Computer Fundamental

History of Computers

The first counting device was used by the primitive people. They used sticks, stones and bones as counting tools. As human mind and technology improved with time more computing devices were developed. Some of the popular computing devices starting with the first to recent ones are described below;

Abacus

The history of computer begins with the birth of abacus which is believed to be the first computer. It is said that Chinese invented Abacus around 4,000 years ago.

It was a wooden rack which has metal rods with beads mounted on them. The beads were moved by the abacus operator according to some rules to perform arithmetic calculations. Abacus is still used in some countries like China, Russia and Japan. An image of this tool is shown below;

Napier's Bones

It was a manually-operated calculating device which was invented by John Napier (1550-1617) of Merchiston. In this calculating tool, he used 9 different ivory strips or bones marked with numbers to multiply and divide. So, the tool became known as "Napier's Bones. It was also the first machine to use the decimal point.

Pascaline

Pascaline is also known as Arithmetic Machine or Adding Machine. It was invented between 1642 and 1644 by a French mathematician-philosopher Biaise Pascal. It is believed that it was the first mechanical and automatic calculator.

Pascal invented this machine to help his father, a tax accountant. It could only perform addition and subtraction. It was a wooden box with a series of gears and wheels. When a wheel is rotated one revolution, it rotates the neighboring wheel. A series of windows is given on the top of the wheels to read the totals. An image of this tool is shown below;

Stepped Reckoner or Leibnitz wheel

It was developed by a German mathematician-philosopher Gottfried Wilhelm Leibnitz in 1673. He improved Pascal's invention to develop this machine. It was a digital mechanical calculator which was called the stepped reckoner as instead of gears it was made of fluted drums. See the following image;

Difference Engine

In the early 1820s, it was designed by Charles Babbage who is known as "Father of Modern Computer". It was a mechanical computer which could perform simple calculations. It was a steam driven calculating machine designed to solve tables of numbers like logarithm tables.

Analytical Engine

This calculating machine was also developed by Charles Babbage in 1830. It was a mechanical computer that used punch-cards as input. It was capable of solving any mathematical problem and storing information as a permanent memory.

Tabulating Machine

It was invented in 1890, by Herman Hollerith, an American statistician. It was a mechanical tabulator based on punch cards. It could tabulate statistics and record or sort data or information. This machine was used in the 1890 U.S. Census. Hollerith also started the Hollerith?s Tabulating Machine Company which later became International Business Machine (IBM) in 1924.

Differential Analyzer

It was the first electronic computer introduced in the United States in 1930. It was an analog device invented by Vannevar Bush. This machine has vacuum tubes to switch electrical signals to perform calculations. It could do 25 calculations in few minutes.

Mark I

The next major changes in the history of computer began in 1937 when Howard Aiken planned to develop a machine that could perform calculations involving large numbers. In 1944, Mark I computer was built as a partnership between IBM and Harvard. It was the first programmable digital computer.

Generations of Computers

A generation of computers refers to the specific improvements in computer technology with time. In 1946, electronic pathways called circuits were developed to perform the counting. It replaced the gears and other mechanical parts used for counting in previous computing machines.

In each new generation, the circuits became smaller and more advanced than the previous generation circuits. The miniaturization helped increase the speed, memory and power of computers. There are five generations of computers which are described below;

First Generation Computers

The first generation (1946-1959) computers were slow, huge and expensive. In these computers, vacuum tubes were used as the basic components of CPU and memory. These computers were mainly depended on batch operating system and punch cards. Magnetic tape and paper tape were used as output and input devices in this generation;

Some of the popular first generation computers are;

- **ENIAC** (Electronic Numerical Integrator and Computer)
- **EDVAC** (Electronic Discrete Variable Automatic Computer)
- **UNIVACI**(Universal Automatic Computer)
- **IBM-701**
- **IBM-650**

Second Generation Computers

The second generation (1959-1965) was the era of the transistor computers. These computers used transistors which were cheap, compact and consuming less power; it made transistor computers faster than the first generation computers.

In this generation, magnetic cores were used as the primary memory and magnetic disc and tapes were used as the secondary storage. Assembly language and programming languages like COBOL and FORTRAN, and Batch processing and multiprogramming operating systems were used in these computers.

Some of the popular second generation computers are;

- **IBM 1620**
- **IBM 7094**
- **CDC 1604**
- **CDC 3600**
- **UNIVAC 1108**

Third Generation Computers

The third generation computers used integrated circuits (ICs) instead of transistors. A single IC can pack huge number of transistors which increased the power of a computer and reduced the cost. The computers also became more reliable, efficient and smaller in size. These generation

computers used remote processing, time-sharing, multi programming as operating system. Also, the high-level programming languages like FORTRON-II TO IV, COBOL, PASCAL PL/1, ALGOL-68 were used in this generation.

Some of the popular third generation computers are;

- **IBM-360 series**
- **Honeywell-6000 series**
- **PDP(Personal Data Processor)**
- **IBM-370/168**
- **TDC-316**

Fourth Generation Computers

The fourth generation (1971-1980) computers used very large scale integrated (VLSI) circuits; a chip containing millions of transistors and other circuit elements. These chips made this generation computers more compact, powerful, fast and affordable. These generation computers used real time, time sharing and distributed operating system. The programming languages like C, C++, DBASE were also used in this generation.

Some of the popular fourth generation computers are;

- **DEC 10**
- **STAR 1000**
- **PDP 11**
- **CRAY-1(Super Computer)**
- **CRAY-X-MP(Super Computer)**

Fifth Generation Computers

In fifth generation (1980-till date) computers, the VLSI technology was replaced with ULSI (Ultra Large Scale Integration). It made possible the production of microprocessor chips with ten million electronic components. This generation computers used parallel processing hardware and AI (Artificial Intelligence) software. The programming languages used in this generation were C, C++, Java, .Net, etc.

Some of the popular fifth generation computers are;

- **Desktop**

- **Laptop**
- **NoteBook**
- **UltraBook**
- **ChromeBook**

Classification of Computers

Types of Computer

We can categorize computer in two ways: on the basis of data handling capabilities and size.

On the basis of data handling capabilities, the computer is of three types:

- Analogue Computer
- Digital Computer
- Hybrid Computer

1) Analogue Computer

Analogue computers are designed to **process analogue data**. Analogue data is continuous data that changes continuously and cannot have discrete values. We can say that analogue computers are used where we don't need exact values always such as speed, temperature, pressure and current.

Analogue computers directly accept the data from the measuring device without first converting it into numbers and codes. They measure the continuous changes in physical quantity and generally render output as a reading on a dial or scale. **Speedometer** and **mercury thermometer** are examples of analogue computers.

