Computer Organization & Architecture

Chapter 8 – Secondary Storage

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- 8.10 Secondary Storage
  - Types of Secondary Storage
  - Magnetic Disk
  - Magnetic Hard Disk
  - Data Organization
  - Disk Capacity
  - Disk Access Time
  - Disk Controller
  - Solved Problems Example 8.6 (P327)
  - Floppy Disks
  - Summary

Types of Secondary Storage

- Magnetic Disk
  - Hard Disk
  - Floppy Disk
- Optical
  - CD
  - CD-ROM
  - CD-Recordable (CD-R)
  - CD-R/W
  - DVD
  - Blu-ray
- Magnetic Tape

Magnetic Disk

- Metal or plastic disk coated with magnetizable material (iron oxide…rust).
- Range of packaging
  - Winchester hard disk
  - Removable hard disk
  - Floppy

Disk Systems

- Physical Characteristics

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

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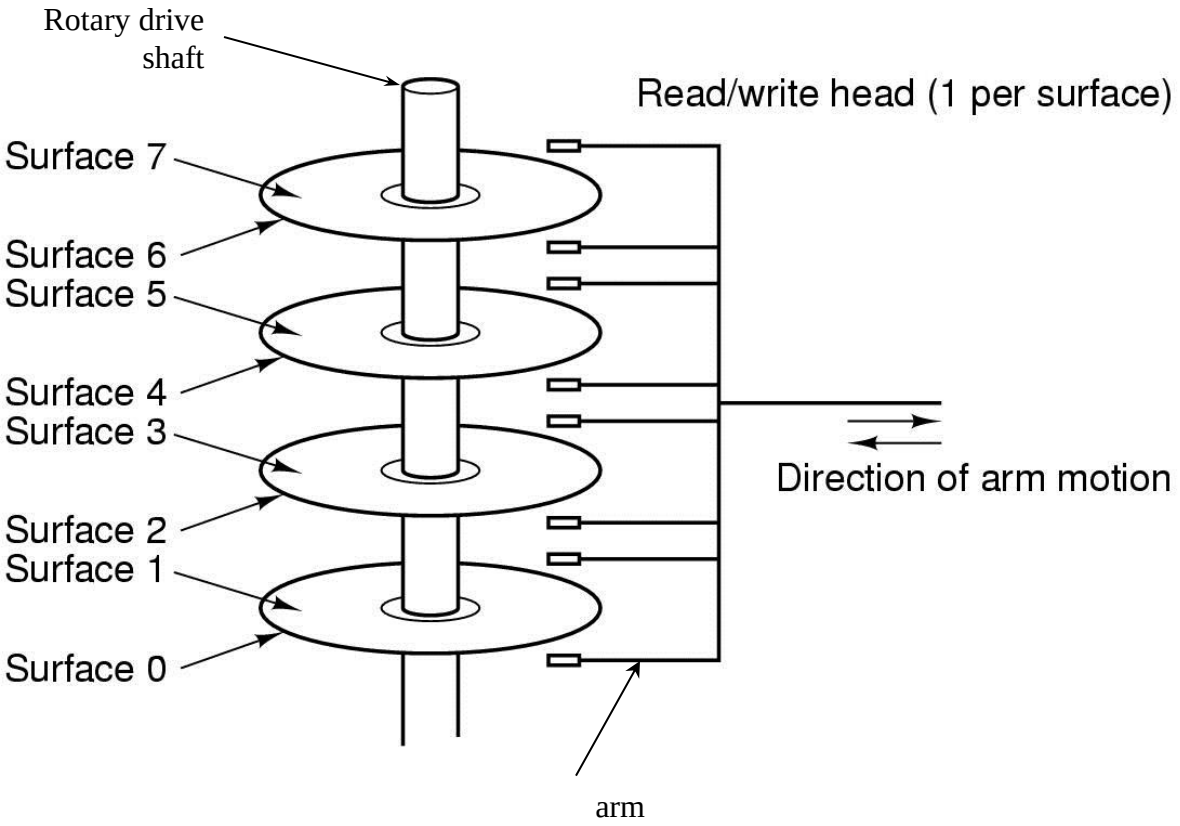
Magnetic Hard Disk (1)

- Mechanical Structure
  - Overall Structure
    - One or more disks (double-sided/single-sided) mounted on a common spindle.
    - A disk is a circular platter constructed of metal or of plastic coated with a magnetizable material.
    - The disks are placed in a rotary drive and they rotate at a uniform speed.

Magnetic Hard Disk (2)

- Mechanical Structure (ctd.)
  - Overall Structure (ctd.)

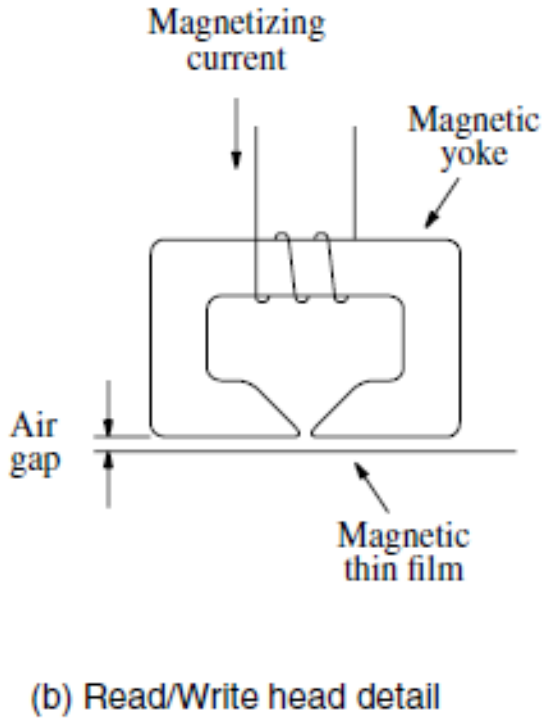


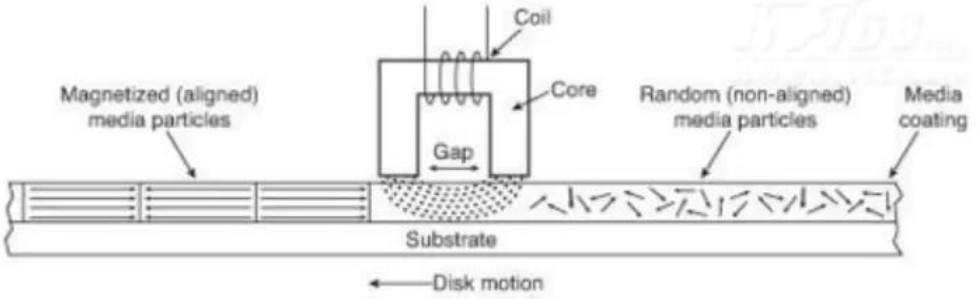
Magnetic Hard Disk (3)

