Introduction to Electrical Engineering

Introduction to Computer Systems

INTRODUCTION TO COMPUTER SYSTEMS

Introduction

Today, almost all of us in the world make use of computers in one way or the other. It finds applications in various fields of engineering, medicine, commercial, research and others. Not only in these sophisticated areas, but also in our daily lives, computers have become indispensable. They are present everywhere, in all the devices that we use daily like cars, games, washing machines, microwaves etc. and in day to day computations like banking, reservations, electronic mails, internet and many more.

The word computer is derived from the word compute. Compute means to calculate. The computer was originally defined as a super fast calculator. It had the capacity to solve complex arithmetic and scientific problems at very high speed. But nowadays in addition to handling complex arithmetic computations, computers perform many other tasks like accepting, sorting, selecting, moving, comparing various types of information. They also perform arithmetic and logical operations on alphabetic, numeric and other types of information. This information provided by the user to the computer is data. The information in one form which is presented to the computer is the input information or input data.

Information in another form is presented by the computer after performing a process on it. This information is the output information or output data.

The set of instructions given to the computer to perform various operations is called as the computer program. The process of converting the input data into the required output form with the help of the computer program is called as data processing. The computers are therefore also referred to as data processors.

Therefore a computer can now be defined as a fast and accurate data processing system that accepts data, performs various operations on the data, has the capability to store the data and produce the results on the basis of detailed step by step instructions given to it.

The terms hardware and software are almost always used in connection with the computer.

The Hardware

The hardware is the machinery itself. It is made up of the physical parts or devices of the computer system like the electronic Integrated Circuits (ICs), magnetic storage media and other mechanical devices like input devices, output devices etc. All these various hardware are linked together to form an effective functional unit. The various types of hardware used in the computers, has evolved from vacuum tubes of the first generation to Ultra Large Scale Integrated Circuits of the present generation.

The Software

The computer hardware itself is not capable of doing anything on its own. It has to be given explicit instructions to perform the specific task. The computer program is the one which controls the processing activities of the computer. The computer thus functions according to the instructions written in the program. Software mainly consists of these computer programs, procedures and other documentation used in the operation of a computer system. Software is a collection of programs which utilize and enhance the capability of the hardware.

The Evolution of Computers

The computers of today are vastly different in appearance and performance as compared to the computers of earlier days. But where did this technology come from and Where is it heading? To fully understand the impact of computers on today's world and the promises they hold for the future, it is important to understand the evolution of computers.

The Abacus, which emerged about 5000 years ago in Asia Minor and is still in use today, allows users to make computations using a system of sliding beads arranged on a rack. Early merchants used Abacus to keep trading transactions.

Abacus **Pascaline**

Fig. 1. Computer "Pre-history"

Blaise Pascal, a French mathematician invented the first mechanical machine, a rectangular brass box, called Pascaline which could perform addition and subtraction on whole numbers. This was in the seventeenth century. Colmar, a Frenchman invented a machine that could perform the four basic arithmetic functions of addition, subtraction, multiplication and division. Colmar's mechanical calculator, "Arithmometer", presented a more practical approach to computing. With its enhanced versatility, the "Arithmometer" was widely used until the First World War, although later inventors refined Colmar's calculator, together with fellow inventors, Pascal and Leibniz, he helped define the age of mechanical computation.

The First Generation

Charles Babbage a British mathematician at Cambridge University invented the first analytical engine or difference engine. This machine could be programmed by instructions coded on punch cards and had mechanical memory to store the results. For his contributions in this field Charles Babbage is known as 'the father of modern digital computer.

The first generation computers made use of:

- Vacuum tube technology,
- Punched cards for data input,
- Punched cards and paper tape for output,
- Machine Language for writing programs,
- Magnetic tapes and drums for external storage.