Advantages of using analogue computers:

- It allows real-time operations and computation at the same time and continuous representation of all data within the rage of the analogue machine.
- In some applications, it allows performing calculations without taking the help of transducers for converting the inputs or outputs to digital electronic form and vice versa.
- The programmer can scale the problem for the dynamic range of the analogue computer. It provides insight into the problem and helps understand the errors and their effects.

Types of analogue computers:

- **Slide Rules**: It is one of the simplest types of **mechanical analogue computers**. It was developed to perform **basic mathematical calculations**. It is made of two rods. To perform the calculation, the hashed rod is slid to line up with the markings on another rod.
- **Differential Analysers**: It was developed to perform **differential calculations**. It performs integration using wheel-and-disc mechanisms to solve differential calculations.
- **Castle Clock**: It was invented by **Al-Jarazi**. It was able to save programming instructions. Its height was around 11 feet and it was provided with the display of time, the zodiac, and the solar and lunar orbits. This device also could allow users to set the length of the day as per the current season.
- **Electronic Analogue Computer**: In this type of analogue computer, electrical signals flow through capacitors and resistors to simulate physical phenomena. Here, the mechanical interaction of components does not take place. The voltage of the electrical signal generates the appropriate displays.

2) Digital Computer

Digital computer is designed to perform calculations and logical operations at high speed. It accepts the raw data as input in the form of digits or binary numbers (0 and 1) and processes it with programs stored in its memory to produce the output. All modern computers like laptops, desktops including smartphones that we use at home or office are digital computers.

Advantages of digital computers:

- It allows you to store a large amount of information and to retrieve it easily whenever you need it.
- You can easily add new features to digital systems more easily.
- Different applications can be used in digital systems just by changing the program without making any changes in hardware
- The cost of hardware is less due to the advancement in the IC technology.
- It offers high speed as the data is processed digitally.
- It is highly reliable as it uses error correction codes.
- Reproducibility of results is higher as the output is not affected by noise, temperature, humidity, and other properties of its components.

3) Hybrid Computer

Hybrid computer has features of both analogue and digital computer. It is **fast like an analogue** computer and has memory and **accuracy like digital computers**. It can process both continuous and discrete data. It accepts analogue signals and convert them into digital form before processing. So, it is widely used in specialized applications where both analogue and digital data is processed. For example, a processor is used in petrol pumps that converts the measurements of fuel flow into quantity and price. Similarly, they are used in airplanes, hospitals, and scientific applications.

Advantages of using hybrid computers:

- Its computing speed is very high due to the all-parallel configuration of the analogue subsystem.
- It produces precise and quick results that are more accurate and useful.
- It has the ability to solve and manage big equation in real-time.
- It helps in the on-line data processing.

On the basis of size, the computer can be of five types:

1) Supercomputer

Supercomputers are the **biggest and fastest computers**. They are designed to process huge amount of data. A supercomputer can **process trillions of instructions in a second**. It has thousands of interconnected processors.

Supercomputers are particularly used in **scientific and engineering applications** such as weather forecasting, scientific simulations and nuclear energy research. The first supercomputer was developed by **Roger Cray in 1976**.

Characteristics or applications of supercomputers:

- It has the ability to decrypt your password to enhance protection for security reasons.
- It produces excellent results in animations.
- It is used for virtual testing of nuclear weapons and critical medical tests.
- It can study and understand climate patterns and forecast weather conditions. It can run in NOAA's system (National Oceanic and Atmospheric Administration) that can execute any type of simple and logical data.
- It helps in designing the flight simulators for pilots at the beginner level for their training.
- It helps in extracting useful information from data storage centres or cloud system. For example, in insurance companies.
- It has played a vital role in managing the online currency world such as stock market and bitcoin.

- It helps in the diagnosis of various critical diseases and in producing accurate results in brain injuries, strokes, etc.
- It helps in scientific research areas by accurately analysing data obtained from exploring the solar system, satellites, and movement of Earth.
- It also used in a smog control system where it predicts the level of fog and other pollutants in the atmosphere.

2) Mainframe computer

Mainframe computers are designed to support hundreds or thousands of users simultaneously. They can support multiple programs at the same time. It means they can execute different processes simultaneously. These features of mainframe computers make them ideal for big organizations like banking and telecom sectors, which need to manage and process high volume of data.

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Characteristics of Mainframe Computers:

- It can process huge amount of data, e.g. millions of transactions in a second in the banking sector.
- It has a very long life. It can run smoothly for up to 50 years after proper installation.
- It gives excellent performance with large scale memory management.
- It has the ability to share or distribute its workload among other processors and input/output terminals.
- There are fewer chances of error or bugs during processing in mainframe computers. If any error occurs it can fix it quickly without affecting the performance.
- It has the ability to protect the stored data and other ongoing exchange of information and data.

Applications of mainframe computers:

- In **health care,** it enabled hospitals to maintain a record of their millions of patients in order to contact them for treatment or related to their appointment, medicine updates or disease updates.
- In the **field of defence**, it allows the defence departments to share a large amount of sensitive information with other branches of defence.

- In the **field of education**, it helps big universities to store, manage and retrieve data related to their courses, admissions, students, teachers, employees and affiliated schools and colleges.
- In the **retail sector**, the retail companies that have a huge customer base and branches use mainframe computers to handle and execute information related to their inventory management, customer management, and huge transactions in a short duration.

3) Mini Computer

It is a **midsize multiprocessing computer**. It consists of two or more processors and can support **4 to 200 users at one time**. Miniframe computers are used in institutes and departments for tasks such as billing, accounting and inventory management. A minicomputer **lies between the mainframe and microcomputer** as it is smaller than mainframe but larger than a microcomputer.

Characteristics of miniframe or minicomputer:

- It is light weight that makes it easy to carry and fit anywhere.
- It is less expensive than mainframe computers.
- It is very fast compared to its size.
- It remains charged for a long time.
- It does not require a controlled operational environment.

Applications of minicomputers:

A minicomputer is mainly used to perform three primary functions, which are as follows:

- **Process control**: It was used for process control in manufacturing. It mainly performs two primary functions that are collecting data and feedback. If any abnormality occurs in the process, it is detected by the minicomputer and necessary adjustments are made accordingly.
- **Data management**: It is an excellent device for small organizations to collect, store and share data. Local hospitals and hotels can use it to maintain the records of their patients and customers respectively.
- **Communications Portal**: It can also play the role of a communication device in larger systems by serving as a portal between a human operator and a central processor or computer.

4) Workstation

Workstation is a **single user computer** that is designed for **technical or scientific applications**. It has a faster microprocessor, a large amount of RAM and high speed graphic adapters. It

generally **performs a specific job with great expertise**; accordingly, they are of different types such as graphics workstation, music workstation and engineering design workstation.

