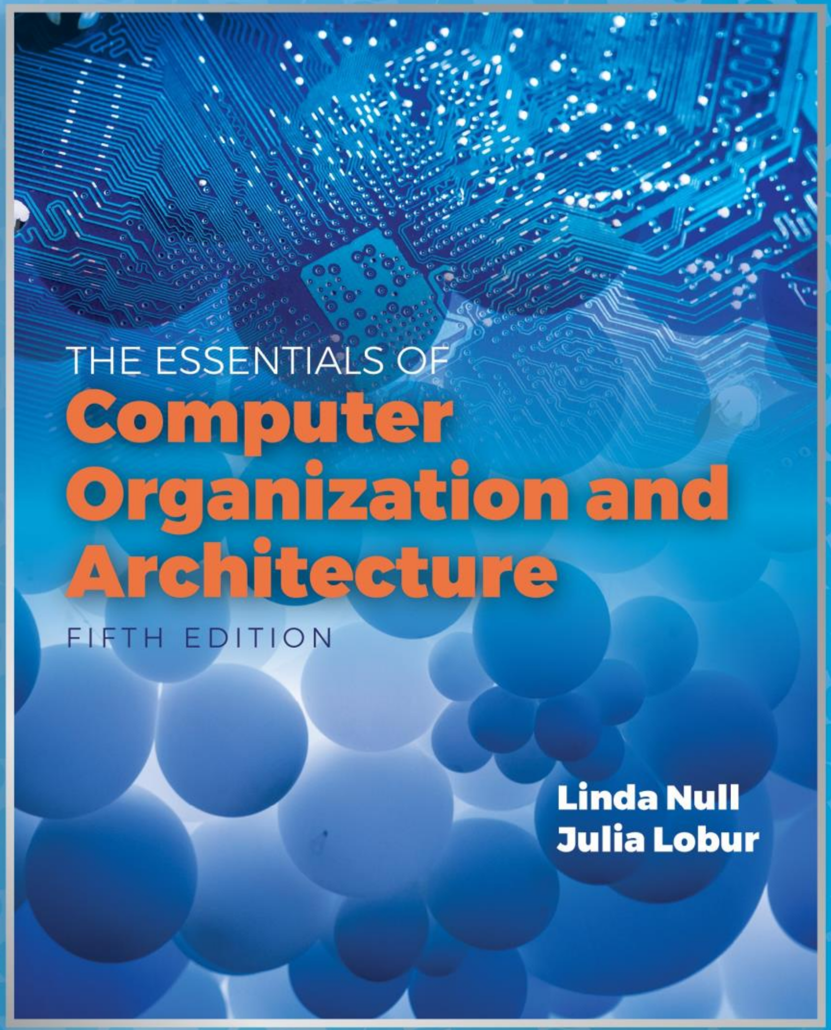
This is the second lecture of Chapter 7

Chapter 7

Input/Output Systems (B)



Quick review of last lecture

- Amdahl's Law
  - Speedup vs Increase
  - Examples

$$S = \frac{1}{(1-f) + (f/k)}$$

- I/O Architectures
  - I/O subsystems
    - I/O modules and device adaptors
  - I/O configuration
  - I/O control methods
    - Programmed I/O,
    - Interrupt-Driven I/O
    - Memory-Mapped I/O
    - Direct Memory Access (DMA)

