Parallel Instruction Execution:

Computer architectures are constantly striving to improve performance of the machine they design. Making the chips run faster by increasing their clock speed is one way, but it has its own limitation. So most computer architects look to parallelism as a way to get even more performance for a given clock speed.

Parallel instruction is mainly concentrated on executing multiple instructions in parallel to each other. Modern computer architectures are centered on the concept of parallel processing. There are various techniques of achieving parallel instruction execution.

There are two types of parallelism:

1. **Instruction level parallelism:** By running parallel instruction with a common processor.
2. **Processor level parallelism:** By running parallel instruction on multiple processors in a single machine.
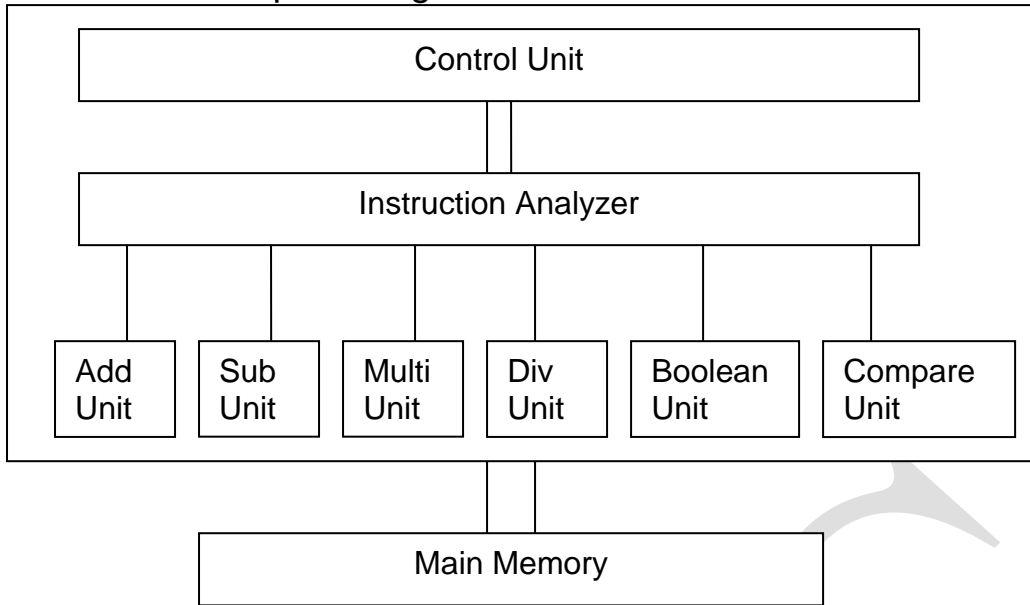
Categories of parallel Machine:

1. **Array Processor:** An array processor is an advanced computer architecture in which many identical processing units are configured in such a way that many data items can be executed with a single instruction under the control of a single unit. An array processor consists of a large number of identical processor that performs the same sequences of instruction on different sets of data.
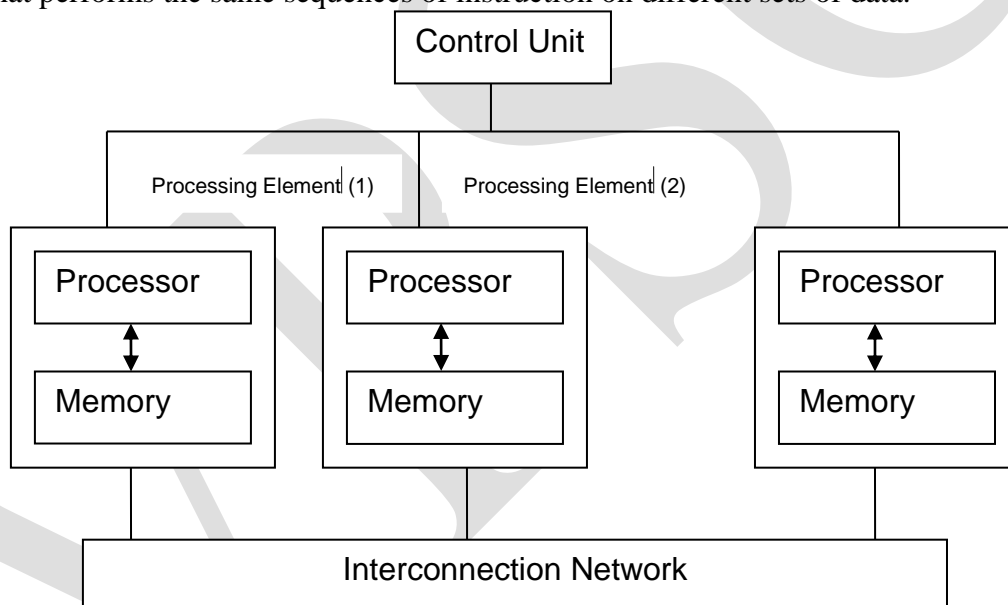
As shown in the figure multiple processor of the array processor performs the same task at the same time on different data items. Hence, such type of processor is useful for processing where common instruction is applied to large amount of data.