Characteristics of workstation computer:

- It is a high-performance computer system designed for a single user for business or professional use.
- It has larger storage capacity, better graphics, and more powerful CPU than a personal computer.
- It can handle animation, data analysis, CAD, audio and video creation and editing.

Any computer that has the following **five features**, can be termed as a workstation or can be used as a workstation.

- **Multiple Processor Cores**: It has more processor cores than simple laptops or computers.
- **ECC RAM**: It is provided with Error-correcting code memory that can fix memory errors before they affect the system's performance.
- **RAID (Redundant Array of Independent Disks)**: It refers to multiple internal hard drives to store or process data. RAID can be of different types, for example, there can be multiple drives to process data or mirrored drives where if one drive does not work than other starts functioning.
- **SSD**: It is better than conventional hard-disk drives. It does not have moving parts, so the chances of physical failure are very less.
- **Optimized, Higher end GPU**: It reduces the load on CPU. E.g., CPU has to do less work while processing the screen output.

5) Microcomputer

Microcomputer is also known as a personal computer. It is a general-purpose computer that is designed for individual use. It has a microprocessor as a central processing unit, memory, storage area, input unit and output unit. Laptops and desktop computers are examples of microcomputers. They are suitable for personal work that may be making an assignment, watching a movie, or at office for office work.

Characteristics of a microcomputer:

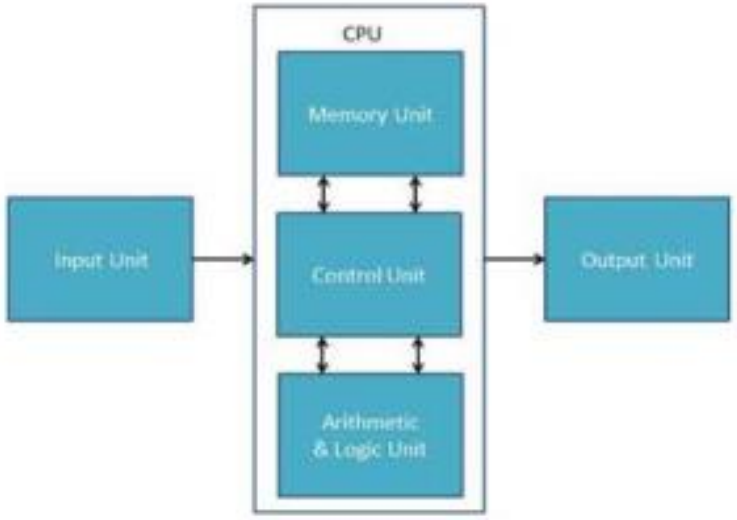
- It is the smallest in size among all types of computers.
- A limited number of software can be used.
- It is designed for personal work and applications. Only one user can work at a time.
- It is less expansive and easy to use.

- It does not require the user to have special skills or training to use it.
- Generally, comes with single semiconductor chip.
- It is capable of multitasking such as printing, scanning, browsing, watching videos, etc.

Basic Structure of Computer

All types of computers follow a same basic logical structure and perform the following five basic operations for converting raw input data into information useful to their users.

Following diagram shows the basic structure of Computer:



Input Unit

This unit contains devices with the help of which we enter data into computer. This unit makes link between user and computer. The input devices translate the information into the form understandable by computer.

CPU (Central Processing Unit)

CPU is considered as the brain of the computer. CPU performs all types of data processing operations. It stores data, intermediate results and instructions(program). It controls the operation of all parts of computer.

CPU itself has following three components

- ALU(Arithmetic Logic Unit)
- Memory Unit
- Control Unit

Output Unit

Output unit consists of devices with the help of which we get the information from computer. This unit is a link between computer and users. Output devices translate the computer's output into the form understandable by users.

Sr.No.	Operation	Description
1	Take Input	The process of entering data and instructions into the computer system
2	Store Data	Saving data and instructions so that they are available for processing as and when required.
3	Processing Data	Performing arithmetic, and logical operations on data in order to convert them into useful information.
4	Output Information	The process of producing useful information or results for the user, such as a printed report or visual display.
5	Control the workflow	Directs the manner and sequence in which all of the above operations are performed.

Input and Output Devices

An input/output device, often known as an IO device, is any hardware that allows a human operator or other systems to interface with a computer. Input/output devices, as the name implies, are capable of delivering data (output) to and receiving data from a computer (input). An input/output (I/O) device is a piece of hardware that can take, output, or process data. It receives data as input and provides it to a computer, as well as sends computer data to storage media as a storage output.

List of Input Devices

Given below is the list of the most common input devices along with brief information about each of them.

1. **Keyboard**

- A simple device comprising keys and each key denotes either an alphabet, number or number commands which can be given to a computer for various actions to be performed
- It has a modified version of typewriter keys
- The keyboard is an essential input device and computer and laptops both use keyboards to give commands to the computer

2. **Mouse**

- It is also known as a pointing device
- Using mouse we can directly click on the various icons present on the system and open up various files and programs
- A mouse comprises 3 buttons on the top and one trackball at the bottom which helps in selecting and moving the mouse around, respectively
- In case of laptops, the touchpad is given as a replacement of the mouse which helps in the movement of the mouse pointer

3. **Joy Stick**

- It is a device which comprises a stick which is attached at an angle to the base so that it can be moved and controlled
- Mostly used to control the movement in video games
- Apart from a computer system, a joystick is also used in the cockpit of an aeroplane, wheelchairs, cranes, trucks, etc. to operate them well

4. **Light Pen**

- It is a wand-like looking device which can directly be moved over the device's screen
- It is light-sensitive
- Used in conjunction with computer's cathode ray tube

5. **Microphone**

- Using a microphone, sound can be stored in a device in its digital form
- It converts sound into an electrical signal
- To record or reproduce a sound created using a microphone, it needs to be connected with an amplifier

6. **Scanner**

- This device can scan images or text and convert it into a digital signal
- When we place any piece of a document on a scanner, it converts it into a digital signal and displays it on the computer screen

7. **Barcode Reader**

- It is a kind of an optical scanner
- It can read bar codes
- A source of light is passed through a bar code, and its aspects and details are displayed on the screen

List of Output Device

The commonly used output devices have been listed below with a brief summary of what their function is and how they can be used.