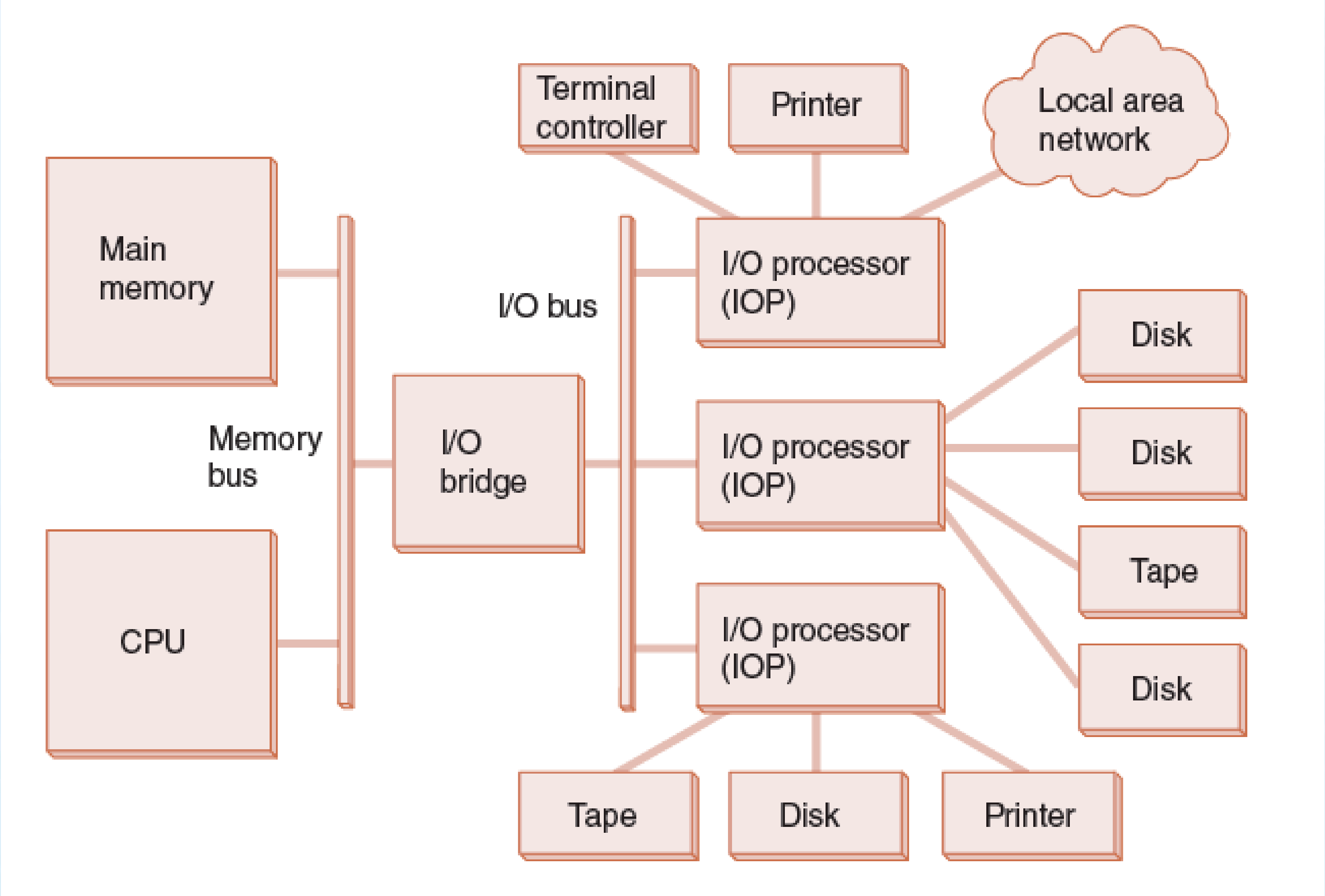
7.4 I/O Architectures (9 of 16)

- Very large systems employ channel I/O.
- Channel I/O consists of one or more I/O processors (IOPs) that control various channel paths.
- Slower devices such as terminals and printers are combined (*multiplexed*) into a single faster channel.
- On IBM mainframes, multiplexed channels are called *multiplexor channels*, the faster ones are called selector channels.

7.4 I/O Architectures (10 of 16)

- Channel I/O is distinguished from DMA by the intelligence of the IOPs.
- The IOP negotiates protocols, issues device commands, translates storage coding to memory coding, and can transfer entire files or groups of files independent of the host CPU.
- The host has only to create the program instructions for the I/O operation and tell the IOP where to find them.