2. **Multifunctional Units:**

Such computer has separate arithmetic units for addition, multiplication, division and other Boolean Operation. There is one control unit, which fetches and decodes instruction. As soon as the type of instruction is known it is sent to the appropriate unit and fetching and decoding of next instruction begins concurrently with the execution of first instruction. A well-timed program may many instructions being executed simultaneously.

```
                    ┌──────────────────────────────────────────────┐
                    │                Control Unit                  │
                    └──────────────────────────────────────────────┘
                    ┌──────────────────────────────────────────────┐
                    │              Instruction Analyzer            │
                    └──────────────────────────────────────────────┘
         ┌────────┐ ┌────────┐ ┌────────┐ ┌────────┐ ┌──────────┐ ┌──────────┐
         │ Add    │ │ Sub    │ │ Multi  │ │ Div    │ │ Boolean  │ │ Compare  │
         │ Unit   │ │ Unit   │ │ Unit   │ │ Unit   │ │ Unit     │ │ Unit     │
         └────────┘ └────────┘ └────────┘ └────────┘ └──────────┘ └──────────┘
                         ┌──────────────────────────────┐
                         │          Main Memory         │
                         └──────────────────────────────┘
```

3 Pipeline machine:

Such machines work on the concept of pipelining the various execution stages of the instruction. Instructions are prefetched in special buffer registers. Prefetching process divides instruction execution in two parts: Fetching and Actual execution. Actually, this pipeline concept divides the instruction execution in more than two parts, and each part is handled by separate piece of hardware. These divisions are called stages. Following figure illustrates 5-stages instruction pipelining.

```
┌────────────┐   ┌────────────┐   ┌────────────┐   ┌────────────┐   ┌────────────┐
│ S1         │   │ S2         │   │ S3         │   │ S4         │   │ S5         │
│ Instruction│ → │ Instruction│ → │ Operand    │ → │ Instruction│ → │ Write      │
│ Fetch Unit │   │ Decode     │   │ Fetch Unit │   │ Execution  │   │ Back Unit  │
│            │   │ Unit       │   │            │   │ Unit       │   │            │
└────────────┘   └────────────┘   └────────────┘   └────────────┘   └────────────┘
```

Stage 1: Fetches the instruction from memory and places it in a buffer until it is needed.
Stage 2: Decodes the instruction, determine its type and what operands it needs.
Stage 3: Locates and fetches the operands, either from register or from memory.
Stage 4: Executes the instruction.
Stage 5: Writes the result back to the proper register.

As shown in the table, pipeline works as function of time.

S1	1	2	3	4	5	6	7	8	9
S2		1	2	3	4	5	6	7	8
S3			1	2	3	4	5	6	7
S4				1	2	3	4	5	6
S5					1	2	3	4	5
Time	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**

During clock cycle 1,
        Stage 1: Fetches instruction 1 from memory.

During clock cycle 2,

Stage 2: Decodes the instruction 1

Stage 1: Fetches the instruction 2 from memory

During clock cycle 3,

Stage 3: Fetches the operands for instruction 1.

Stage 2: Decodes the instruction 2.

Stage 1: Fetches the instruction 3.

During clock cycle 4,

Stage 4: Executes instruction 1.

Stage 3: Fetches the operands for instruction 2.

Stage 2: Decodes the instruction 3.

Stage 1: Fetches the instruction 4.

During clock cycle 5,

Stage 5: Stores the result of instruction 1 back to register/memory.

Stage 4: Executes instruction 2.

Stage 3: Fetches the operands for instruction 3.

Stage 2: Decodes the instruction 4.

Stage 1: Fetches the instruction 5.

The above process is repeated till the instructions in the program are executed in this manner.

