INTRODUCTION TO COMPUTER SYSTEMS

Introduction

A system is a collection of interconnected or interrelated elements, components, or parts that work together to achieve a common objective or goal. These elements interact and function as a unified whole, with each part contributing to the overall behavior and functionality of the system. Systems can be found in various domains, including engineering, biology, computer science, social sciences, and more. In computing, there many systems such as management information system, computer system decision support system etc. the above-mentioned systems are made up of components that are working together to solve human computation needs.

Computers referred to as system because they are made up of many interconnected component or element working together for the purpose aiding humans in performing their data processing tasks.

To accurately define computer system, it is important to state explicitly that they are made up of different electronic component working together as a unit. Thus, Computer system is a collection of interconnected electronic components that accepts data as input, processes the inputted data by performing mathematical and logical operations on it, and gives the desired output. A computer system is made up of the following:

## CLASSIFICATION OF COMPUTER

Computers are classified based on the following criteria:

1. Classification of computer by types
2. Classification of computer by purpose
3. Classification of computer by size

Classification Of Computer By Types

- A digital computer uses distinct values to represent the data internally. All information are represented using the digits Os and 1s. Represent its variable in the form of digits. It counts the data it deals with, whether representing numbers, letters or other symbols, are converted into binary form on input to the computer. The data undergoes a processing after which the binary digits are converted back to alpha numeric form for output for human use. Because of the fact that business applications like inventory control, invoicing and payroll deal with discrete values they are best processed with digital computers. As a result of this, digital computers are mostly used in commercial and business places today. The computers that we

use at our homes and offices are digital computers also wrist watches & calculators.

- Analog computer is another kind of a computer that represents data as variable across a continuous range of values. The earliest computers were analog computers. Analog computers are used for measuring of parameters that vary continuously in real time, such as temperature, pressure and voltage. Analog computers may be more flexible but generally less precise than digital computers. Slide rule is an example of an analog computer. They computers that transfer data by continuous changes in physical quantities. Analog Computer measures rather than counts, thus they are taking to measuring instruments such as Thermometer, fuel gauges, blood pressure measuring machines, traffic light, wrist watches, and speedometer.

- Hybrid: As their name suggests, are computer that have the combined features of digital and analog computers. In some cases, the user may wish to obtain the output from an analog computer as processed by a digital computer or vice versa. To achieve this, he set up a hybrid machine where the two are connected and the analog computer may be regarded as a peripheral of the digital computer. In such a situation, a hybrid system attempts to gain the advantage of both the digital and the analog elements in the same machine. This kind of machine is usually a special-purpose device which is built for a specific task. It needs a conversion element which accepts analog inputs, and output digital value. Such converters are called digitizers. There is need for a converter from analog to digital also. It has the advantage of giving real-time response on a continuous basis. Complex calculations can be dealt with by the digital elements, thereby requiring a large memory, and giving accurate results after programming. They are mainly used in aerospace and process control applications e.g. GSM phone, modems, fax machines.

### Classification by Purpose

*A special purpose computer*: A special purpose computer is one that is designed to solve a restricted class of problems. Such computers may even be designed and built to handle only one job. In such machines, the steps or operations that the computer follows may be built into the hardware. Most of the computers used for military purposes fall into this class. Other example of special purpose computers include:

- Computers designed specifically to solve navigational problems.
- Computers designed for tracking airplane or missiles.
- Computers used for process control applications in industries such as oil refinery,

chemical manufacture, steel processing and power generation.

- Computers used as robots in factories like vehicles assembly plants and glass industries

Thus Special purpose computers: as their name suggests, are designed for a particular job only; to solve problems of a restricted nature. Examples are computers designed for use in digital watches, in petrol pumps or in weapons guidance systems.

A General-Purpose Computers: General-Purpose computers are computers designed to handle wide range of problems. Theoretically, a general-purpose computer can be adequate by means of some easily alterable instructions to handle any problems that can be solved by computation. In practice however, there are limitations imposed by memory size, speed and the type of input/output devices. Examples of areas where the general purpose are employed include the following:

- Payroll
- Banking
- Billing
- Sales analysis
- Cost accounting
- Manufacturing scheduling
- Inventory control

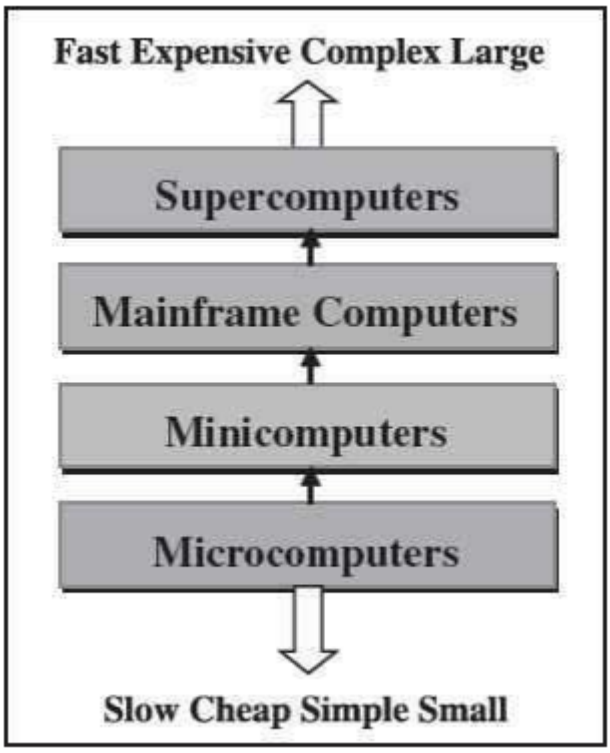
Thus General purpose computers: are designed to solve a wide variety of problems. Within the limitations imposed by their particular design capabilities, they can be adapted to perform particular tasks or solve problems by means of specially written programs. The distinction is not as sharp as it first appears because a general purpose computer can temporarily become special purpose through adaptation. A word processor is a special purpose computer used in the production of office documents, letters, contracts, etc. a general purpose computer can run a word processing program and hence temporarily become special purpose.

## Classification by Size

The computers are broadly classified into four categories (Figure 1.8) based on their size

1. Microcomputers,

2. Minicomputers,
3. Mainframe computers, and
4. Supercomputer.




## Microcomputers

Microcomputers are small, low-cost and single-user digital computer. They consist of CPU, input unit, output unit, storage unit and the software. Although microcomputers are stand-alone machines, they can be connected together to create a network of computers that can serve more than one user. IBM PC based on Pentium microprocessor and Apple Macintosh are some examples of microcomputers. Microcomputers include desktop computers, notebook computers or laptop, tablet computer, handheld computer, smart phones and netbook, as shown in Figure 1.9.


- Desktop Computer or Personal Computer (PC) is the most common type of microcomputer. It is a stand-alone machine that can be placed on the desk. Externally, it consists of three units keyboard, monitor, and a system unit containing the CPU, memory, hard disk drive, etc. It is not very expensive and is suited to the needs of a single user at home, small business units, and organizations. Apple, Microsoft, HP, Dell and Lenovo are some of the PC manufacturers.
- Notebook Computers or Laptop resemble a notebook. They are portable and have allthe features of a desktop computer. The advantage of the laptop is that it is small in size (can be put inside a briefcase), can be carried anywhere, has a battery backup and has all the functionality of the desktop. Laptops can be placed on the lap while working (hence the name).

Laptops are costlier than the desktop machines.

- Netbook These are smaller notebooks optimized for low weight and low cost, and are designed for accessing web-based applications. Starting with the earliest netbook in late 2007, they have gained significant popularity now. Netbooks deliver the performance needed to enjoy popular activities like streaming videos or music, emailing, Websurfing or instant messaging. The word netbook was created as a blend of Internet and notebook.
- Tablet Computer has features of the notebook computer but it can accept input froma stylus or a pen instead of the keyboard or mouse. It is a portable computer. Tablet computer are the new kind of PCs.
- Handheld Computer or Personal Digital Assistant (PDA) is a small computer that can be held on the top of the palm. It is small in size. Instead of the keyboard, PDA uses a pen or a stylus for input. PDAs do not have a disk drive. They have a limited memory and are less powerful. PDAs can be connected to the Internet via a wireless connection. Casio and Apple are some of the manufacturers of PDA. Over the last few years, PDAs have merged into mobile phones to create smart phones.
- Smart Phones are cellular phones that function both as a phone and as a small PC. They may use a stylus or a pen, or may have a small keyboard. They can be connected to the Internet wirelessly. They are used to access the electronic-mail, download music, play games, etc. Blackberry, Apple, HTC, Nokia and LG are some of the manufacturers of smart phones.