1. **Monitor**

- The device which displays all the icons, text, images, etc. over a screen is called the Monitor
- When we ask the computer to perform an action, the result of that action is displayed on the monitor
- Various types of monitors have also been developed over the years

2. **Printer**

- A device which makes a copy of the pictorial or textual content, usually over a paper is called a printer
- For example, an author types the entire book on his/her computer and later gets a print out of it, which is in the form of paper and is later published
- Multiple types of printers are also available in the market, which can serve different purposes

3. **Speakers**

- A device through which we can listen to a sound as an outcome of what we command a computer to do is called a speaker
- Speakers are attached with a computer system and also are a hardware device which can be attached separately
- With the advancement in technology, speakers are now available which are wireless and can be connected using BlueTooth or other applications

4. **Projector**

- An optical device which presents an image or moving images onto a projection screen is called a projector
- Most commonly these projectors are used in auditoriums and movie theatres for the display of the videos or lighting
- If a projector is connected to a computer, then the image/video displayed on the screen is the same as the one displayed on the computer screen

5. **Headphones**

- They perform the same function as a speaker, the only difference is the frequency of sound

- Using speakers, the sound can be heard over a larger area and using headphones, the sound is only audible to the person using them
- Also known as earphones or headset

Computer Memory

Computer memory is just like the human brain. It is used to store data/information and instructions. It is a data storage unit or a data storage device where data is to be processed and instructions required for processing are stored.

Types of Computer Memory

In general, computer memory is of three types:

- Primary memory
- Secondary memory
- Cache memory

Now we discuss each type of memory one by one in detail:

1. Primary Memory

It is also known as the main memory of the computer system. It is used to store data and programs or instructions during computer operations. It uses semiconductor technology and hence is commonly called semiconductor memory. Primary memory is of two types:

- **RAM (Random Access Memory):** It is a volatile memory. Volatile memory stores information based on the power supply. If the power supply fails/ interrupted/stopped, all the data and information on this memory will be lost. RAM is used for booting up or start the computer. It temporarily stores programs/data which has to be executed by the processor. RAM is of two types:
    - **S RAM (Static RAM):** S RAM uses transistors and the circuits of this memory are capable of retaining their state as long as the power is applied. This memory consists of the number of flip flops with each flip flop storing 1 bit. It has less access time and hence, it is faster.
    - **D RAM (Dynamic RAM):** D RAM uses capacitors and transistors and stores the data as a charge on the capacitors. They contain thousands of memory cells. It needs refreshing of charge on capacitor after a few milliseconds. This memory is slower than S RAM.
- **ROM (Read Only Memory):** It is a non-volatile memory. Non-volatile memory stores information even when there is a power supply failed/ interrupted/stopped. ROM is used to store information that is used to operate the system. As its name refers to read-only memory, we can only read the programs and data that is stored on it. It contains some electronic fuses that can be programmed for a piece of specific information. The information stored in the ROM in binary format. It is also known as permanent memory. ROM is of four types:
    - **MROM(Masked ROM):** Hard-wired devices with a pre-programmed collection of data or instructions were the first ROMs. Masked ROMs are a type of low-cost ROM that works in this way.
    - **PROM (Programmable Read Only Memory):** This read-only memory is modifiable once by the user. The user purchases a blank PROM and uses a PROM program to put the required contents into the PROM. Its content can’t be erased once written.
    - **EPROM (Erasable Programmable Read Only Memory):** EPROM is an extension to PROM where you can erase the content of ROM by exposing it to Ultraviolet rays for nearly 40 minutes.

- **EEPROM (Electrically Erasable Programmable Read Only Memory):** Here the written contents can be erased electrically. You can delete and reprogramme EEPROM up to 10,000 times. Erasing and programming take very little time, i.e., nearly 4 -10 ms(milliseconds). Any area in an EEPROM can be wiped and programmed selectively.

2. Secondary Memory

It is also known as auxiliary memory and backup memory. It is a non-volatile memory and used to store a large amount of data or information. The data or information stored in secondary memory is permanent, and it is slower than primary memory. A CPU cannot access secondary memory directly. The data/information from the auxiliary memory is first transferred to the main memory, and then the CPU can access it.

Characteristics of Secondary Memory

- It is a slow memory but reusable.
- It is a reliable and non-volatile memory.
- It is cheaper than primary memory.
- The storage capacity of secondary memory is large.
- A computer system can run without secondary memory.
- In secondary memory, data is stored permanently even when the power is off.

Types of Secondary Memory

1. Magnetic Tapes: Magnetic tape is a long, narrow strip of plastic film with a thin, magnetic coating on it that is used for magnetic recording. Bits are recorded on tape as magnetic patches called RECORDS that run along many tracks. Typically, 7 or 9 bits are recorded concurrently. Each track has one read/write head, which allows data to be recorded and read as a sequence of characters. It can be stopped, started moving forward or backward, or rewound.

2. Magnetic Disks: A magnetic disk is a circular metal or a plastic plate and these plates are coated with magnetic material. The disc is used on both sides. Bits are stored in magnetized surfaces in locations called tracks that run in concentric rings. Sectors are typically used to break tracks into pieces.

3. Optical Disks: It's a laser-based storage medium that can be written to and read. It is reasonably priced and has a long lifespan. The optical disc can be taken out of the computer by occasional users.

Types of Optical Disks

CD – ROM

- It's called compact disk. Only read from memory.
- Information is written to the disc by using a controlled laser beam to burn pits on the disc surface.
- It has a highly reflecting surface, which is usually aluminium.
- The diameter of the disc is 5.25 inches.
- 16000 tracks per inch is the track density.
- The capacity of a CD-ROM is 600 MB, with each sector storing 2048 bytes of data.
- The data transfer rate is about 4800KB/sec. & the new access time is around 80 milliseconds.

WORM-(WRITE ONCE READ MANY)

- A user can only write data once.
- The information is written on the disc using a laser beam.
- It is possible to read the written data as many times as desired.
- They keep lasting records of information but access time is high.
- It is possible to rewrite updated or new data to another part of the disc.
- Data that has already been written cannot be changed.
- Usual size – 5.25 inch or 3.5 inch diameter.
- The usual capacity of 5.25 inch disk is 650 MB,5.2GB etc.

DVDs

- The term "DVD" stands for "Digital Versatile/Video Disc," and there are two sorts of DVDs:
    - DVDR (writable)
    - DVDRW (Re-Writable)

- **DVD-ROMS (Digital Versatile Discs)**: These are read-only memory (ROM) discs that can be used in a variety of ways. When compared to CD-ROMs, they can store a lot more data. It has a thick polycarbonate plastic layer that serves as a foundation for the other layers. It's an optical memory that can read and write data.
- **DVD-R**: DVD-R is a writable optical disc that can be used just once. It's a DVD that can be recorded. It's a lot like WORM. DVD-ROMs have capacities ranging from 4.7 to 17 GB. The capacity of 3.5 inch disk is 1.3 GB.

3. Cache Memory

It is a type of high-speed semiconductor memory that can help the CPU run faster. Between the CPU and the main memory, it serves as a buffer. It is used to store the data and programs that the CPU uses the most frequently.

Advantages of Cache Memory

- It is faster than the main memory.
- When compared to the main memory, it takes less time to access it.
- It keeps the programs that can be run in a short amount of time.
- It stores data in temporary use.