Multiple processors:

It has two or more CPUs sharing a common memory. Usually each CPU has its own programs to run, with no interaction between the CPUs. A computer with multiple processors that share a common memory is known as *multiprocessor.*
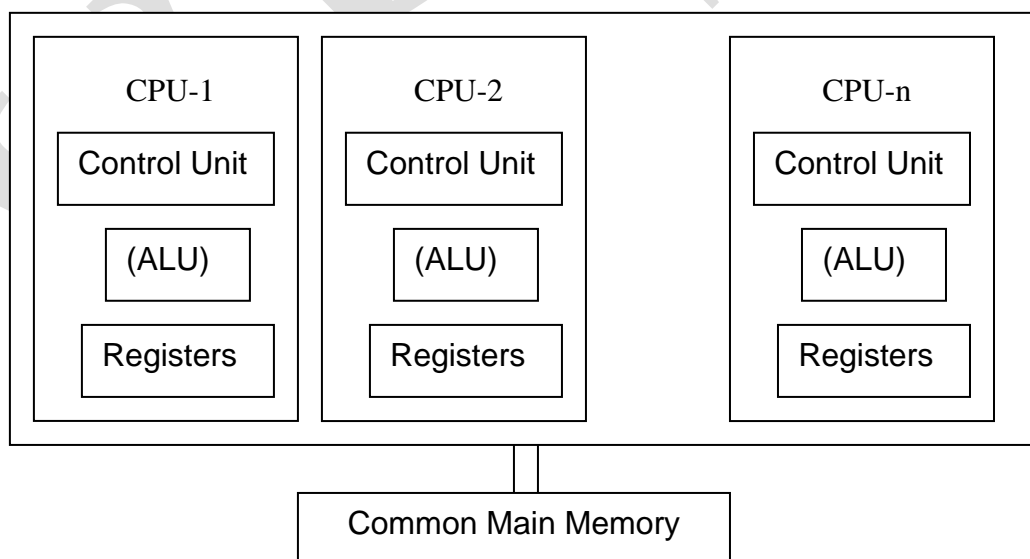
Memory

Primary Memory:

The primary storage, also known as main memory, is used to hold pieces of program instructions and data, processing, of the job(s), which the computer system is currently working on. These pieces of information are represented electronically in the main memory chip's circuitry, and while it remains in the main memory, the central processing unit can access it directly at a very fast speed. However, the primary storage can hold information only while the computer system is on. As soon as the computer system is switched off or reset, the information held in the primary storage disappears. Moreover, the primary storage normally has limited storage capacity, because it is very expensive. The primary storage of modern computer system is made up of semiconductor devices.

RAM:

Random access memory or *RAM* most commonly refers to computer chips that temporarily store dynamic data to enhance computer performance. By storing frequently used or active files in random access memory, the computer can access the data faster than if it to retrieve it from the far-larger hard drive. Random access memory is also used in printers and other devices.

Masked ROM:

In this type of ROM bits are stored permanently by marking and metallization process. This is done by manufacturers. This type of ROM can be programmed only one-by the manufacture.

PROM:

Data are written into a ROM at the time of manufacture. However, a programmable ROM (PROM) allows the data to be loaded by the user, by connecting a fuse between the emitter and the bit-line. PROMs provide flexible and economical storage for fixed programs and data, where high production volumes are involved.

EPROM:

The Erasable PROM chip allows the stored data to erase and new data can be reprogrammed. It provides more flexibility during the development phase of digital system. The contents of EPROM cells can be erased by increasing the discharge rate of the storage capacitors.

EEPROM:

In electricity erasable PROM, the contents of cells can be erased by the application of a high voltage. Advantages with EEPROMs are: it need not be physically removed for reprogramming and the process can be made selective since electrical erasure is used.

Cache Memory:

A **CPU cache** is a cache used by the central processing unit of a computer to reduce the average time to access memory. The cache is a smaller, faster memory which stores copies of the data from the most frequently used main memory locations.

Cache memory is random access memory (RAM) that a computer microprocessor can access more quickly than it can access regular RAM. As the microprocessor processes data, it looks first in the cache memory and if it finds the data there, it does not have to do the more time-consuming reading of data from larger memory.

Registers: As the instructions are interpreted and executed by the CPU, there is a movement of information between the various units of the computer system. In order to handle this process satisfactorily, and to speed up the rate of information transfer, the computer uses a number of special memory units, called registers.

1. **Memory Address Register (MAR)**: It holds the address of the active memory location. It is loaded from the program control register, when an instruction is read from memory.
2. **Memory Buffer Register (MBR)**: It holds the contents of the memory word read from, or written in, memory. An instruction word placed in this register is transferred to the instruction register.
3. **Program Control Register (PC)**: It holds the address of the next instruction to be executed.
4. **Accumulator Register (A)**: It holds the data to be operated upon, the intermediate results, and the results of processing. It is used during the execution of most instructions.
5. **Instruction Register (IR)**: It holds the current instruction, which is being executed.
6. **Input/Output Register (I/O)**: It is used to communicate with the   input/output devices.