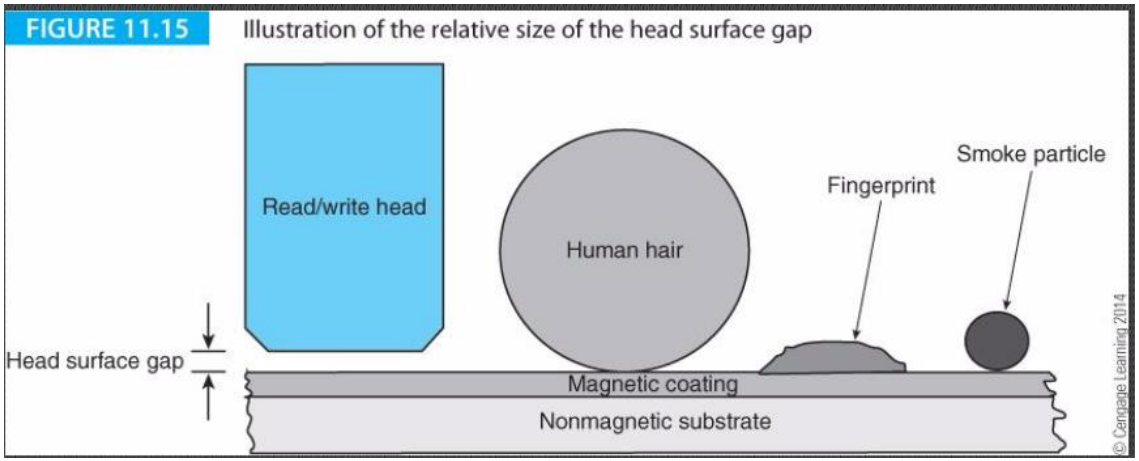
- Read/Write Head
  - Fixed Head
    - One read/write head per track.
    - Heads mounted on fixed ridged arm.
    - Expensive, no longer production.
  - Movable Head
    - One read/write head per side.
    - Mounted on a movable arm.
  - Detail
    - Each head consist of a magnetic yoke and a magnetizing coil.
    - Read/Write must be maintained at a very small distance from the moving disk surfaces.

Magnetic Hard Disk (4)

- Read/Write Head (ctd.)
  - Detail





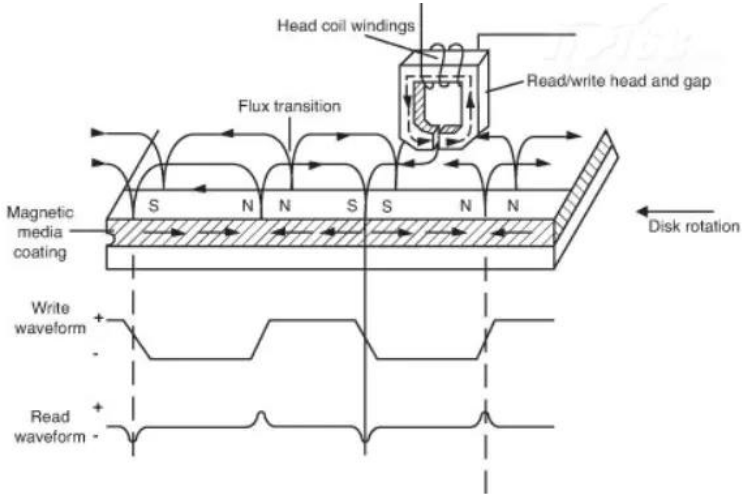


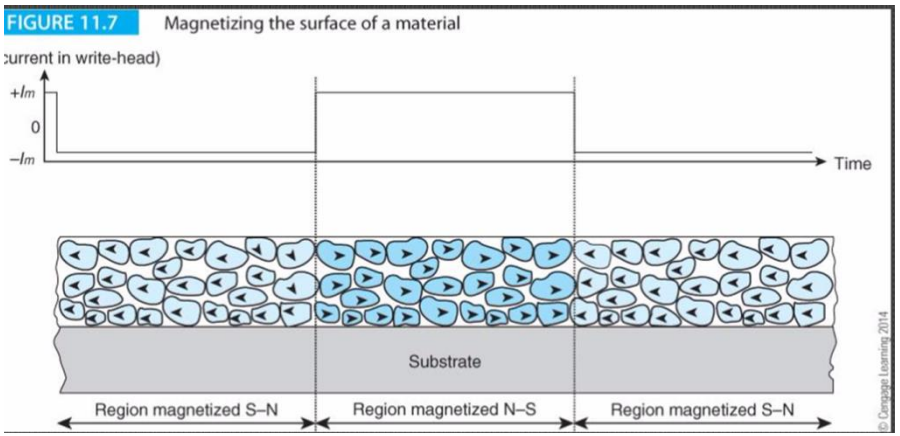
Magnetic Hard Disk (5)

- Read/Write Mechanism
  - Recording and retrieval via conductive coil(s) called a head(s).
  - May be single read/write head or separate ones.
  - During read/write, head is stationary (actually moves radially to platters) and platter rotates beneath head.

Magnetic Hard Disk (6)

- Read/Write Mechanism (ctd.)
  - Hard Drive Write
    - Current through coil produces magnetic field.
    - Pulses sent to head.
    - Magnetic pattern recorded on surface below.





Magnetic Hard Disk (7)

- Read/Write Mechanism (ctd.)
  - Hard Drive Read (Traditional)
    - Magnetic field ***moving*** relative to coil produces current. – Analogous to a generator or alternator.
    - Coil can be the same for read and write.

Magnetic Hard Disk (8)

- Disk Portability: Removable or Fixed
  - Removable disk
    - Can be removed from drive and replaced with another disk.
    - E.g. floppy, zip
    - Provides unlimited storage capacity.
    - Easy data transfer between systems.
  - Nonremovable disk
    - Permanently mounted in the drive.