### Minicomputers

Minicomputers are digital computers, generally used in multi-user systems. They have high processing speed and high storage capacity than the microcomputers. Minicomputers can support 4–200 users simultaneously. The users can access the minicomputer through their PCs or terminal. They are used for real-time applications in industries, research centers, etc. PDP 11, IBM (8000 series) are some of the widely used minicomputers

## Mainframe Computers

Mainframe computers are multi-user, multi-programming and high performance computers. They operate at a very high speed, have very large storage capacity and can handle the workload of many users. Mainframe computers are large and powerful systems generally used in centralized databases. The user accesses the mainframe computer via a terminal that may be a dumb terminal, an intelligent terminal or a PC. A dumb terminal cannot store data or do processing of its own. It has the input and output device only. An intelligent terminal has the input and output device, can do processing, but cannot store data of its own. The dumb and the intelligent terminal use the processing power and the storage facility of the mainframe computer. Mainframe computers are used in organizations like banks or companies, where many people require frequent access to the same data. Some examples of mainframes are CDC 6600 and IBM ES000 series.

## Supercomputers

Supercomputers are the fastest and the most expensive machines. They have high processing speed compared to other computers. The speed of a supercomputer is generally measured in FLOPS (FLoating point Operations Per Second). Some of the faster supercomputers can perform trillions of calculations per second. Supercomputers are built by interconnecting thousands of processors that can work in parallel.

Supercomputers are used for highly calculation-intensive tasks, such as, weather forecasting, climate research (global warming), molecular research, biological research, nuclear research and aircraft design. They are also used in major universities, military agencies and scientific research laboratories. Some examples of supercomputers are IBM Roadrunner, IBM Blue gene and Intel ASCI red. PARAM is a series of supercomputer assembled in India by C-DAC (Center for Development of Advanced Computing), in Pune. PARAM Padma is the latest machine in this series. The peak computing power of PARAM Padma is 1 Tera FLOP (TFLOP).

## COMPONENT OF COMPUTER

A computer system consists of several essential components that collaborate harmoniously to execute tasks. These components can be broadly categorized into hardware and software

### Computer Hardware

Computer hardware are the parts of computer that you can see and touch. These are the tangible components that are likely fitted together inside your computer case and installed with a screwdriver. The computer hardware can be divided into four unit. They are Input/Output unit, processing unit (system unit) and storage unit and motherboard.

- **Input/Output(I/O) Unit**

  User interacts with the computer via the I/O unit. The Input unit accepts data from the user and the Output unit provides the processed data i.e. the information to the user. The Input unit converts the data that it accepts from the user, into a form that is understandable by the computer. Similarly, the Output unit provides the output in a form that is understandable by the user

  *Classification of input device with their Examples*

  1. Text Input Devices:
     - Keyboard: Allows users to input alphanumeric characters, numbers, symbols, and commands.
     - Keypad: Numeric keypads or numpads, often found on keyboards, calculators, and certain peripherals.
     - Touchscreen Keyboard: Virtual keyboards on touch-enabled devices, like smartphones and tablets.
  2. Pointing Input Devices:
     - Mouse: Moved across a surface to control the cursor's movement on the screen.
     - Trackball: A stationary device with a rotating ball for cursor control.
     - Touchpad: Sensitive surface that responds to finger movements for cursor control.
     - Stylus/Pen Input: Used for drawing and precise interactions on graphic tablets and touchscreens.

3. Audio Input Devices:
    - Microphone: Captures sound and converts it into an electrical signal.
    - Midi keyboard: They are use to send musical input to computer system for further processing.
4. Image Input Devices:
    - Scanner: Converts physical images or documents into digital formats.
    - Digital Camera: Captures images and transfers them to the computer.
5. Video Input Devices:
    - Webcam: Captures video footage and streams it to the computer.
    - Video Capture Cards: Record and digitize video from external sources.
6. Biometric Input Devices:
    - Fingerprint Scanner: Captures and analyzes fingerprint patterns for security and authentication.
    - Iris/Retina Scanner: Scans and analyzes the unique patterns in the iris or retina for identification.
7. Gesture Recognition Devices:
    - Motion Sensors: Detects body movements and gestures for gaming, virtual reality, and user interactions.
8. Specialized Input Devices:
    - Joysticks and Game Controllers: Used for gaming and simulations.
    - Barcode Reader/Scanner: Scans barcodes to retrieve information.
    - Light Pen: Used on some touchscreen devices to select and interact with items.

*Classification of output devices with their examples*

1. Visual Output Devices:
    - Monitor/Display: Displays visual information, text, images, videos, and graphical interfaces to the user.
    - Projector: Displays computer-generated content on a larger screen or surface, often

used for presentations and entertainment.

2. Print Output Devices:
    - Printer: Produces hard copies of documents, images, graphics, and other digital content.
        - Inkjet Printer: Sprays tiny droplets of ink onto paper.
        - Laser Printer: Uses toner and heat to fuse text and images onto paper.
        - Dot Matrix Printer: Creates images using a matrix of dots, often used for forms and receipts.
3. Audio Output Devices:
    - Speakers: Produce sound output, including music, alerts, and audio from multimedia content.
    - Headphones/Earphones: Provide private audio output directly to the user's ears.

*Computer peripherals devices that serve as both input and output devices*

There are so many devices that contain the characteristics of both input and output. They can perform both operations as they receive data and provide results. Some of them are mentioned below.

- USB Drive: USB Drive is one of the devices which perform both input and output operations as a USB Drive helps in receiving data from a device and sending it to other devices.
- Modem: Modems are one of the important devices that helps in transmitting data using telephonic lines.
- CD and DVD: CD and DVD are the most common device that helps in saving data from one computer in a particular format and send data to other devices which works as an input device to the computer.

- Central Processing Unit (CPU)

  CPU is a large integrated circuit (IC) also known as chip that is attach onto computer motherboard that does all processing activities in a computer system. In layman terms, it is referred to as the brain of the computer system. CPU consists:

  1. Arithmetic Logic Unit

     This unit consists of two units; Arithmetic unit and Logic unit.

The arithmetic unit performs arithmetic operations on the data that is made available to it. Some of the arithmetic operations supported by the arithmetic unit are—addition, subtraction, multiplication and division.

The logic unit of ALU is responsible for performing logic operations. Logic unit performs comparisons of numbers, letters and special characters. Logic operations include testing for greater than, less than or equal to condition.

ALU performs arithmetic and logic operations, and uses registers to hold the data that is being processed.

2. Registers

- Registers are high-speed storage areas within the CPU, but have the least storage capacity. Registers are not referenced by their address, but are directly accessed and manipulated by the CPU during instruction execution.
- Registers store data, instructions, addresses and intermediate results of processing. Registers are often referred to as the CPU's working memory.
- The data and instructions that require processing must be brought in the registers of CPU before they can be processed. For example, if two numbers are to be added, both numbers are brought in the registers, added and the result is also placed in a register.
- Registers are used for different purposes, with each register serving a specific purpose. Some of the important registers in CPU are as follows:

  i. Accumulator (ACC) stores the result of arithmetic and logic operations.

  ii. Instruction Register (IR) contains the current instruction most recently fetched.

  iii. Program Counter (PC) contains the address of next instruction to be processed.

  iv. Memory Address Register (MAR) contains the address of next location in the memory to be accessed.

  v. Memory Buffer Register (MBR) temporarily stores data from memory or the data to be sent to memory.

  vi. Data Register (DR) stores the operands and any other data

3. Control Unit

The control unit is a crucial component of a CPU that plays a fundamental role in coordinating and managing the overall operation of the system. It is a part of the central processing unit (CPU) and serves as the "brain" of the computer. The primary function of the control unit is to fetch, decode, and execute instructions, ensuring that the computer performs tasks in the correct sequence and order. Key Responsibilities of the Control Unit:

- Instruction Fetch: The control unit fetches instructions from the memory, one at a time, based on the program counter (PC) value. The program counter keeps track of the memory address of the next instruction to be executed.
- Instruction Decode: Once an instruction is fetched, the control unit decodes it to understand the operation it represents and the operands involved.
- Instruction Execution: After decoding the instruction, the control unit initiates the appropriate operations in the arithmetic logic unit (ALU) and other parts of the CPU to execute the instruction.
- Data Flow Control: The control unit manages the flow of data between various components of the CPU, such as registers, ALU, and memory, ensuring the correct data is accessed and processed.
- Time Sequencing: The control unit generates and synchronizes timing signals that control the flow of data and operations within the CPU, ensuring that each operation occurs at the correct time.
- Control Signals: The control unit generates control signals that enable or disable specific components or pathways within the CPU based on the instruction being executed.
- Error Handling: The control unit detects and manages errors or exceptions that may occur during the execution of instructions, such as division by zero or invalid memory access.

