessary in case of a disk failure, just a copy to the replacement disk Under certain circumstances, RAID 1 can sustain multiple simultaneous drive failures Simplest RAID storage subsystem design	Highest disk overhead of all RAID types (100%)—inefficient	Accounting Payroll Financial Any application requiring very high availability
2	Extremely high data transfer rates possible The higher the data transfer rate required, the better the ratio of data disks to ECC disks Relatively simple controller design compared to RAID levels 3, 4, & 5	Very high ratio of ECC disks to data disks with smaller word sizes—inefficient Entry level cost very high—requires very high transfer rate requirement to justify	No commercial implementations exist/not commercially viable
3	Very high read data transfer rate Very high write data transfer rate Disk failure has an insignificant impact on throughput Low ratio of ECC (parity) disks to data disks means high efficiency	Transaction rate equal to that of a single disk drive at best (if spindles are synchronized) Controller design is fairly complex	Video production and live streaming Image editing Video editing Prepress applications Any application requiring high throughput

URS

RAID Comparison

Level	Advantages	Disadvantages	Applications
4	Very high Read data transaction rate Low ratio of ECC (parity) disks to data disks means high efficiency	Quite complex controller design Worst write transaction rate and Write aggregate transfer rate Difficult and inefficient data rebuild in the event of disk failure	No commercial implementations exist/not commercially viable
5	Highest Read data transaction rate Low ratio of ECC (parity) disks to data disks means high efficiency Good aggregate transfer rate	Most complex controller design Difficult to rebuild in the event of a disk failure (as compared to RAID level 1)	File and application servers Database servers Web, e-mail, and news servers Intranet servers Most versatile RAID level
6	Provides for an extremely high data fault tolerance and can sustain multiple simultaneous drive failures	More complex controller design Controller overhead to compute parity addresses is extremely high	Perfect solution for mission critical applications

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Solid State Drives

One of the **most significant developments** in **computer architecture** in recent years is the increasing use of **solid state drive (SSD)** to **complement** or **even replace hard disk drive (HDD)**, both as **internal** and **external secondary** memory.

The term **solid state** refers to electronic circuitry **built with** semiconductors. An SSD is a memory device **made with** solid state components that can be used as a **replacement** to a **hard disk drive**. The **SSDs** now on the market and coming on line **use** NAND flash memory.

SSD Compared to HDD

As the **cost** of flash-based SSDs has **dropped** and the **performance** and **bit density increased**, **SSDs** have become increasingly **competitive** with **HDDs**.

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Table shows typical measures of comparison between SSD & HDD

Comparison of Solid State Drives and Disk Drives

	NAND Flash Drives	Seagate Laptop Internal HDD
File copy/write speed	200–550 Mbps	50–120 Mbps
Power draw/battery life	Less power draw, averages 2–3 watts, resulting in 30 + minute battery boost	More power draw, averages 6–7 watts and therefore uses more battery
Storage capacity	Typically not larger than 1 TB for notebook size drives; 4 max for desktops	Typically around 500 GB and 2 TB max for notebook size drives; 10 TB max for desktops
Cost	Approx. $0.20 per GB for a 1-TB drive	Approx. $0.03 per GB for a 4-TB drive

SSDs have the following advantages over HDDs:

- **High-performance input/output operations per second (IOPS):** Significantly **increases performance** I/O subsystems.
- **Durability:** **Less susceptible** to **physical shock** and **vibration**.
- **Longer lifespan:** SSDs are not **susceptible** to **mechanical wear**.
- **Lower power consumption:** **SSDs** use considerably **less power** than comparable-size **HDDs**.
- **Quieter and cooler running capabilities:** **Less space** required, **lower energy costs,** and **a greener enterprise**.
- **Lower access times and latency rates:** Over **10 times faster** than the **spinning disks** in an **HDD**.

Currently, **HDDs** enjoy a **cost per bit advantage** and a **capacity advantage**, but these **differences** are **shrinking**.