Winchester Hard Disk

- Developed by IBM in Winchester (USA)
- Sealed unit
- One or more platters (disks)
- Heads fly on boundary layer of air as disk spins (crash into disk!)
- Very small head to disk gap
- Getting more robust.
- Universal
- Cheap
- Fastest external storage

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Data Organization of Hard Disk (1)

- Each surface is divided into concentric tracks, and each track is divided into sectors.

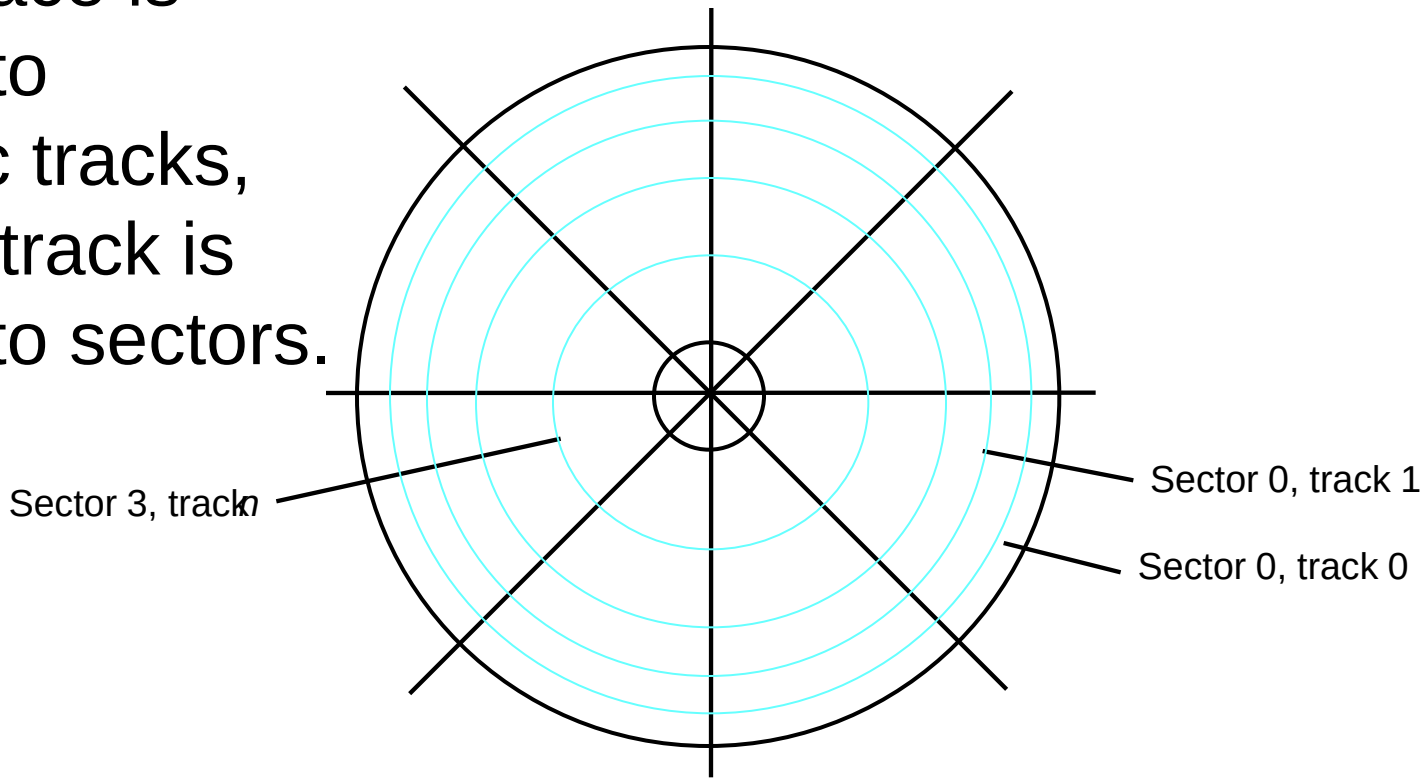
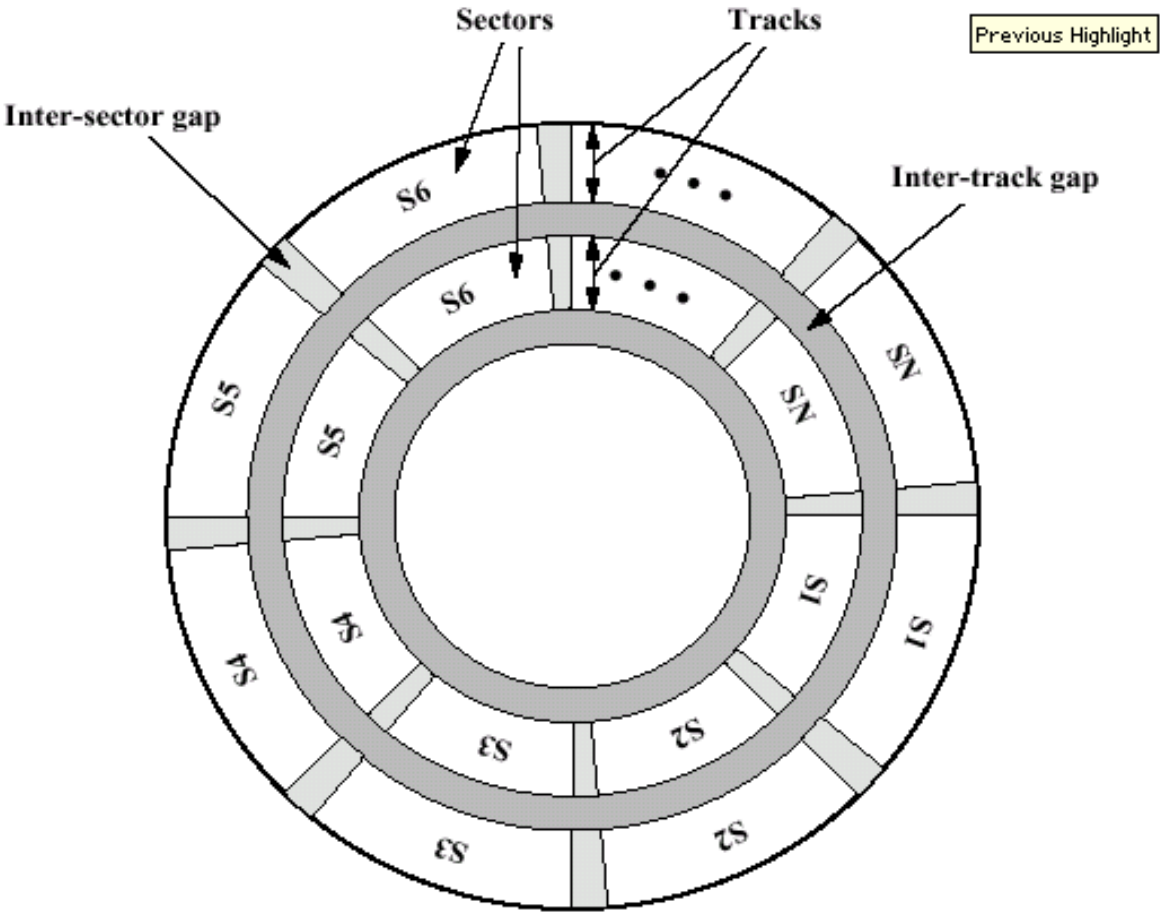


