Hardware devices

Hardware devices if the computer system refers to the physical parts of the computer system. The things that can be seen and touch.

These can be output, input processing or storages devices

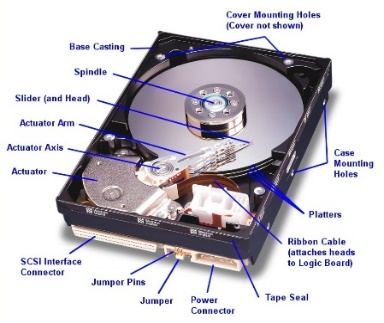
Computer requires storage for it to operate. There are two types of storage that is used by any computer.

* Primary-memory
* Secondary –

Secondary Storage

Secondary Storage includes storage devices that are **not directly accessible by the CPU.** They are non-volatile devices which allow data to be stored as long as required by the user.

Magnetic Disk

Hard disk drives (HDD)

Hard disk drives (HDD) are still one of the most common methods used to store data on a computer.

Data is stored in a digital format on the magnetic surfaces of the disks (or platters, as they are frequently called).

The hard disk drive has a number of platters which can spin at about 7000 times a second.

A number of read-write heads can access all of the surfaces in the disk drive.

Each platter will have two surfaces which can be used to store the data.

Data is stored on the surface each platter in sectors and tracks.

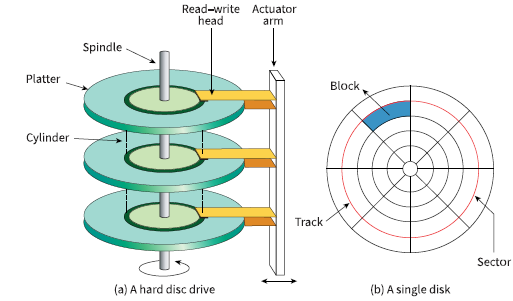
A sector on a given track will contain a fixed number of bytes.

Data access is very slow when compared to RAM

A schematic diagram of a hard disk is shown in below.

A hard disk are composed of:

* there is more than one platter (disk)
* each platter has a read–write head for each side
* the platters spin in unison (all together and at the same speed)
* the read–write heads are attached to actuator arms which allow the heads to move over the surfaces of the platters
* the motion of each read–write head is synchronised with the motion of the other heads
* a cushion of air ensures that a head does not touch a platter surface.



Data is organized in concentric tracks, with each track containing a sequence of bits. These tracks share a common center. The bits within the tracks are grouped into sectors, where each sector holds a specific number of bytes. Sectors serve as the smallest units of storage. Since the movement of the read/write heads is synchronized, related data can be stored on the same tracks across different disks. Accessing this data only requires a single movement of the head. The collection of tracks together is referred to as a "cylinder."

When storing a file, an adequate number of sectors must be allocated. However, these sectors may or may not be located next to one another. As files are created, deleted, or edited, the utilization of sectors becomes increasingly fragmented, which negatively impacts disk performance. To restore performance, a defragmentation program can reorganize the allocation of sectors to files.

Numerous applications necessitate continuous movement of the read-write heads to locate the appropriate data blocks, resulting in a high volume of head movements. Consequently, the impact of latency becomes highly consequential. Latency refers to the duration required for a particular data block on a data track to rotate and reach the read-write head.

Users may occasionally experience the effects of latency when encountering messages such as "Please wait" or, at its most severe, "not responding."

A hard drive is considered a direct-access read-write device because it allows for the selection of any sector for reading or writing. However, the data within a sector must be read sequentially in its designated order

Solid State SSD

Solid-state storage has emerged as a powerful competitor to optical technology due to the continuous improvement in its technology. The foundation of solid-state storage is flash memory, a semiconductor technology that lacks moving parts. Flash memory circuits consist of arrays of transistors functioning as memory cells. The widely utilized NAND technology employs memory cells connected in series, resembling a NAND logic gate.

NAND flash controllers handle the reading and writing operations of the memory. An essential feature of flash memory is the ability to erase entire blocks of memory cells simultaneously, known as "in a flash." Before writing data to a memory block, the existing data within the block must be erased. A block comprises multiple pages of memory, and reading data involves retrieving a single page in a single operation.

