Computer Architecture

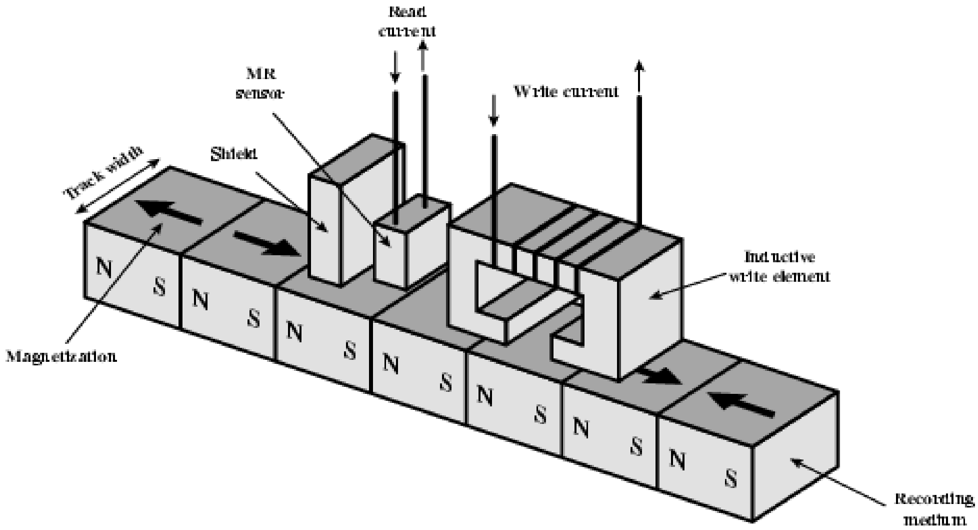
Module II - External Memory and Input/ Output

1. Magnetic Disk

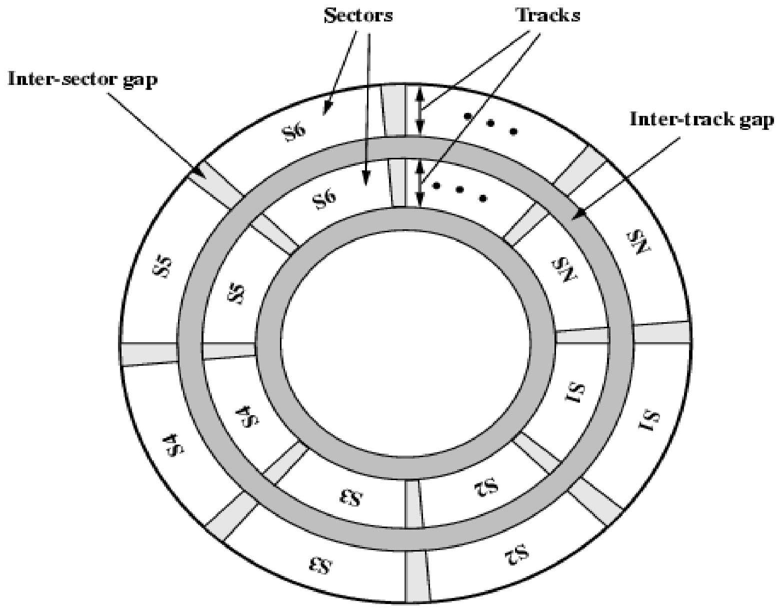
- A disk is a circular platter constructed of nonmagnetic material, called the substrate, coated with a magnetizable material.
- Substrate used to be aluminium or aluminum alloy material
- Now glass substrate is introduced

2. Read and Write Mechanisms

- Data is Recorded & retrieved from the disk via conductive coil called a head
- May be single read/write head or separate heads for read and write
- **Write**
  - → 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 of the disk.
  - → Different patterns are recorded for positive and negative currents.
- **Traditional Read Mechanism**
  - → Magnetic field moving relative to coil produces electric current in the coil
  - → When the surface of the disk passes under the head, it generates a current of the same polarity as the one already recorded.
  - → Coil is the same for read and write process
- **Contemporary Read Mechanism**
  - → Separate read head, close to write head
  - → The read head consists of Partially shielded magneto resistive (MR) sensor
  - → Electrical resistance depends on direction of magnetic field
  - → By passing a current through the MR sensor, resistance changes are detected as voltage signals.
  - → High frequency operation
  - → Higher storage density and speed