Figure 8.28. Organization of one surface of a disk.

Data Organization of Hard Disk (2)

- Tracks & Sectors

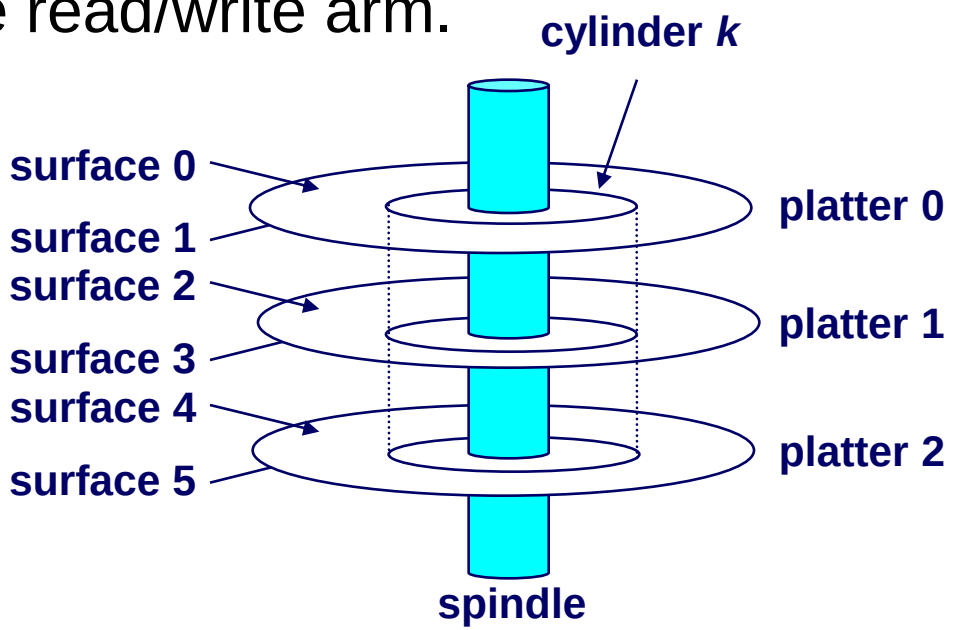


Data Organization of Hard Disk (3)

- Tracks & Sectors (ctd.)
  - Each track has the same number of sectors.
  - Outer tracks have more sectors. (Applied in large disks)
  - Tracks usually
    - 500 – 2000 tracks per surface
  - Sectors usually
    - Typically 512K bytes
    - 10 – 100 sectors per track
- Disk address: (surface number, track number, sector number)

Data Organization of Hard Disk (4)

- Cylinders
  - A cylinder is the set of tracks at a given radius of a disk pack.
    - i.e. a cylinder is the set of tracks that can be accessed without moving the disk arm.
    - All the information on a cylinder can be accessed without moving the read/write arm.

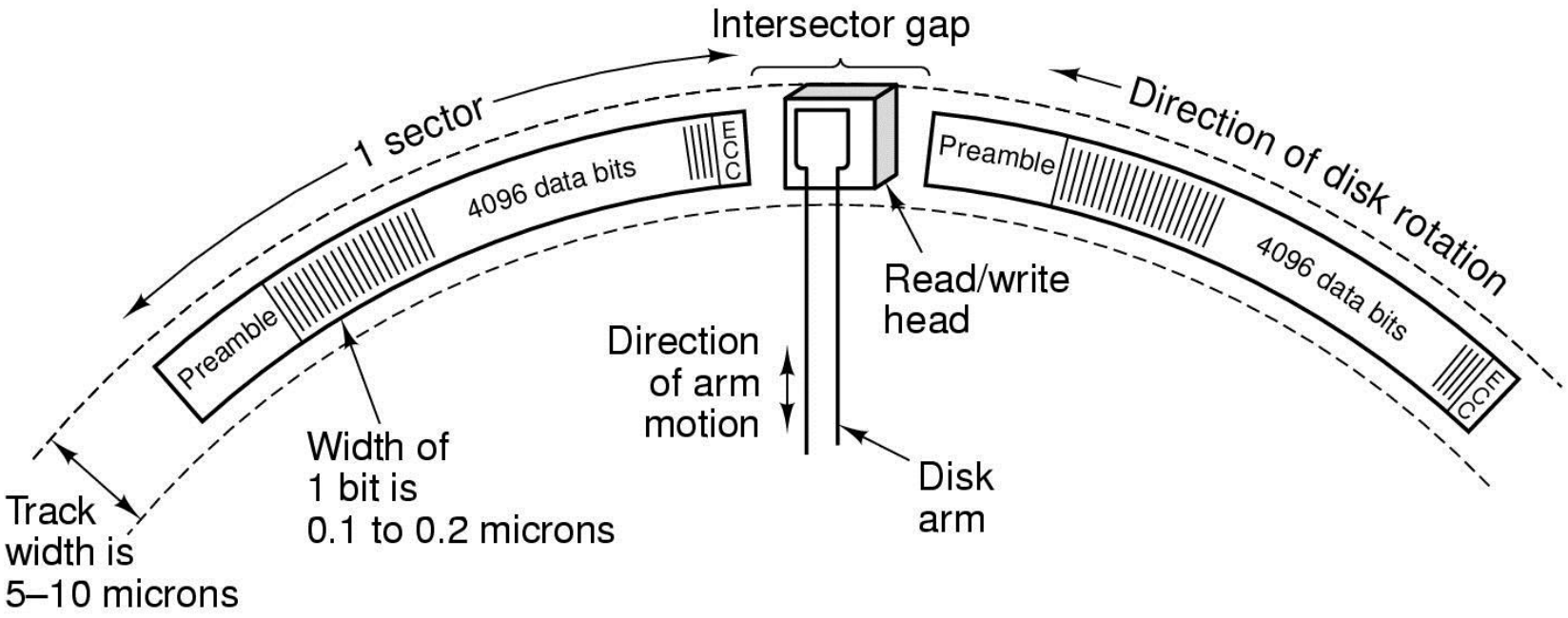


Data Organization of Hard Disk (5)