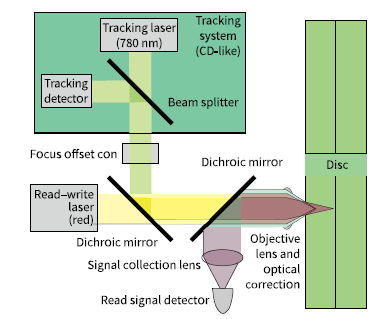
The primary applications for flash memory are memory cards and USB flash drives (memory sticks). In the case of USB flash drives, the flash memory is incorporated into a device with a standard USB connector. Currently, this technology is widely used for removable data storage, although the future remains uncertain with the development of alternative technologies like phase-change random access memory (PRAM).

Another use of flash memory is as a substitute for traditional hard disk drives, known as solid-state drives (SSDs). SSDs do not have moving parts and are composed solely of solid-state components. While it may seem that SSDs would last indefinitely due to the absence of mechanical components, there is a gradual degradation of the construction material with continuous use. However, this degradation can be detected and corrected for, ensuring the longevity of the SSD. Additionally, SSDs offer faster access speeds compared to traditional hard drives.

Optical media

Optical storage technology has its roots in existing technology not directly associated with computing systems. The development of optical storage began with the compact disc (CD), which later evolved into CD Digital Audio (CD-DA) and became the standard technology used in CD-ROMs. CD-ROMs were widely used for software distribution but did not provide a suitable replacement for floppy disks.

To address the need for a read-write capability, the CD-RW (CD-ReWritable) format was introduced. This innovation made CDs a complete alternative to floppy disks, allowing users to write data onto the discs. However, the CD format eventually gave way to the DVD (Digital Versatile Disc), initially designed for digital video but later renamed as "digital versatile disc" to reflect its expanded functionality. DVDs offered higher storage capacities compared to CDs, making them more suitable for storing larger amounts of data.

The latest and most advanced optical storage technology is the Blu-ray disc (BD). Blu-ray discs are capable of storing high-definition video and large volumes of data, surpassing the storage capacity of CDs and DVDs. The development of Blu-ray technology represented a significant leap forward in optical storage capabilities.

In an optical disc drive, a laser is used to read data from the disc. For CD reading, an infrared laser with a wavelength of 780 nm is employed, while a red laser with a wavelength of 680 nm is used for DVDs. The disc itself has a single spiral track that runs from the inner extreme to the outer edge. During operation, the disc spins, and the laser moves across the track to ensure continuous focus on the spiral track.

The track on the disc's surface contains small indentations called "pits" and flat areas called "lands." When the laser beam is reflected from the surface of the disc, the difference in reflection between a pit and a land can be detected. This difference in the intensity of the reflected light is then interpreted as binary code, allowing the reading of data from the disc.

CD-RW and DVD-RW technologies utilize a special alloy material as the reflective surface of the disc. When data is being written (the "burn" process), the laser light generates heat, causing the alloy material to change to a liquid form. The intensity of the laser determines whether the material reverts to a crystalline or an amorphous solid form when it cools. During the reading process, the laser light is reflected from the crystalline solid but not from the amorphous solid, allowing the coding of 1s and 0s.

Although an optical disc has only one track, it functions as a direct-access device because the laser can move forwards or backwards along the track. Data on the disc is formatted into sectors, similar to the formatting used in magnetic hard disks. This sector-based formatting enables efficient access to specific data locations on the disc.

The storage capacity of an optical disc is influenced by two main factors: the speed of rotation and the wavelength of the light used. Shorter wavelength light can be better focused, allowing for higher storage capacities. As a result, DVDs can store more data than CDs, and Blu-ray discs, with their shorter wavelength blue-violet lasers, offer even larger capacities

As with the magnetic tape medium, optical storage was developed from existing technology not associated with computing systems. The compact disc (CD) evolved into CD digital audio (CD-DA) and this became the technology used in the CD-ROM. This was extensively used for distributing software but was of no value as a replacement for the floppy disk. The read–write version (CD-RW) which came later finally meant CD was a complete alternative to floppy disks. However, the CD has now given way

to the DVD (originally ‘digital video disc’ but later renamed as ‘digital versatile disc’). The latest and most powerful technology is the Blu-ray disc (BD).

