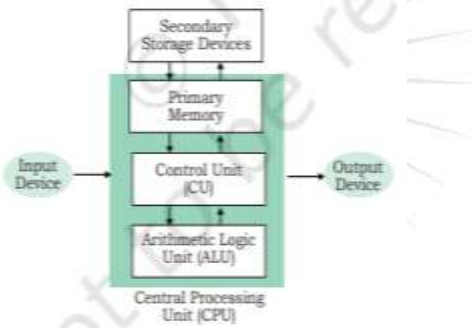
Computer System

INTRODUCTION TO COMPUTER SYSTEM

A computer is an electronic device that can be programmed to accept data (input), process it and generate result (output). A computer along with additional hardware and software together is called a computer system.

A computer system primarily comprises a central processing unit (CPU), memory, input/output devices and storage devices. All these components function together as a single unit to deliver the desired output. A computer system comes in various forms and sizes. It can vary from a high-end server to personal desktop, laptop, tablet computer, or a Smartphone.

Figure shows the block diagram of a computer system. The directed lines represent the flow of data and signal between the components.



Components of a computer system

Central Processing Unit (CPU)

It is the electronic circuitry of a computer that carries out the actual processing and usually referred as the brain of the computer. It is commonly called processor also. Physically, a CPU can be placed on one or more microchips called integrated circuits (IC). The ICs comprise semiconductor materials.

The CPU is given instructions and data through programs. The CPU then fetches the program and data from the memory and performs arithmetic and logic operations as per the given instructions and stores the result back to memory.

While processing, the CPU stores the data as well as instructions in its local memory called registers. Registers are part of the CPU chip and they are limited in size and number. Different registers are used for storing data, instructions or intermediate results.

Other than the registers, the CPU has two main components — Arithmetic Logic Unit (ALU) and Control Unit (CU). ALU performs all the arithmetic and logic operations that need to be done as per the instruction in a program. CU controls sequential instruction execution, interprets instructions and guides data flow through the computer's memory, ALU and input or output devices. CPU is also popularly known as microprocessor.

Input Devices

Input devices

The devices through which control signals are sent to a computer are termed as input devices. These devices convert the input data into a digital form that is acceptable by the computer system. Some examples of input devices include keyboard, mouse, scanner, touch screen, etc., as shown in. Specially designed Braille keyboards are also available to help the visually impaired for entering data into a computer. Besides, we can now enter data through voice, for example, we can use Google voice search to search the web where we can input the search string through our voice.

Data entered through input device is temporarily stored in the main memory (also called RAM) of the computer system. For permanent storage and future use, the data as well as instructions are stored permanently in additional storage locations called secondary memory.