Secondary Memory:

The secondary storage, also known as auxiliary storage, is used to take care of the limitations of the primary storage. That is, it is used to supplement the limited storage capacity and the volatile characteristic of primary storage. This is because secondary storage is much cheaper than primary storage, and it can retain information even when the computer system is switched off or reset. The secondary storage is normally used to hold the program instructions, data, and information of those jobs, on which the computer system is not working on currently, but needs to hold them for processing later. The most commonly used secondary storage medium is the magnetic disk.

CD (Compact Disk): A compact disc (CD) is a flat, round, portable, storage medium that is usually 4.75 inches in diameter and less than one-twentieth of an inch thick.
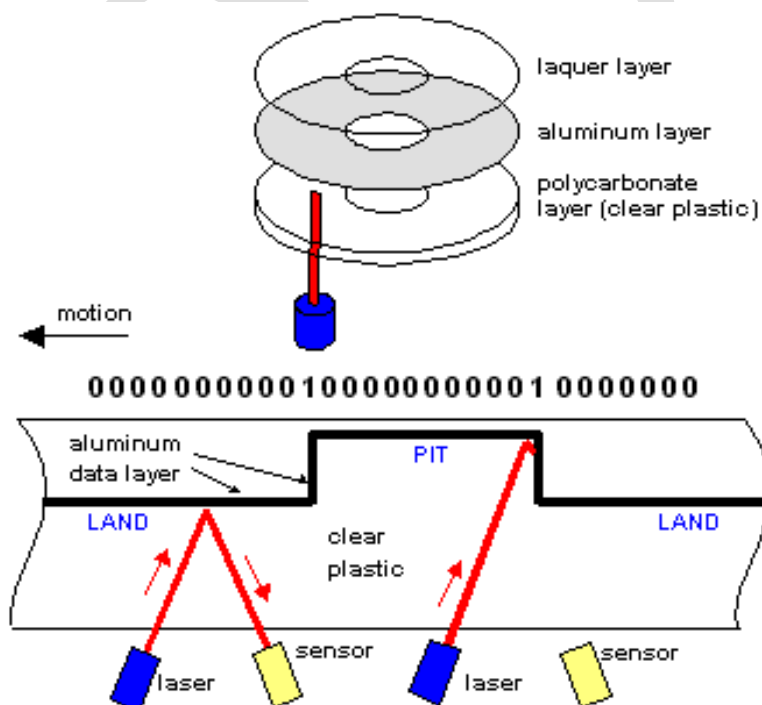
- Compact discs store items by using microscopic pits and land that are in the middle layer of the disc.
- A compact disc stores items in a single track, which is also divided into evenly sized sectors, that spirals from the center of the disc to the edge of the disc.
- The drive destination of a compact disk drive usually follows alphabetically after that of the hard

disk (i.e. if the hard disk is drive C, then the compact disk is drive D).
- Variations of compact discs designed for use with computers include
- Most manufacturers guarantee that a properly cared for compact disc will last up to 50 years.

Advantages:
- Advantages of compact disc over hard disk include
  - ✓ A compact disc is more portable than a hard disk.
- Advantages of compact disc over floppy disk include
  - ✓ The storage capacity of a compact disc is very much larger than that of a floppy disk.
  - ✓ The average access time of a compact disc is faster than that of a floppy disk.

Disadvantages:
- Some kinds of compact discs are read only (CD-ROM and DVD-ROM).
- The average access time of a compact disc is slower than that of a hard disk.

DVD (Digital Video Disc or Digital Versatile Disc) :

- DVD is an optical disc storage media format, and was invented and developed by Philips, Sony, Toshiba, and Time Warner in 1995.
- Its main uses are video and data storage. DVDs are of the same dimensions as compact discs (CDs), but are capable of storing more than six times as much data.
- Variations of the term DVD often indicate the way data is stored on the discs: DVD-ROM (read only memory) has data that can only be read and not written; DVD-R and DVD+R (recordable) can record data only once, and then function as a DVD-ROM; DVD-RW (re-writable), DVD+RW, and DVD-RAM (random access memory) can all record and erase data multiple times.