- Track Organization
  - Sector Header
    - Contains identification (addressing) information used to find the desired sector on the selected track.
  - ECC (Error-correcting Code) bits
    - Detect and correct errors that may have occurred in writing or reading of the 512 data bytes.
  - Intersector Gap
    - Distinguish between two consecutive sectors easily

Data Organization of Hard Disk (6)

- Track Organization (ctd.)
  - Figure



Disk Format

- Divide the disk into tracks and sectors.
- The formatting process may discover some defective sectors or even whole tracks.
- The formatting information accounts for about 15 percent of the total information that can be stored on a disk.

Disk Capacity (1)

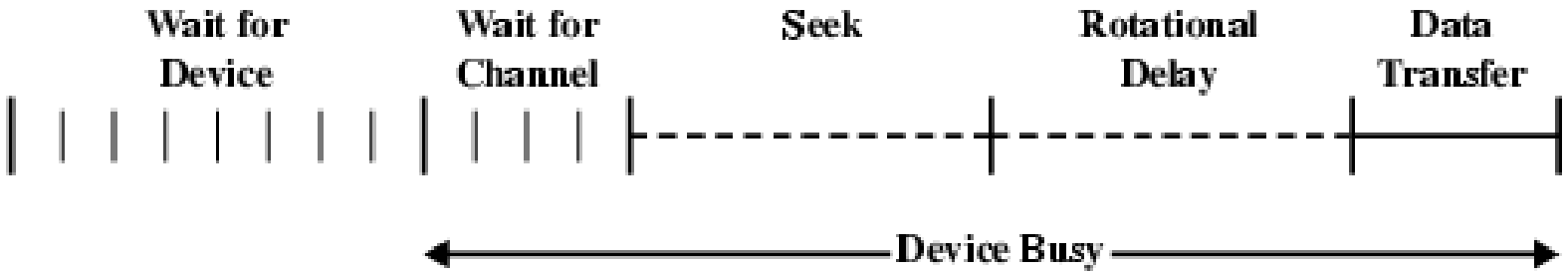
- Capacity: maximum number of bits that can be stored.
- Vendors express capacity in units of gigabytes (GB), where 1 GB = 10^9 Bytes).
- Capacity is determined by these technology factors:
  - Recording density (bits/in): number of bits that can be squeezed into a 1 inch segment of a track.
  - Track density (tracks/in): number of tracks that can be squeezed into a 1 inch radial segment. (tpi)
  - Areal density (bits/in^2): product of recording and track density.

Disk Capacity (2)

- Capacity = (# bytes/sector) x (avg. # sectors/track) x (# tracks/surface) x (# surfaces/platter) x (# platters/disk)
- Example
  - 512 bytes/sector
  - 300 sectors/track (on average)
  - 20,000 tracks/surface
  - 2 surfaces/platter
  - 5 platters/disk
  - Capacity = 512 x 300 x 20000 x 2 x 5 = 30,720,000,000 = 30.72 GB

Disk Access Time

- The time to access a sector in a track on a surface is divided into 3 components:
  - Seek time: Time to move the read/write arm to the correct cylinder. (5-15ms)
  - Rotational delay (or latency): Time it takes for the disk to rotate so that the desired sector is under the read/write head. (4-8ms)
  - Transfer time: Once the read/write head is positioned over the data, this is the time it takes for transferring data. (25-100us)



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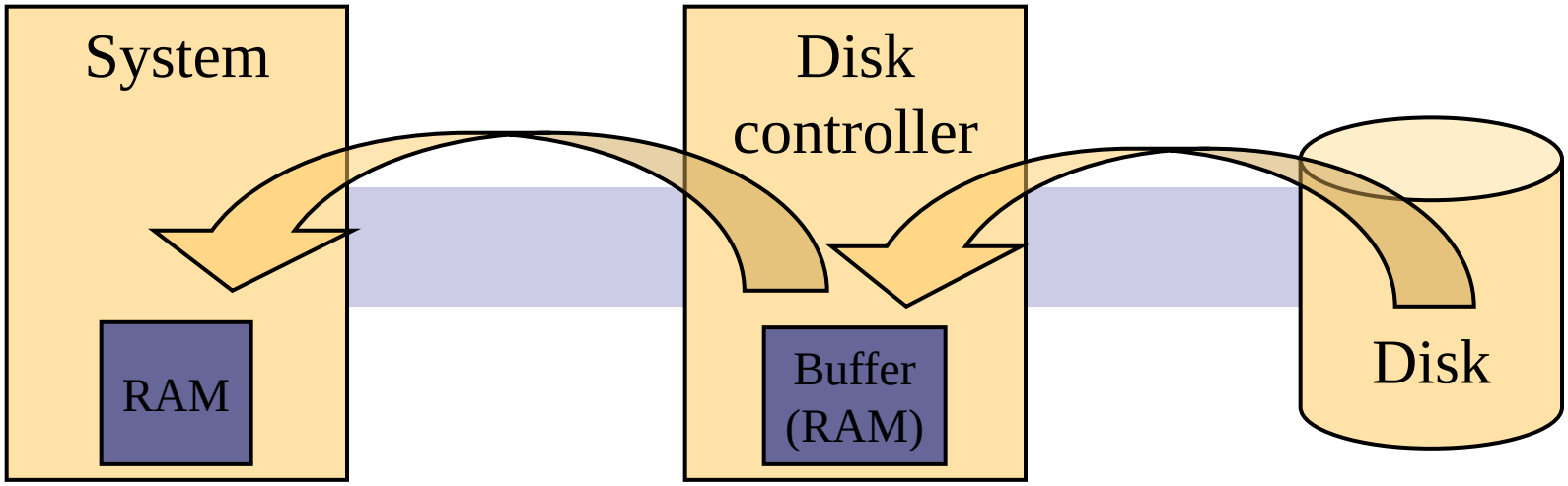
Disk Controller (1)

- Interface between the disk drive and the system is known as a disk controller.
- A primary function is to ensure data read/write operations are from/to the correct sector.
- Since data rate to/from the disk is different than data rate to/from system memory, “buffering” is needed.