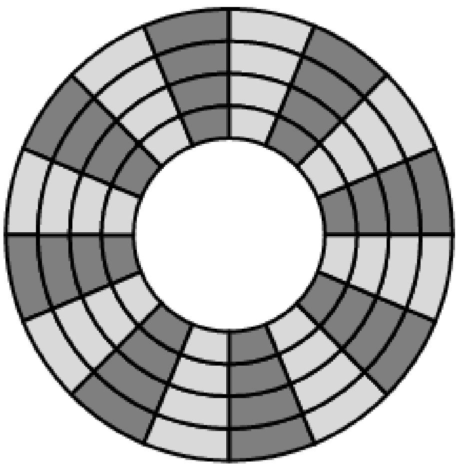
3. Data Organization and Formatting



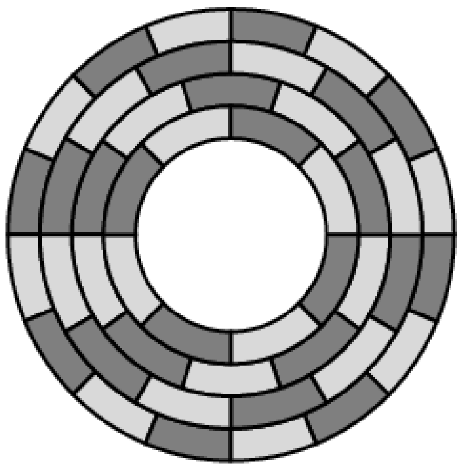
- The head is a relatively small device capable of reading from or writing to a portion of the platter rotating beneath it
- Data on the platter is organized in a concentric set of rings, called **tracks**
  - Each track is the same width as the head.
  - There are thousands of tracks per surface.
  - Adjacent tracks are separated by **gaps.**
  - Data are transferred to and from the disk in **sectors.**
  - There are typically hundreds of sectors per track
  -

4. Disk Layout

- Bit near centre of rotating disk passes head slower than bit on outside of disk
- Increase spacing between bits in different tracks to adjust the variation in speed
- Rotate disk at **constant angular velocity (CAV)**
  - → 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
    - o Lower data density
- To increase density, modern hard disk systems use a technique known as **multiple zone recording**
  - → the surface is divided into a number of concentric zones.
  - → Within a zone, the number of bits per track is constant.
  - → Zones farther from the center contain more bits (more sectors) than zones closer to the center.



(a) Constant angular velocity



(b) Multiple zoned recording

5. Physical Characteristics of Magnetic Disk

1) Fixed/Movable Head Disk

- → Fixed/Movable Head Disk
  - o One read write head per track
  - o Heads mounted on fixed ridged arm

→ Movable head
  - One read write head per side
  - Mounted on a movable arm

2) Removable or Not

→ Removable disk
  - Can be removed from drive and replaced with another disk
  - Provides unlimited storage capacity
  - Easy data transfer between systems
  - Eg : Floppy disks

→ Non removable disk
  - Permanently mounted in the drive
  - Hard disk

3) Single or double (usually) sided

→ For most disks, the magnetizable coating is applied to both sides of the platter, which is called **double sided.**

→ Some less expensive disk systems use **single-sided disks.**

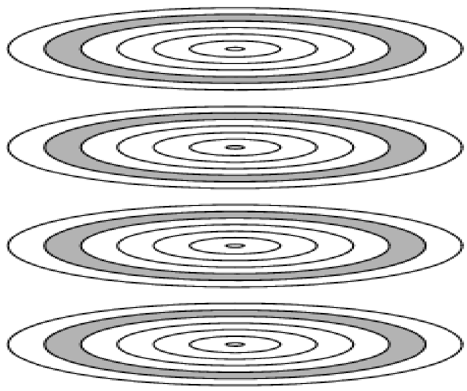
4) Single or multiple platter

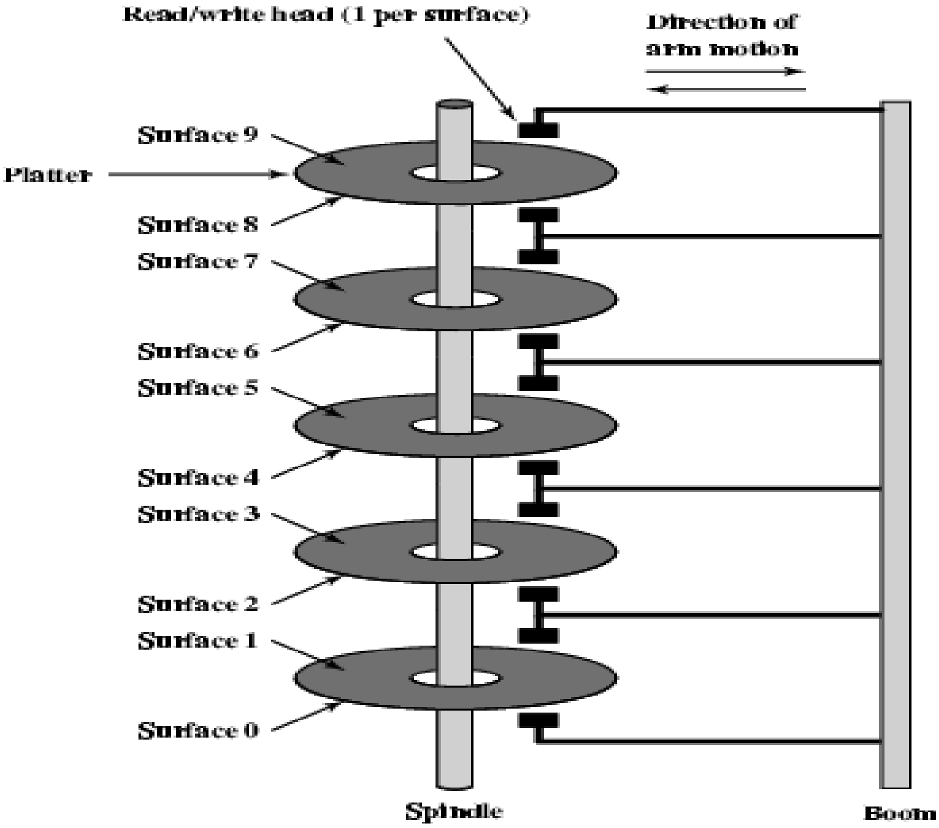
→ One head per side

→ Heads are joined and aligned

→ Aligned tracks on each platter form cylinders
  - reduces head movement
  - Increases speed (transfer rate)