- Storage Unit

Computer storage unit can be described as a part of computer system that is similar to the part of human brain that allows one to retain instructions and data either for a short time or long time. It is considered as the storage house in the system that holds data and instructions. The whole system of storage is divided into small sets of modules that are termed as cells. These cells are located in the memory at a unique address that allows easy storage of data.

Computer storage unit can be classified in primary and secondary storage

## *Primary storage*

Primary storage is a group computer memory that can be access directly by the processor. It is made up of the following type of memory

### *Cache Memory*

Cache memory is a very high speeded memory designed to increase CPU processing during data. Cache memory is a storage buffer that stores the data that is used more often, temporarily, and makes them available to CPU at a fast rate. During processing, CPU first checks cache for the required data. If data is not found in cache, then it looks in the RAM for data.

Cache memory may be built into the processor, and may also be located next to it on a separate chip between the CPU and RAM. Cache built into the CPU is faster than separate cache, running at the speed of the microprocessor itself. However, separate cache is roughly twice as fast as RAM.

Cache memory is very expensive, so it is smaller in size. Generally, computers have cache memory of sizes 256 KB to 2 MB.

There are two type of cache:

- Primary Cache

  This memory is located on the processor chip and is small. It is referred to as L1 (level 1) cache. The access time of processor registers and primary cache is comparable.

- Secondary Cache

  This memory is located between the primary cache which is normally located on the processor chip and the main memory. It is referred to as the L2 (level 2) cache.

### *Random Access Memory (RAM)*

RAM is a memory that stores data and instructions during computer operations. The data and instructions that need to be operated upon by CPU are first fetched to RAM from the secondary storage or receive from input devices. CPU interacts with RAM to get the data and instructions for processing. RAM loses data and information stored on it when the computer is powered off, thus, it is referred to as a volatile memory. RAM can further be classified into two types as follows:

1. SRAM (Static Random Access Memory): SRAM is a type of RAM that uses flip-flops to store each bit of data. It is called "static" because it retains its data as long as power is supplied to the memory chip. SRAM is faster and more power-efficient compared to DRAM (Dynamic RAM) but is more expensive and has a lower storage capacity. Due to its speed, SRAM is commonly used as cache memory to provide fast access to frequently used data by the CPU.
2. DRAM (Dynamic Random Access Memory): DRAM is another type of RAM that uses capacitors to store each bit of data. Unlike SRAM, DRAM needs to be refreshed regularly to retain its data, hence the term "dynamic." DRAM is less expensive and offers higher storage capacity compared to SRAM but is slower and consumes more power. It is the most common type of RAM used as main memory (RAM) in computer systems due to its cost-effectiveness and capacity.

*Read Only Memory*

ROM is a non-volatile primary memory; does not lose its content when the power is switched off. As the name implies, its content can only read but cannot be written onto, thus it is often comes preinstalled by the manufacturers.

It stores standard processing programs that permanently reside in the computer. ROM stores the data needed for the startup of the computer. The instructions that are required for initializing the devices attached to a computer are stored in ROM.

The ROM memory chip stores the Basic Input Output System (BIOS). BIOS provides the processor with the information required to boot the system. It provides the CPU with the settings and resources that are available on the system. BIOS is a permanent part of the computer. It does not load from disk but instead is stored in a ROM memory chip. The program code in the BIOS differs from ordinary software since it acts as an integral part of the computer. When the computer is turned on, the BIOS does the following operations:

1. **Power-On Self-Test (POST)**: The BIOS conducts a series of diagnostic tests known as the POST. It checks hardware components such as the central processing unit (CPU), memory (RAM), graphics card, storage devices, and other peripherals to ensure they are functioning correctly. Any errors detected during this test are typically indicated by error codes or beeps.
2. **Bootstrap Loader Search**: After a successful POST, the BIOS searches for the bootable device that contains the operating system (OS). It follows a predefined boot order, which typically includes the computer's hard drive, CD/DVD drive, USB drives, and

network boot options.

3. **Boot Device Selection**: Once a bootable device is identified, the BIOS loads the first sector, called the boot sector or master boot record (MBR), from that device into memory. This boot sector contains a small program known as the bootstrap loader.
4. **Bootstrap Loader Execution**: The bootstrap loader is executed by the BIOS. It is responsible for loading a more advanced bootloader or operating system kernel. The bootstrap loader often displays a boot menu if there are multiple OS options installed on the system.
5. **Hardware Initialization**: While the OS takes over the management of most hardware components, the BIOS initializes essential hardware settings. This includes configuring system clocks, setting memory parameters, and initializing input/output (I/O) interfaces.
6. **CMOS Setup**: The BIOS reads configuration data stored in the CMOS memory. This memory retains settings even when the computer is powered off. Users can access the BIOS setup utility by pressing a designated key during boot-up (e.g., Del, F2) to modify hardware settings.
7. **System Services**: The BIOS provides a set of system services that allow applications and device drivers to communicate with the hardware. These services are accessible through BIOS interrupt calls.
8. **BIOS Update Check**: Some modern BIOS versions have the capability to connect to the internet and check for updates to the BIOS firmware. This helps keep the system up-to-date with the latest features and improvements.
9. **Pass Control to Bootloader or OS**: Once the bootloader or OS kernel is loaded into memory, control is handed over from the BIOS to the loaded software. The OS takes control of the system, and the user interface of the operating system is presented.

Type of ROM

1. PROM (Programmable Read-Only Memory): PROM is a type of ROM that can be programmed only once by the user after manufacturing. It is initially blank, and the user can use a special programming device to burn specific data or instructions into the memory. Once programmed, the data remains permanently and cannot be changed.
2. EPROM (Erasable Programmable Read-Only Memory): EPROM is similar to PROM but allows for erasing and reprogramming multiple times. To erase the data, EPROM chips

need exposure to ultraviolet (UV) light for a specified period. After erasing, new data can be programmed into the EPROM. However, this process requires removing the chip from the circuit board, making it less convenient than other types of memory.

3. EEPROM (Electrically Erasable Programmable Read-Only Memory): EEPROM is an improved version of EPROM, which allows for erasing and reprogramming without the need for UV light exposure. The erasing process is performed electronically using an electric signal, making it more convenient than EPROM. EEPROM can be reprogrammed multiple times while still offering non-volatile storage.

*Secondary Memory*

The secondary memory stores data and instructions permanently. The information can be stored in secondary memory for a long time (years), and is generally permanent in nature unless erased by the user. It is a non-volatile memory.

It provides back-up storage for data and instructions. Hard disk drive, floppy drive and optical disk drives are some examples of storage devices. The data and instructions that are currently not being used by CPU, but may be required later for processing, are stored in secondary memory. Secondary memory has a high storage capacity than the primary memory but it takes longer time to access the data and instructions stored in secondary memory than in primary memory.

a. The Floppy Disk: The floppy disk is a circular flat piece of plastic made of a flexible (or floppy) magnetic material on which data are recorded. Floppy disk drives store data on both sides of the disks. Earlier computers stored data on only a single side of the floppy disk.

b. The Hard Disk: The hard disk is generally not visible because hard disks are usually enclosed within the system unit. The hard disk is a stack of metal platters that spin on one spindle like a stack of rigid floppy disks. Unlike floppy disks where the disk and drive are separate, the hard-disk drive, or hard drive is the whole unit. Generally you cannot remove the hard disk from its drive; however some manufacturers make removable hard disks that plug into a separate drive unit.

c. The CD-ROM: CD-ROM disc are hard, plastic, silver like coated surface disc. CD-ROM is an acronym for Compact Disc Read – Only Memory. This implies that the disc can only be read. You cannot change or overwrite the contents of a CD-ROM disk.