Disk Controller (2)

- Disk Controller As a Buffer

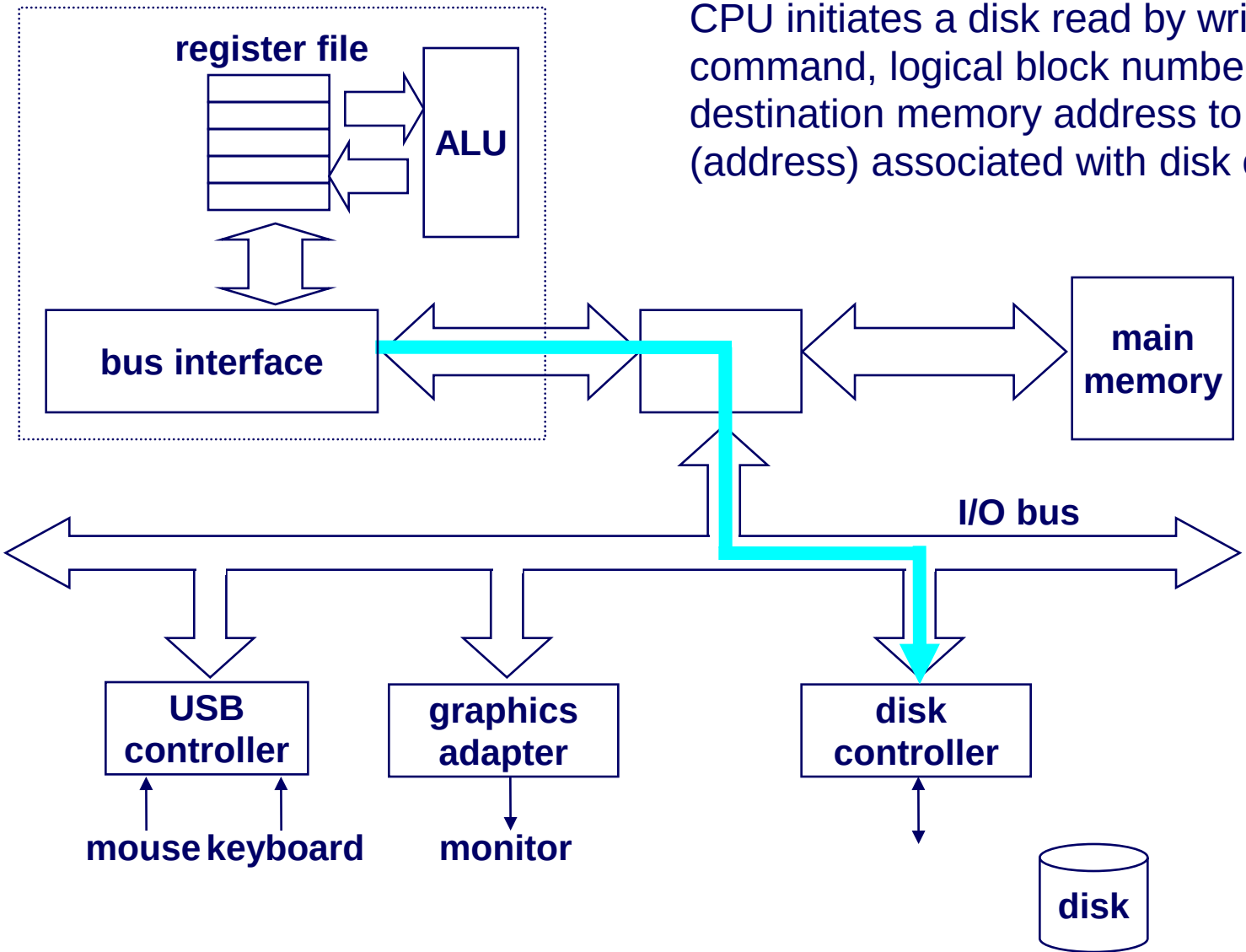


2. Transfer data from buffer to system RAM (Note: this is a DMA operation)

1. Read data from disk into a buffer in the disk controller

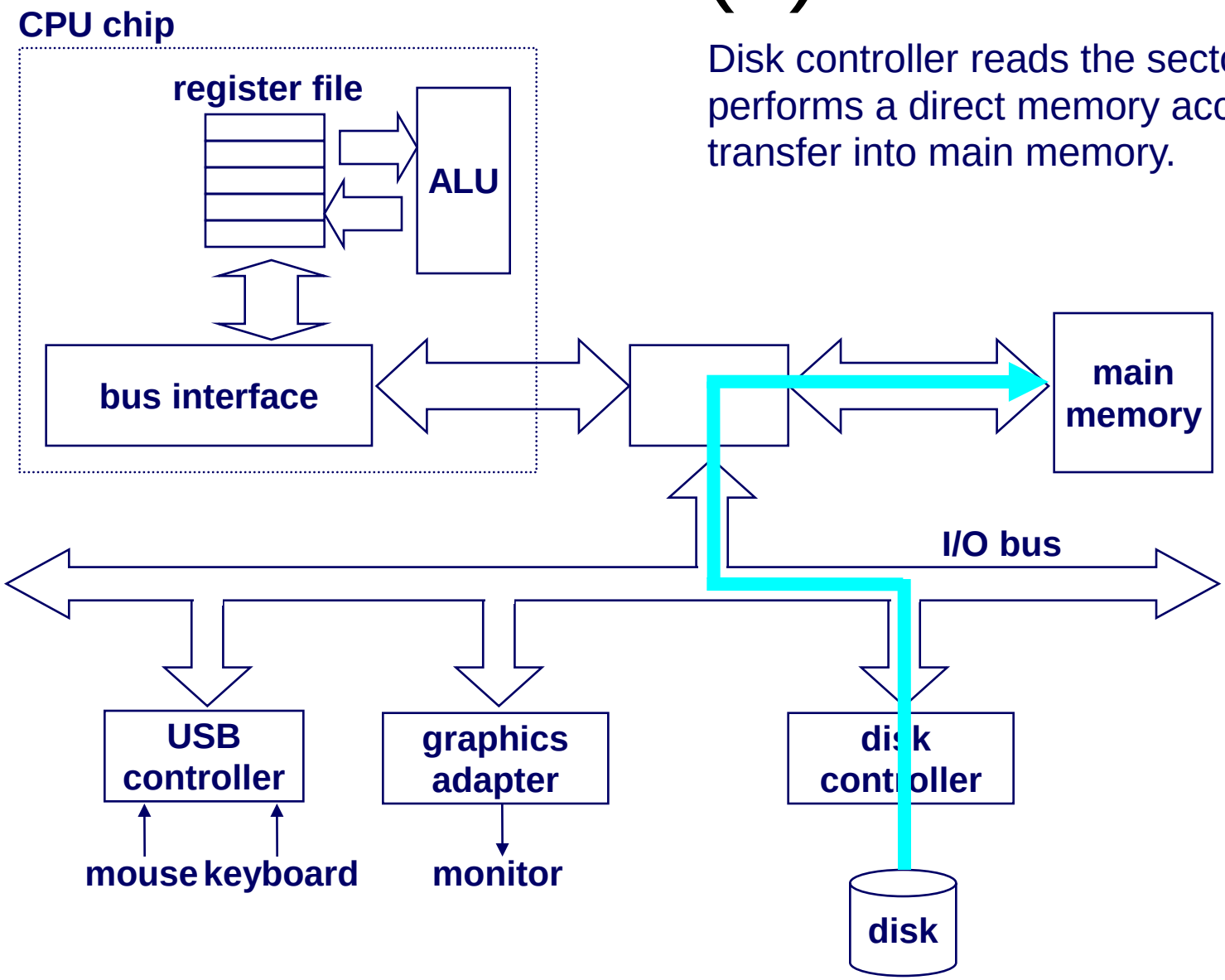
Disk Controller (3)

- DMA Transfer Using Disk Controller