Output Devices

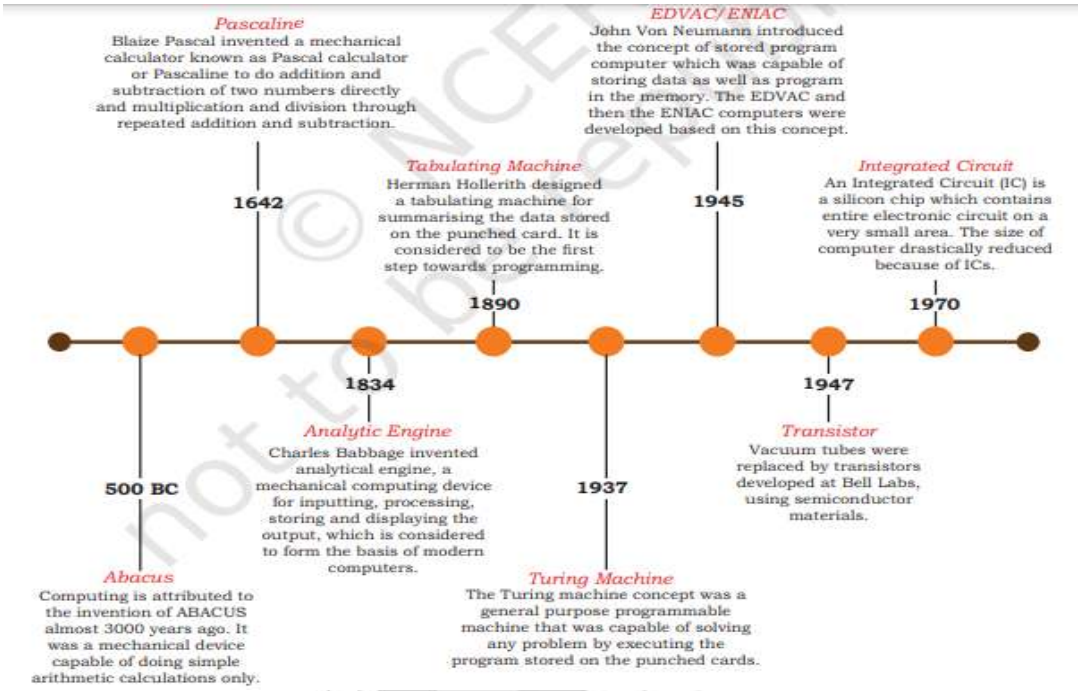
Output devices

The device that receives data from a computer system for display, physical production, etc., is called output device. It converts digital information into human-understandable form. For example, monitor, projector, headphone, speaker, printer, etc. Some output devices are shown in Figure. A Braille display monitor is useful for a visually challenged person to understand the textual output generated by computers.

A printer is the most commonly used device to get output in physical (hardcopy) form. Three types of commonly used printers are inkjet, LaserJet and dot matrix. Now-a-days, there is a new type of printer called 3D-printer, which is used to build physical replica of a digital 3D design. These printers are being used in manufacturing industries to create prototypes of products. Their usage is also being explored in the medical field, particularly for developing body organs.

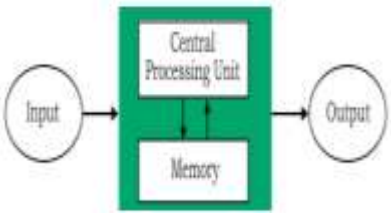
EVOLUTION OF COMPUTER

From the simple calculator to a modern day powerful data processor, computing devices have evolved in a relatively short span of time. The evolution of computing devices in shown through a timeline in Figure.



Timeline showing key inventions in computing technology

The Von Neumann architecture is shown in Figure. It consists of a Central Processing Unit (CPU) for processing arithmetic and logical instructions, a memory to store data and programs, input and output devices and communication channels to send or receive the output data. Electronic Numerical Integrator and Computer (ENIAC) is the first binary programmable computer based on Von Neumann architecture.



: *Von Neumann architecture for the computer*

In 1965, Intel co-founder Gordon Moore introduced Moore's Law which predicted that the number of transistors on a chip would double every two years while the costs would be halved.

During the 1970s, Large Scale Integration (LSI) of electronic circuits allowed integration of complete CPU on a single chip, called microprocessor. Moore's Law predicted exponential growth in the number of transistors that could be assembled in a single microchip. In 1980s, the processing power of computers increased exponentially by integrating around 3 million components on a small-sized chip termed as Very Large Scale Integration (VLSI). Further advancement in technology has made it feasible to fabricate

high density of transistors and other components (approx 106 components) on a single IC called Super Large Scale Integration (SLSI) as shown in Figure.

IBM introduced its first personal computer (PC) for the home user in 1981 and Apple introduced Macintosh machines in 1984. The popularity of the PC surged by the introduction of Graphical User Interface (GUI) based operating systems by Microsoft and others in place of computers with only command line interface, like UNIX or DOS. Around 1990s, the growth of World Wide Web (WWW) further accelerated mass usage of computers and thereafter computers have become an indispensable part of everyday life.

Further, with the introduction of laptops, personal computing was made portable to a great extent. This was followed by Smart phones, tablets and other personal digital assistants. These devices have leveraged the technological advancements in processor miniaturization, faster memory, high speed data and connectivity mechanisms.

The next wave of computing devices includes the wearable gadgets, such as smart watch, lenses, headbands, headphones, etc. Further, smart appliances are becoming a part of the Internet of Things (IoT), by leveraging the power of Artificial Intelligence (AI).