Disadvantages of Cache Memory

- Because of the semiconductors used, it is very expensive.
- The size of the cache (amount of data it can store) is usually small.

Number System

The technique to represent and work with numbers is called **number system**. **Decimal number system** is the most common number system. Other popular number systems include **binary number system, octal number system, hexadecimal number system,** etc.

Decimal Number System

Decimal number system is a **base 10** number system having 10 digits from 0 to 9. This means that any numerical quantity can be represented using these 10 digits. Decimal number system is also a **positional value system**. This means that the value of digits will depend on its position. Let us take an example to understand this.

Say we have three numbers – 734, 971 and 207. The value of 7 in all three numbers is different−

- In 734, value of 7 is 7 hundreds or 700 or 7×100 or 7×10^2
- In 971, value of 7 is 7 tens or 70 or 7×10 or 7×10^1
- In 207, value 0f 7 is 7 units or 7 or 7×1 or 7×10^0

The weightage of each position can be represented as follows −

10^5	10^4	10^3	10^2	10^1	10^0

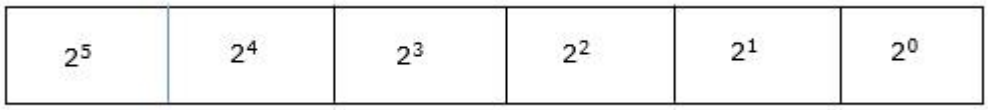
In digital systems, instructions are given through electric signals; variation is done by varying the voltage of the signal. Having 10 different voltages to implement decimal number system in digital equipment is

difficult. So, many number systems that are easier to implement digitally have been developed. Let's look at them in detail.

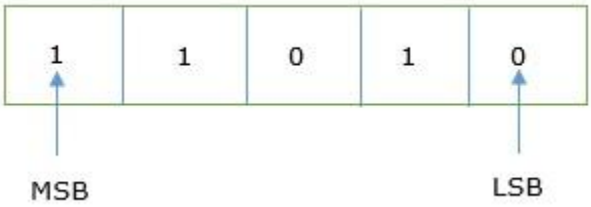
Binary Number System

The easiest way to vary instructions through electric signals is two-state system – on and off. On is represented as 1 and off as 0, though 0 is not actually no signal but signal at a lower voltage. The number system having just these two digits – 0 and 1 – is called **binary number system**.

Each binary digit is also called a **bit**. Binary number system is also positional value system, where each digit has a value expressed in powers of 2, as displayed here.



In any binary number, the rightmost digit is called **least significant bit (LSB)** and leftmost digit is called **most significant bit (MSB)**.



And decimal equivalent of this number is sum of product of each digit with its positional value.

$11010_2 = 1\times2^4 + 1\times2^3 + 0\times2^2 + 1\times2^1 + 0\times2^0$

$= 16 + 8 + 0 + 2 + 0$

$= 26_{10}$

Computer memory is measured in terms of how many bits it can store. Here is a chart for memory capacity conversion.

- 1 byte (B) = 8 bits
- 1 Kilobytes (KB) = 1024 bytes
- 1 Megabyte (MB) = 1024 KB
- 1 Gigabyte (GB) = 1024 MB
- 1 Terabyte (TB) = 1024 GB
- 1 Exabyte (EB) = 1024 PB
- 1 Zettabyte = 1024 EB
- 1 Yottabyte (YB) = 1024 ZB

Octal Number System

Octal number system has eight digits – 0, 1, 2, 3, 4, 5, 6 and 7. Octal number system is also a positional value system with where each digit has its value expressed in powers of 8, as shown here −

Decimal equivalent of any octal number is sum of product of each digit with its positional value.

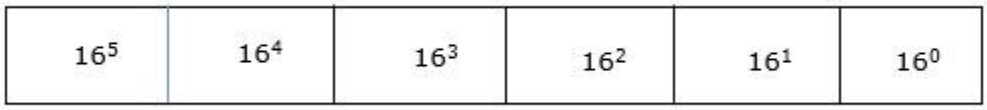
$726_8 = 7\times8^2 + 2\times8^1 + 6\times8^0$

$= 448 + 16 + 6$

$= 470_{10}$

Hexadecimal Number System

Octal number system has 16 symbols – 0 to 9 and A to F where A is equal to 10, B is equal to 11 and so on till F. Hexadecimal number system is also a positional value system with where each digit has its value expressed in powers of 16, as shown here −



Decimal equivalent of any hexadecimal number is sum of product of each digit with its positional value.

$27FB_{16} = 2\times16^3 + 7\times16^2 + 15\times16^1 + 10\times16^0$

$= 8192 + 1792 + 240 + 10$

$= 10234_{10}$

Number System Relationship

The following table depicts the relationship between decimal, binary, octal and hexadecimal number systems.