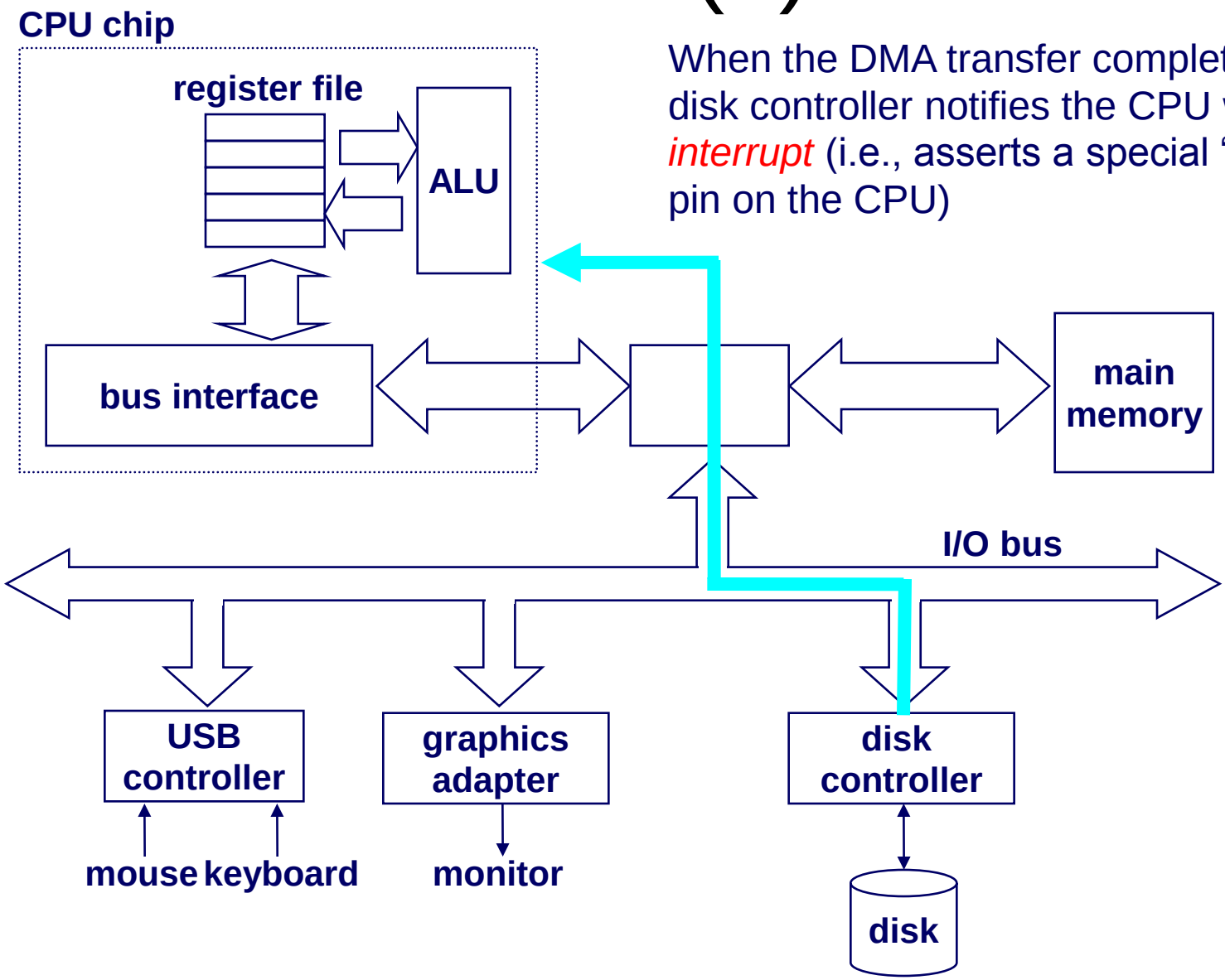
CPU initiates a disk read by writing a command, logical block number, and destination memory address to a port (address) associated with disk controller.

Disk Controller (4)



Disk controller reads the sector and performs a direct memory access (DMA) transfer into main memory.

Disk Controller (5)



When the DMA transfer completes, the disk controller notifies the CPU with an *interrupt* (i.e., asserts a special “interrupt” pin on the CPU)

Disk Controller (6)

- Main Functions of Disk Controller (from the disk drive's viewpoint)
  - Seek: Causes the disk drive to move the read/write head from its current position to the desired track.
  - Read: Initiates a Read operation, starting at the address specified in the disk address register.
  - Write: Transfers data to the disk, using a control method similar to that for Read operation.
  - Error checking: Computes the ECC value for the data read from a given sector and compares it with the corresponding ECC value read from the disk.

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Solved Problems (1)

- Example 8.6 **Problem:** Consider a long sequence of accesses to a disk with an average seek time of 6 ms and an average rotational delay of 3 ms. The average size of a block being accessed is 8K bytes. The data transfer rate from the disk is 34 Mbytes/sec.
  - (*a*) Assuming that the data blocks are randomly located on the disk, estimate the average percentage of the total time occupied by seek operations and rotational delays.
  - (*b*) Repeat part (*a*) for the situation in which disk accesses are arranged so that in 90 percent of the cases, the next access will be to a data block on the same cylinder.

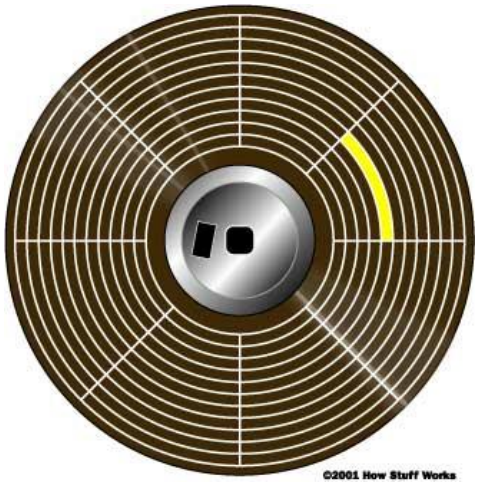
Solved Problems (2)

- Example 8.6 **Solution:** It takes 8K/34M = 0.23 ms to transfer a block of data.
  - (*a*) The total time needed to access each block is 6 + 3 + 0.23 = 9.23 ms. The portion of time occupied by seek and rotational delay is 9/9.23 = 0.97 = 97%.
  - (*b*) In 90% of the cases, only rotational delays are involved. Therefore, the average time to access a block is 0.9 × 3 + 0.1 × 9 + 0.23 = 3.83 ms. The portion of time occupied by seek and rotational delay is 3.6/3.83 = 0.94 = 94%.

Floppy Disks (1)

- A **floppy disk** is a data storage medium that is composed of a disk of thin, flexible ("floppy") magnetic storage medium encased in a square or rectangular plastic shell.
- Invented by IBM, floppy disks in 8-inch (200 mm), 5¼-inch (133.35 mm), and 3½-inch (90 mm) formats enjoyed many years as a popular and ubiquitous form of data storage and exchange, from the mid-1970s to the late 1990s.
- They have now been largely superseded by USB flash drives

8-inch, 5¼-inch, and 3½-inch floppy disks



Floppy Disks (2)

Disk format	Year introduced	Formatted Storage capacity in KB (1024 bytes) if not stated	Marketed capacity[1]
8-inch - IBM 23FD (read-only)	1971	79.7	?
8-inch - **SSSD** IBM 33FD / Shugart 901	1973	237.25	3.1 Mbits unformatted
8-inch - **DSSD** IBM 43FD / Shugart 850	1976	500.5	6.2 Mbits unformatted
8-inch **DSDD** IBM 53FD / Shugart 850	1977	980 - 1200 (MS-DOS FAT)	1.2 MB
5¼-inch DD	1978	360 or 800	360 KB
3½-inch HP single sided	1982	280	264 kB
3-inch	1982	360	125 kB
3½-inch (DD at release)	1984	720 (400 SS, 800 DS on Macintosh, 880 DS on Amiga)	1 MB
5¼-inch HD	1982 YE Data YD380	1,182,720 bytes	1.2 MB
3-inch DD	1984	720	?
2-inch	1985	720	?
5¼-inch Perpendicular	1986	100 MB	?
3½-inch HD	**1987**	**1440**	**1.44 MB** (2.0 MB unformatted)
3½-inch ED	1987	2880	2.88 MB
3½-inch Floptical (LS)	1991	21000	21 MB
3½-inch LS-120	1996	120.375 MB	120 MB
3½-inch LS-240	1997	240.75 MB	240 MB
3½-inch HiFD	1998/99	150/200 MB	150/200 MB

Summary

- 知识点: Magnetic Hard Disk
  - Capacity
  - Data Organization
  - Access Time
  - Cylinder

Homework

- P332 8.22(1)(2)
- 查阅资料，了解SSD的发展历史、原理用途和发展趋势，撰写报告。

Exercise (1)

- 1. The data of all tracks of a _____ can be accessed without moving the read-write head.
  - A. surface
  - B. platter
  - C. sector
  - D. cylinder

- Solution:
  - D. cylinder

Exercise (2)

- 2. According to the specifications of a particular hard disk, a seek takes 3 ms between adjacent tracks. If the disk has 100 cylinders, how long will it take for the head to move from the innermost cylinder to the outermost cylinder?
  - A. 3ms
  - B. 30ms
  - C. 300ms
  - D. 3000ms
- Solution:
  - C. 300ms

Exercise (3)

- 3. A hard disk with 5 double-sided platters has 2048 tracks/platter, how many movable heads does it have?
  - A. 5
  - B. 10
  - C. 2048×5
  - D. 2048×10

- Solution:
  - B.10

Exercise (4)

- 4. When we read a block of data from a disk into memory, the seek time refers to ( ).
  - A. the time required to move the read-write head to the proper track
  - B. the time required to position the read-write head and transfer the data block
  - C. the time required to rotate the correct sector under the head
  - D. none of the above
- Solution:
  - A

Exercise (5)

- 5. The amount of time required to read a block of data from a disk into memory is composed of seek time, rotational latency, and transfer time. Rotational latency refers to ( ).
  - A. the time it takes for the platter to make a full rotation
  - B. the time it takes for the read-write head to move into position over the appropriate track
  - C. the time required to rotate the correct sector under the head
  - D. none of the above
- Solution: C

Exercise (6)

- A hard disk with 5 platters has 2048 tracks/platter, 1024 sectors/track (fixed number of sectors per track), and 512 byte sectors. What is its total capacity?
  - A. 5G；
  - B. 10G；
  - C. 15G；
  - D. 20G；
- Solution:
  - A. 5G；