COMPUTER MEMORY

A computer system needs memory to store the data and instructions for processing. Whenever we talk about the 'memory' of a computer system, we usually talk about the main or primary memory. The secondary memory (also called storage device) is used to store data, instructions and results permanently for future use.

Units of Memory

A computer system uses binary numbers to store and process data. The binary digits 0 and 1, which are the basic units of memory, are called bits. Further, these bits are grouped together to form words. A 4-bit word is called a Nibble. Examples of nibble are 1001, 1010, 0010, etc. A two nibble word, i.e., 8-bit word is called a byte, for example, 01000110, 01111100, 10000001, etc.

Like any other standard unit, bytes are grouped together to make bigger chunks or units of memory. Table shows different measurement units for digital data stored in storage devices.

Measurement units for digital data

Unit	Description	Unit	Description
KB (Kilobyte)	1 KB = 1024 Bytes	PB (Petabyte)	1 PB = 1024 TB
MB (Megabyte)	1 MB = 1024 KB	EB (Exabyte)	1 EB = 1024 PB
GB (Gigabyte)	1 GB = 1024 MB	ZB (Zettabyte)	1 ZB = 1024 EB
TB (Terabyte)	1 TB = 1024 GB	YB (Yottabyte)	1 YB = 1024 ZB

Types of Memory

Human beings memorize many things over a lifetime, and recall from memory to make a decision or some action. However, we do not rely on our memory completely, and we make notes and store important data and information using other media, such as notebook, manual, journal, document, etc. Similarly, computers have two types of memory — primary and secondary.

(A) Primary Memory

Primary memory is an essential component of a computer system. Program and data are loaded into the primary memory before processing. The CPU interacts directly with the primary memory to perform read or write operation. It is of two type viz. (i) Random Access Memory (RAM) and (ii) Read Only Memory (ROM).

RAM is volatile, i.e., as long as the power is supplied to the computer, it retains the data in it. But as soon as the power supply is turned off, all the contents of RAM are wiped out. It is used to store data temporarily while the computer is working. Whenever the computer is started or a software application is launched, the required program and data are loaded into RAM for processing. RAM is usually referred to as main memory and it is faster than the secondary memory or storage devices.

On the other hand, ROM is non-volatile, which means its contents are not lost even when the power is turned off. It is used as a small but faster permanent storage for the contents which are rarely changed. For example, the startup program (boot loader) that loads the operating system into primary memory, is stored in ROM.

(B) Cache Memory

RAM is faster than secondary storage, but not as fast as a computer processor. So, because of RAM, a CPU may have to slow down. To speed up the operations of the CPU, a very high speed memory is placed between the CPU and the primary memory known as cache. It stores the copies of the data from frequently accessed primary memory locations, thus, reducing the average time required to access data from primary memory. When the CPU needs some data, it first examines the cache. In case the requirement is met, it is read from the cache, otherwise the primary memory is accessed.

(C) Secondary Memory

Primary memory has limited storage capacity and is either volatile (RAM) or read-only (ROM). Thus, a computer system needs auxiliary or secondary memory to permanently store the data or instructions for future use. The secondary memory is non-volatile and has larger storage

capacity than primary memory. It is slower and cheaper than the main memory. But, it cannot be accessed directly by the CPU. Contents of secondary storage need to be first brought into the main memory for the CPU to access. Examples of secondary memory devices include Hard Disk Drive (HDD), CD/ DVD, Memory Card, etc., as shown in Figure.

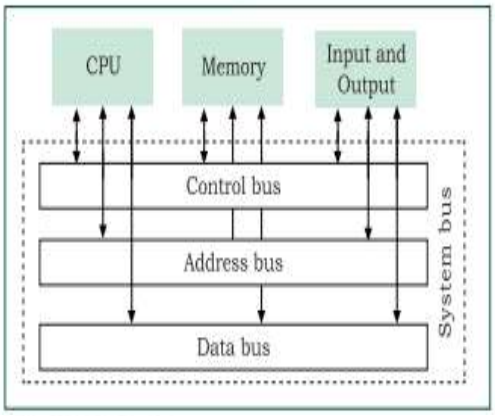
Storage devices

However, these days, there are secondary storage devices like SSD which support very fast data transfer speed as compared to earlier HDDs. Also, data transfer between computers have become easier and simple due to the availability of small-sized and portable flash or pen drives.