Tracks and Cylinders





5) Speed
- → Seek time
  - o On a movable-head system, the time it takes to position the head at the track is known as seek time.
- → Rotational latency or Rotational Delay
  - o The time it takes for the beginning of the sector to reach the head is known as rotational delay, or rotational latency.
- → Access time
  - o The sum of the seek time, if any, and the rotational delay equals the access time,
- → Transfer rate
  - o Once the head is in position, the read or write operation is then performed as the sector moves under the head; the time required for the transfer is the transfer time.

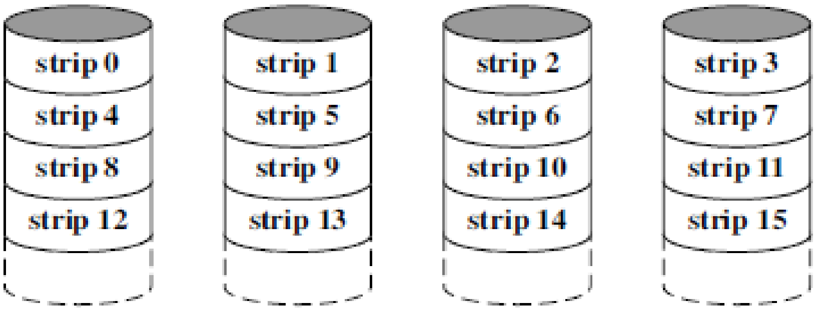
6. RAID

- → Redundant Array of Independent Disks
- → The RAID scheme consists of seven levels, zero through six.
- → These levels do not have a hierarchical relationship.
- → RAID is a set of physical disk drives viewed by the operating system as a single logical drive
- → Data distributed across physical drives
- → Redundant disk capacity is used to store parity information, which is used to recover data in case of a disk failure

6.1 RAID 0

- → No redundancy
- → Data striped across all disks

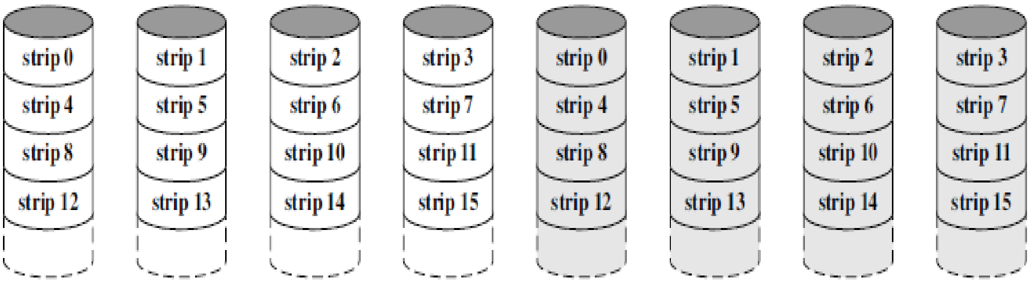
→ Round Robin striping
  - Increase speed
  - Multiple data requests probably not on same disk
  - Disks seek in parallel
  - The data are striped across the available disks.



(a) RAID 0 (Nonredundant)

6.2 RAID 1

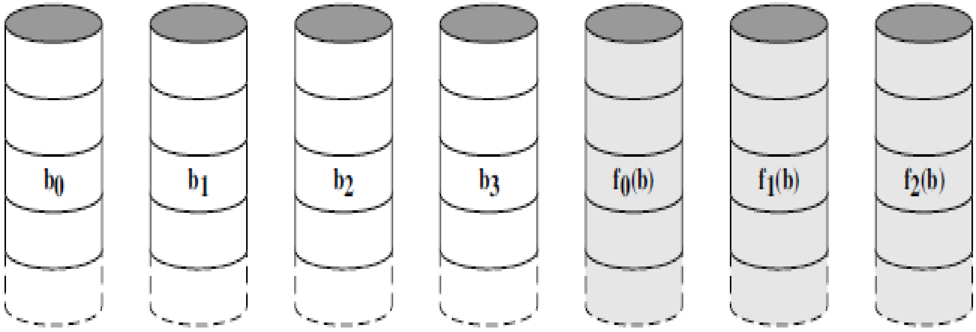
→ In RAID 1, redundancy is achieved by duplicating all the data.
→ Data is striped across disks
→ 2 copies of each stripe on separate disks (mirrored disks)
→ A read request can be serviced by either of the two disks that contains the requested data
→ A write request requires that both corresponding strips be updated, but this can be done in parallel.
→ Recovery
  - When a drive fails, the data may still be accessed from the second drive
→ Disadvantage of RAID 1 is the cost; it requires twice the disk space.