7.4 I/O Architectures (11 of 16)
A channel I/O configuration



7.4 I/O Architectures (12 of 16)

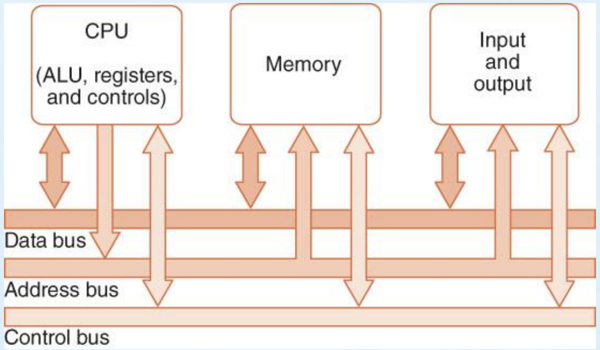
- Character I/O devices process one byte (or character) at a time.
  - Examples include modems, keyboards, and mice.
  - Keyboards are usually connected through an interrupt-driven I/O system.
- Block I/O devices handle bytes in groups.
  - Most mass storage devices (disk and tape) are block I/O devices.
  - Block I/O systems are most efficiently connected through DMA or channel I/O.

7.4 I/O Architectures (13 of 16)

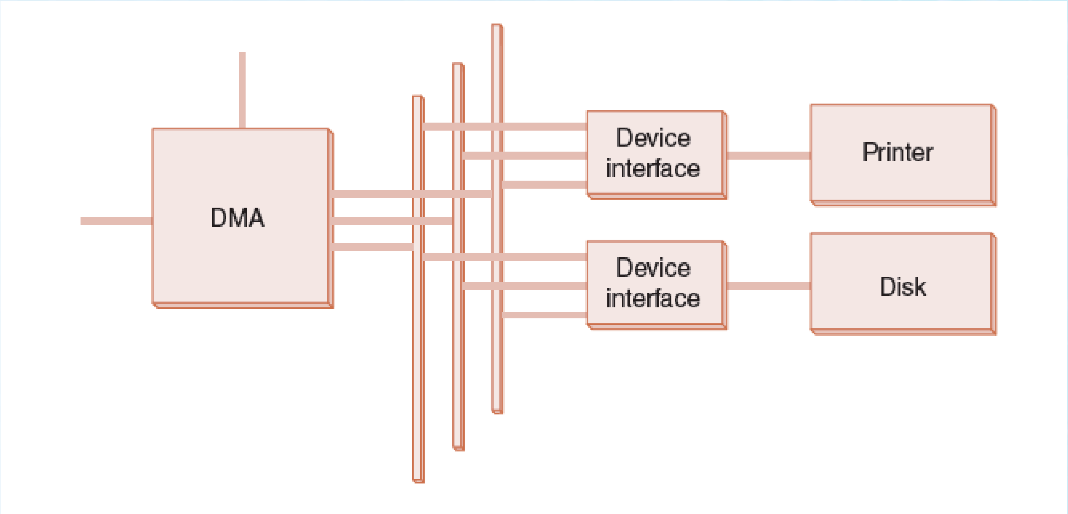
- I/O buses, unlike memory buses, operate asynchronously. Requests for bus access must be arbitrated among the devices involved.
- Bus control lines activate the devices when they are needed, raise signals when errors have occurred, and reset devices when necessary.
- The number of data lines is the *width* of the bus.
- A bus clock coordinates activities and provides bit cell boundaries.