DATA TRANSFER BETWEEN MEMORY AND CPU

Data need to be transferred between the CPU and primary memory as well as between the primary and secondary memory.

Data are transferred between different components of a computer system using physical wires called bus. For example, bus is used for data transfer between a USB port and hard disk or between a hard disk and main memory. Bus is of three types— (i) Data bus to transfer data between different components, (ii) Address bus to transfer addresses between CPU and main memory. The address of the memory location that the CPU wants to read or write from is specified in the address bus, and (iii) Control bus to communicate control signals between different components of a computer. All these three buses collectively make the system bus, as shown in Figure.



Data transfer between components through system bus

As the CPU interacts directly with main memory, any data entered from input device or the data to be accessed from hard disk needs to be placed in the main memory for further processing. The data is then transferred between CPU and main memory using bus.

The CPU places on the address bus, the address of the main memory location from which it wants to read data or to write data. While executing the instructions, the CPU specifies the read or write control signal through the control bus.

As the CPU may require to read data from main memory or write data to main memory, a data bus is bidirectional. But the control bus and address bus are unidirectional. To write data into memory, the CPU places the data on the data bus, which is then written to the specific address provided through the address bus. In case of read operation, the CPU specifies the address, and the data is placed on the data bus by a dedicated hardware, called memory controller. The memory controller manages the flow of data into and out of the computer's main memory.

MICROPROCESSORS

Microprocessor is a small-sized electronic component inside a computer that carries out various tasks involved in data processing as well as arithmetic and logical operations. These days, a microprocessor is built over an integrated circuit comprising millions of small components like resistors, transistors and diodes.

Generations of Microprocessor

Generation	Era	Chip type	Word size	Maximum memory size	Clock speed	Cores	Example*
First	1971-73	LSI	4 / 8 bit	1 KB	108 KHz-200 KHz	Single	Intel 8080
Second	1974-78	LSI	8 bit	1 MB	Upto 2 MHz	Single	Motorola 6800 Intel 8085
Third	1979-80	VLSI	16 bit	16 MB	4 MHz - 6 MHz	Single	Intel 8086
Fourth	1981-95	VLSI	32 bit	4 GB	Upto 133 MHz	Single	Intel 80386 Motorola 68030
Fifth	1995 till date	SLSI	64 bit	64 GB	533 MHz - 34 GHz	Multicore	Pentium, Celeron, Xeon

*few prominent examples are included.

SOFTWARE

Till now, we have studied about the physical components or the hardware of the computer system. But the hardware is of no use on its own. Hardware needs to be operated by a set of instructions. These sets of instructions are referred to as software. It is that component of a computer system, which we cannot touch or view physically. It comprises the instructions and data to be processed using the computer hardware. The computer software and hardware complete any task together.

The software comprises a set of instructions which on execution deliver the desired outcome. In other words, each software is written for some computational purpose. Some examples of software include operating systems like Ubuntu or Windows 7/10, word processing tool like LibreOffice or Microsoft Word, video player like VLC Player, photo editors like GIMP and LibreOffice draw. A document or image stored on the hard disk or pen drive is referred to as a soft-copy. Once printed, the document or an image is called a hard-copy.

Need of Software

The sole purpose of a software is to make the computer hardware useful and operational. A software knows how to make different hardware components of a computer work and communicate with each other as well as with the end-user. We cannot instruct the hardware of a computer directly. Software acts as an interface between human users and the hardware.

Hardware refers to the physical components of the computer system which can be seen and touched. For example, RAM, keyboard, printer, monitor, CPU, etc. On the other hand, software is a set of instructions and data that makes hardware functional to complete the desired task.

Depending on the mode of interaction with hardware and functions to be performed, the software can be broadly classified into three categories viz. (i) System software, (ii) Programming tools and (iii) Application software.