- As CD-ROM is read only, no changes can be made into the data contained in it.

- Since there is no head touching the disc, but a laser light, CD-ROM does not get worn out easily.
- The storage density of CD-ROM is very high and cost is low as compared to floppy disk and hard disk.
- Access time of CD-ROM is less. CD-ROM drives can read data at 150Kbps.
- It is a commonly used medium for distributing software and large data.

d. DVD-ROM: Digital Video Disk-Read Only Memory (DVD-ROM) is an optical storage device used to store digital video or computer data (Figure 3.17).

- DVDs look like CDs, in shape and physical size. It is an improvement on CD technology.
- It is a high-density medium with increased track and bit density.
- DVD-ROM uses special data compression technologies, in which a full-length movie can be stored on a single disk.
- DVD-ROM can store 4.7 GB of data.

e. Magnetic Tape: A tape drive is a device that reads and writes data to the surface of a magnetic tape, generally used for backing up or restoring the data of an entire hard disk.

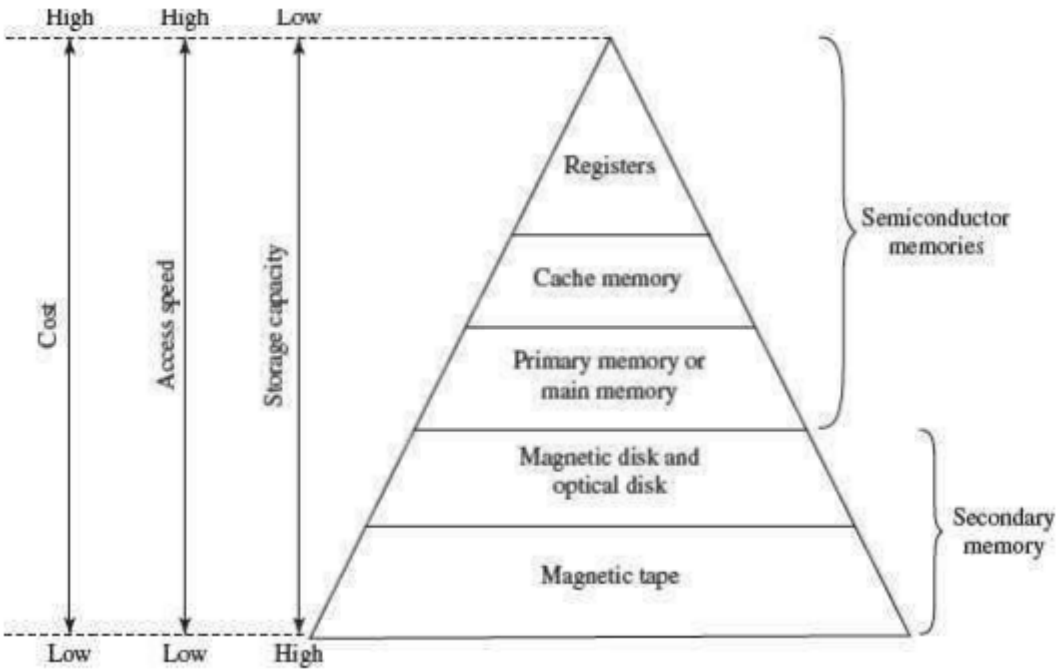
f. The Zip Drive: Zip drives are an alternative to tape backup units or tape drives. A zip drive can be internal or external. Zip drives have 16 removable cartridges or disk. A zip drive holds about 100MB to 250 MB of Data.

g. Flash Drive: A flash drive, also known as a thumb drive, USB drive, or memory stick, is a portable data storage device that uses flash memory to store and retrieve data. Flash memory is a type of non-volatile computer storage technology that retains data even when the power supply is turned off. It is widely used in various electronic devices, including USB flash drives, solid-state drives (SSDs), memory cards, smartphones, tablets, and digital cameras. Flash drive is a small, compact device that connects to a computer's USB (Universal Serial Bus) port. Flash drives have become popular due to their convenience, portability, and ease of use.

### Memory Hierarchy

The memory is characterized on the basis of two key factors—capacity and access time. Capacity is the amount of information (in bits) that a memory can store. Access time is the

time interval between the read/write request and the availability of data. The lesser the access time, the faster is the speed of memory. Ideally, we want the memory with fastest speed and largest capacity. However, the cost of fast memory is very high. The computer uses a hierarchy of memory that is organized in a manner to enable the fastest speed and largest capacity of memory. The hierarchy of the different memory types is shown in the figure below.



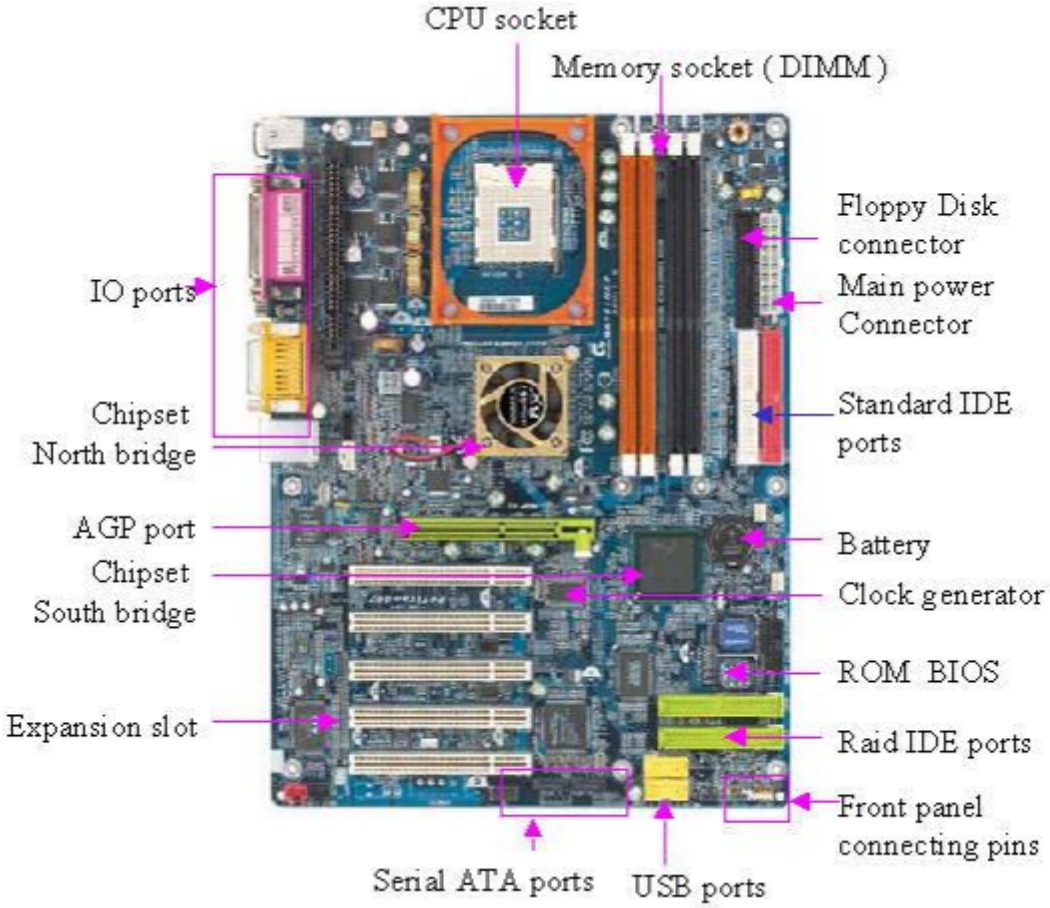

Computer Memory Measurement Units

| No. | Unit | Description |
|---|---|---|
| 1 | Bit (Binary Digit) | A binary digit is logical 0 & 1 |
| 2 | Nibble | 1 Nibble = 4 bits |
| 3 | Byte (B) | 1 Byte = 8 bits |
| 4 | Kilobyte (KB) | 1 KB = 1024 B |

| | | |
|---|---|---|
| 5 | Megabyte (MB) | 1 MB = 1024 KB |
| 6 | Gigabyte (GB) | 1 GB = 1024 MB |
| 7 | Terabyte (TB) | 1 TB = 1024 GB |
| 8 | Petabyte (PB) | 1 PB = 1024 TB |
| 9 | Exabyte (EB) | 1 EB = 1024 PB |
| 10 | Zettabyte (ZB) | 1 ZB = 1024 EB |
| 11 | Yottabyte (YB) | 1 YB = 1024 ZB |