(b) RAID 1 (Mirrored)

6.3 RAID 2

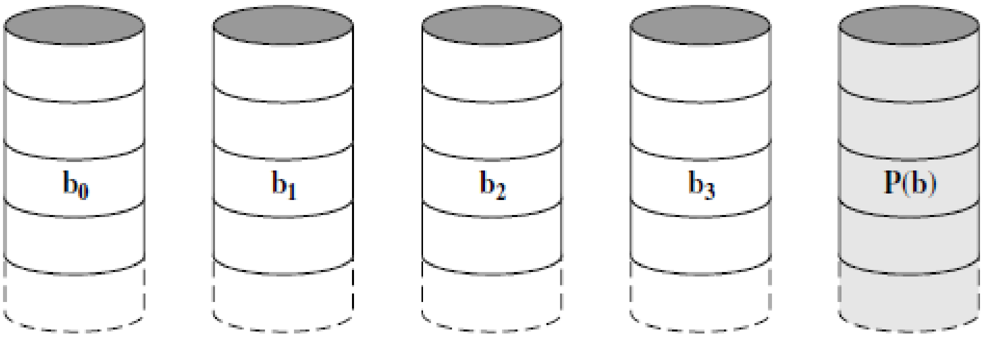
→ With RAID2, an error-correcting code is calculated across corresponding bits on each data disk
→ The bits of the code are stored in the corresponding bit positions on multiple parity disks.
→ Usually, a Hamming code is used which is able to correct single-bit errors and detect double-bit errors.
→ Lots of redundancy
  - Expensive
  - Not used



(c) RAID 2 (Redundancy through Hamming code)

6.4 RAID 3

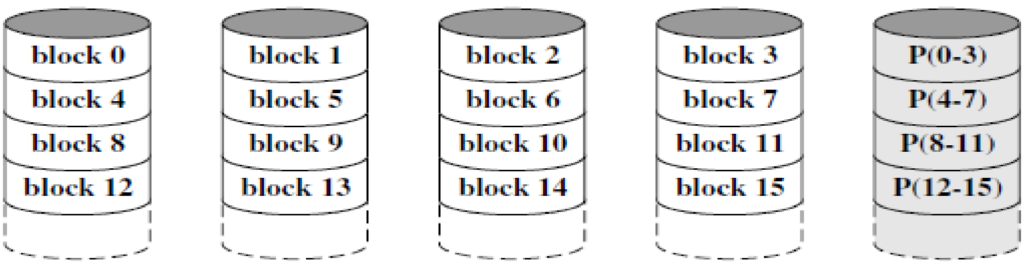
- → Similar to RAID 2
- → Only one redundant disk
- → parallel data access, with data distributed in small strips.
- → Instead of an error-correcting code, a simple parity bit is computed for the set of individual bits in the same position on all of the data disks.
- → In the event of a drive failure, the parity drive is accessed and data is reconstructed from the remaining devices.
- → Data on failed drive can be reconstructed from surviving data and parity info
- → Very high transfer rates



(d) RAID 3 (Bit-interleaved parity)

6.5 RAID 4

- → Each disk operates independently so that separate I/O requests can be satisfied in parallel
- → Good for high I/O request rate
- → Large stripes
- → Bit by bit parity calculated across stripes on each disk
  - o Parity stored on parity disk

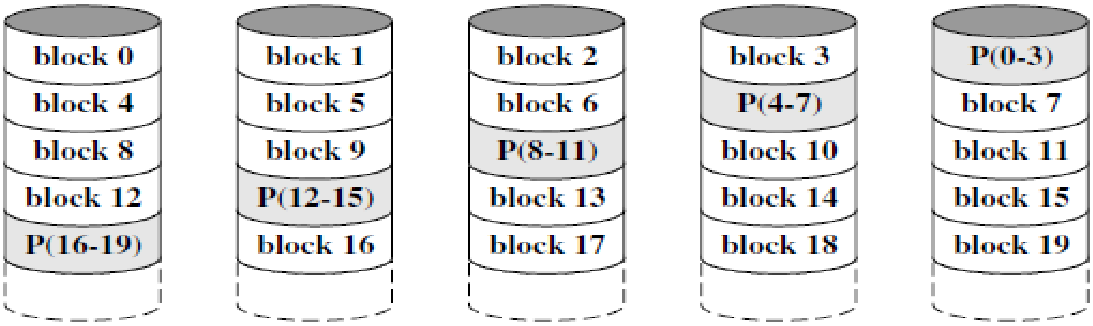


(e) RAID 4 (Block-level parity)

6.6 RAID 5

- → Like RAID 4

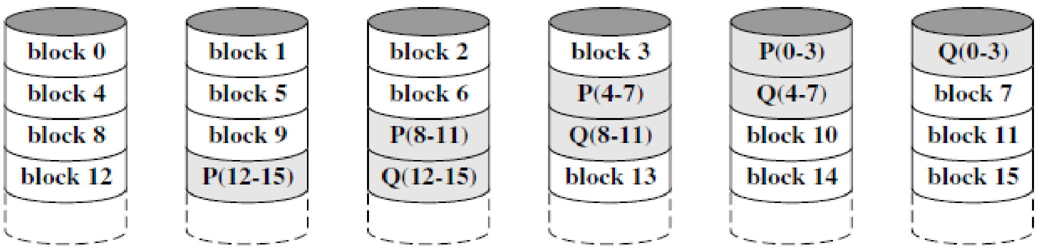
→ Parity striped across all disks
→ Round robin allocation for parity stripe
→ Avoids RAID 4 bottleneck at parity disk
→ Commonly used in network servers



(f) RAID 5 (Block-level distributed parity)