A schematic diagram of a design for an optical disc drive is shown in Figure 3.03. This is equipped to read a CD with infrared laser light of wavelength 780 nm or a DVD with red laser light of wavelength 680 nm.

The important features for the process of reading data from the disc are as follows.

* The optical disc has one spiral track running from the inner extreme of the surface to the outer
* edge.
* During operation, the disc spins.
* Simultaneously the laser moves across ensuring that it is continuously focused on the spiral track.
* The track on the surface of the disc has what are referred to as ‘pits’ and ‘lands’.
* The laser beam is reflected from the surface of the disc.
* The difference between the reflection from a pit compared to that from a land can be detected.
* This difference in the intensity of the light the detector receives can be interpreted as either a 1 or a

0 to allow a binary code to be read from the disc.

For CD-RW and DVD-RW technologies, the reflective surface is a special alloy material. When data is being written to the disc (the ‘burn’ process) the heat generated by the absorption of the laser light changes the material to liquid form. Depending on the intensity of the laser light the material reverts to either a crystalline or an amorphous solid form when it cools. When the disc is read, the laser light is

reflected from the crystalline solid but not from the amorphous solid, allowing the coding of a 1 or 0.

Despite there being only one track the disc functions as a direct-access device because the laser can move forwards or backwards. The data is formatted into sectors along the track in a similar way to the formatting of a magnetic hard disk.

Another similarity with magnetic disk technology is that the storage capacity is dependent on how close together individual physical representations of a binary digit can get. There are two aspects governing this for an optical disc. The speed of rotation is one but the most important is the wavelength of the light. Shorter wavelength light can be better focused. This is why a DVD can store more than a CD but

much less than a Blu-ray disc.

Primary Storage

Main memory (sometimes called primary storage) refers to storage locations that are directly accessible by the processor. Main memory offers very fast read/write speeds but is typically much lower capacity than secondary storage devices.

Types of memory

* ROM
* RAM

The RAM inside a computer holds all of the data and instructions that are currently being processed. In order for any program to be executed, it must first be loaded into the RAM from Secondary storage. This is because RAM has quicker read and write speeds than secondary storage devices. The processor will fetch instructions (and any necessary data) from the RAM directly before decoding and executing them.

Within the RAM, the memory is split up into separate locations, each of which is given a unique memory address. The processor will use these addresses to access the data stored in RAM. Any of the locations in RAM can be accessed in the same amount of time, unlike other storage devices where a sensor (such as a read/write head) needs to be moved into place. This is why it is called random access: any location can be accessed "at random" with no impact on speed.

RAM is volatile, meaning power is required to hold the data, and if the power is switched off all the data stored in RAM is lost. Any data that needs to be stored permanently must be moved out of RAM before a computer is switched off. If you have ever lost a document or piece of code you were working on because you hadn't saved it and your computer switched off, you have seen the impact of RAM's volatility.

Although the capacity of RAM is typically lower than secondary storage devices, it is often the highest capacity form of main memory.

ROM

ROM is typically used to store the boot sequence (BIOS) for a computer. Unlike RAM, it is non-volatile and will not lose its data when the power is switched off. The contents of ROM are set by the computer manufacturer and, as the name implies, your computer usually only reads from ROM. Which is good because it is crucial to your computer system and any changes you make could stop the computer booting up properly.

The BIOS (Basic Input/Output System) stored on ROM is a very limited sequence of instructions that checks that the core components of the computer system (RAM, fundamental input/output devices, secondary storage) are connected and responding correctly.