7.4 I/O Architectures (14 of 16)

A generic DMA configuration showing how the DMA circuit connects to a data bus



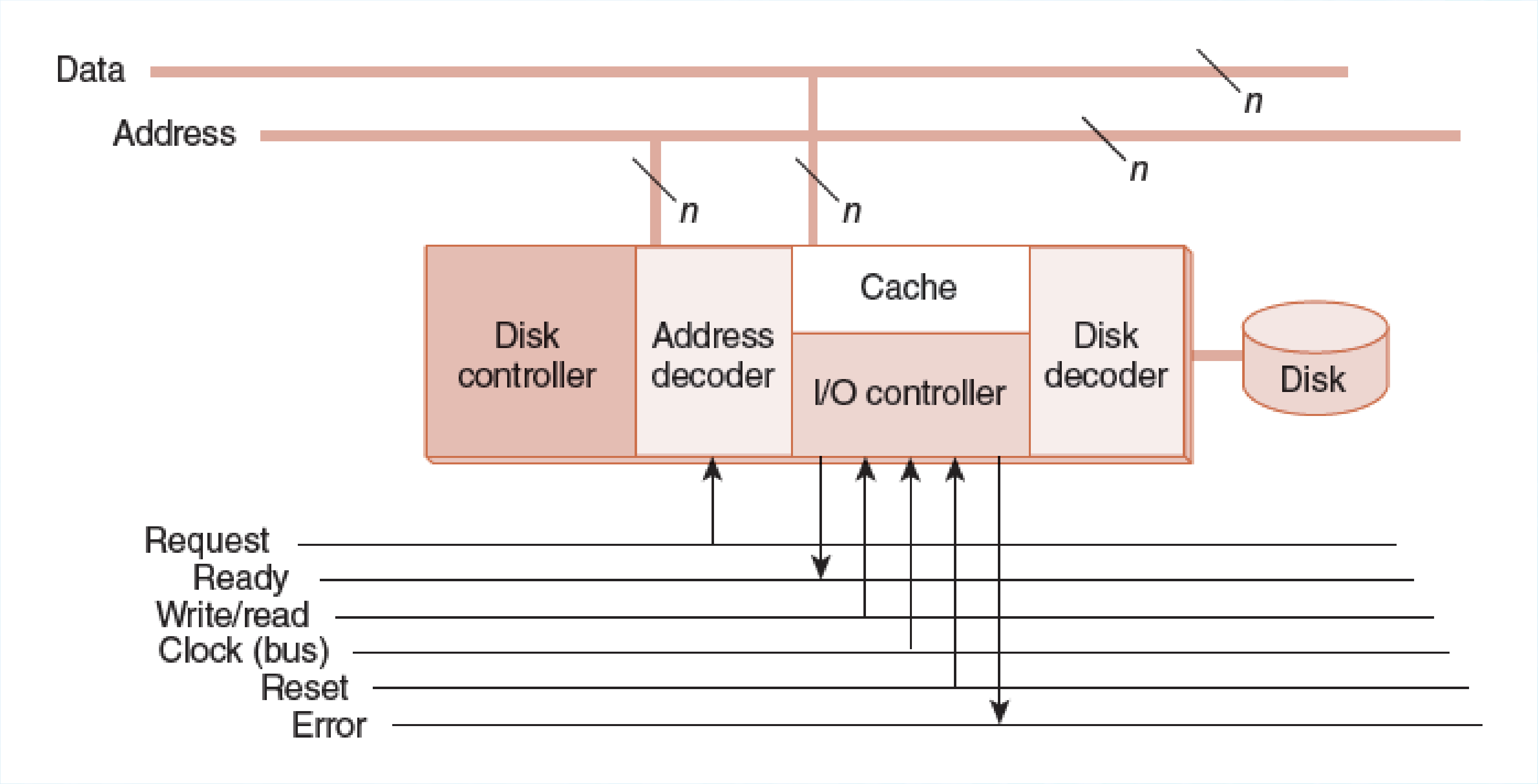
High-Level View of a System Bus



DMA Configuration Showing Separate Address, Data, and Control Lines

7.4 I/O Architectures (15 of 16)