6.7 RAID 6

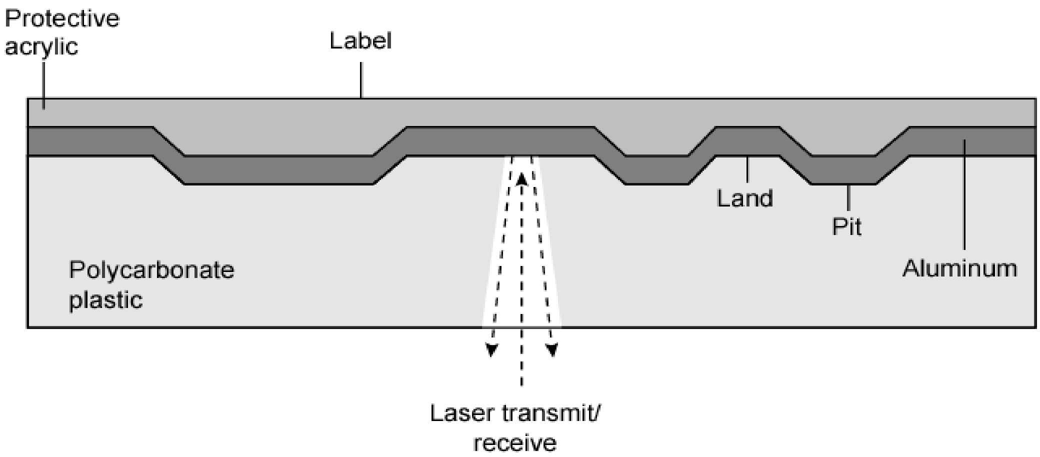
→ In the RAID 6 scheme, two different parity calculations are carried out and stored in separate blocks on different disks.
→ User requirement of N disks needs N+2
→ High data availability
  - Three disks need to fail for data loss
  - write process difficult because each write affects two parity blocks



(g) RAID 6 (Dual redundancy)

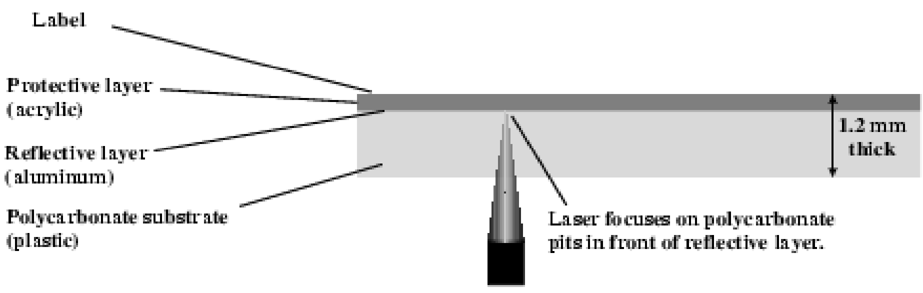
7. Optical Storage CD-ROM

→ The disk is formed from a resin, such as polycarbonate.
→ Digitally recorded information is imprinted as a series of microscopic pits on the surface of the polycarbonate.
→ Information is retrieved from a CD by a low-powered laser in an optical-disk player, or drive unit.
→ The laser shines through the clear polycarbonate while a motor spins the disk.
→ The intensity of the reflected light of the laser changes on a pit.
→ The areas between pits are called lands.
→ A land reflects back at higher intensity.
→ The change between pits and lands is detected by a photo sensor and converted into a digital signal.
→ The beginning or end of a pit represents a **1**; when no change in elevation occurs between intervals, a **0** is recorded.

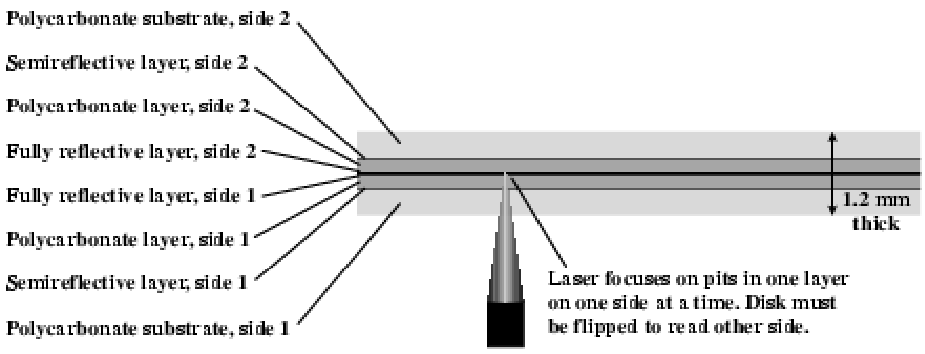


8. DVD

- → Digital Video Disk
  - o Used to indicate a player for movies
  - o Only plays video disks
- → Digital Versatile Disk
  - o Used to indicate a computer drive
  - o Will read computer disks and play video disks
- → Multi-layer
- → Very high capacity (4.7G per layer)
- → Full length movie on single disk
- → The DVD’s greater capacity is due to three differences from CDs
  - o Bits are packed more closely on a DVD
  - o The DVD employs a second layer of pits and lands on top of the first layer
  - o The DVD-ROM can be two sided, whereas data are recorded on only one side of a CD.