## MOTHERBOARD

The motherboard is mounted inside the case and is securely attached via small screws through pre-drilled holes. Motherboard contains ports to connect all of the internal components. It provides a single socket for CPU whereas for memory, normally one or more slots are available. Motherboards provide ports to attach floppy drive, hard drive, and optical drives via ribbon cables. Motherboard carries fans and a special port designed for power supply. There is a peripheral card slot in front of the motherboard using which video cards, sound cards and other expansion cards can be connected to motherboard. On the left side, motherboards carry a number of ports to connect monitor, printer, mouse, keyboard, speaker, and network cables. Motherboards also provide USB ports which allow compatible devices to be connected in plugin plug-out fashion for example, pen drive, digital cameras etc.




## Components of the Motherboard

The computer motherboard comprises of many components, below are the most common:

1. CLOCK GENERATOR: is a component responsible for generating the clock signal of the system bus and front side bus clock of the motherboard. It controls the speed of components on the motherboard.

2. CPU SOCKET: this is a slot unto which the processor (CPU) can be inserted.

3. MEMORY SOCKET (DIMM (Dual Inline Memory Module) SOCKET): This is a slot unto which the

RAM memory can be inserted.

4. ROM BIOS: BIOS (Basic Input Output System) is a component that holds the startup instructions. BIOS will start work immediately when the PC is powered on, BIOS will make the hardware ready and the IO (input output devices) works at the initial state, Floppy disk and CDROM able to read and boot, PC able to detect the installed hard disk, the screen able to display, all this will help us to be able to install the Operating System or install Windows.

5. CMOS RAM (Complementary Metal-Oxide-Semiconductor): Every time the PC is powered on, BIOS will use the above information, these information may be changed by the user and must retained in the memory even though the electric power is removed from the system, the memory that is used to store these information is called CMOS Ram, CMOS Ram is located on the mother board and will need the power from battery during PC powered off to retain the information.

6. BATTERY: the battery supplies the power to CMOS ram for CMOS ram to retain the information during system powered off, When the battery is weak the PC will show and inaccurate time of day clock, or show CMOS check sum error message during boot, at this time the user defined information in the CMOS ram may be lost, the PC may be still able to run by using the default value in the BIOS that was defined by manufacturer.

7. CHIP SET: These are set of integrated Circuits which works together to provide support to CPU and I/O ( input/out device ) and make the whole system works, currently the chipset are integrated in to very few large scale IC.

8. EXPANSION SLOT: Expansion slot or Expansion bus is the slot that enables the user to add the adapter card for additional function to the system for example, Sound card or Multimedia card, LAN card, SCSI controller card, Internal Modem card, TV tuner card, Additional hard disk controller card. And other special purpose adapter card.

9. AGP PORT: AGP stands for Accelerated Graphics Port. It is an older type of expansion port used in computer systems to connect a graphics card (also known as a video card or GPU) to the motherboard. AGP was developed to provide a dedicated and faster connection for graphics processing compared to the standard PCI (Peripheral Component Interconnect) slots.

10. IDE PORTS: IDE stands for Integrated Drive Electronics, which is a standard interface used to connect storage devices like hard disk drives (HDDs) and optical drives (CD/DVD drives) to a computer's motherboard. IDE was widely used in older computer systems before being largely replaced by SATA (Serial (Advanced Technology Attachment) interfaces.

11. FLOPPY DISK PORT: this is used to connect the Floppy disk to the motherboard.

12. I/O CONNECTOR/USB PORTS: is used to connect peripheral devices like the keyboard, mouse, printer microphone, e.t.c to the motherboard.

13. POWER CONNECTOR: this receives Power supply connector from power supply and delivers it to the motherboard

## Computer Buses

System buses are pathways or communication channels that facilitate the transfer of data and control signals between different components of a computer system. They serve as the backbone of the system, allowing the CPU, memory, and other peripherals to exchange information efficiently. There are several types of system buses in a computer, below are the most common.

1. Address Bus: The address bus is a unidirectional bus used by the CPU to send memory addresses to the memory or other devices. The width of the address bus determines the maximum memory capacity that the CPU can address. For example, a 32-bit address bus can address up to 4GB of memory (2^32 addresses).
2. Data Bus: The data bus is a bi-directional bus that carries data between the CPU, memory, and peripherals. It transfers the actual data being read from or written to memory. The width of the data bus determines the number of bits that can be transferred in parallel. For example, a 64-bit data bus can transfer 64 bits of data at once.
3. Control Bus: The control bus is a bidirectional bus used to carry control signals between the CPU and other components. It includes signals like read, write, interrupt requests, and clock signals, which synchronize the activities of different components in the system.
4. Front Side Bus (FSB): The front side bus is a specific type of system bus that connects the CPU to the Northbridge, which is a chipset that controls interactions between the CPU, memory, and graphics card. The FSB speed affects the overall system performance.
5. Back Side Bus (BSB): The back side bus connects the CPU to the Level 2 (L2) cache. It allows for faster data transfer between the CPU and the cache, reducing the latency in accessing frequently used data.
6. Expansion Bus: The expansion bus is used to connect peripheral devices and expansion cards, such as graphics cards, network cards, and sound cards, to the motherboard. Examples include PCI (Peripheral Component Interconnect) and PCIe (PCI Express) buses.
7. I/O Bus (Input/Output Bus): The I/O bus is responsible for data transfer between the CPU and peripheral devices, such as keyboards, mice, printers, and external storage devices. USB

(Universal Serial Bus) is a common example of an I/O bus.

## COMPONENTS OF COMPUTER SOFTWARE

A computer system consists of hardware and software. The computer hardware cannot perform any task on its own. It needs to be instructed about the tasks to be performed. Software is a set of programs that instructs the computer about the tasks to be performed. Software tells the computer how the tasks are to be performed; hardware carries out these tasks. Different sets of software can be loaded on the same hardware to perform different kinds of tasks. For example, a user can use the same computer hardware for writing a report or for running a payroll program. The components like monitor, keyboard, processor, and mouse, constitute the hardware. In this chapter, we will discuss the different categories of computer software.

If a computer is to function, software is not optional. Everything that a computer does, from the time you turn the power switch on until you shut the system down, is under the control of software. There are two general categories of software: system software and application software. Most computer programs clearly fit into one of these two categories. Let's take a closer look at each.

Software is a set of instructions that operate a computer, manipulate the data and execute particular functions or tasks. In other words, it is a programs, routines, and symbolic languages that control the function of the hardware. For software (the instructions) to perform various functions, it must be programmed. That is, the instructions need to be written in a programming language that the computer can understand. Without a program, a computer is useless. Computer program is a sequence of instructions that can be executed by a computer to carry out a process. There are two kinds of software, systems software and applications software.