System Software

The software that provides the basic functionality to operate a computer by interacting directly with its constituent hardware is termed as system software. A system software knows how to operate and use different hardware components of a computer. It provides services directly to the end user, or to some other software. Examples of system software include operating systems, system utilities, device drivers, etc.

(A) Operating System

As the name implies, the operating system is a system software that operates the computer. An operating system is the most basic system software, without which other software cannot work. The operating system manages other application programs and provides access and security to the users of the system. Some of the popular operating systems are Windows, Linux, Macintosh, Ubuntu, Fedora, Android, IOS, etc.

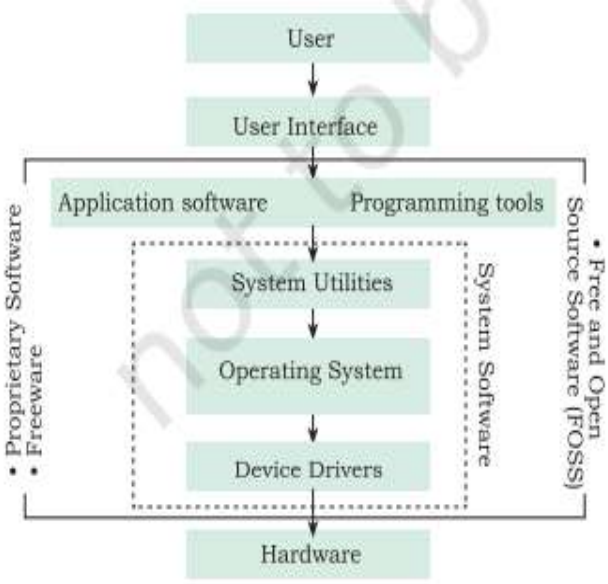
(B) System Utilities

Software used for maintenance and configuration of the computer system is called system utility. Some system utilities are shipped with the operating system for example disk defragmentation tool, formatting utility, system restore utility, etc. Another set of utilities are those which are not shipped with the operating system but are required to improve the performance of the system, for example, anti-virus software, disk cleaner tool, disk compression software, etc.

(C) Device Drivers

As the name signifies, the purpose of a device driver is to ensure proper functioning of a particular device. When it comes to the overall working of a computer system, the operating system does the work. But everyday new devices and components are being added to a computer system. It is not possible for the operating system alone to operate all of the existing and new devices, where each device has diverse characteristics. The responsibility for overall control, operation and management of a particular device at the hardware level is delegated to its device driver.

The device driver acts as an interface between the device and the operating system. It provides required services by hiding the details of operations performed at the hardware level of the device. Just like a language translator, a device driver acts as a mediator between the operating system and the attached device. The categorization of software is shown in Figure.



Categorisation of software

Programming Tools

In order to get some work done by the computer, we need to give instructions which are applied on the input data to get the desired outcome. Computer languages are developed for writing these instructions. It is important to understand here that computers and humans understand completely different languages. While humans are able to write programs in high-level language, computers understand machine language. There is a continuous need for conversion from high level to machine level language, for which translators are needed. Also, to write the instruction, code editors (e.g., IDLE in Python) are needed. We will briefly describe here the programming languages, language translators and program development tools.

A) Classification of Programming Languages

It is very difficult for a human being to write instructions in the form of 1s and 0s. So different types of computer programming languages are developed to simplify the coding. Two major categories of computer programming languages are low-level languages and high-level languages.

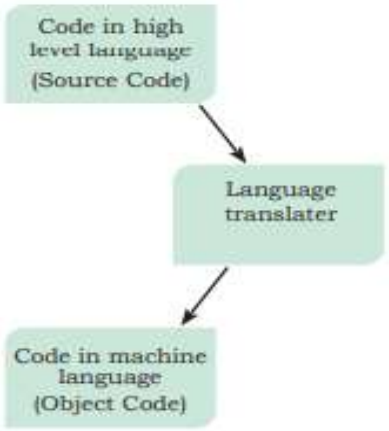
Low-level languages are machine dependent languages and include machine language and assembly language. Machine language uses 1s and 0s to write instructions which are directly understood and executed by the computer. But writing a code in machine language is difficult as one has to remember all operation codes and machine addresses. Also finding errors in the code written in machine language is difficult.

To simplify the writing of code, assembly language was developed that allowed usage of English-like words and symbols instead of 1s and 0s. But one major drawback of writing a code in this language is that the code is computer specific, i.e., the code written for one type of CPU cannot be used for another type of CPU.

High level languages are machine independent and are simpler to write code into. Instructions are using English like sentences and each high level language follows a set of rules, similar to natural languages. However, these languages are not directly understood by the computer. Hence, translators are needed to translate high-level language codes into machine language. Examples of high level language include C++, Java, Python, etc.

(B) Language Translators

As the computer can understand only machine language, a translator is needed to convert program written in assembly or high level language to machine language. The program code written in assembly or high-level language is called source code. The source code is converted by a translator into the machine understandable form called object (machine) code as depicted in Figure.



Translator to convert source code into object code

As we have different types of computer languages, different translators are needed to convert the source code to machine code. The three types of translators used in computing systems are assembler, compiler and interpreter.

The translator used to convert the code written in assembly language to machine language is called assembler. Each assembler can understand a specific microprocessor instruction set only and hence, the machine code is not portable.

We also need translators to convert codes written in high level language (source code) to machine understandable form (machine code) for execution by the computer. Compiler converts the source code into machine code. If the code follows all syntactic rules of the language, then it is executed by the computer. Once translated, the compiler is not needed.

An interpreter translates one line at a time instead of the whole program at one go. Interpreter takes one line, converts it into executable code if the line is syntactically correct, and then it repeats these steps for all lines in the source code. Hence, interpreter is always needed whenever a source code is to be executed.

Application Software

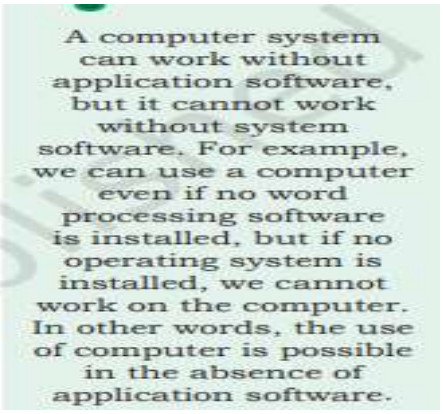
The system software provides the core functionality of the computer system. However, different users need the computer system for different purposes depending upon their requirements. Hence, a new category of software is needed to cater to different requirements of the end-users. This specific software that works on top of the system software is termed as application software. There are again two broad categories of application software — general purpose and customized application software.

(A) General Purpose Software

The application software developed for generic applications, to cater to a bigger audience in general are called general purpose software. Such ready-made application software can be used by end users as per their requirements. For example, spreadsheet tool Calc of LibreOffice can be used by any computer user to do calculation or to create account sheet. Adobe Photoshop, GIMP, Mozilla web browser, iTunes, etc., fall in the category of general purpose software.

(B) Customized Software

These are custom or tailor-made application software, that are developed to meet the requirements of a specific organization or an individual. They are better suited to the needs of an individual or an organization, considering that they are designed as per special requirements. Some examples of user-defined software include websites, school management software, accounting software, etc. It is similar to buying a piece of cloth and getting a tailor-made garment with the fitting, colour, and fabric of our choice.



OPERATING SYSTEM

An operating system (OS) can be considered to be a resource manager which manages all the resources of a computer, i.e., its hardware including CPU, RAM, Disk, Network and other input-output devices. It also controls various application software and device drivers, manages

system security and handles access by different users. It is the most important system software. Examples of popular OS are Windows, Linux, Android, and Macintosh and so on.

The primary objectives of an operating system are two-fold. The first is to provide services for building and running application programs. When an application program needs to be run, it is the operating system which loads that program into memory and allocates it to the CPU for execution. When multiple application programs need to be run, the operating system decides the order of the execution.

The second objective of an operating system is to provide an interface to the user through which the user can interact with the computer. A user interface is a software component which is a part of the operating system and whose job is to take commands or inputs from a user for the operating system to process.