(a) CD-ROM - Capacity 682 MB



(b) DVD-ROM, double-sided, dual-layer - Capacity 17 GB

9. High Definition Optical Disks

- → High-definition optical disks are designed to store high-definition videos and to provide 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 DVD.
- → Two disk formats are available:
    - o HD DVD and Blu-ray DVD.
- → The HD DVD scheme can store 15 GB on a single layer on a single side.
- → Blu-ray positions the data layer on the disk closer to the laser.
- → This enables a tighter focus and less distortion and thus 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 re-recordable (BD-RE).

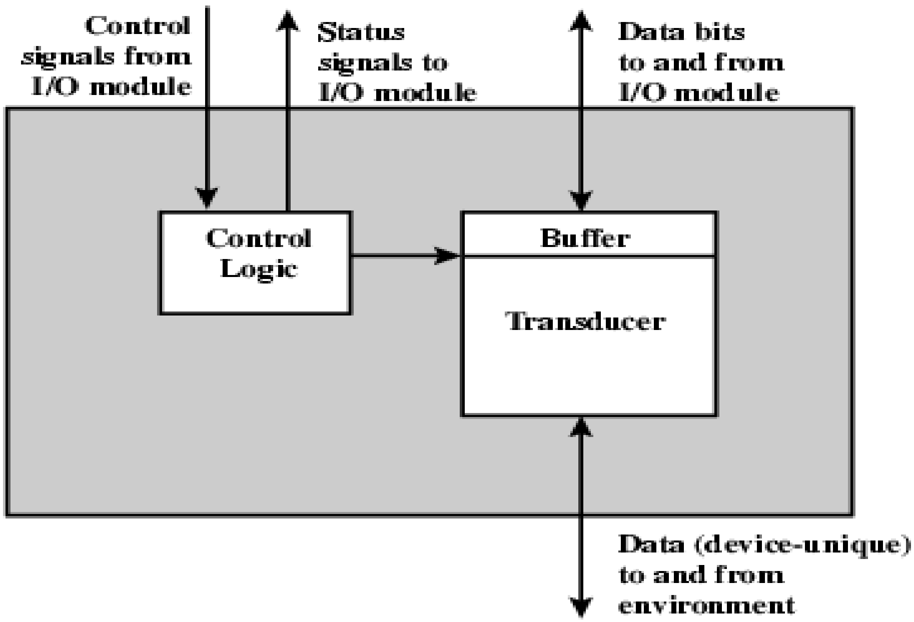
10. External Devices

- → I/O operations are done by external devices that exchange data between the external environment and the computer.
- → An external device attaches to the computer by a link to an I/O module
- → The link is used to exchange control, status, and data between the I/O module and the external device.
- → An external device connected to an I/O module is referred to as *a peripheral device* or, a *peripheral*.
- → External devices are classified into three categories:
    - o Human readable:
        - i. Suitable for communicating with the computer user

ii. Eg: video display terminals (VDTs) and printers.

- Machine readable:
  i. Suitable for communicating with equipment
  ii. Eg: magnetic disk and tape systems, and sensors
- Communication:
  i. Suitable for communicating with remote devices
  ii. Communication devices allow a computer to exchange data with a remote device, which may be a human-readable device, such as a terminal, a machine-readable device, or even another computer

10.1 External Device Block Diagram



→ The interface to the I/O module is in the form of control, data, and status signals.

→ Control signals determine the function that the device will perform, such as
- send data to the I/O module (INPUT or READ),
- accept data from the I/O module (OUTPUT or WRITE),
- report status,
- or perform some control function particular to the device (e.g., position a disk head).

→ Data are in the form of a set of bits to be sent to or received from the I/O module.

→ Status signals indicate the state of the device.
- Examples are READY/NOT-READY to show whether the device is ready for data transfer.

→ Control logic associated with the device controls the device’s operation in response to direction from the I/O module.

→ The transducer converts data from electrical to other forms of energy during output and from other forms to electrical during input.

→ Typically, a buffer is associated with the transducer to temporarily hold data being transferred between the I/O module and the external environment; a buffer size of 8 to 16 bits is common.

11. Keyboard/Monitor

→ The most common means of computer/user interaction is a keyboard/monitor arrangement.

- → The user provides input through the keyboard.
- → This input is then transmitted to the computer and may also be displayed on the monitor.
- → In addition, the monitor displays data provided by the computer.
- → The basic unit of exchange is the character.
- → The most commonly used text code is the International Reference Alphabet (IRA).
- → Each character in this code is represented by a unique 7-bit binary code; thus, 128 different characters can be represented.
- → Characters are of two types: printable and control.
- → Printable characters are the alphabetic, numeric, and special characters that can be printed on paper or displayed on a screen.
- → Some of the control characters have to do with controlling the printing or displaying of characters, an example is carriage return.
- → For keyboard input, when the user presses a key, this generates an electronic signal that is interpreted by the transducer in the keyboard and translated into the corresponding IRA code.
- → This bit pattern is then transmitted to the I/O module in the computer.
- → At the computer, the text can be stored in the same IRA code.
- → On output, IRA code characters are transmitted to an external device from the I/O module.
- → The transducer at the device interprets this code and sends the required electronic signals to the output device either to display the indicated character or perform the requested control function.