### Types of Software

Software can be broadly classified in two categories:

1. System Software, and
2. Application Software.

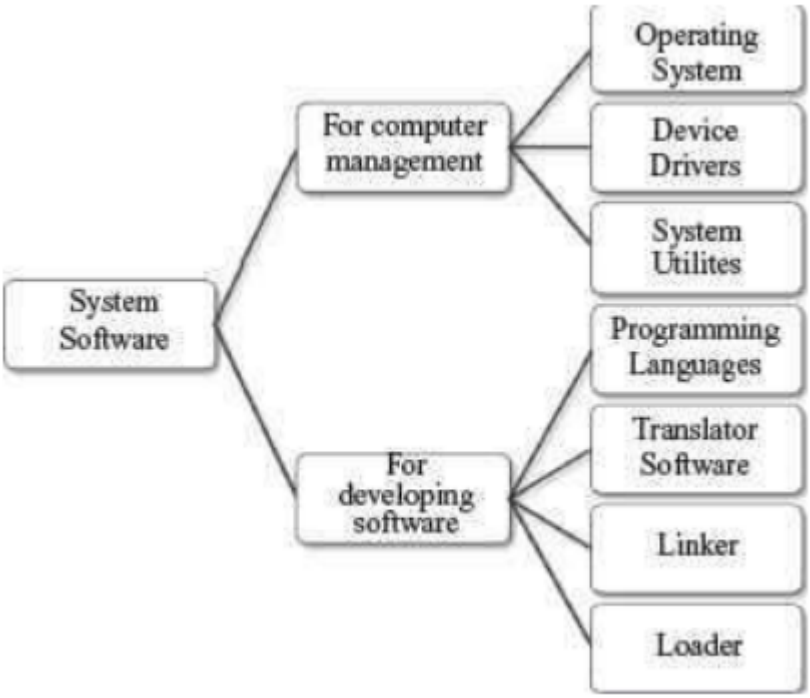
### SYSTEM SOFTWARE

The system software is a collection of programs designed to operate, control, and extend the processing capabilities of the computer itself. System software is generally prepared by the computer manufacturers. These software products comprise of programs written in low-level languages, which interact with the hardware at a very basic level. System software serves as the interface between the hardware and user application software.

The purposes of the system software are:

- To provide basic functionality to computer,
- To control computer hardware, and
- To act as an interface between user, application software and computer hardware

On the basis of their functionality, system software may be broadly divided into two categories (Figure 6.3) as follows




*System software for the management*

System software for the management and functionality are group of software that insures the smooth running of a computer system. They are Operating system, Device Drivers, and System Utilities constitute the system software for management of computer and its resources.

1. *Operating System*

An operating system (OS) is system software that manages computer hardware, software

resources, and provides common services for computer programs.

An operating system is the most fundamental set of programs on a computer. The operating system controls the internal operations of the computer's hardware, manages all of the devices connected to the computer, allows data to be saved to and retrieved from storage devices, and allows other programs to run on the computer.

Operating System (OS) is an important part of a computer. OS intermediates between the user of a computer and the computer hardware. Different kinds of application software use specific hardware resources of a computer like CPU, I/O devices and memory, as needed by the application software. OS controls and coordinates the use of hardware among the different application software and the users. It provides an interface that is convenient for the user to use, and facilitates efficient operations of the computer system resources. The key functions of OS are:

- It provides an environment in which users and application software can do work.
- It manages different resources of the computer like the CPU time, memory space, file storage, I/O devices etc. During the use of computer by other programs or users, operating system manages various resources and allocates them whenever required, efficiently
- It controls the execution of different programs to prevent occurrence of error.
- It provides a convenient interface to the user in the form of commands and graphical interface, which facilitates the use of computer.
- Booting of Computer: This is the first process which takes place the moment the computer's electrical switch is put on. During this process all the peripherals connected to the computer are checked and validated; at the end of the validation process, the OS signals the user to begin working on the computer.
- Some of the other services that an OS provides to programs are:
    - Saving files to disk reading them from disk into memory
    - Checking available disk or memory space
    - Allocating memory to hold data for a program

Some available operating systems are Microsoft Disk Operating System (MS-DOS),

Windows 7, Windows XP, Linux, UNIX, and Mac OS X Snow Leopard.

2. *Device Driver*

A device driver acts as a translator between the hardware and the software that uses the devices. In other words, it intermediates between the device and the software, in order to use the device.

Some devices that are commonly connected to the computer are: keyboard, mouse, hard disk, printer, speakers, microphone, joystick, webcam, scanner, digital camera, and monitor. For proper working of a device, its corresponding device driver must be installed on the computer. For example, when we give a command to read data from the hard disk, the command is sent to the hard disk driver and is translated to a form that the hard disk can understand. The device driver software is typically supplied by the respective device manufacturers.

Nowadays, the operating system comes preloaded with some commonly used device drivers, like the device driver for mouse, webcam, and keyboard. The device drivers of these devices are preinstalled on the computer, such that the operating system can automatically detect the device when it is connected to the computer. Such devices are called plug and play devices. In case the computer does not find the device driver, it prompts the user to insert the media (like a CD which contains the corresponding device driver) provided along with the device. Most device manufacturers, host the device drivers for their devices on their companies' websites; users can download the relevant driver and install it on their computer.

- Each device has its own device driver
- Whenever a new device is connected to a computer, its device driver has to be loaded in the computer's memory, to enable use of the device. When you buy a new printer, you get the device driver CD with it. You must install the device driver on your computer, to use the new printer. Each printer comes with its own device driver. If you replace your old printer with a new model, you need to install the device driver for the new printer.

3. *System Utilities*

Utility Programs: A utility program performs a specialized task that enhances the computer's operation or safeguards data. Examples of utility programs are virus scanners, file compression programs, and data backup programs. System utility software is required for the maintenance of computer. System utilities are used for supporting and enhancing the programs and the data in computer. Some system utilities may come embedded with OS and

others may be added later on. Some examples of system utilities are:

- Anti-virus utility to scan computer for viruses
- Data Compression utility to compress the files
- Cryptographic utility to encrypt and decrypt files.
- Disk Compression utility to compress contents of a disk for increasing the capacity of a disk.
- Disk Partitioning to divide a single drive into multiple logical drives. Each drive is then treated as an individual drive and has its own file system
- Disk Cleaners to find files that have not been used for a long time. It helps the user to decide what to delete when the hard disk is full.
- Backup Utility to make a copy of all information stored on the disk. It also restores the backed up contents in case of disk failure.
- System Profiling Utility provides detailed information about the software installed on the computer and the hardware attached to it.
- Network Managers to check the computer network and to log events.

*System software for developing software*

System software for developing software are group of software provides services required for the development and execution of software. They provide tool needed by programmer to produce new Software product. This software include programming language software, translator software, loader, and linker

1. Programming language

   This are set of Languages use to write instruction that directs computer to perform a given task. Set of instruction that tell computer what to do is called program.

   Programming language can be categorized into two. They are low level language and high level language.

   *Low Level Language (LLL)*

   LLL is a programming language that provides little abstraction (Assembly language) or no abstraction (machine language) from a computer's instruction set architecture.

   1. Machine Language

A program written in machine language is a collection of binary digits or bits that the computer reads and interprets. It is a system of instructions and data executed directly by a computer's CPU. It is also referred to as machine code or object code. It is written as strings of 0's and 1·s.

Some of the features of a program written in machine language are as follows:

- The computer can understand the programs written in machine language directly. No translation of the program is needed.

- Program written in machine language can be executed very fast (Since no translation is required).

- Machine language is defined by the hardware of a computer. It depends on the type of the processor or processor family that the computer uses, and is thus machine-dependent. A machine- level program written on one computer may not work on another computer with a different processor

- It is difficult to write a program in machine language as it has to be written in binary code. For e.g., 00010001 11001001.

- Since writing programs in machine language is very difficult, programs are hardly written in machine language.

2. Assembly Language

Assembly language is LLL that uses symbolic representation of machine codes needed to program a particular processor (CPU) or processor family. Symbolic operation codes are in an easy-to-remember form called mnemonics, this representation is usually defined by the CPU manufacturer, and is based on abbreviations (called mnemonics) that help the programmer remember individual instructions, registers, etc. Small, English-like representation is used to write the program in assembly language.

Assembly language programs are easier to write than the machine language programs, since assembly language programs use short, English-like representation of machine code. For e.g.

ADD 2, 3 LOAD A, SUB A, B, MOV

- The program written in assembly language is the source code, which has to be converted into machine code, also called object code, using translator software,

namely, assembler.

- Each line of the assembly language program is converted into one or more lines of machine code. Hence assembly language programs are also machine-dependent.
- Although assembly language programs use symbolic representation, they are still difficult to write.
- Assembly language programs are generally written where the efficiency and the speed of program are the critical issues, i.e. programs requiring high speed and efficiency.