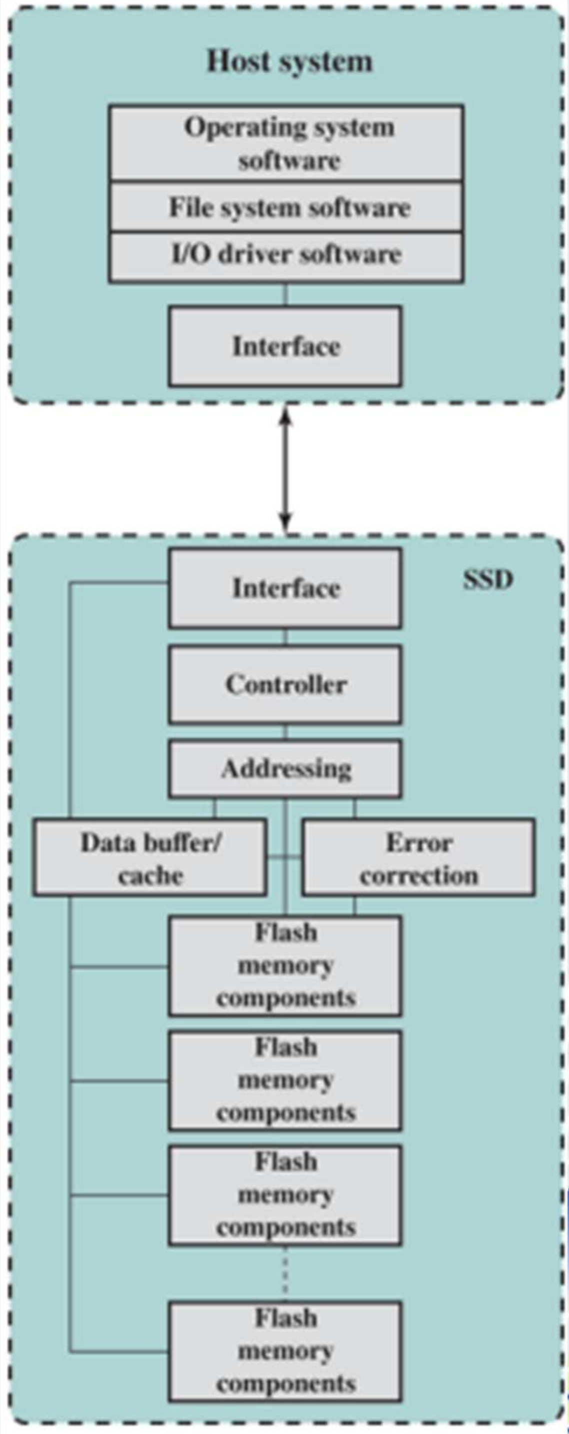
SSD Organization

On the **host system**, the operating system invokes file system software to access data on the disk. The file system, in turn, invokes I/O driver software. The I/O driver software provides host access to the particular SSD product.

The interface component in **figure** refers to the **physical** and **electrical interface** between the **host processor** and the **SSD peripheral device**.

If the device is an internal hard drive, a **common interface** is **PCIe**. For external devices, one **common interface** is **USB**.

PCIe (Peripheral Component Interconnect Express) is a **high-speed interface standard used** for **connecting components,** such as **graphics cards, solid-state drives (SSDs), network cards,** and **more**, to a computer's motherboard. It is commonly used in **internal devices** due to its **fast data transfer capabilities** and **versatility**.



Solid State Drive Architecture

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Solid State Drive Architecture

In addition to the interface to the host system, the SSD contains the following components:

- **Controller:** Provides SSD device **level interfacing** and **firmware execution**.
- **Addressing: Logic** that performs the **selection function across** the **flash memory components.**
- **Data buffer/cache: High speed RAM memory components** used for **speed matching** and to **increased data throughput**.
- **Error correction: Logic** for **error detection** and **correction.**
- **Flash memory components: Individual NAND flash chips**.

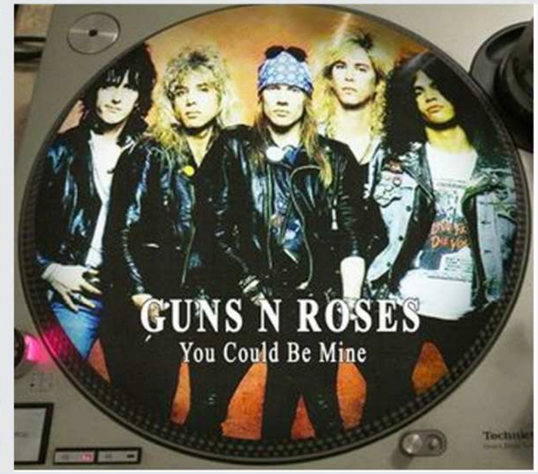
Optical Memory

In 1983, one of the most successful consumer products of all time was introduced: the **compact disk (CD) digital audio system**. The CD is a nonerasable disk that can **store** more than 60 minutes of audio information.

The **huge commercial success** of the **CD** enabled the **development** of **low-cost optical-disk storage technology** that has **revolutionized computer data storage**.

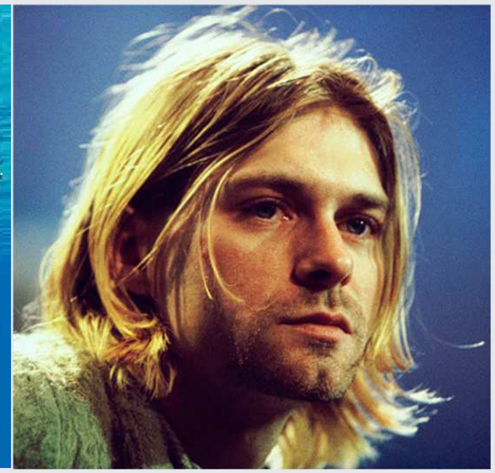

METALLICA

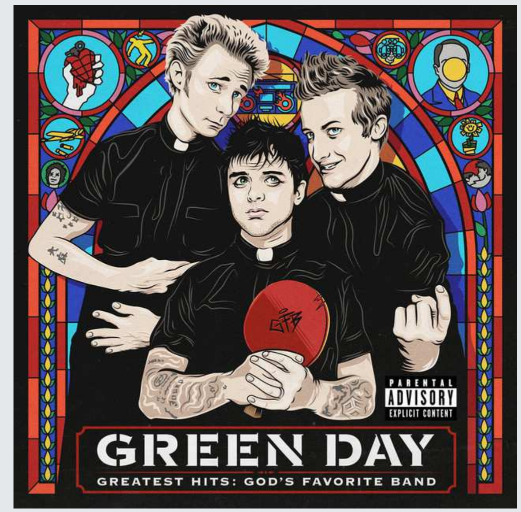

piano / vocal / guitar
bent
matchbox
TWENTY


GUNS N ROSES
You Could Be Mine

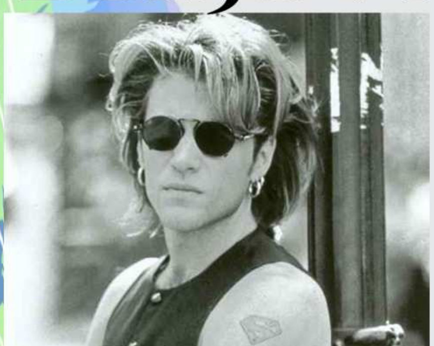

RED BLOOD
PARENTAL ADVISORY
EXPLICIT LYRICS


NIRVANA
NEVERMIND

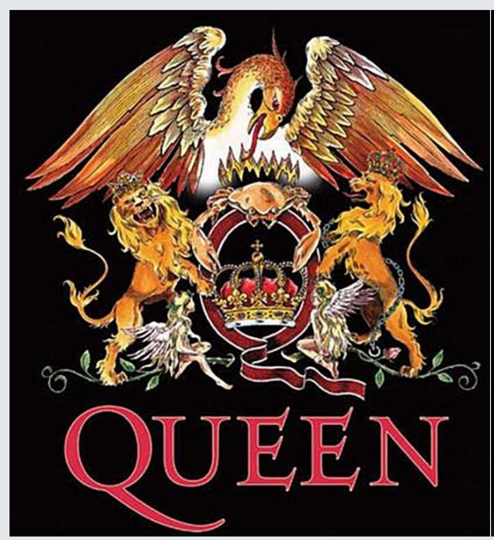



PARENTAL ADVISORY
EXPLICIT CONTENT
GREEN DAY
GREATEST HITS: GOD'S FAVORITE BAND

BON JOVI




AEROSMITH


QUEEN

CD-ROM Disk

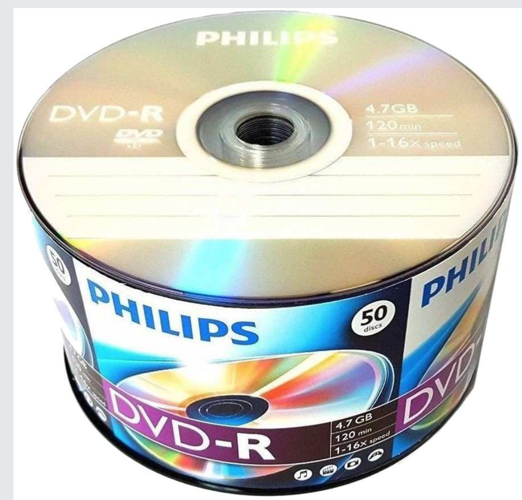

SONY
CD-R
700MB


52X MAX
LG


Verbatim
CD-RW
700
8-12x


NIRVANA
UNPLUGGED
IN NEW YORK
Heart-Shaped Box


INCEPTION
GoZmit


PHILIPS
DVD-R
4.7GB
120 min
1-16x speed
50


BEN AFFLECK AARON ECKHART UMA THURMAN
PAYCHECK


Verbatim
DVD+RW
4.7
4x
120


NICOLAS CAGE
KNOWING

URS

A variety of optical-disk systems have been introduced

Optical Disk Products

CD Compact Disk. A nonerasable disk that stores digitized audio information. The standard system uses 12-cm disks and can record more than 60 minutes of uninterrupted playing time.
CD-ROM Compact Disk Read-Only Memory. A nonerasable disk used for storing computer data. The standard system uses 12-cm disks and can hold more than 650 Mbytes.
CD-R CD Recordable. Similar to a CD-ROM. The user can write to the disk only once.
CD-RW CD Rewritable. Similar to a CD-ROM. The user can erase and rewrite to the disk multiple times.

A variety of optical-disk systems have been introduced

DVD Digital Versatile Disk. A technology for producing digitized, compressed representation of video information, as well as large volumes of other digital data. Both 8 and 12 cm diameters are used, with a double-sided capacity of up to 17 Gbytes. The basic DVD is read-only (DVD-ROM).
DVD-R DVD Recordable. Similar to a DVD-ROM. The user can write to the disk only once. Only one-sided disks can be used.
DVD-RW DVD Rewritable. Similar to a DVD-ROM. The user can erase and rewrite to the disk multiple times. Only one-sided disks can be used.
Blu-ray DVD High-definition video disk. Provides considerably greater data storage density than DVD, using a 405-nm (blue-violet) laser. A single layer on a single side can store 25 Gbytes.

Optical Memory

In 1983, one of the most successful consumer products of all time was introduced: the **compact disk (CD) digital audio system**. The CD is a nonerasable disk that can **store** more than 60 minutes of audio information.

The **huge commercial success** of the **CD** enabled the **development** of **low-cost optical-disk storage technology** that has **revolutionized computer data storage**.

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Compact Disk

CD-ROM

Both the **audio CD** and the **CD-ROM (compact disk read-only memory)** share a similar technology. The **main difference** is that CD-ROM players are **more rugged** and **have error correction devices** to **ensure** that **data** are **properly transferred from disk to computer**. Both **types** of **disk** are **made** the **same way**.

The **disk** is **formed from a resin**, such as polycarbonate. Digitally recorded information (either music or computer data) is imprinted as a series of microscopic pits on the surface of the polycarbonate. This is done, first of all, with a **finely focused, high-intensity** laser to **create** a **master** disk. The **master** is used, in turn, to make a die to stamp out copies onto polycarbonate. The pitted surface is then coated with a highly reflective surface, usually aluminum or gold. This **shiny surface** is protected against dust and scratches by a top coat of clear acrylic. Finally, a **label** can be silkscreened onto the acrylic.

Compact Disk

CD-R (CD Recordable)

To accommodate applications in which only one or a small number of copies of a set of data is needed, the **write-once read-many CD**, known as the **CD recordable (CD-R)**, has been **developed**.

For **CD-R**, a disk is prepared in such a way that it can be subsequently **written once** with a laser beam of modest intensity. **More expensive** disk controller **than** for **CD-ROM**, the customer can write once as well as read the disk.

CD-R, the medium includes a dye layer. The dye is **used** to **change reflectivity** and is **activated** by a **high-intensity laser**. The **resulting disk** can be read on a CD-R drive or a CD-ROM drive.

The CD-R optical disk is attractive for **archival storage** of documents and files. It provides a permanent record of large volumes of user data.

Computer Organization and Architecture 11th Ed William Stallings Pearson Education Inc 2019

Compact Disk

CD-RW (CD Rewritable)

The CD-RW optical disk can be **repeatedly written** and **overwritten**, as with a **magnetic disk**. Although a number of approaches have been tried, the **only pure optical approach** that has **proved attractive** is called **phase change**. The phase change disk uses a material that has two significantly **different reflectivities** in two **different phase states**.

There is an **amorphous state**, in which the molecules exhibit a random orientation that reflects light **poorly**; and a **crystalline state**, which has a **smooth** surface that reflects light **well**. A beam of **laser light** can **change** the material from **one phase** to the **other**. The primary **disadvantage** of phase change optical disks is that the **material** eventually and permanently **loses** its **desirable properties**. Current materials can be used for between 500,000 and 1,000,000 **erase** cycles.

The CD-RW has the obvious **advantage** over **CD-ROM** and **CD-R** that it can be **rewritten** and thus used as a **true secondary storage**. It competes with magnetic disks. A key **advantage** of the optical disk is that the **engineering tolerances** for **optical disks** are much less severe **than** for **high-capacity magnetic disks**. They exhibit higher reliability and longer life.

Compact Disk

DVD (Digital Versatile Disk)

With the capacious **digital versatile disk (DVD),** the electronics industry has at last found an acceptable **replacement** for the **analog VHS video tape**. The DVD has replaced the videotape used in video cassette recorders (VCRs) and also replaced the CD-ROM in personal computers and servers.

The **DVD** takes **video** into th**e digital age**. It delivers movies with impressive picture quality, and it can be randomly accessed **like audio CDs,** which **DVD machines can also play**. **Vast volumes** of **data** can be crammed **onto** the **disk**, currently **seven times** as much as a **CD-ROM**. With DVD's huge storage capacity and vivid quality, PC games have become more realistic and educational software incorporates more video.

cram – force something into small space

The DVD's greater capacity is due to three differences from CDs

1. Bits are packed **more closely** on a DVD. The **spacing between loops** of a **spiral** on a **CD** is **1.6µm** and the **minimum distance between pits along** the **spiral** is **0.834µm**.

The **DVD** uses a laser with shorter wavelength and achieves a **loop spacing** of **0.74** and a **minimum distance between pits** of **0.4µm** . The result of these two improvements is about a **seven-fold increase** in capacity, to about **4.7 GB**.

2. The DVD employs a second layer of pits and lands on top of the first layer. A dual-layer DVD has a semireflective layer on top of the reflective layer, and by **adjusting focus**, the lasers in DVD drives can **read each layer separately**. This **technique almost doubles** the **capacity** of the disk (DVD), to about **8.5 GB**. The **lower** reflectivity of the **second layer limits** its **storage capacity**, so that a **full doubling** is not achieved.

3. The DVD-ROM **can be** two sided, whereas data are recorded on **only one side** of a CD. This **brings total capacity** up to **17 GB**.

As with the CD, DVDs **come in** writeable as well as read-only versions

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LaserDisc (LD)

A **LaserDisc** (**LD**) is an **analog video storage medium** introduced in **1978**, which was an **early form** of **optical disc technology** before CDs and DVDs became mainstream. Unlike **CDs** and **DVDs**, which store **digital data, LaserDiscs store analog video** and **audio data,** and they are much **larger** in **size**—about **30 cm (12 inches)** in diameter.

It was widely used for video content **before being replaced** by **DVDs**. **LaserDiscs** offered better video quality **compared** to **VHS tapes** but were eventually overshadowed by the superior features and convenience of digital formats.

LaserDiscs never **achieved widespread popularity** due to their **high cost** and the **inability** to **record TV programs**, despite offering **superior picture** and **sound**. They were more **popular** among **videophiles** and **collectors**, particularly in regions like **Japan**.

LaserDisc technology laid the **foundation** for **later optical formats** such as CDs, DVDs, and Blu-ray. The format remained in use until 2009 when the last players were produced.

https://nextstopnostalgia.com/laserdiscs/

https://en.wikipedia.org/wiki/LaserDisc

High-Definition Optical Disks

High-definition optical disks are designed **to store high-definition videos** and **to provide** significantly **greater storage capacity** compared to **DVDs**. The higher bit density is **achieved** by **using** a **laser** with a **shorter wavelength**, in the blue-violet range.

The data pits, which **constitute** the digital 1s and 0s, are **smaller** on the **high-definition optical disks** compared to **DVDs** because of the **shorter laser wavelength**.

Two competing **disk formats** and **technologies** initially **competed** for market acceptance: **HD DVD** and **Blu-ray DVD**. The Blu-ray scheme **ultimately achieved** market dominance. The HD DVD scheme can store **15 GB** on a single layer on a single side. Blu-ray disc have **smaller** pits and tracks. Blu-ray can store **25 GB** on a single layer. Three **versions** are available: **read only (BD-ROM)**, **recordable once (BD-R)**, and **rerecordable (BD-RE)**.

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