12. Disk Drive

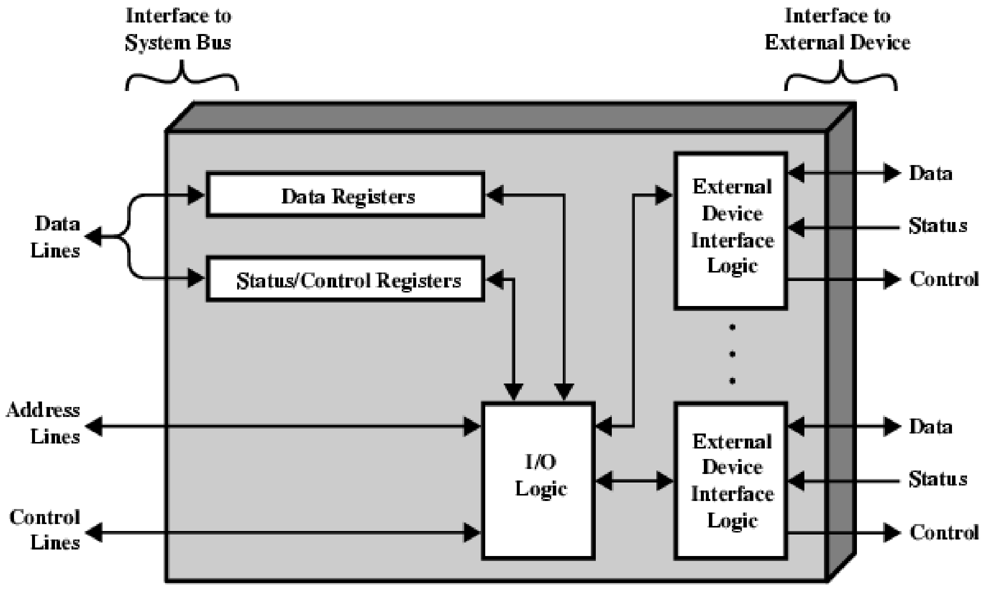
- → A disk drive performs exchanging data, control, and status signals with an I/O module and control the disk read/write mechanism.
- → In a fixed-head disk, the transducer is capable of converting between the magnetic patterns on the moving disk surface and bits in the device's buffer.
- → A moving-head disk must also be able to cause the disk arm to move radially in and out across the disk's surface.

13. I/O Module Function

- → The major functions of an I/O module are:
  - Control & Timing
    - To coordinate the flow of traffic between internal resources and external devices.
  - CPU Communication
    - **Command decoding:** The I/O module accepts commands from the processor, typically sent as signals on the control bus.
    - **Data:** Data are exchanged between the processor and the I/O module over the data bus.
    - **Status reporting :** Status reporting of I/O devices
    - **Address recognition :** To identify the I/O device
  - Device Communication
    - This communication involves commands, status information, and data
  - Data Buffering
  - Error Detection
- → the control of the transfer of data from an external device to the processor might involve the following sequence of steps

- CPU checks I/O module device status
- I/O module returns status
- If the device is ready, CPU requests data transfer
- I/O module gets data from device
- I/O module transfers data to CPU

14. I/O Module Structure

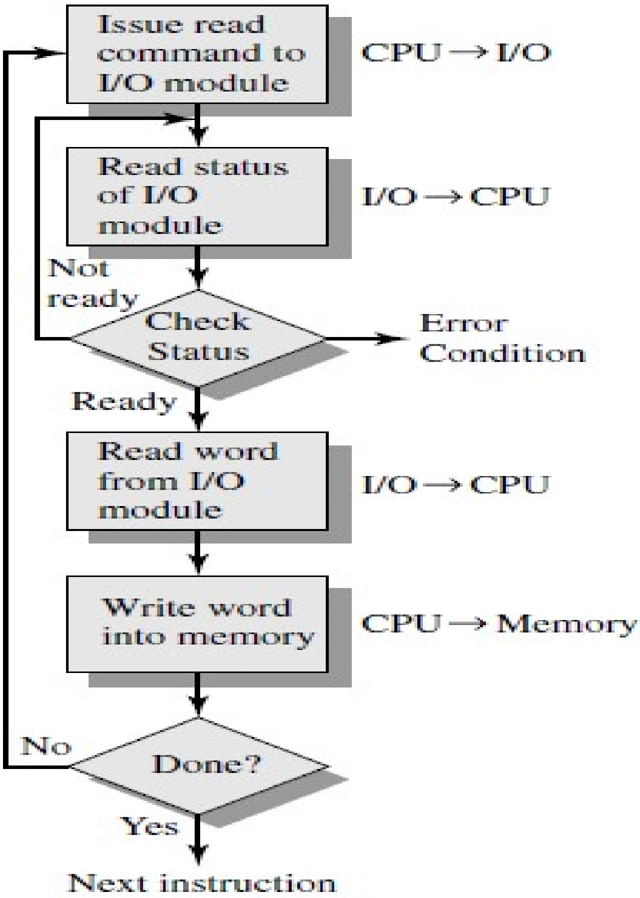


→ The I/O module connects I/O devices to the rest of the computer through a set of signal lines (e.g., system bus lines).
→ Data transferred to and from the module are buffered in one or more data registers.
→ There may also be one or more status registers that provide current status information.
→ A status register may also function as a control register, to accept detailed control information from the processor.
→ The logic within the module interacts with the processor via a set of control lines.
→ The processor uses the control lines to issue commands to the I/O module.
→ Some of the control lines may be used by the I/O module (e.g., for arbitration and status signals).
→ The module must also be able to recognize and generate addresses associated with the devices it controls.
→ Each I/O module has a unique set of addresses for the external devices that it control.
→ The I/O module contains logic specific to the interface with each device that it controls.