Punched cards **Paper tape** **Vacuum tube**

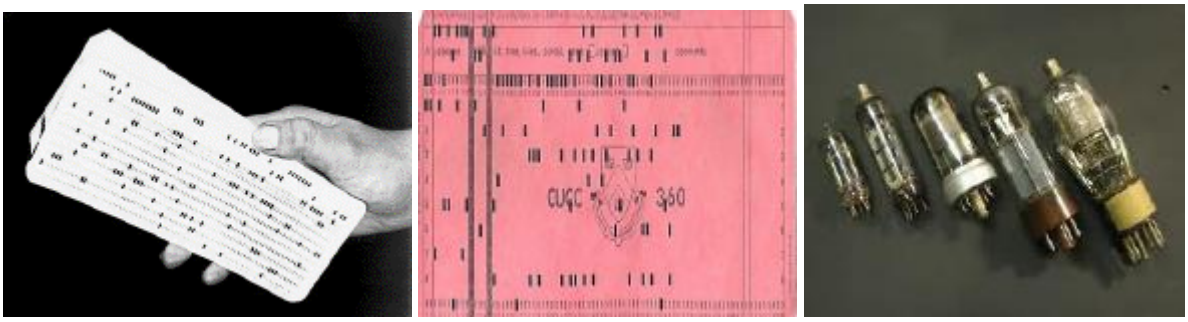

Fig. 2. The first generation computer technology

The computers of the first generation were very bulky and emitted large amount of heat which required air conditioning. They were large in size and cumbersome to handle. They had to be manually assembled and had limited commercial use. The concept of operating systems was not known at that time. Each computer had a different binary coded program called a machine language that told it how to operate.

Some of the early computers included:

Mark I – This was the first fully automatic calculating machine. It was designed by Howard Aiken of Harvard University in collaboration with IBM. This machine was an electronic relay computer. Electromagnetic signals were used for the movement of mechanical parts. Mark I could perform the basic arithmetic and complex equations. Although this machine was extremely reliable, it was very slow (it took about 3-5 seconds per calculation) and was complex in design and large in size.

Atanasoff-Berry Computer (ABC) – This computer developed by John Atanasoff and Clifford Berry was the world's first general purpose electronic digital computer. It made use of vacuum tubes for internal logic and capacitors for storage.

ENIAC (Electronic Numeric Integrator and Calculator) – The first all electronic computer was produced by a partnership between the US Government and the University of Pennsylvania. It was built using 18,000 vacuum tubes, 70,000 resistors and 1,500 relays and consumed 160 kilowatts of electrical power. The ENIAC computed at speed about thousand times faster than Mark I. However, it could store and manipulate only a limited amount of data. Program modifications and detecting errors were also difficult.

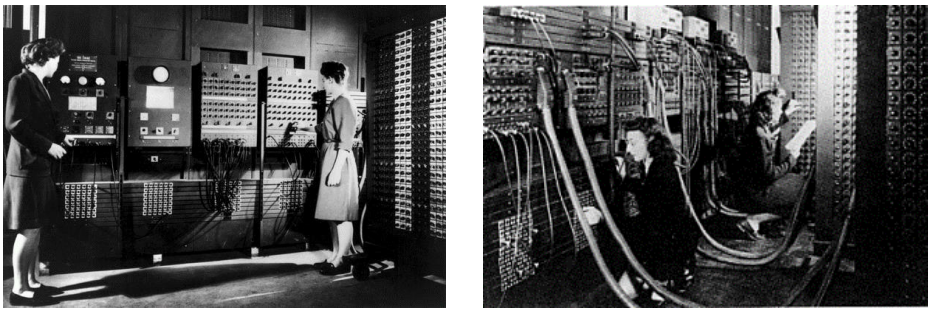

Fig. 3. ENIAC

EDVAC – In the mid 1940's Dr. John von Neumann designed the Electronic Discrete Variable Automatic Computer with a memory to store both program and data. This was the first machine which used the stored program concept. It had five distinct units - arithmetic, central control, memory, input and output. The key element was the central control. All the functions of the computer were co-ordinate through this single source, the central control. The programming of the computers was done in machine language

UNIVAC I – Remington Rand designed this computer specifically for business data processing applications. The Universal Automatic Computer was the first general purpose commercially available computer.

Fig. 4. UNIVAC

The Second Generation

In the second generation computers:

- Vacuum tube technology was replaced by transistorized technology,
- Size of the computers started reducing,
- Assembly language started being used in place of machine language,
- Concept of stored program emerged,
- High level languages were invented.

This was the generation of Transistorized Computers. Vacuum tubes were replaced by transistors. As a result, the size of the machines started shrinking. These computers were smaller, faster, more reliable and more energy efficient. The first transistorized computer was TX-0. The first large scale machines that took advantage of the transistor technology were the early supercomputers, Stretch by IBM and LARC by Sperry Rand. These machines were mainly developed for atomic energy laboratories. Typical computers of the second generation were the IBM 1400 and 7000 series, Honeywell 200 and General Electric.

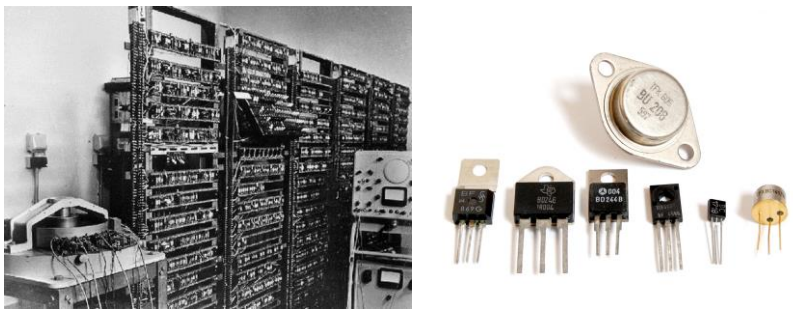

Fig. 5. Transistors

IBM 1401 was universally accepted throughout the industry and most large businesses routinely processed financial information using second generation computers. The machine language was replaced by assembly language. Thus the long and difficult binary code was replaced with abbreviated programming code which was relatively easy to understand.

The stored program concept and programming languages gave the computers flexibility to finally be cost effective and productive for business use. The stored program concept implied that the instructions to run a computer for a specific task were held inside the computer's memory and could quickly be modified or replaced by a different set of instructions for a different function. High level languages like

COBOL, FORTRAN and AL- GOL were dev eloped. Computers started finding vast and varied applications. The entire software industry began with the second generation computers.

The Third Generation

The third generation computers were characterized by:

- Use of Integrated circuits,
- Phenomenal increase in computation speed,
- Substantial reduction in size and power consumption of the machines,
- Use of magnetic tapes and drums for external storage,
- Design-of Operating systems and new higher level languages,
- Commercial production of computers.

This generation was characterized by the invention of Integrated Circuits (ICs). The 1C combined electronic components onto a small chip which was made from quartz.

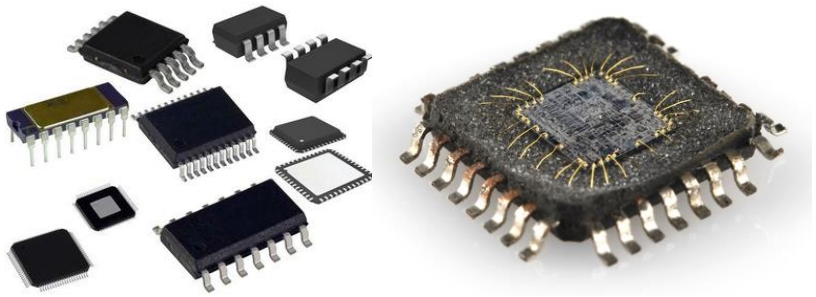

Fig. 6. Integrated Circuits

Later, even more components were fitted onto a single chip, called a semiconductor. This reduced the size even further. The weight and power consumption of computers decreased and the speed increased tremendously. Heavy emphasis was given to the development of software. Operating systems were designed which allowed the machine to run many different programs at once. A central program monitored and co-ordinate the computer s memory. Multiprogramming was made possible, whereby the machine could perform several jobs at the same time. Computers achieved speeds of executing millions of instructions per second. Commercial production became easier and cheaper. Higher level languages like Pascal and Report Program Generator (RPG) were introduced and applications oriented languages like FORTRAN, COBOL, and PL/1 were developed.

The Fourth Generation

The general features of the fourth generation computers were:

- Use of Very Large Scale Integration,
- Invention of microcomputers,
- Introduction of Personal Computers,
- Networking,
- Fourth Generation Languages.

The third generation computers made use of ‘Integrated Circuits that had 10-20 components on each chip, this was Small Scale Integration (SSI). The Fourth Generation realized Large Scale Integration (LSI) which could fit hundreds of components on one chip and Very Large Scale integration (VLSI) which squeezed thousand of components on one chip. The Intel 4004 chip, located all the components of a computer (central processing unit, memory, input and output controls) on a single chip and microcomputers were introduced. Higher capacity storage media like magnetic disks were developed. Fourth generation languages emerged and applications software’s started becoming popular.

Computer production became inexpensive and the era of Personal Computers (PCs) commenced. In 1981, IBM introduced its personal computer for use in office, home and schools. In direct competition,

the Macintosh was introduced by Apple in 1984. Shared interactive systems and user friendly environments were the features of these computers.

Fig. 7. IBM PC and Apple Macintosh

As the computers started becoming more and more powerful, they could be linked together or networked to share not only data but also memory space and software. The networks could reach enormous proportions with local area networks. A global web of computer circuitry, the Internet, links the computers worldwide into a single network of information.

The Fifth Generation

Defining the fifth generation computers is somewhat difficult because the field is still in its infancy. The computers of tomorrow would be characterized by Artificial Intelligence (At). An example of Al is Expert Systems. Computers could be developed which could think and reason in much the same way as humans. Computers would be able to accept spoken words as input (voice recognition).

Many advances in the science of computer design and technology are coming together to enable the creation of fifth generation computers. Two such advances are parallel processing where many CPUs work as one and advance in superconductor technology which allows the flow of electricity with little or no resistance, greatly improving the speed of information flow.

Classification of Computers

Computers are broadly classified into two categories depending upon the logic used in their design as:

Analog computers

In analog computers, data is recognized as a continuous measurement of a physical property like voltage, speed, pressure etc. Readings on a dial or graphs are obtained as the output, ex. Voltage, temperature; pressure can be measured in this way.

Digital Computers

These are high speed electronic devices. These devices are programmable. They process data by way of mathematical calculations, comparison, sorting etc. They accept input and produce output as discrete signals representing high (on) or low (off) voltage state of electricity. Numbers, alphabets, symbols are all represented as a series of 1s and Os. Digital Computers are further classified as General Purpose Digital Computers and Special Purpose Digital Computers. General Purpose computers can be used for any applications like accounts, payroll, data processing etc. Special purpose computers are used for a specific job like those used in automobiles, microwaves etc.

Another classification of digital computers is done on the basis of their capacity to access memory and size like:

Small Computers:

I) Microcomputers: Microcomputers are generally referred to as Personal Computers (PCs). They have Smallest memory and less power. They are widely used in day to day applications like office automation, and professional applications.
II) Note Book and Laptop Computers: These are portable in nature and are battery operated. Storage devices like CDs, floppies etc. and output devices like printers can be connected to these computers. Notebook computers are smaller in physical size than lap top computers. However, both have powerful processors, support graphics, and can accept mouse driven input.
III) Hand Held Computers: These types of computers are mainly used in applications like collection of field data. They are even smaller than the note book computers.

Microcomputer **Notebook or Laptop** **Handheld Computer**

Fig. 8. Small Computers

Hybrid Computers: Hybrid Computers are a combination of Analog and Digital computers. They combine the speed of analog computers and accuracy of digital computers. They are mostly used in specialized applications where the input data is in an analog form i.e. measurement. This is converted into digital form for further processing. The computers accept data from sensors and produce output using conventional input/output devices.

Mini Computers: Mini computers are more powerful than the micro computers. They have higher memory capacity and more storage capacity with higher speeds. These computers are mainly used in

process control systems. They are mainly used in applications like payrolls, financial accounting, Computer aided design etc. ex. VAX, PDP-11

Mainframe Computers: Main frame computers are very large computers which process data at very high speeds of the order of several million instructions per second. They can be linked into a network with smaller computers, micro computers and with each other. They are typically used in large organizations, government departments etc. ex. IBM4381, CDC

Super Computers: A super computer is the fastest, most powerful and most expensive computer which is used for complex tasks that require a lot of computational power. Super computers have multiple processors which process multiple instructions at the same time. This is known as parallel processing. These computers are widely used in very advanced applications like weather forecasting, processing geological data etc. ex. CRAY-2, NEC - 500, PARAM.

Applications of Computers

Today computers find widespread applications in all activities of the modern world. Some of the major application areas include:

Scientific, Engineering and Research: This is the major area where computers find vast applications. They are used in areas which require lot of experiments, mathematical calculations, weather forecasting, and complex mathematical and engineering applications. Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM) help in designing robotics, automobile manufacturing, automatic process control dev ices etc.

Business: Record keeping, budgets, reports, inventory, payroll, invoicing, accounts are all the areas of business and industry where computers are used to a great extent. Database management is one of the major area where computers are used on a large scale. The areas of application here include banking, airline reservations, etc. where large amounts of data need to be updated, edited, sorted, searched from large databases.

Medicine: Computerized systems are now in widespread use in monitoring patient data like , pulse rate, blood pressure etc. resulting in faster and accurate diagnosis. Modern day medical equipment are highly computerized today. Computers are also widely used in medical research.

Information: This is the age of information. Television, Satellite communication, Internet, networks are all based on computers.

Education: The use of computers in education is increasing day by day. The students develop the habit of thinking more logically and are able to formulate problem solving techniques. CDs on a variety of subjects are available to impart education. On line training programs for students are also becoming popular day by day. All the major encyclopedias, dictionaries and books are now available in the digital form and therefore are easily accessible to the student of today. Creativity in drawing, painting, designing, decoration, music etc. can be well developed with computers.

Games and Entertainment: Computer games are popular with children and adults alike. Computers are nowadays also used in entertainment areas like movies, sports, advertising etc.

Advantages and Disadvantages of Computers

Advantages of Computers

Speed: The speed of a computer is measured in terms of the number of instructions that it can perform or execute in a second. The speeds of computers are measured in milliseconds (10~3 sec), micro-seconds (10*6 sec), and nano-seconds (10~9sec). Computers are superfast machines and can process millions of instructions per second. Smaller computers can execute thousands of instructions per second, while the more complex machines can execute millions of instructions per second.

Accuracy: Computers are very accurate. They are capable of executing hundreds of instructions without any errors. They do not make mistakes in their computations. They perform each and every calculation with the same accuracy.

Efficiency: The efficiency of computers does not decrease with age. The computers can perform repeated tasks with the same efficiency any number of times without exhausting there selves. Even if they are instructed to execute millions of instructions, they are capable of executing them all with the same speed and efficiency without exhaustion.

Storage Capability: Computers are capable of storing large amounts of data in their storage devices. These dev ices occupy very less space and can store millions of characters in condensed forms. These storage devices typically include floppy disks, tapes, hard disks, CDs etc, the data stored on these devices can be retrieved and reused whenever it is required in future

Versatility: Computers are very versatile. They are capable not only of performing complex mathematical tasks of science and engineering, but also other nonnumerical operations fielding air-line reservation, electricity bills, data base management etc.

Limitations of Computers

Although the computers of today are highly intelligent and sophisticated they have their own limitations. The computer cannot think on its own, since it does not have its own brain. It can only do what is has been programmed to do. It can execute only those jobs that can be expressed as a finite set of instructions to achieve a specific goal. Each of the steps has to be clearly defined. The computers do not learn from previous experience nor can they arrive at a conclusion without going through all the intermediate steps. However the impact of computers on today's society in phenomenal and they are today an important part of the society.

Similarities and Difference between Human and Computer

Computer is a very effective and efficient machine which performs several activities in few minutes, which otherwise would have taken several days if performed naturally. Besides there would have been a doubt about the accuracy, finish etc. The computer may be faster; more accurate but it cannot compete with human brain. However there are some similarities between the human and the computer which would make the computer more understandable.

Human	Computer
# Like human beings has ears, nose, eyes etc.	Computers have input devices such as keyboard, scanner, touch screen, mouse etc to get information.
# Like we remember things	Computer also stores information.
#We recollect certain information as required.	The computer also retrieves information when times,
#We express ourselves by speech, writing etc	Computer expresses through screen, Printouts etc which We call as output.
#When we watch, hear, learn certain things and analyze.	with the help of software, computer also can analyze Information and draw conclusions.
#The place where we store,analyze,	The computer brain is known as CPU conclude information is known as the brain (Central Processing Unit) where it analyses information.

The computer has storage devices like floppies, hard disks, compact disks to store and retrieve information. However computer does not understand emotions, it does not understand meaning beyond words, it cannot read between the lines like the human. We learn many things unknowingly, certain things knowingly; we call it as upbringing. But computers can learn everything only knowingly. We learn many things on our own, but computer has to be taught to do everything.

Computer Systems

Any system is defined as a group of integrated parts which are designed to achieve a common objective. Thus, a system is made up of more than one element or part, where each element performs a specific function and where all the elements (parts) are logically related and are controlled in such a way that the goal (purpose) of the system is achieved.

A computer is made up of a number of integrated elements like

- The central processing unit,
- The input and output devices and
- The storage devices.

Each of these units performs a specific task. However, none of them can function independently on their own. They are logically related and controlled to achieve a specific goal. When they are thus integrated they form a fully fledged computer system.

The Central Processing Unit

This is the brain of any computer system. The central processing unit or CPU is made of three parts:

- The control unit.
- The arithmetic logic unit
- The primary storage unit

The Control Unit: The Control Unit controls the operations of the entire computer system. The control unit gets the instructions from the programs stored in primary storage unit interprets these instruction and subsequently directs the other units to execute the instructions. Thus it manages and coordinates the entire computer system.

The Arithmetic Logic Unit: The Arithmetic Logic Unit (ALU) actually executes the instructions and performs all the calculations and decisions. The data is held in the primary storage unit and transferred to the ALU whenever needed. Data can be moved from the primary storage to the arithmetic logic unit a number of times before the entire processing is complete. After the completion, the results are sent to the output storage section and the output devices.

The Primary Storage Unit: This is also called as Main Memory. Before the actual processing starts the data and the instructions fed to the computer through the input units are stored in this primary storage unit. Similarly, the data which is to be output from the computer system is also temporarily stored in the primary memory. It is also the area where intermediate results of calculations are stored. The main memory has the storage section that holds the computer programs during execution. Thus the primary unit:

- Stores data and programs during actual processing
- Stores temporary results of intermediate processing
- Stores results of execution temporarily

Input and Output

The Input Unit: Input devices are the devices which are used to feed programs and data to the computer. The input system connects the external environment with the computer system. The input dev ices are the means of communication between the user and the computer system. Typical input devices include the keyboard, floppy disks, mouse, microphone, light pen, joy stick, magnetic tapes etc. The way in which the data is fed into the computer through each of these devices is different. However, a computer can accept data only in a specific form. Therefore these input devices transform the data fed to them, into a form which can be accepted by the computer. These devices are a means of communication and inter1 station between the user and the computer systems.

Thus the functions of the input unit are:

- accept information (data) and programs.

- convert the data in a form which the computer can accept.
- provide this converted data to the computer for further processing.

The Output Unit: The output devices give the results of the process and computations to the outside world. The output units accept the results produced by the computer, convert them into a human readable form and supply them to the users. The more common output devices are printers, plotters, display screens, magnetic tape drives etc.

Input Devices and Output Devices

The devices of the computer system which are a means of communication between the computer system and the outside world are called as peripheral devices. Those devices which accept data from the user are input devices, and those devices that give information from the computer to the user or store it in secondary storage devices for later use are output devices.

Input Output Interfaces are the processors which convert the data input by the user into a form which can be understood by the computer and also convert output generated by the computer into a human readable form. Data can be entered in the computer directly i.e. online or after first preparing it and entering later i.e. offline.

The various input devices are:

- Keyboard - is the most commonly used device for on line data entry. It is very easy to use, inexpensive and allows on-line data editing.
- Mouse -is a pointing device used along with a keyboard to control cursor movement, select data etc. Light pen, joystick and track ball are also similar devices used for cursor control.
- Digitizer - This converts pictorial data into a digital form which can be directly entered and stored in a computer.
- Scanner – It can directly enter text and images into computer memory using light source or magnetic ink recognition.
- Voice recognition system – It converts the speech of the operator into electrical signals for data entry.
- Cameras – They input images or video.
- Storage devices – These devices insert digital data of various forms into the computer.

The common output devices are:

- Display Terminals such as monitors or a terminal which is a combination of a monitor and keyboard together.
- Printers which transfer data and results to paper.
- Plotters which are mainly use for output of graphs and drawings.
- Speakers and head phones to output sound.

Fig. 9. Input and Output Devices

Primary Storage and Secondary Storage Devices

A storage unit is that part of the computer system which is used to store the data and instructions to be processed. There are two types of storage:

1) Primary storage
2) Secondary storage.

Primary memory is also known as internal memory. This is a section of the CPU which holds program instructions, input data and intermediate results. Primary memory is also known as main memory.

Secondary storage is a memory that is stored external to the computer. It is used mainly for permanent and long term storage of programs and data.

Characteristics of Storage units:

The storage units have special characteristics which decide the:

- Speed of operation of the computer,
- Its efficiency,
- Cost and
- The amount of data which the computer can store.

The storage unit of the computer is graded according to the following characteristics (whether primary or secondary):

Access time: This is the time required to locate and retrieve a particular data from the storage unit. A fast access to data and programs always yields higher efficiency.

Storage Capacity: Storage capacity is the amount of data that can be stored by a storage unit. Large capacity of data storage is always desirable. As seen earlier, the smallest unit of data which the computer understands is the bit. A group of 8 bits forms a byte. The storage capacity of a computer system is defined in terms of bytes or words. One kilobyte (1 KB) is 2^ or 1024 bytes, eg. 4 KB memory implies that it can store 4 x 1024 bytes or characters. Storage capacities of primary and secondary units are measured in Kilobytes, megabytes, gigabytes.

Cost: Low cost storage media are always desirable. Thus, storage units with faster access time, higher storage capacity and low costs are the ones which are considered to be of a superior nature.

Primary Storage

Primary storage is characterized by faster access time, less storage capacity and higher costs as compared to secondary storage units. Primary storage or main memory is that part of the computer system which stores the programs, data and intermediate results during the program execution.

A primary storage comes as an integral part of all computer systems. It comprises of a number of small locations. Each location has a unique number assigned to it. This is called as the address of the location and it is used to identify the location. Each location has a capacity to store a fixed number of bits. The number of bits that a location can store is called as word length. Each location contains the same number of bits.

Normally, primary memory size ranges from a few kilobytes on small computers to several thousand kilo bytes and megabytes on larger machines. The primary storage is volatile. Whenever the power is turned off the data is lost. Primary storage is also called Random Access Memory (RAM). RAM means it is possible to randomly select and use any storage location for storage and retrieval of data. RAM is also called a read/write memory because data can both be read from and written onto these units. When the power is switched off the data stored in the RAM is lost.

ROM: ROM is Read Only Memory. In this type of memory the data is permanently stored. The information can only be read and new data cannot be written onto this memory. However the contents of the ROM are not lost even when the power is turned off i.e. this memory is non-volatile. Such memories are also called as field stores, or permanent stores.

There are a number of high level functions which are required to be performed by the computer system. Such functions are performed by writing special programs called micro programs. Micro programs generally execute the low level machine functions. These programs are mainly used as a substitute for hardware. Such programs can be stored on ROMs and be used again and again. This results in reducing the hardware of the system. ROM helps to increase the efficiency of the CPU as it can perform specialized tasks. ROM comes in the form of a chip. Once information is stored on a ROM chip it cannot be changed or altered.

Cache Memory: This is a very special type of high speed memory. This memory cannot be accessed by the user. The main function of this cache memory is to make the programs and data available to the CPU very fast. Access time of memory is generally very high as compared to the execution time of the GPU. Therefore a cache, which is a very small but fast memory, is used between the CPU and the main memory. This memory also called a high speed buffer. A cache stores those segments of programs and data which are frequently needed. It makes available this data to the CPU at a very fast rate thus increasing the efficiency.

Registers: Registers are used to retain information temporarily. These are special memory units which are not actual parts of the main memory, but allow efficient movement of information between the various units of the computer system. The registers receive information, hold it temporarily and make it available as and when required. A computer uses a number of registers, where each register performs a specific function. Some of the common registers are:

1) Memory Address Register (MAR): The function of this register is to hold the address of the current or active memory location.
2) Memory Buffer Register (MBR): This register holds the contents of the address from which data is read or to which data has been written.
3) Program Control Register: It holds the address of the next instruction to be executed.
4) Accumulator Register: It holds the initial data, the intermediate results and the final data of the program under execution.
5) Instruction Register: This register holds the current instruction being executed.
6) Input/output Register: The function of this register is to communicate with the Input/output devices.

The storage capacity of primary storage is limited. It is normally not sufficient to accommodate all the data. Therefore secondary storage medium is used to store large volumes of data. The cost of secondary memory is much less as compared to primary memory, however access time of primary memory is very fast. The data stored on secondary storage is transferred to the primary storage as and when required. Secondary storage is also called auxiliary memory. Secondary storage is used for storing copies of data and programs. This is a non volatile memory and is stored external to the computer.

Fig. 10. Internal storage devices

Secondary Storage Devices

Secondary storage devices are used to store large amounts of data. Secondary storage devices are cheaper as compared to primary storage. However their data access time is longer. Secondary storage is non volatile and stored external to the computer.

There are two ways in which data can be accessed from the secondary devices:

- sequential access, and
- random access.

Punched paper tape and magnetic tape are sequential access devices. Punched paper tapes are nowadays not being used. Magnetic tapes can store unlimited data and have a high data density. They are also low in cost and portable. But since information can be accessed only sequentially, they are slow.

Direct access or random access devices allow the access of data from any storage location randomly, without having to follow the sequence in which it has been stored. Some random access devices are:

- A magnetic disk, or hard disk, is made of a thin Mylar platter and coated on both sides by magnetic material. Data is recorded as magnetic spots on this disk. A number of such disks are mounted on a disk pack. Each disk is divided into a number of concentric circles called tracks. All the corresponding tracks in all the surfaces together are called as a cylinder. These disks are also called hard disks and can be permanently installed in a disk drive in the computer.
- Floppy disks are made of flexible mylar coated with iron oxide. The floppy disks came in various sizes like 8 inch, 5 ¼ inch, 3 ½ inch. Floppy disks were relatively cheap and could store data online. They were also very portable. They are not used any more.
- Optical laser techniques are used to write data onto optical devices like optical disks, CDs or DVDs. The storage capacities of these devices is usually very large.
- Solid-state storage (SSS) is a type of computer storage media that stores data electronically and has no moving parts. Solid state storage is made from silicon microchips. Because there are no moving parts, SSDs require less power and produce far less heat than spinning hard disk drives or magnetic tape.

Fig. 11. External Storage Devices