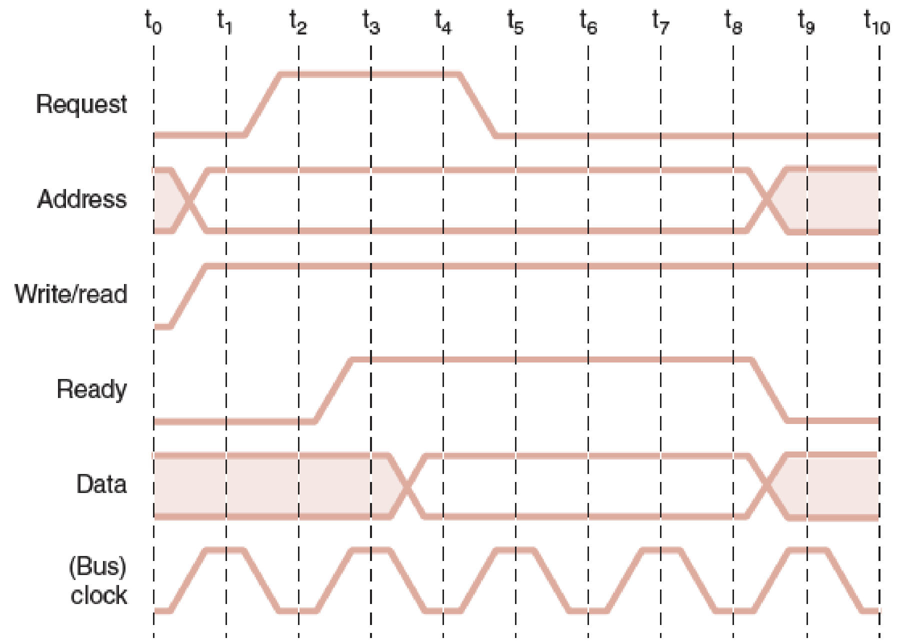
How a bus connects to a disk drive



A Disk Controller Interface with Connections to the I/O Bus

7.4 I/O Architectures (16 of 16)

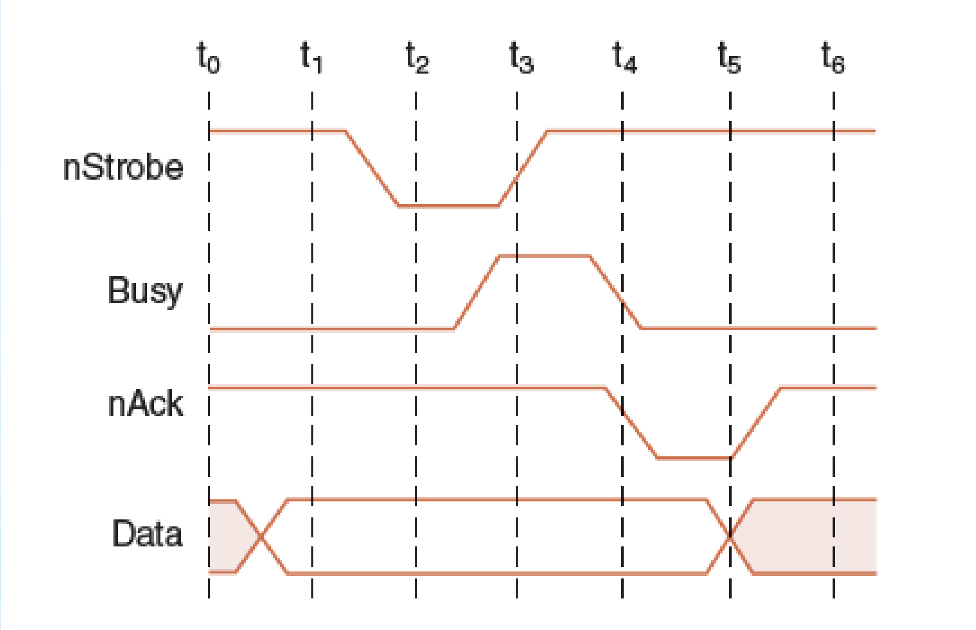
Timing diagrams define bus operation in detail.