Once done, the boot sequence loads the essential parts of the main operating system from secondary storage into RAM. From this point, the operating system will oversee the operation of the computer, managing memory, storage, and requests for input/output.

|  |  |  |
| --- | --- | --- |
| **Characteristic** | **RAM** | **ROM** |
| **Purpose** | Stores data and instructions during processing | Stores boot-up instructions set by the manufacturer |
| **Volatility** | Volatile, data lost without power | Non-volatile, data remains after power switched off |
| **Read/Write** | Read and write | Read only |
| **Capacity** | Usually several gigabytes | A few megabytes in size |

Types of RAM

DRAM stands for dynamic random-access memory. This type of random-access semiconductor memory is commonly used for a computer's main memory because it is relatively cheap to manufacture.

DRAM memory cells are usually made up of a capacitor and a transistor. The capacitor in the cell will store a charge to represent a single bit value. Typically, a charged capacitor will represent the value 0,0 and a discharged capacitor will represent 1,1. The transistor in the cell will act as a switch to set or change the value.

The charge on a capacitor will leak over time, so the system will need a frequent memory refresh to restore the capacitors to their original charge. This operation happens constantly in the background so it will not be evident to the user.

SRAM stands for static random-access memory. This type of memory uses a different type of circuitry (flip-flops), which does not need to be refreshed. SRAM is generally twice as fast to access (read or write) as DRAM. However, it is more expensive to manufacture so is generally used for areas where speed is most important, for example for registers and cache memory.

DRAM and SRAM are both types of volatile memory. They require a constant power supply to maintain the memory charge.

| **sram** | **dram** |
| --- | --- |
| Doesn’t need to refresh hence uses less power and faster access time | Has to be refreshed, hence has slower access times and needs higher power |
| More complex circuitry, hence more expensive | Only single transistor & capacitor, hence less expensive to purchase |
| Each bit stored in flip-flop | Each bit stored as a charge |
| Has lower data density | Has higher data density |
| Used in cache memory | Used in main memory |

Types of ROM

Most electronic devices contain read-only memory (ROM). As the name implies, ROM is not intended to be written to, and traditional ROM circuits, called mask ROM, have their contents written during the manufacturing process, after which they cannot be changed.

PROM stands for programmable read-only memory, which is a type of ROM that can be written to once (only) after the circuit has been manufactured. This type of ROM is often used when an electronic device has a relatively low production volume, and the cost of writing the contents during the manufacturing process is not cost effective. The PROM is supplied empty (with no contents) and then the required data is written to the circuit by the supplier of the electronic device. This approach also allows the supplier to write the latest version of the software for the device without needing an expensive redesign of part of the manufacturing process. PROM is typically used in microcontrollers, games consoles, mobile phones, and RFID tags (to name but a few).

EPROM stands for erasable programmable read-only memory. If the contents of the ROM need to be changed, the memory unit is removed from the system and ultraviolet light is used to erase the data; all of the contents are erased in a single operation. This is a specialist operation and needs special equipment and operator expertise.

EPROM technology has been superseded by EEPROM, which stands for electrically erasable programmable read-only memory. This type of memory device allows individual bytes to be erased electronically and the device can then be reprogrammed. EEPROM is typically used in smart cards and remote keyless systems. Some EEPROM devices have additional security features to protect the device from hackers who may wish to attempt to reprogram it.

Monitoring and Control Systems

* + Monitoring System
    - Monitors some state external to computer system
    - No changes made to environment by the system and hence no feedback
  + Control System
    - Regulates the behaviour of other devices or systems.
    - Event-driven system: the controller alters the state of the system in response to some event.
    - Time-driven system: the controller takes action at a specific point in time
  + Hardware typically used in a system
    - Sensor: measures an (analogue) property and transmits it to a processing unit, generally as an electrical or optical signal.
    - Actuators: switch on/off heavy appliances (e.g. heater to heat/fan to cool)
    - ADC: converts analogue signals to digital signals
    - Transmission cable: to transfer signals
  + Feedback Systems
    - Output from system affects the input of sensors.
    - Ensures system operates within the given criteria
    - By enabling the system output to affect subsequent system inputs, it may cause a change in the actions taken by the system
    - Thus enables the system to automatically adjust conditions in a continuous process