HEXADECIMAL	DECIMAL	OCTAL	BINARY
0	0	0	0000
1	1	1	0001

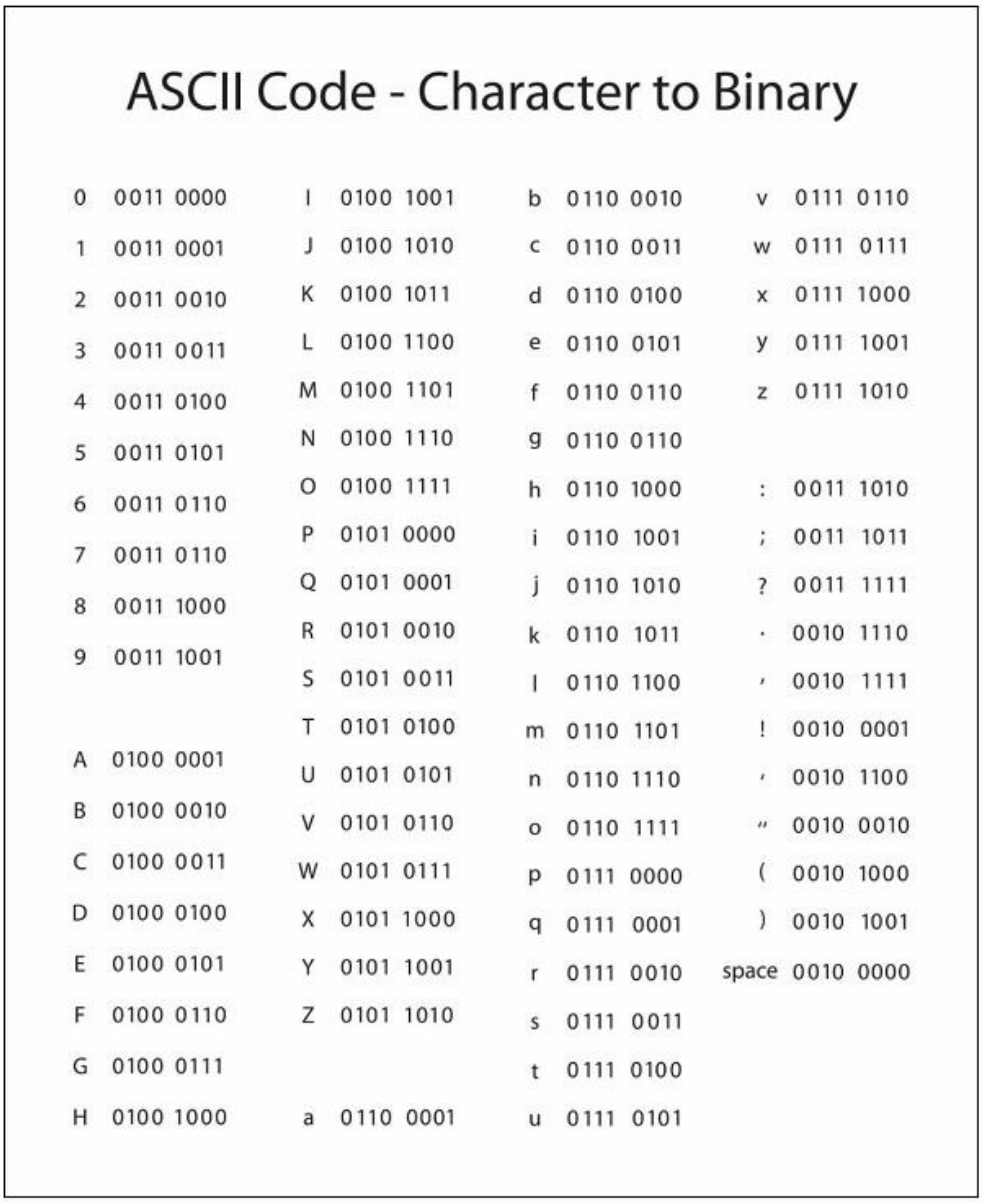
2	2	2	0010
3	3	3	0011
4	4	4	0100
5	5	5	0101
6	6	6	0110
7	7	7	0111
8	8	10	1000
9	9	11	1001
A	10	12	1010
B	11	13	1011
C	12	14	1100
D	13	15	1101
E	14	16	1110
F	15	17	1111

ASCII

Besides numerical data, computer must be able to handle alphabets, punctuation marks, mathematical operators, special symbols, etc. that form the complete character set of English language. The complete set of characters or symbols are called alphanumeric codes. The complete alphanumeric code typically includes −

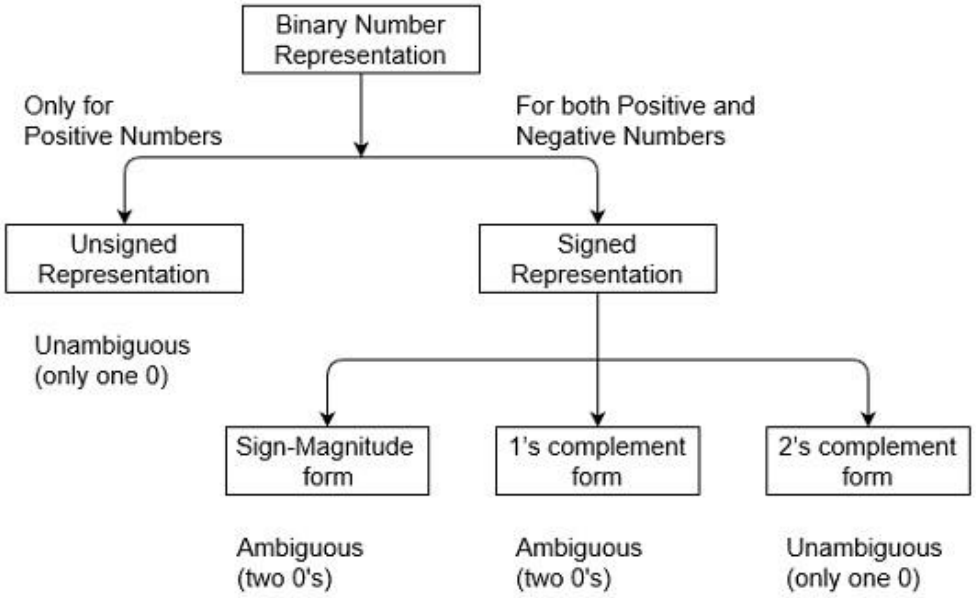
- 26 upper case letters
- 26 lower case letters
- 10 digits
- 7 punctuation marks
- 20 to 40 special characters

Now a computer understands only numeric values, whatever the number system used. So all characters must have a numeric equivalent called the alphanumeric code. The most widely used alphanumeric code is American Standard Code for Information Interchange (ASCII). ASCII is a 7-bit code that has 128 (27) possible codes.



Unsigned and Signed Binary Numbers

Binary numbers can be represented in signed and unsigned way. Unsigned binary numbers do not have sign bit, whereas signed binary numbers uses signed bit as well or these can be distinguishable between positive and negative numbers. A signed binary is a specific data type of a signed variable.



1. Unsigned Numbers:

Unsigned numbers don't have any sign, these can contain only magnitude of the number. So, representation of unsigned binary numbers are all positive numbers only. For example, representation of positive decimal numbers are positive by default. We always assume that there is a positive sign symbol in front of every number.

Representation of Unsigned Binary Numbers:

Since there is no sign bit in this unsigned binary number, so N bit binary number represent its magnitude only. Zero (0) is also unsigned number. This representation has only one zero (0), which is always positive. Every number in unsigned number representation has only one unique binary equivalent form, so this is unambiguous representation technique. The range of unsigned binary number is from 0 to (2^n-1).

Example-1: Represent decimal number 92 in unsigned binary number.

Simply convert it into Binary number, it contains only magnitude of the given number.
$= (92)_{10}$

$= (1x2^6+0x2^5+1x2^4+1x2^3+1x2^2+0x2^1+0x2^0)_{10}$

$= (1011100)_2$

It's 7 bit binary magnitude of the decimal number 92.

Example-2: Find range of 5 bit unsigned binary numbers. Also, find minimum and maximum value in this range.

Since, range of unsigned binary number is from 0 to (2^n-1). Therefore, range of 5 bit unsigned binary number is from 0 to (2^5-1) which is equal from minimum value 0 (i.e., 00000) to maximum value 31 (i.e., 11111).

2. Signed Numbers:

Signed numbers contain sign flag, this representation distinguish positive and negative numbers. This technique contains both sign bit and magnitude of a number. For example, in representation of negative decimal numbers, we need to put negative symbol in front of given decimal number.