Time	Salient bus signal	Meaning
t_0	Assert write	Bus is needed for writing (not reading)
t_0	Assert address	Indicates where bytes will be written
t_1	Assert request	Request write to address on address lines
t_2	Assert ready	Acknowledges write request, bytes placed on data lines
t_3–t_7	Data lines	Write data (requires several cycles)
t_8	Lower ready	Release bus

7.5 Data Transmission Modes (1 of 2)

- Bytes can be conveyed from one point to another by sending their encoding signals simultaneously using *parallel data transmission* or by sending them one bit at a time in *serial data transmission*.
  - Parallel data transmission for a printer resembles the signal protocol of a memory bus:



7.5 Data Transmission Modes (2 of 2)

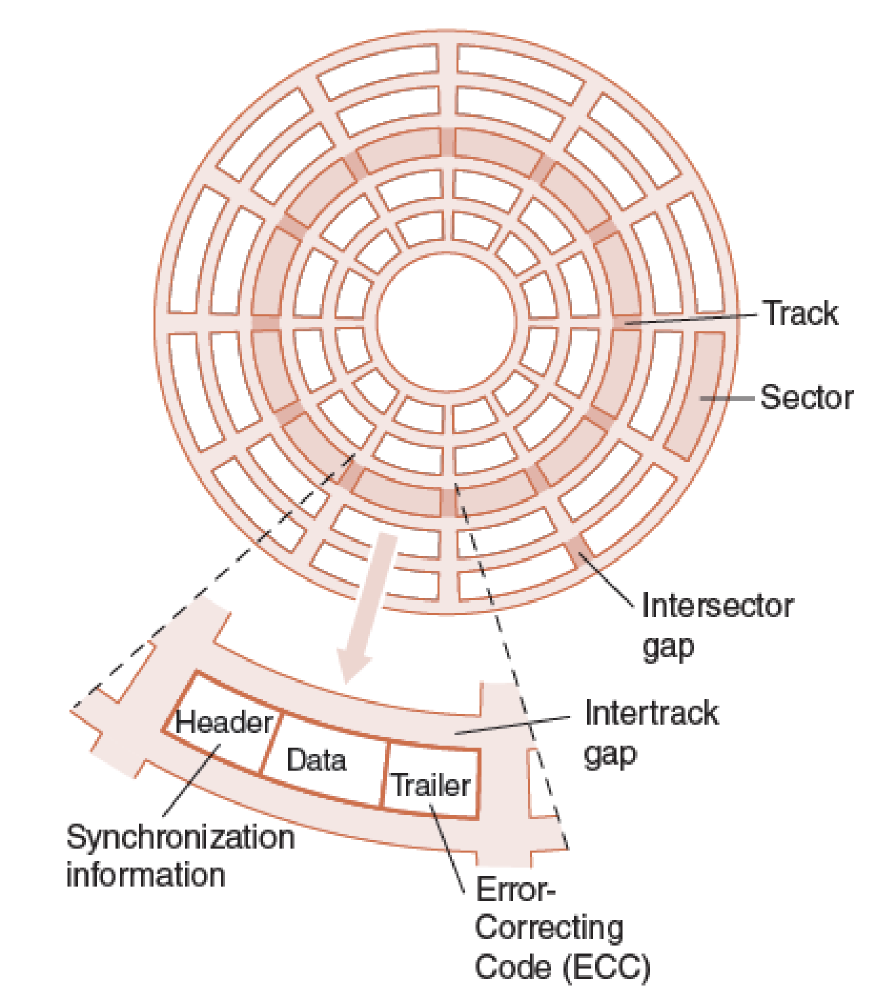
- In parallel data transmission, the interface requires one conductor for each bit.
- Parallel cables are fatter than serial cables.
- Compared with parallel data interfaces, serial communications interfaces:
  - Require fewer conductors.
  - Are less susceptible to attenuation.
  - Can transmit data farther and faster.
- Serial communications interfaces are suitable for time-sensitive (*isochronous*) data such as voice and video.