Advantages:
- Superior Data Storage - Advantage DVD
  When it was developed, the only serious competition of DVD was from 3.5 inch floppies. The floppies had been in existence for quite a long time and had slowly been coming down in size from 10 inch to 5.5 inches and then to the standard 3.5 inches.
- High density advantage of DVD: The capacity of floppies remained at a measly 1.44 MB, whereas the CD could store 700 MB and the DVD could store initially 4.5 GB and now you can have double sided double layer storing up to 17 GB. This had the advantage of storing 11000 times more data at just double the size of floppy.
- Cost advantage of DVD: The cost of blank DVD is just 4 to 10 times that of the floppy or the audio CD, but the data storage capacity is huge and thus the cost per bit of data stored comes down considerably. With the costs coming down rapidly, the cost advantage of DVD becomes further obvious.
- Duplication advantage of DVD: With DVD writers becoming just as cheap as the CD writers, the cost of carrying of data with you has reduced considerably. You can carry the data as cheaply and easily as the floppies themselves. You can do this without bothering about the costs.

Hard Disk:
- Hard disk is made up of smooth metal plates coated on both sides with a thin film of magnetic material.
- A hard disk usually consists of several inflexible, circular disks, called platters, on which items are stored electronically.
- A set of such magnetic plates are fixed to a spindle one below the other to make up a disk pack.
- A disk pack is sealed and mounted on a disk drive. Such a disk drive is known as a Winchester disk drive.

- A disk drive consists of a motor to rotate the disk pack about its axis at a speed of about 7200 revolutions per minute.
- The drive has a set of magnetic heads mounted on arms.
- The arm assembly is capable of moving in and out in radial direction.
- A set of concentric tracks are recorded on each surface of disk pack is called a cylinder.
- If a disk pack has n plates, there are 2n surfaces. Thus the no. of tracks per cylinder is 2n.
- A track is divided into sectors.
- Assume that 5 bytes are stored per sector, p sectors are there per track, t tracks per surface, and m surfaces then:

    Capacity = s * p * t * m bytes

    If d is the diameter of disk then

    Density = (s * p) / (π * d) bytes/inch

- The hard disk in most desktop and laptop computers is housed inside the system unit, and is considered fixed disks because being not portable.
- Hard disks are sealed tightly to keep out of contaminants (e.g., dust and smoke particles), which may result in head crash.
- Hard disks undergo two formatting steps: a low-level format and a high-level format.
- Some computers are able to improve the hard disk access time by using disk caching.
- The flow of data, instructions, and information to and from a hard disk is managed by a special purpose chip and its associated electronic circuits called the hard disk controller (HDC).
- Some manufacturers develop a type of hard disk system, called RAID(Redundant Array of inexpensive Disk), which connects several smaller disks into a single unit that acts like a single large hard disk.
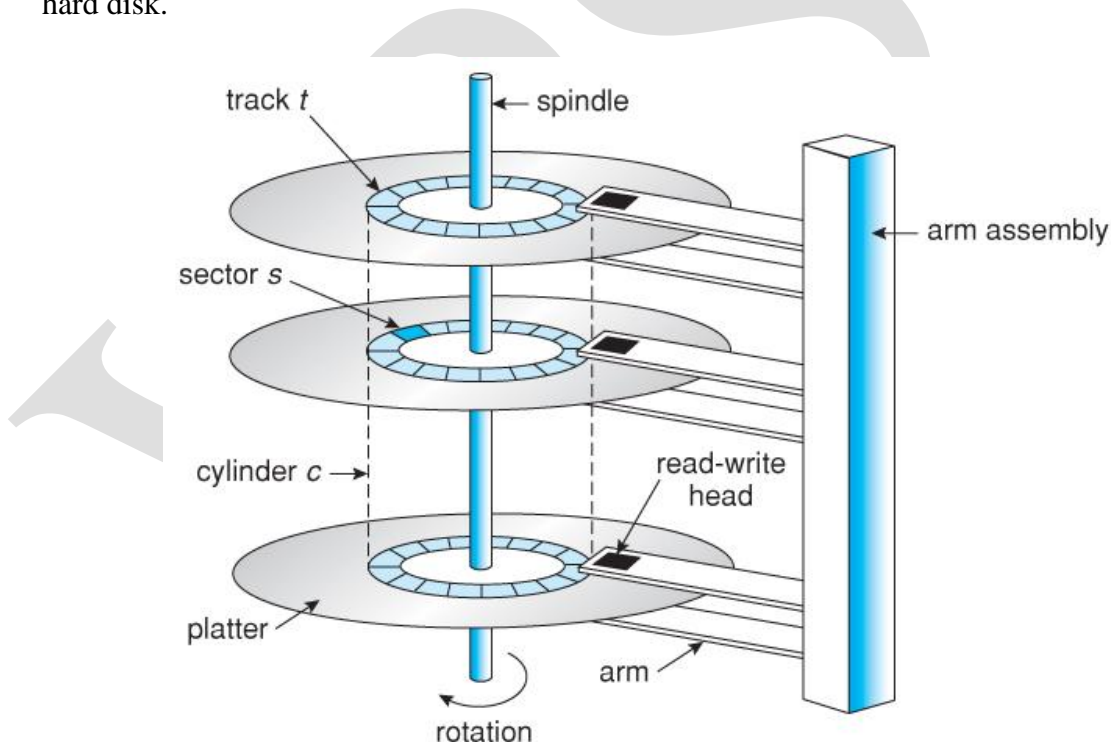
Advantages:

Advantages of hard disks over floppy disk include
- ✓ Hard disks provide far larger storage capacities and much faster access times than floppy disks.
- ✓ Hard disk is cheaper than floppy disk per Megabyte.
- ✓ Hard disk is usually more reliable than floppy disk (a better protection against dust and dirt).

Disadvantages:

Disadvantages of hard disk when compared with floppy disk include
- ✓ Hard disk is not portable (except removable hard disk, which is usually more expensive).
- ✓ Data becomes less secure if left on the hard disk.
- ✓ Head crash may occur due to extreme shock or contaminants.

Memory Stick:
- Memory Stick is a removable <u>flash</u> <u>memory card</u> format, launched by <u>Sony</u> in October 1998, and is also used in general to describe the whole family of Memory Sticks.
- In addition to the original Memory Stick, this family includes the Memory Stick PRO, a revision that allows greater maximum storage capacity and faster file transfer speeds; Memory Stick Duo, a small-form-factor version of the Memory Stick (including the PRO Duo); and the even smaller Memory Stick Micro (M2). In December 2006 Sony added the Memory Stick PRO-HG, a high speed variant of the PRO to be used in high definition still and video cameras.
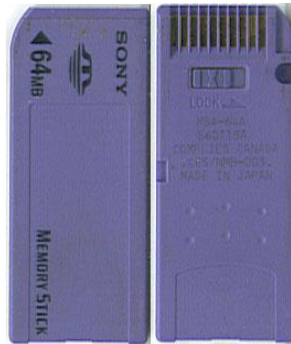
Advantages:
- Very easily allows you to transport documents from one computer to another.
- Small, therefore easy to carry around with you.
- They are very useful when doing school work or running businesses - any work done at home can be used at work/ school as well.
- It holds a lot more data than a floppy disk.
- It is a USB drive so it can be used on any computer system.

Disadvantages:
- If you want a memory stick that hold a very big amount of data (like if you are going to use it for a lot of large document) they can be quite expensive to buy.
- Small so easy to lose and they can take viruses from one computer to another.

Pen Drive:
- A USB flash drive consists of a flash memory data storage device integrated with a USB (Universal Serial Bus) 1.1 or 2.0 interface.
- USB flash drives are typically removable and rewritable, and physically much smaller than a floppy disk. Most weigh less than 30 g (1 oz). Storage capacities in 2010 can be as large as 256 GB with steady improvements in size and price per capacity expected. Some allow 1 million write or erase cycles and have a 10-year data retention cycle.
- Flash drives use the USB mass storage standard, supported natively by modern operating systems such as Windows, Mac OS X, Linux, and other Unix-like systems. USB drives with USB 2.0 support can store more data and transfer faster than a much larger optical disc drive and can be read by most other systems such as the Play Station-3.

Flash Memory Card:

- A memory card or flash card is an electronic flash memory data storage device used for storing digital contents. They are commonly used in many electronic devices, including digital cameras, mobile phones, laptop computers, MP3 players, and video game consoles. They are small, re-recordable, and they can retain data without power.
- The most common type of memory card in use today is the SD card,[1] which comes in capacities of up to 64 Gigabytes. In addition to these and other types of memory cards, there are also non-solid-state memory cards that do not use flash memory, and there are different types of flash memory. Many cards incorporate wear leveling algorithms in their design.

ROM (Read Only Memory)

➢ **Read-o***nly* **m***emory*, computer memory on which data has been prerecorded. Once data has been written onto a ROM chip, it cannot be removed and can only be read.

➢ It is a class of storage media used in computers and other electronic devices. Data stored in ROM cannot be modified, or can be modified only slowly or with difficulty. ROM refers only to mask ROM (the oldest type of solid state ROM), which is fabricated with the desired data permanently stored in it, and thus can never be modified. However, more modern types such as EPROM and flash EEPROM can be erased and re-programmed multiple times; they are still described as "read-only memory"(ROM) because the reprogramming process is generally infrequent, comparatively slow, and often does not permit random access writes to individual memory locations.

Ex: CD ROM is a Static ROM

Floppy Disk

➢ Floppy disk is the popular direct access secondary storage medium for micro and mini computers.

➢ Floppy disk is also referred as a flexible disk or diskettes or floppies.

➢ Floppy disk is first introduced by IBM. As the material used in disk is flexible plastic material, is called as floppy disk.

➢ The floppy disk is a single, flexible plastic disk. The disk is coated with special magnetic material on which information is stored. The flexile disk is enclosed within a square plastic or cardboard jacket.Below fig shows structure of a floppy disk.

FLASH DRIVE:

A **USB flash drive** is a data storage device that includes flash memory with an integrated Universal Serial Bus (USB) interface. USB flash drives are typically removable and rewritable, and physically much smaller than a floppy disk. Most weigh less than 30 g.[1] As of September 2011 drives of 256 gigabytes (GB) are available.[2] Storage capacities as large as 2 terabytes are planned, with steady improvements in size and price per capacity expected.[3] Some allow up to 100,000 write/erase cycles, depending on the exact type of memory chip used, and a 10 year shelf storage time.[4][5][6]

USB flash drives are often used for the same purposes for which floppy disks or CD-ROMs were used. They are smaller, faster, have thousands of times more capacity, and are more durable and reliable because they have no moving parts. Until approximately 2005, most desktop and laptop computers were supplied with floppy disk drives, but floppy disk drives have been abandoned in favor of USB ports.

USB flash drives use the USB mass storage standard, supported natively by modern operating systems such as Linux, Mac OS X, Windows, and other Unix-like systems, as well as many BIOS boot ROMs. USB drives with USB 2.0 support can store more data and transfer faster than much larger optical disc drives like CD-RW or DVD-RW drives and can be read by many other systems such as the Xbox 360, PlayStation 3, DVD players and in some upcoming mobile smartphones.

Nothing moves mechanically in a flash drive; the term *drive* persists because computers read and write flash drive data using the same system commands as for a mechanical disk drive, with the storage appearing to the computer operating system and user interface as just another drive. Flash drives are very robust mechanically.

A flash drive consists of a small printed circuit board carrying the circuit elements and a USB connector, insulated electrically and protected inside a plastic, metal, or rubberized case which can be carried in a pocket or on a key chain, for example. The USB connector may be protected by a removable cap or by retracting into the body of the drive, although it is not likely to be damaged if unprotected. Most flash drives use a standard type-A USB connection allowing plugging into a port on a personal computer, but drives for other interfaces also exist.

USB flash drives draw power from the computer via the USB connection. Some devices combine the functionality of a digital audio player with USB flash storage; they require a battery only when used to play music.

Que: What is Latency?

Latency is a measure of time delay experienced in a system, the precise definition of which depends on the system and the time being measured. Latencies may have different meaning in different contexts

Latency is the amount of time that it takes for information from your computer to travel to the source. Latency should not be confused with bandwidth, as bandwidth measures how much data you can move in a given period of time, but not necessarily how fast it moves.

For example, if I am connected to a computer in the next country, latency measures how long it takes for each letter that I type to travel to the other computer. Latency is important when someone is directly

interacting with another computer, as the amount of "lag" between the two computers can make some tasks very difficult (such as editing a file).

Floppy Disk:
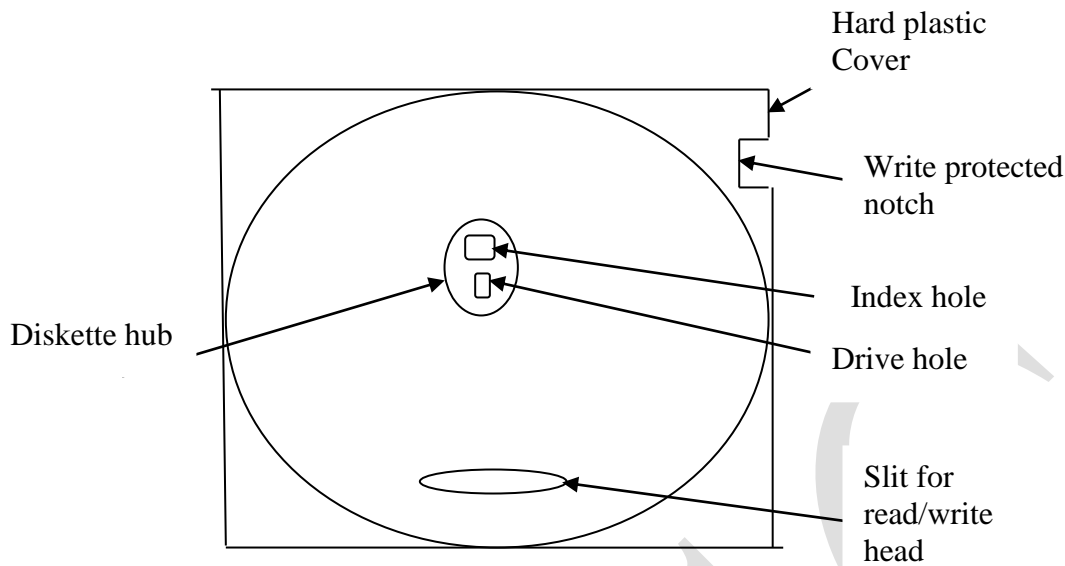
- ➢ For accessing information stored in floppy disk, floppy drive is used. When floppy disk is inserted into floppy drive, the slit for read/write access is open when disk start rotating.

- ➢ The drive hole holds the floppy disk in contact with drive. If write protected notch is open then information can be written into floppy disk and if it is closed then information can be read form disk.

- ➢ Floppy disks are typically 5.25, 3.5 or 8 inches in a diameter. The floppy disk surface is divided into tracks and sectors as shown in below fig.
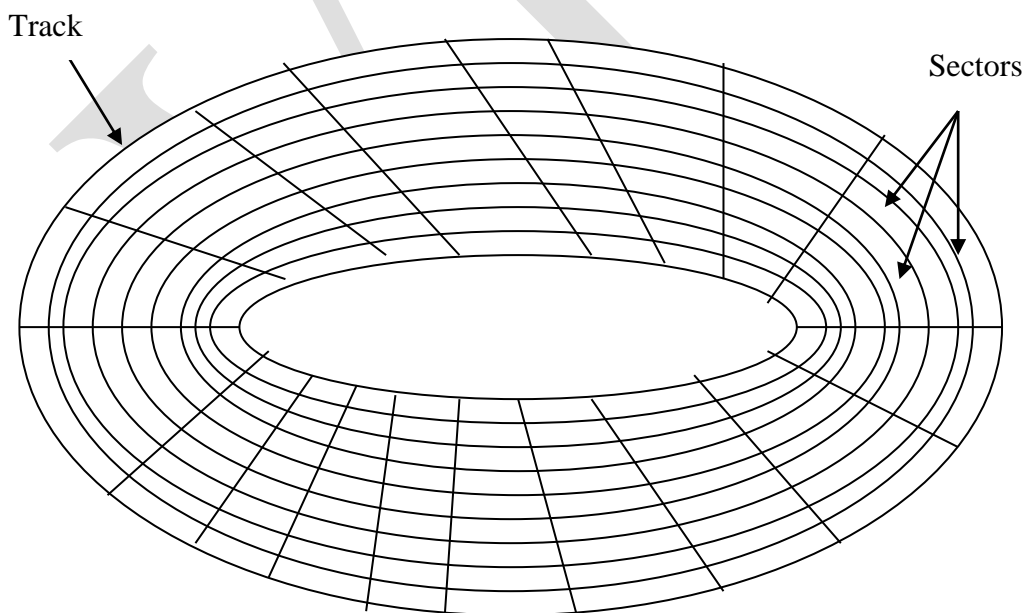
Information is stored as tiny invisible magnetic spot on tracks.
Many floppy disks have 80 tracks on each side of disk and there are 18 sectors per track

So if the floppy disk has 80 tracks then there are total 80 * 18 = 1440 sectors per side so the total sectors are 2 * 1440 = 2880 sectors.

Based on surface utility, the floppy disk can be categorized into two types.

1. Single Sided Double Density (SSDD) Disks
2. Double Sided Double Density (DSDD) Disks

In a SSDD disk, only one side (surface) of disk is used to stored information.
In a DSDD disk, both surfaces are used to stored information.

Maximum storage capacity of today's floppy disk is 1.44 MB and the data transfer rate is up to 100 Kbps

Advantages
➢ It is movable i.e. one can take it from one to another place
➢ Less costly
➢ Removable
➢ Retrieval of information from disk is instant

Disadvantages
➢ Low storage capacity
➢ It should be kept away from magnetic field or dust full atmosphere
➢ One should not bend it