15. Input Output Techniques

→ Three techniques are possible for I/O operations
- Programmed I/O
- Interrupt driven I/O
- Direct Memory Access (DMA)

16. Programmed I/O

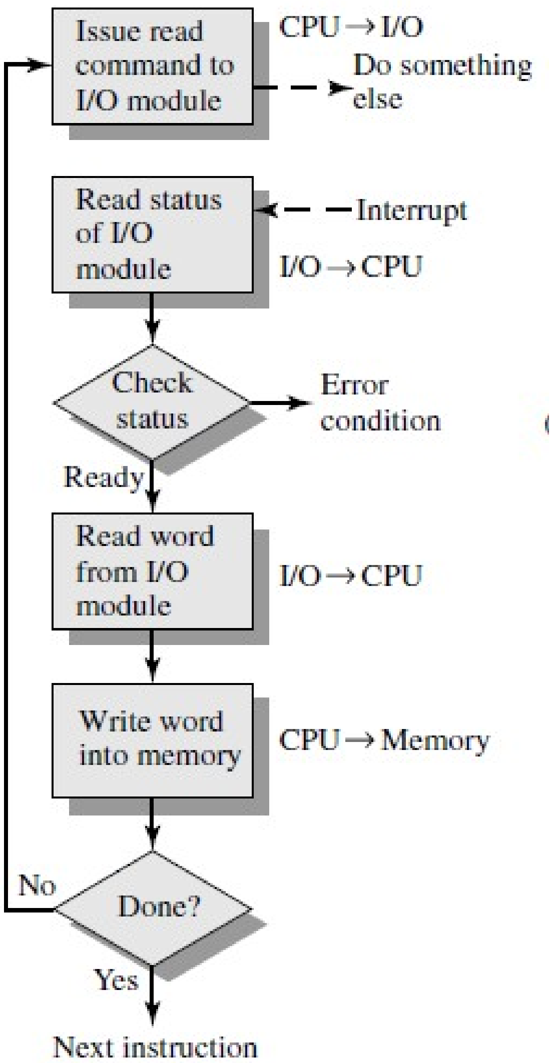


(a) Programmed I/O

- → With *programmed I/O, data are* exchanged between the processor and the I/O module.
- → The processor executes a program that gives it direct control of the I/O operation, including sensing device status, sending a read or write command, and transferring the data.
- → When the processor issues a command to the I/O module, it must wait until the I/O operation is complete.
- → If the processor is faster than the I/O module, this is wasteful of processor time.

17. INTERRUPT-DRIVEN I/O

- → The problem with programmed I/O is that the processor has to wait a long time for the I/O module of concern to be ready for either reception or transmission of data.
- → The processor, while waiting, must repeatedly interrogate the status of the I/O module.
- → As a result, the level of the performance of the entire system is degraded.
- → An alternative is for the processor to issue an I/O command to a module and then go on to do some other useful work.
- → The I/O module will then interrupt the processor to request service when it is ready to exchange data with the processor.
- → The processor then executes the data transfer, as before, and then resumes its former processing.



18. Direct Memory Access

→ Interrupt-driven I/O and programmed I/O has the following drawbacks:
  - o The I/O transfer rate is limited by the speed with which the processor can test and service a device.
  - o The processor is tied up in managing an I/O transfer; a number of instructions must be executed for each I/O transfer.

→ When large volumes of data are to be moved, a more efficient technique is required: direct memory access (DMA).

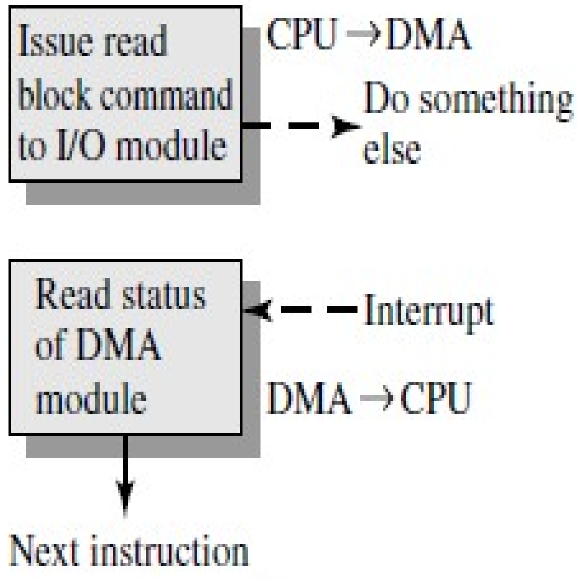
→ When the processor wishes to read or write a block of data, it issues a command to the DMA module.

→ The processor then continues with other work.

→ The DMA module transfers the entire block of data, one word at a time, directly to or from memory, without going through the processor.

→ When the transfer is complete, the DMA module sends an interrupt signal to the processor.

→ Thus, the processor is involved only at the beginning and end of the data transfer.



(c) Direct Memory Access