7.6 Disk Technology

- Magnetic disks offer large amounts of durable storage that can be accessed quickly.
- Disk drives are called *random* (or *direct*) *access storage devices*, because blocks of data can be accessed according to their location on the disk.
  - This term was coined when all other durable storage (e.g., tape) was sequential.
- Magnetic disk organization is shown on the following slide.

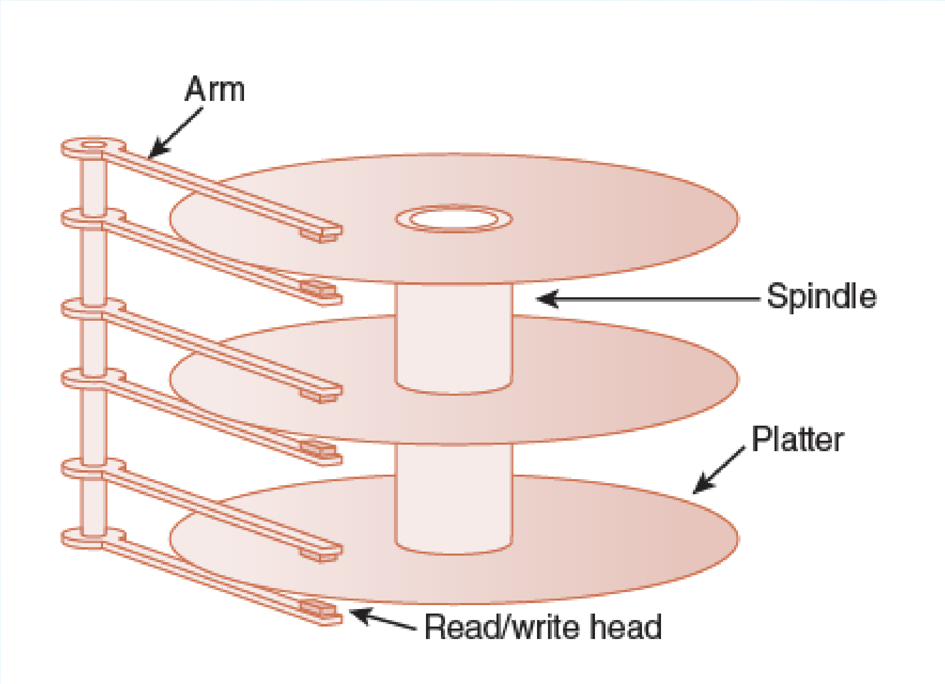
7.6.1 Rigid Disk Drives (1 of 6)

- Disk tracks are numbered from the outside edge, starting with zero.



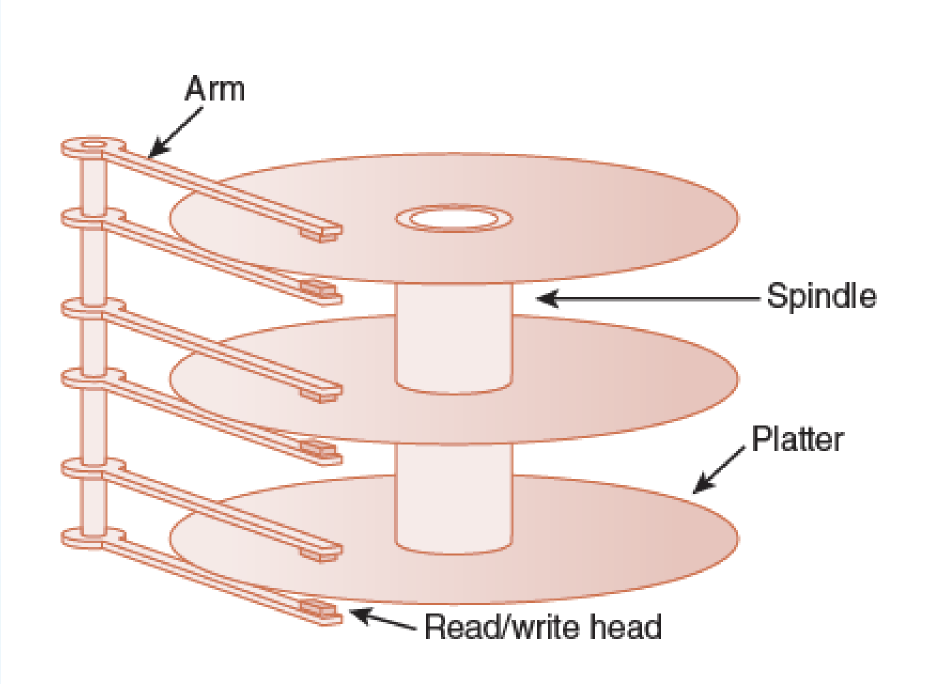
7.6.1 Rigid Disk Drives (2 of 6)

- Hard disk platters are mounted on spindles.
- Read/write heads are mounted on a comb that swings radially to read the disk.



7.6.1 Rigid Disk Drives (3 of 6)

- The rotating disk forms a logical cylinder beneath the read/write heads.
- Data blocks are addressed by their cylinder, surface, and sector.



7.6.1 Rigid Disk Drives (4 of 6)

- There are a number of electromechanical properties of hard disk drives that determine how fast its data can be accessed.
- ***Seek time*** is the time that it takes for a disk arm to move into position over the desired cylinder.
- ***Rotational delay*** is the time that it takes for the desired sector to move into position beneath the read/write head.
- **Seek time + rotational delay =** ***access time***.

7.6.1 Rigid Disk Drives (5 of 6)

- ***Transfer rate*** gives us the rate at which data can be read from the disk.
- ***Average latency*** is a function of the rotational speed:

$$\frac{\dfrac{60 \text{ seconds}}{\text{disk rotation speed}} \times \dfrac{1000 \text{ ms}}{\text{second}}}{2}$$

- ***Mean Time To Failure*** (***MTTF***) is a statistically-determined value often calculated experimentally.
  - It usually doesn't tell us much about the actual expected life of the disk. Design life is usually more realistic.

Figure 7.15 in the text shows a sample disk specification.

CONFIGURATION:	
Formatted capacity, TB	3
Integrated controller	SATA
Encoding method	EPRML
Buffer size	32MB
Platters	8
Data surfaces	16
Tracks per surface	16,383
Track density	190,000tpi
Recording density	1,462Kbpi
Bytes per sector	512
Sectors per Track	63
PHYSICAL:	
Height	26.1mm
Length	147.0mm
Width	101.6mm
Weight	720g
Temperature (°C)	
Operating	5°C to 55°C
Nonoperating/storage	–40°C to 71°C
Relative humidity	5% to 95%
Acoustic noise	20dBA, idle

RELIABILITY AND MAINTENANCE:	
MTTF	1,000,000 hours
Start/stop cycles	50,000
Design life	5 years (minimum)
Data errors	
(nonrecoverable)	<1 per 10^{15} bits read
PERFORMANCE:	
Seek times	
Track to track	
Read	0.3ms
Write	0.5ms
Average	
Read	4.5ms
Write	5.0ms
Average latency	4.17ms
Rotational speed	
(+/–0.20%)	7,200rpm
Data transfer rate:	
From disk	1.2MB/sec
To disk	3GB/sec
Start time	
(0 to drive ready)	9 sec

Fig 7.15