Representation of Signed Binary Numbers:

There are three types of representations for signed binary numbers. Because of extra signed bit, binary number zero has two representation, either positive (0) or negative (1), so ambiguous representation. But 2's complementation representation is unambiguous representation because of there is no double representation of number 0. These are: Sign-Magnitude form, 1's complement form, and 2's complement form which are explained as following below.

2.(a) Sign-Magnitude form:

For n bit binary number, 1 bit is reserved for sign symbol. If the value of sign bit is 0, then the given number will be positive, else if the value of sign bit is 1, then the given number will be negative. Remaining (n-1) bits represent magnitude of the number. Since magnitude of number zero (0) is always 0, so there can be two representation of number zero (0), positive (+0) and negative (-0), which depends on value of sign bit. Hence these representations are ambiguous generally because of two representation of number zero (0). Generally sign bit is a most significant bit (MSB) of representation. The range of Sign-Magnitude form is from $(2^{(n-1)}-1)$ to $(2^{(n-1)}-1)$.

For example, range of 6 bit Sign-Magnitude form binary number is from $(2^5\text{-}1)$ to $(2^5\text{-}1)$ which is equal from minimum value -31 (i.e., 1 11111) to maximum value +31 (i.e., 0 11111). And zero (0) has two representation, -0 (i.e., 1 00000) and +0 (i.e., 0 00000).

2.(b) 1's complement form:

Since, 1's complement of a number is obtained by inverting each bit of given number. So, we represent positive numbers in binary form and negative numbers in 1's complement form. There is extra bit for sign representation. If value of sign bit is 0, then number is positive and you can directly represent it in simple binary form, but if value of sign bit 1, then number is negative and you have to take 1's complement of given binary number. You can get negative number by 1's complement of a positive number and positive number by using 1's complement of a negative number. Therefore, in this representation, zero (0) can have two representation, that's why 1's complement form is also ambiguous form. The range of 1's complement form is from $(2^{(n-1)}\text{-}1)$ to $(2^{(n-1)}\text{-}1)$.

For example, range of 6 bit 1's complement form binary number is from $(2^5\text{-}1)$ to $(2^5\text{-}1)$ which is equal from minimum value -31 (i.e., 1 00000) to maximum value +31 (i.e., 0 11111). And zero (0) has two representation, -0 (i.e., 1 11111) and +0 (i.e., 0 00000).

2.(c) 2's complement form:

Since, 2's complement of a number is obtained by inverting each bit of given number plus 1 to least significant bit (LSB). So, we represent positive numbers in binary form and negative numbers in 2's complement form. There is extra bit for sign representation. If value of sign bit is 0, then number is positive and you can directly represent it in simple binary form, but if value of sign bit 1, then number is negative and you have to take 2's complement of given binary number. You can get negative number by 2's complement of a positive number and positive number by directly using simple binary representation. If value of most significant bit (MSB) is 1, then take 2's complement from, else not. Therefore, in this representation, zero (0) has only one (unique) representation which is always positive. The range of 2's complement form is from $(2^{(n-1)})$ to $(2^{(n-1)}\text{-}1)$.

For example, range of 6 bit 2's complement form binary number is from (2^5) to $(2^5\text{-}1)$ which is equal from minimum value -32 (i.e., 1 00000) to maximum value +31 (i.e., 0 11111). And zero (0) has two representation, -0 (i.e., 1 11111) and +0 (i.e., 0 00000).

Translators

A program written in high-level language is called as source code. To convert the source code into machine code, translators are needed.

A translator takes a program written in source language as input and converts it into a program in target language as output.

It also detects and reports the error during translation.

Roles of translator are:

• Translating the high-level language program input into an equivalent machine language program.

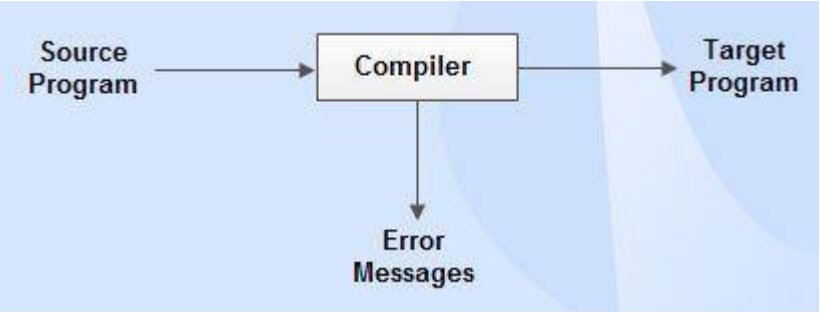
• Providing diagnostic messages wherever the programmer violates specification of the high-level language program.

Different type of translators

The different types of translator are as follows:

Compiler

Compiler is a translator which is used to convert programs in high-level language to low-level language. It translates the entire program and also reports the errors in source program encountered during the translation.

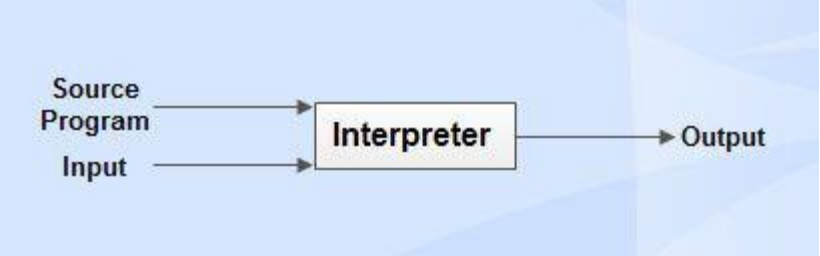


Interpreter

Interpreter is a translator which is used to convert programs in high-level language to low-level language. Interpreter translates line by line and reports the error once it encountered during the translation process.

It directly executes the operations specified in the source program when the input is given by the user.

It gives better error diagnostics than a compiler.



Differences between compiler and interpreter

SI. No	Compiler	Interpreter
1	Performs the translation of a program as a whole.	Performs statement by statement translation.
2	Execution is faster.	Execution is slower.
3	Requires more memory as linking is needed for the generated intermediate object code.	Memory usage is efficient as no intermediate object code is generated.
4	Debugging is hard as the error messages are generated after scanning the entire program only.	It stops translation when the first error is met. Hence, debugging is easy.
5	Programming languages like C, C++ uses compilers.	Programming languages like Python, BASIC, and Ruby uses interpreters.

Assembler

Assembler is a translator which is used to translate the assembly language code into machine language code.

Problem Solving

Today, we use computers in every field for various purposes. But, we know that they cannot solve the problems all by themselves. Furthermore, we have to give step by step instructions to the computer for solving the problem. We can define problem-solving as a process of understanding the problem, finding solutions for the problem, and finally implementing the solution to it. We can design the solution before coding in the form of algorithms and flowcharts. Moreover, the identification of arithmetic and logical operations is very important in developing the program.