Addressing Techniques

Addressing techniques in computer architecture refer to the methods used to specify the location of data or instructions in memory for processing by the CPU. Different addressing techniques are employed to efficiently access data and execute instructions based on the CPU's design and instruction set architecture. Below are few come addressing techniques along with examples for each:

1. Direct Addressing: Example: MOV R1, [1000] Explanation: In direct addressing, the memory location (1000) is directly specified in the instruction. The instruction MOV (move) copies the data from memory location 1000 to register R1.
2. Indirect Addressing: Example: MOV R2, [R1] Explanation: In indirect addressing, the instruction MOV copies the data from the memory location pointed to by the content of register R1 to register R2. The actual memory address is stored in R1, and the instruction accesses the data indirectly through the content of R1.
3. Register Addressing: Example: ADD R1, R2 Explanation: In register addressing, the instruction ADD adds the content of register R2 to the content of register R1. Both operands are directly specified by their register names.
4. Immediate Addressing: Example: MOV R4, 42 Explanation: In immediate addressing, the instruction MOV moves the constant value 42 into register R4. The value 42 is directly included in the instruction as an immediate operand.

3. High-level Language

A program in a high-level language is written in English-like language. Such languages

hide the details of CPU operations and are easily portable across computers. The HLL began to appear in the 1950‟s – COBOL is an example of such early HLL used to create complex computer programs without necessarily knowing how the CPU works and without writing a large number of low-level instructions. The HLL uses English like statements such as PRINT, WHILE, GOTO etc.

Some of the features of a program written in high-level language are as follows:

- Programs are easier to write, read or understand in high-level languages than in machine language or assembly language. For example, a program written in C++ is easier to understand than a machine language program
- Programs written in high-level languages is the source code which is converted into the object code (machine code) using translator software like interpreter or compiler.
- A line of code in high-level program may correspond to more than one line of machine code.
- Programs written in high-level languages are easily portable from one computer to another.

## Language Translators

As established above, Computers do not understand any language apart from machine language. Therefore, language translator are special Software that converts any program written in a language other than machine language into machine language. There are three type of translator:

*Assembler*

An assembler is a program that translates assembly language code, which is a low-level programming language, into machine code (binary code) that the computer's CPU can directly execute. Assembly language uses human-readable mnemonics to represent machine instructions and provides a more convenient way for programmers to interact with the hardware. The assembler converts these mnemonics into the corresponding binary representation, creating an object file containing machine code instructions and data.

*Compiler*

Compiler is the software that translates a program written in a high-level language to machine language. The program written in high-level language is referred to as the source code and

compiled program is referred as the object code. Compiler convert the entire source code into object code in which the object code can be executed many times without recompiling the source code again. Each programming language has its own compiler. Some languages that use a compiler are C++, COBOL, Pascal, and Java. Compiler translates the high-level programs to machine code either directly or via assembler.

*Interpreter*

Interpreter is a language translator that converts High Level Language program to machine code one instruction at a time. Interpreter reads the source code line-by-line, converts it into machine understandable form, executes the line, and then proceeds to the next line. Some languages that use an interpreter are BASIC and Python.

Linker

Linker is a program that links several object modules and libraries to a single executable program. A source code of a program is often very large consisting of several hundred or more lines. The source code may also include reference to libraries. All these independent modules may not be stored in a single object file. The code is broken down into many independent modules for easy debugging and maintenance. Before execution of the program, these modules and the required libraries are linked together using the linker software. The compiled and the linked program are called the executable code.

*Loader*

The loader software is used to load and re-locate the executable program in the main memory. Software has to be loaded into the main memory during execution. Loader assigns storage space to the program in the main memory for execution.

## NUMBER SYSTEM

A number system is defined as a system of writing to express numbers. It is the mathematical notation for representing numbers of a given set by using digits or other symbols in a consistent manner. It provides a unique representation of every number and represents the arithmetic and algebraic structure of the figures. It also allows us to perform arithmetic operations like addition, subtraction and division.

Computer architecture supports following number systems.

i. Binary number system (Base 2)
ii. Octal number system (Base 8)
iii. Decimal number system (Base 10)
iv. Hexadecimal number system (Base 16)

1. Binary Number System

A Binary number system has only two digits, which are 0 and 1. Every number (value) is represented with 0 and 1 in this number system. The base of binary number system is 2, because it has only two digits. Though DECIMAL (No 3) is more frequently used in Number representation, BINARY is the number system form which the system/machine accepts.

2. Octal number system

Octal number system has only eight (8) digits from 0 to 7. Every number (value) is represented with 0,1,2,3,4,5,6 and 7 in this number system. The base of octal number system is 8, because it has only 8 digits.

3. Decimal number system

Decimal number system has only ten (10) digits from 0 to 9. Every number (value) is represented with 0,1,2,3,4,5,6, 7,8 and 9 in this number system. The base of decimal number system is 10, because it has only 10 digits.

4. Hexadecimal number system

A Hexadecimal number system has sixteen (16) alphanumeric values from 0 to 9 and A to F. Every number (value) represents with 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E and F in this number system. The base of hexadecimal number system is 16, because it has 16 alphanumeric values. Here, we have 0 to 9, representing 0 – 9 but from 10, we have A is 10, B is 11, C is 12, D is 13, E is 14 and F is 15.

The table below shows the sample representations

| Number system | Base | Used digits | Example |
|---|---|---|---|
| Binary | 2 | 0,1 | (11110000)2 |
| Octal | 8 | 0,1,2,3,4,5,6,7 | (360)8 |
| Decimal | 10 | 0,1,2,3,4,5,6,7,8,9 | (240)10 |
| Hexadecimal | 16 | 0,1,2,3,4,5,6,7,8,9,A,B,C,D,E,F | (F0)16 |

## Number System Conversions

There are three types of conversion:

- Decimal Number System to Other Base
  [for example: Decimal Number System to Binary Number System e.g. Base 10 to Base 2 etc.]
- Other Base to Decimal Number System
  [for example: Binary Number System to Decimal Number System e.g. Base 2 back to Base 10 etc.]
- Other Base to Other Base
  [for example: Binary Number System to Hexadecimal Number System e.g. Base 2 to Base 16 etc.]
  Let's pick them one after the other to see how the computations are done and the underlying logic behind them!

*Decimal Number System to Other Bases*

The underlisted are the steps/procedures:

A) Divide the Number (Decimal Number) by the base of target base system (in which you want to convert the number to e.g. Binary (2), Octal (8) OR Hexadecimal (16)).

B) Write the remainder from step 1 as a Least Signification Bit (LSB) to Step last as a Most Significant Bit (MSB); that is, write from down-up.
Example 1: Convert 1234510 to Base 2

Solution

Decimal Number is : $(12345)_{10}$

| | | | |
|---|---|---|---|
| 2 | 12345 | 1 | LSB |
| 2 | 6172 | 0 | |
| 2 | 3086 | 0 | |
| 2 | 1543 | 1 | |
| 2 | 771 | 1 | |
| 2 | 385 | 1 | |
| 2 | 192 | 0 | |
| 2 | 96 | 0 | |
| 2 | 48 | 0 | |
| 2 | 24 | 0 | |
| 2 | 12 | 0 | |
| 2 | 6 | 0 | |
| 2 | 3 | 1 | |
| | 1 | 1 | MSB |

Binary Number is $(11000000111001)_2$

**Example 2:** Convert same no ($12345_{10}$) this time, to Base 8

**Solution 2:**

| Decimal to Octal Conversion | Result |
|---|---|
| Decimal Number is : **$(12345)_{10}$** | Octal Number is **$(30071)_8$** |

| | | | |
|---|---|---|---|
| 8 | 12345 | 1 | LSB |
| 8 | 1543 | 7 | |
| 8 | 192 | 0 | |
| 8 | 24 | 0 | |
| | 3 | 3 | MSB |

**Example 3:** Convert $12345_{10}$ to Base 16

**Solution 3:**

| Decimal to Hexadecimal Conversion | Result |
|---|---|
| **Example 1**<br>Decimal Number is : **$(12345)_{10}$** | Hexadecimal Number is **$(3039)_{16}$** |

| | | | |
|---|---|---|---|
| 16 | 12345 | 9 | LSB |
| 16 | 771 | 3 | |
| 16 | 48 | 0 | |
| 8 | 3 | 3 | MSB |

**A more complex Example 4:**

Convert $725_{10}$ to Base 16

Decimal Number is : **$(725)_{10}$**

| | |
|---|---|
| 16 | 725 |
| 16 | 45 |
| | 2 |

| | | |
|---|---|---|
| 5 | 5 | LSB |
| 13 | D | |
| 2 | 2 | MSB |

Hexadecimal Number is

**$(2D5)_{16}$**

**Convert**

**10, 11, 12, 13, 14, 15**

**to its equivalent...**

**A, B, C, D, E, F**

Example 5: Convert 11011012 to Base 10

Solution:

Binary to Decimal Conversion

1 * 2 + 1 * 2 + 0 * 2 + 1 * 2 + 1 * 2 + 0 * 2 + 1 * 2 (Comment: What we did here is in line with step A e.g. we multiply the given/source base's number (e.g. Base 2 - 1101101) with the base index e.g. 2.

