Introduction to Computer Organisation and Architecture

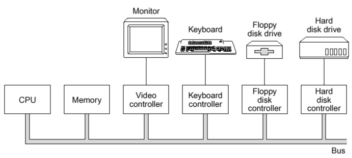
Peripheral Devices

Contents

- Magnetic Disk
- RAID
- Optical Disk
- CRT
- LCD

Peripheral Devices

- ***Peripherals***: devices that are separate from the basic computer (Not the CPU, memory, power supply)



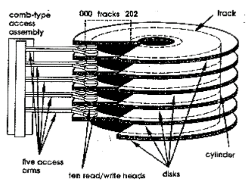
- Classified into input, output and storage
  - ✓ ***Output*** peripherals - Video Display, Printers
  - ✓ ***Input*** peripherals - Keyboard, Mouse, Joystick, Scanners
  - ✓ ***Storage*** Peripherals – hard disk
- Connected through:
  - ✓ Ports (parallel, USB, serial)
  - ✓ Interface to system bus (SCSI, IDE, PCMCIA)

Storage Devices

- ***Storage devices*** also known as mass media or auxiliary storage, refers to the various media on which a computer system can store data.
- There are two type of storage:
  - Primary memory
    - Volatile
    - Temporary
  - Secondary storage
    - Non volatile
    - Permanent
- No matter how big the main memory is, it is always too small.

Magnetic Disk

- A disk drive often has several disks stacked vertically.
- Each disk surface requires at least one radially movable head to read or write information from the disk
- A disk is a circular ***platter*** (3- to 12-cm diameter) constructed of non-magnetic material, called the ***substrate*** (aluminum or aluminum alloy, or recently glass), coated with a magnetizable material (iron oxide…rust).



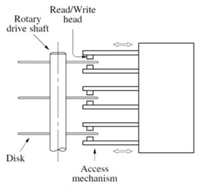
- The assembly is placed in a drive that causes it to rotate at a constant speed.

Magnetic Disk

- Traditionally, the substrate can be made from aluminium or aluminium alloy.
- Recently, glass subtrates have been introduced because of the following reasons:
  1. Improvement in surface uniformity of the magnetic film surface → higher reliability
  2. Reduction in surface defects → Reduced read/write errors
  3. Better stiffness → to reduce disc dynamics
  4. Better shock and damage resistance

Read and Write Mechanism

- Data access is performed mechanically: The disk is spinned on the ***spindle*** or ***rotary drive shaft***.
- Data are recorded on and later retrieve from the disk via a conducting coil named the ***head***.
- The read/write head moves to the correct position by extending/contracting the ***access arm***.



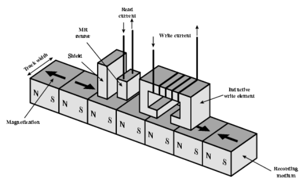
(a) Mechanical structure

- A head performs either a read or write operation, the head is stationary while platter rotates beneath it at an uniform speed.
- In most modern hard disk, the thin magnetic film is deposited on both sides. The same head (***read/write*** head) is also typically used to perform both read and write.

Read and Write Mechanism

- The ***write*** mechanism exploits the fact that electricity flowing through a coil produces a magnetic field. Electrical pulses of suitable polarity are sent to the write head. The magnetization of the film in the area immediately below the head will switch to a direction parallel to the applied field.
- Traditional ***read*** head :
  - During read, the coil serves as a sense coil. ***Changes in the magnetic field*** in the vicinity of the head caused by the movement of the film relative to the yoke induce a voltage in the coil. The polarity of the voltage detected by the coil is used to determine the binary state.
  - Uses the same coil for both read and write.
  - Slow due to mechanical constraint (bigger size of the read/write head)

Read and Write Mechanism



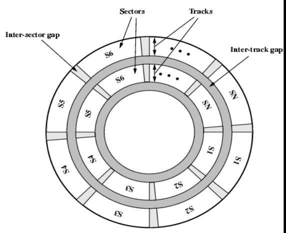
- Contemporary ***read*** head:
  - Separate read head, close to write head
  - Partially shielded magneto resistive (MR) sensor.
  - Electrical resistance will change depending on the direction of the magnetic field.
  - By passing current to the MR sensor, resistance changes will be detected as voltage signals (V = IR)
  - Able to perform at higher frequency and density

Data Organization and Formating

- Before any data can be read/written into disk, it must be formatted.
- Formatting is the process of dividing the disk into track and sector.

Tracks

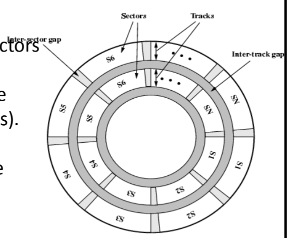
- Track is the organization of data on the platter in concentric set of rings.
- Adjacent tracks are separated by **gaps** to prevent or minimize errors due to misalignment of the head or interference of magnetic fields
- A typical disk may contain >100 to several thousand tracks.



Data Organization and Formating

Sector

- Tracks are divided into sectors, normally between 64 and 128 sectors per track
- Each sector typically contains one ***block*** of data 512 bytes (4096 bits).
- To avoid unreasonable precision requirement adjacent sectors are separated by inter-sector gaps.



Cluster

- A group of segments belonging to the same track

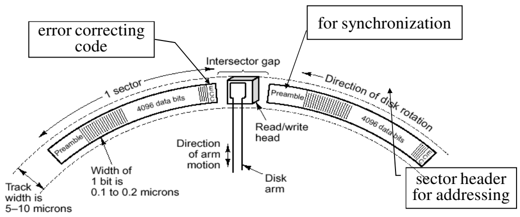
Cylinder

- The set of tracks at a given radial position (distance from spindle)

cylinders in the disk = #tracks in a single platter

Data Organization and Formating

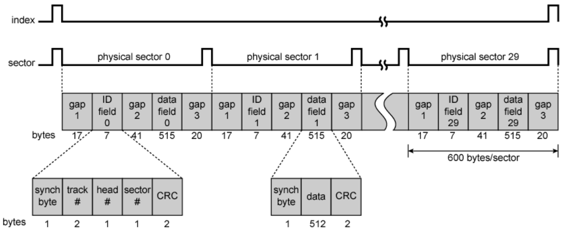
- Each sector contains 512 bytes.
- The data is preceded by a header which contains the ID of the sector. The data is followed by the error-correcting code (ECC) to detect and correct errors that may have occurred in writing or reading the data bytes.



A portion of a disk track. Two sectors are illustrated.

Winchester Disk Format (Seagate ST506)

Example of disk formatting:



- 30 fixed-length sectors of 600 bytes each
- 12 bytes of data + control information
- ID is the unique identifier (address) to a particular sector
- SYNC delimits the beginning of the field

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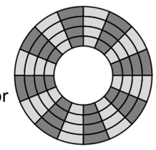
Disk Velocity

- Bit near centre of rotating disk passes fixed point slower than bit on outside of disk (the same amount of time is used to cover a longer distance in the outer tracks) → inconsistency in speed.
- How to handle speed inconsistency?
  - Constant Angular Velocity (CAV)
  - Multiple Zoned Recording (MZR)

Contant Angular Velocity (CAV)

- Rotate disk at constant angular velocity (CAV) Increase spacing between bits in different tracks
- Gives pie shaped sectors and concentric tracks
- Individual tracks and sectors addressable
- Move head to given track and wait for given sector
- Waste of space on outer tracks
  - Lower data density



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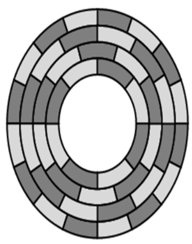
Multiple Zoned Recording

- Track are groups into concentric zones based on their distance to the spindle. Within each zone, the number of bits per track is constant. Zones farther from the center contain more bits than zones closer to the center.
- Designed to support high density secondary storage
- Same number of bits per sector but different number of sectors per track (Fewer sector in the inner tracks).
- Transfer rate will become inconstant for different sectors (need different speed for the read head, since rotation speed is constant).
- Data on the outer most zone will have the highest data transfer rate. This is typically where the OS is stored.



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Physical Characteristics of Disk Systems

- *Fixed* (rare) or *movable* head
  - Fixed: one read write head per track. Arm is rigid
  - Movable: one read write head per side. Arm is movable
- *Removable* or *fixed*
  - *Removable:* can be removed from drive. Smaller capacity
  - *Fixed:* permanently mounted such as HDD
- Single or double (usually) sided

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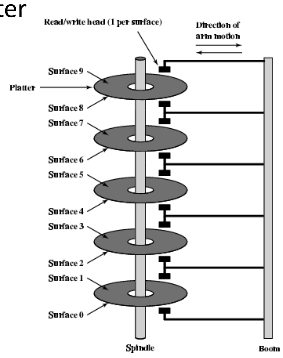
Physical Characteristics of Disk Systems

- Single or multiple platter
  - For multiple patters, all the heads are mechanically fixed so that all are at the same distance from the center of the disk → moves at the same time.



Example of a multiple Platter Disk

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Physical Characteristics of Disk Systems

- Head Mechanism
  - Contact (floppy)
  - Fixed gap between the head and the tracks
  - Aerodynamic Gap (Winchester).
    - The head must be sufficiently near to the surface to generate (sense) sufficiently strong electromagnetic field to write/read properly.
    - The narrower the head → the narrower the track → the denser the disk (desirable)
    - The narrower the head, the closer the head needs to be to the disk.
    - Winchestor head is an aerodynamic foil that rests lightly on the surface when motionless. It fly on boundary layer of air as disk spins → very small head to disk gap.

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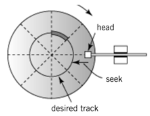
Magnetic Disk

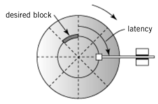
- **Average Seek time**
  - Average time to move the head from one track to the destination track
  - Average seek time for magnetic disk range from 5 to 8ms



- **Average Latency time**

Avg. Latency time = 0.5 * (1/rotational_speed)

  - Average time to rotate to the beginning of the sector.
  - On average, this is half a rotation of a disk
  - Rotational_speed is specified in terms #rotations/min or #rotations/sec
  - 1/rotational_speed is the time needed to complete reading 1 track

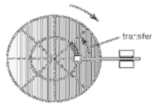


Disk Access Time

- **Average block transfer time**

(1/rotation_speed) / #sectors_in_one_track

  - ✓ The time required to transfer a block of data (one segment) to the disk controller buffer
  - ✓ Equivalent to the time to perform one rotation divided by the #sectors in one track



- **Average time to access a disk block**

average seek time + average latency time + average block transfer time

- **Data Transfer Rate**

bytes in a track * rotation_speed

  - ✓ The rate of data movement between the disk and the computer

Disk Access Time

Example 1:

Suppose a disk system has the following properties

- 20 data-recording surfaces
- 15,000 cylinders (= #tracks per surface)
- An average of 400 sectors per track
- Each sector contains 512 bytes of data
- Average seek time = 6ms
- Average latency = 3ms
- Rotation = 10K rotations per minute

What is the total capacity of the disk?

$20 \times 15{,}000 \times 400 \times 512 \approx 60$ gigabytes

What is the transfer rate (for each surface) in bytes/sec?

10K rotations/minute = 10K/60 = 1666.67 rotations/sec

Transfer rate = #bytes_per_track x rotations_per_sec

= 400 x 512 x 1666.67 = 341334016 bytes/second

= 341.334016 x 10^6 bytes/sec ~ 341MB/sec

Disk Access Time

Example 2:

Consider a disk unit with 24 recording surfaces, 14K cylinders and average 400 sectors per track. Each block contains 512 bytes of data. The rotational speed is 7200 rotations per minute (rpm).

What is the capacity of the disk?

Capacity = #surfaces x #tracks x #sectors_per_track x #bytes_per_block

= 24 x 14000 x 300 x 512 = 68,812,800,000 = 68.8 x10^9 bytes ~ 69 GB.

What is the data transfer rate ?

7200 rotations per minute → 7200/60 = 120 rotations per second.

Size of one track = #sectors x # bytes_per _block = 400 x 512 = 204,800 byte

Number of bytes per second = size of one track x #rotations per second

= 204,800 x 120 = 24576000 ~ 25MB/sec

What is the maximum and minimum latency time for this disk?

Minimum latency time = 0 s (when the head is parked at the desired sector)

Maximum latency time ~ Time for 1 rotation = 60/7200 seconds

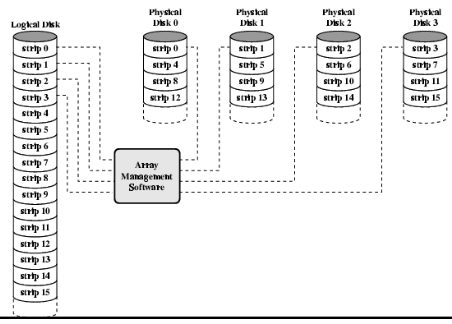
= 0.0083125 seconds

RAID

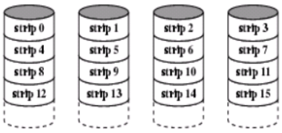
- Speed improvement for storage devices cannot keep up with the speed improvement of processor and even semiconductor memory.
- Reliability improvement to recover data when any hard disk crashes.
- Solution: use multiple magnetic disk drives operating in parallel to provide a high-performance and high-reliability storage unit
- RAID: Redundant Array of Inexpensive Disk.
- Set of several physical disks but viewed as a single logical drive by the OS
- Data is distributed across physical drives while redundant capacity can be used to store parity information

RAID 0 – Stripped Array

- ***Data Stripping***: A single large file is stored in several separate disk units by breaking the file into a number of blocks, which are then written simultaneously to different disks (round robin stripping)

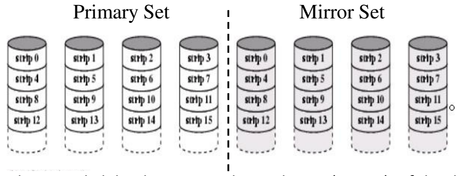


RAID 0 – Stripped Array



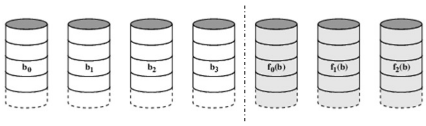
- **Array management software** (can execute as part of the disk subsystem or host computer) maps the logical to the physical disk space.
- When read, all disk are accessed in parallel.
- Individual pieces of the data are buffered, and the complete file are reassembled and transferred to the memory as a single entity.
- In a **transaction-oriented environment** (many I/O requests by one/different applications), **load balancing** is required.
- Advantage:
  - High transfer rate if the size of data to be transferred is much larger than the strip size
- Disadvantage:
  - Cannot recover data if any disk is corrupted.

RAID 1 – Mirror Array



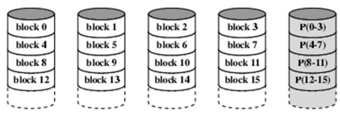
- Provides better reliability by storing identical copy (mirror) of the data in another disk set rather than just one.
- For write operations, write to both disks – performance is governed by the slowest disk. No write penalty.
- For read operations, read request is serviced by the disk with the minimum seek time plus the rotational latency.
- If a read failure occurs in one of the drives, the data are read from another drive and the bad block marked to prevent future use of block, increasing system reliability.
- Very costly way to improve reliability (identical copies of data)
- In a transaction environment, good for read, no advantage for write.

RAID 2



- Make use of **parallel access** technique
- Very ***small stripes***
  - Often single byte/word
- Disks are ***synchronized*** – Disk heads are in the same position on each disk at any given time.
- **Error correction calculated across corresponding bits on disks**
- Multiple parity disks store ***Hamming code*** error correction in corresponding positions
- Requires fewer disk than RAID1 but still lots of redundancy
  - Expensive
  - Not used

RAID 3

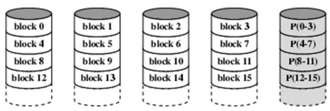


- Similar to RAID 2 (**parallel access** technique)
- Only one redundant disk, no matter how large the array
- **Simple parity bit** for each set of corresponding bits

  X4(i) = X3(i) ⊕ X2(i) ⊕ X1(i) ⊕ X0(i)
- Data on failed drive can be reconstructed from surviving data and parity info. Assuming X1 has been corrupted, X1 can be *recovered* using the following operation:

  X1(i) = X4(i) ⊕ X3(i) ⊕ X2(i) ⊕ X1(i)
- Strength: Very high transfer rates because data is stripped in very small strips
- Weakness: Only *one* I/O request can be executed at a time → Not good for transaction-oriented environment (many I/O requests at a time)

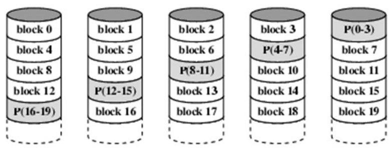
RAID 4



- Different from RAID 2 and RAID 3, each disk operates independently (no synchronization of disk heads)
- Good for transaction-oriented environment (high I/O request rate)
- Large stripes.
- Bit by bit parity calculated across stripes on each disk.
- Weakness: Slow write operation. When X1 changes to X1_new, to avoid reading from all *user* strips (4 reads + 1 write), we can compute the new parity bit X4_new using only X4, X1 and X1_new (involves two read and two write):

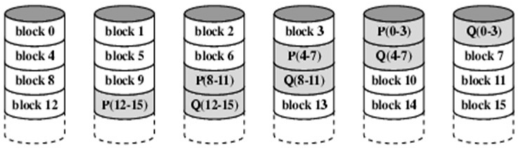
X4_new(i) = X3 ⊕ X2 ⊕ X1_new ⊕ X0
= X3 ⊕ X2 ⊕ X1_new ⊕ X0 ⊕ 0
= X3 ⊕ X2 ⊕ X1_new ⊕ X0 ⊕ X1 ⊕ X1
= X3 ⊕ X2 ⊕ X1 ⊕ X0 ⊕ X1_new ⊕ X1
= X4 ⊕ X1_new ⊕ X1

RAID 5



- Like RAID 4
- Parity striped across all disks
- Round robin allocation for parity stripe
- Avoids RAID 4 bottleneck at parity disk
- Commonly used in network servers

RAID 6

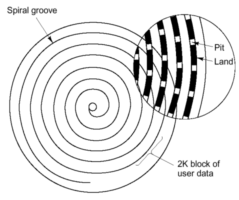


- High data availability
  - Three disks need to fail for data loss
  - Significant write penalty
- Uses two parity bits so that it is possible to
- Stored in separate blocks on different disks
- User requirement of N disks needs N+2

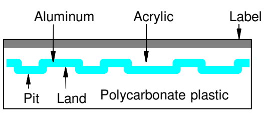
Optical Memory (CD-ROM)

- Compact Disk Read Only Memory (CD-ROM)
  - Technology used for audio CD and computer CD-ROM are similar.
  - Data is stored on an optical medium (reflective materials) and read using a laser light source
  - Non-erasable read-only memory for storing computer data.
  - Typical capacity for a 12-cm disk is more than 650Mbytes (70 minutes of audio)

Optical Memory (CD-ROM)



Recording structure of a Compact Disc or CD-ROM.

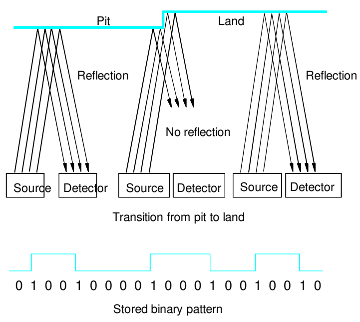


Cross-section

- Different from magnetic disk, ***there is only one physical track, spiralling from the middle of the disk toward the outer track.***
- But, it is customary to regard each circular path spanning 360 degrees as a separate track.
- The disk is made from a poly-carbonate (functions as a clear glass base), coated with a highly reflective aluminium surface.
- Digital data is imprinted as a series of microscopic (indented) ***pits*** and (un-indented) ***lands*** on the reflective surface.

Optical Memory (CD-ROM)

- The intensity of the reflected light of the **laser** changes as it encounters a transition from a pit to a ***land*** (light cancels out each other)
- Dark spot represents a 1, bright spot represents a 0)
- In practice, a more complex encoding scheme for representation. Each byte is represented by a 14-bit code for error detection capability.



Optical Memory (CD-ROM)

- Data is packed evenly across the disk in segments of the same size.
- The pits are read by the laser at a ***constant linear velocity*** (CLV), i.e. the disk rotates more slowly for accesses near the outer edge than those near the centre.
- Advantage of CD-ROM
  - large storage capacity;
  - can easily mass replicate inexpensively;
  - removable, allowing for archival storage.
- Disadvantage of CD-ROM
  - read-only cannot be updated;
  - access time much longer than magnetic disk

Optical Memory (CD-ROM)

Capacity of CD-ROM

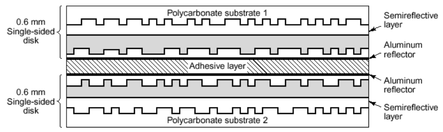
Track-to-track spacing	= 1.6 um
Recordable width along the radius	= 32.55 mm
	= 32550 um
Number of tracks	= 32550 / 1.6
	= 20344 tracks
The total length of the spiral	= 5.27 km
The linear velocity of the CD-ROM	= 1.2 m/sec
The total time for reading/playing	= 4391 sec
	= 73.2 min
Data rate from disk	= 176.4 Kbyte/sec
Total storage capacity for CD-ROM	= 774.57 Mbytes

Optical Memory (DVD)

- Digital Versatile Disk (DVD)
  - Same general design as CDs. High capacity disc capable of storing 4.7 to 17GB.
  - What is new is the use of
    - smaller pits (0.4 microns versus 0.8 microns for CDs)
    - a tighter spiral (0.74 microns between tracks versus 1.6 microns for CDs)
    - a red laser (at 0.65 microns versus 0.78 microns for CDs)
  - A 4.7 GB DVD can hold 133 min. of full-screen, full-motion video at high resolution (720 × 480), plus soundtracks in up to 8 languages and subtitles in 32 more.
  - Some DVD has dual layer, where different focus is used to read different layer.

Optical Memory (DVD)

- capacity
  - single-sided, single-layer (4.7 GB)
  - single-sided, dual-layer (8.5 GB)
  - doubled-sided, single-layer (9.4 GB)
  - doubled-sided, dual-layer (17 GB)



A double-sided, dual layer DVD disk.

Optical Memory

- BD-ROM (Blu-ray Discs-ROM)
- HD DVD-ROM (High-density DVD-ROM)
  - Both are more expensive, have higher capacity and better quality than standard DVDs
  - BD-ROM currently have a storage capacity of up to 100GB and HD DVD-ROM up to 60GB.