Therefore, we can say that a successful problem-solving process depends on the following factors:

- understanding the problem and defining it precisely.
- designing proper algorithms and flowcharts of the solution.
- implementing the algorithm successfully.

When the problems are easy we can easily search out a solution. Whereas, complex problems require step by step process to solve. Hence, this means that we have to apply problem-solving techniques to solve the problem. Furthermore, this starts with finding a precise definition of the problem and ends with a successful solution. Moreover, the identification of arithmetic and logical operations plays a vital role while designing the algorithm. Here, we will study the algorithms and flowcharts.

Designing the solution

After understanding the relationship between input and output and the functionalities required we have to design an algorithm or flowchart. Furthermore, the algorithm should contain all the necessary functions to solve the problem. Moreover, it should produce a proper output for every input.

Hence, we can say that before writing the exact code for the problem it is necessary to define a solution. We can do this by starting with an initial plan and improvising it till it gives perfect results. Moreover, there can be more than one possible solution for a problem. Therefore, it is the responsibility of the programmer to choose the best solution.

While designing a problem we can represent it in algorithms and flowcharts. Hence, before writing the program code we can design the solution either in the form of an algorithm or a flowchart.

Algorithm in C language

An algorithm is a sequence of instructions that are carried out in a predetermined sequence in order to solve a problem or complete a work. A function is a block of code that can be called and executed from other parts of the program.

A set of instructions for resolving an issue or carrying out a certain activity. In computer science, algorithms are used for a wide range of operations, from fundamental math to intricate data processing.

Features of the algorithm

It defines several important features of the algorithm, including:

- **Inputs**: Algorithms must receive inputs that can be represented as values or data.
- **Output**: The algorithm should produce some output. It can be a consequence of a problem or a solution designed to solve it.
- **Clarity**: Algorithms must be precisely defined, using unambiguous instructions that a computer or other system can follow unambiguously.
- **Finiteness**: The algorithm requires a limited steps. It means that it should be exited after executing a certain number of commands.
- **Validity**: The algorithm must be valid. In other words, it should be able to produce a solution to the problem that the algorithm is designed to solve in a reasonable amount of time.
- **Effectiveness:** An algorithm must be effective, meaning that it must be able to produce a solution to the problem it is designed to solve in a reasonable amount of time.
- **Generality:** An algorithm must be general, meaning that it can be applied to a wide range of problems rather than being specific to a single problem.

Algorithm Analysis

Algorithmic analysis is the process of evaluating algorithm performance in terms of efficiency, complexity and other criteria.Typically, this is done to evaluate many algorithms and select the optimal solution for a certain issue or a software.

Analysis of algorithms usually involves measuring their time and space complexity.

As with space complexity, which describes the amount of memory or disk space needed, time complexity describes how long an algorithm determines to perform a task.

There are different ways to analyze the time complexity of algorithms, such as Big O and Omega notation. The Omega symbol provides an upper bound for the algorithm's time complexity, while the Omega symbol provides a lower bound.

In addition to measuring time and space complexity, algorithm analysis also includes other criteria such as stability, parallelism, and scalability.

1. **Stability**:- This refers to the ability of the algorithm to maintain the relative order of the elements in the data set.
2. **Parallelization**:- This is referring to the capacity to execute operations in parallel across several processors.
3. **Scalability**:- On the other hand, it refers to the ability of an algorithm to handle large volumes of data and other inputs.

How to write an algorithm

1. First define the problem you want the algorithm to solve.

For example, suppose we want to write an algorithm to find the maximum value from a list of numbers.

2. Break the problem down into smaller, manageable steps.

- Initialize the 'max' variable to the first value in the list.
- For each subsequent value in the list, compare with "max".
- If the value is greater than "max", set "max" to that value.
- Continue doing this until every value in the list has been compared.
- Returns the final "max" value.

3. Write your algorithm in pseudocode or a programming language.

Algorithm written in pseudo code:

```
1. MAX (list)
2.     max = list[0]
3.     For i = 1 the length of the list
```

4. list IF[i] > max
5. max = list[i]
6. End **for**
7. Maximum **return**
8. Maximum end

4. Test your algorithm to make sure it is correct and efficient.

You can test the algorithm by entering different lists of numbers and verifying that it returns the maximum correct value. You can also analyze the time complexity of your algorithm to determine how well it scales for larger inputs.

Example:-

Input: [1, 5, 2, 7, 3]

Output: 7.

Explanation: 7 is the maximum value in the list.

5. Optimize the algorithm.

Look for ways to optimize algorithms for making them faster and more efficient. This may involve modifying pseudocode or implementing more efficient data structures or algorithms.

Basic writing of algorithms

Example: - The sum of two integers.

Step 1 - Get started

Step 2 - Declare three integers a, b, c

Step 3 - Define the values of a and b

Step 4 - Add the values of a and b

Step 5 - Save the output of step 4 in c

Step 6 - Print c

Step 7 - Stop

Flowcharts

It is basically a diagrammatic representation of an algorithm. Furthermore, it uses various symbols and arrows to describe the beginning, ending, and flow of the program. Moreover, the programmers use it to depicting the flow of data and instructions while problem-solving. **Flowcharting** is the process of drawing a flowchart for an algorithm.

Symbols in a flowchart

The flowchart uses various symbols in the representation. These basic symbols are as follows:

Terminal Box - Start / End	
Input / Output	
Process / Instruction	
Decision	
Connector / Arrow	

Rules For Creating Flowchart :

A flowchart is a graphical representation of an algorithm.it should follow some rules while creating a flowchart

Rule 1: Flowchart opening statement must be ‘start’ keyword.
Rule 2: Flowchart ending statement must be ‘end’ keyword.
Rule 3: All symbols in the flowchart must be connected with an arrow line.
Rule 4: The decision symbol in the flowchart is associated with the arrow line.

Advantages of Flowchart:

- Flowcharts are a better way of communicating the logic of the system.
- Flowcharts act as a guide for blueprint during program designed.

- Flowcharts help in debugging process.
- With the help of flowcharts programs can be easily analyzed.
- It provides better documentation.
- Flowcharts serve as a good proper documentation.
- Easy to trace errors in the software.
- Easy to understand.
- The flowchart can be reused for inconvenience in the future.
- It helps to provide correct logic.

Disadvantages of Flowchart:

- It is difficult to draw flowcharts for large and complex programs.
- There is no standard to determine the amount of detail.
- Difficult to reproduce the flowcharts.
- It is very difficult to modify the Flowchart.
- Making a flowchart is costly.
- Some developer thinks that it is waste of time.
- It makes software processes low.
- If changes are done in software, then the flowchart must be redrawn

Example : Draw a flowchart to input two numbers from the user and display the largest of two numbers