Now, to complete the conversion computation, superscript the index position starting from 0 backward increasing downward. For instance, the equation becomes:

$$1 * 2^6 + 1 * 2^5 + 0 * 2^4 + 1 * 2^3 + 1 * 2^2 + 0 * 2^1 + 1 * 2^0$$
$$= 1 * 64 + 1 * 32 + 0 * 16 + 1 * 8 + 1 * 4 + 0 * 2 + 1 * 1$$
$$= 64 + 32 + 0 + 8 + 4 + 0 + 1$$
$$= 109_{10} \text{ (QED)}$$

Example 6: Convert $53_8$ to Base 10

Solution:

Octal to Decimal Conversion

5 * 8 + 3 * 8 (Comment: What we did here is in line with step A e.g. we multiply the given/source base's number (e.g. Base 8 - 53) with the base index e.g. 8.

Now, to complete the conversion computation, superscript the index position starting from 0 backward increasing downward. For instance, the equation becomes:

$$5 * 8^1 + 3 * 8^0 \quad = 5 * 8 + 3 * 1 = 40 + 3 \quad = \quad 43_{10} \quad \text{(QED)}$$

Example 7: Convert $294_8$ to Base 10

Solution:

Octal to Decimal Conversion

2 * 8 + 9 * 8 + 4 * 8 (Comment: What we did here is line with step A e.g. we multiply the given/source base's number (e.g. Base 8 - 294) with the base index e.g. 8.

Now, to complete the conversion computation, superscript the index position starting from 0 backward increasing downward. For instance, the equation becomes:

$2 * 8^2 + 9 * 8^1 + 4 * 8^0 = 2 * 64 + 9 * 8 + 4 * 1 = 128 + 72 + 4$

$= 204_{10}$ (QED)

Example 8: Convert $3F6_{16}$ to Base 10

Solution:

Hexadecimal to Decimal Conversion

3 * 16 + F(15) * 16 + 6 * 16 (Comment: What we did here is line with step A e.g. we multiply the given/source base's number (e.g. Base 16 – 3F6) with the base index e.g. 16.

Now, to complete the conversion computation, superscript the index position starting from 0 backward increasing downward. For instance, the equation becomes:

$3 * 16^2 + 15 * 16^1 + 6 * 16^0 = 3 * 256 + 15 * 16 + 6 * 1 = 768 + 240 + 6$

$= 1014_{10}$ (QED)

Example 9: Convert $2C4E_{16}$ to Base 10

Solution:

Hexadecimal to Decimal Conversion

2 * 16 + C(12) * 16 + 4 * 16 + E(14) * 16 (Comment: What we did here is line with step A e.g. we multiply the given/source base's number (e.g. Base 16 – 2C4E) with the base index e.g. 16.

Now, to complete the conversion computation, superscript the index position starting from 0 backward increasing downward. For instance, the equation becomes:

$2 * 16^3 + 12 * 16^2 + 4 * 16^1 + 14 * 16^0 = 2 * 4096 + 12 * 256 + 4 * 16 + 14 * 1$

$= 8192 + 3072 + 64 + 14 = 11342_{10}$ (QED)

Other Base System to Decimal Number Base

To execute this type of conversion, simply convert the given base to base ten, then convert to the target base.

Example 10: Convert $10011_2$ to base 8

Solution:

$1 * 2^4 + 0 * 2^3 + 0 * 2^2 + 1 * 2^1 + 1 * 2^0 = 1 * 16 + 0 * 8 + 0 * 4 + 1 * 2 + 1 * 1$

$16 + 0 + 0 + 2 + 1 = 19_{10}$ ……this is the conversion to base ten; now to eight:

| 8 | 19 |
|---|---|
| 8 | 2 |

| 3 |
|---|
| 2 |

So, $10011_2 = 23_8$

Binary arithmetic

Addition of binary numbers is the same as addition of decimal numbers, except that we carry at

2 (i.e. binary 10) instead of at 10, and we use the addition table for binary digits:

| | | + |
|---|---|---|
| 1 | 1 | 10 |
| 1 | 0 | 1 |
| 0 | 1 | 1 |
| 0 | 0 | 0 |

Example

```
 110011
+ 11101
 ,,,,,
-------
1010000
```

Advice: Adding three or more binary numbers at once is dangerous, because we may have to carry into two or more columns at once, and the result is confusing. It's best to add several binary numbers one at a time

Example

Add 1111, 111, 1110 all in base 2

Solution

$$\begin{array}{r} 1111 \\ +\ 111 \\ \hline 10110 \\ +\ 1110 \\ \hline 100100 \end{array}$$

Multiplication of Binary Numbers

Multiplication of binary digits is easy:

| | | × |
|---|---|---|
| 1 | 1 | 1 |
| 1 | 0 | 0 |
| 0 | 1 | 0 |
| 0 | 0 | 0 |

Example: Multiple 1101 by 1011 all in base 2

Solution: multiplication in base 2 is the same as in base 10. Just use the tips above.

1101

x 1011

1101

1101

0000

+ 1101

10001111

Subtraction Of Binary Numbers

Binary subtraction is similar to that one of decimal. The only difference is, when you barrow 1 from and add it to the lower unit it become two instead of 10 as in decimal.

Example: Subtract 11 from 100 all in base 2

Solution: remember any time you barrow, you are barrowing 2

100

-11

001

Example: Subtract 1001 from 1110 all in base 2

Solution

1110

-1001

0101

Binary Division

The binary division is much easier than the decimal division when you remember the following division rules. The main rules of the binary division include:

1÷1 = 1

1÷0 = Meaningless

0÷1 = 0

0÷0 = Meaningless

Similar to the decimal number system, the binary division is similar, which follows the four-step process:

Divide

Multiply

Subtract

Bring down

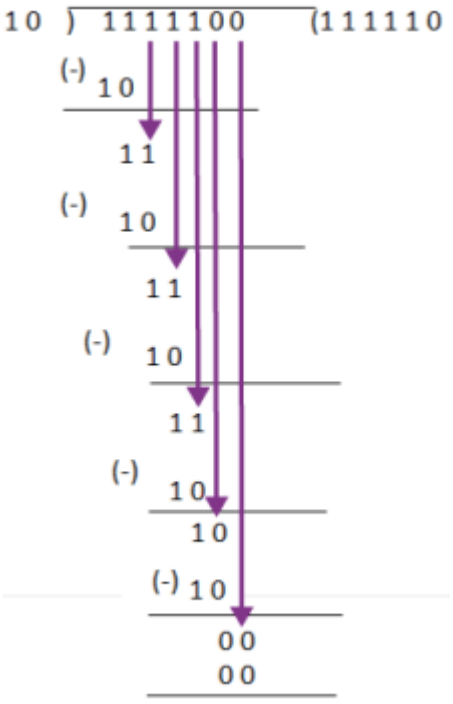
*Important Note*: Binary division follows the long division method to find the resultant in an easy way.

Example 1. Solve 01111100 ÷ 0010 all in binary

Solution:

Here the dividend is 01111100, and the divisor is 0010

Remove the zero's in the Most Significant Bit in both the dividend and divisor, that doesn't change the value of the number and use the long division method.




Example 2: Solve using the long division method: 101101 ÷ 101

Solution: