Class Notes of

Basic Electronics Engineering

1st Semester

of

Electrical Engineering

Under SCTE&VT , Odisha.

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Basic Electronics Engineering.
Chapter-1

1. ELECTRONIC DEVICES
Define Electronics & its application.

The world's reliance on electronics is so great that commentators claim people live in an "electronic age." People are surrounded by electronics—televisions, radios, computers, mobiles, Laptop and DVD players, along with products with major electric components, such as microwave ovens, refrigerators, and other kitchen appliances, automatic vehicles, Robotics, as well as hearing aids and medical instruments and numerous applications in industry.

***Definition**: The branch of engineering which deals with current conduction through a Vacuum or Gas or Semiconductor is known as* **Electronics.** An *electronic device* is that in which current flows through a vacuum or gas or semiconductor. This control of electrons is accomplished by devices that resist, carry, select, steer, switch, store, manipulate, and exploit the electron.

Or

Electronics deals with electrical circuits that involve active electrical components such as vacuum tubes, transistors, diodes and integrated circuits, and associated passive interconnection technologies. Commonly, electronic devices contain circuitry consisting primarily or exclusively of active semiconductors supplemented with passive elements; such a circuit is described as an electronic circuit.

Pre Knowledge (Some of the basic definitions):
Passive Components: Capable of operating without an external power source. Typical passive components are resistors, capacitors, inductors.
Active components: Requiring a source of power to operate. Includes transistors (all types), integrated circuits (all types), TRIACs, SCRs, LEDs, etc.

APPLICATIONS of Electronics:

E*lectronic components*: capacitor (C), cathode ray tube (CTR), diode (D), digital signal processor (DSP, field effect transistor (FET), integrated circuit (IC), junction gate field effect transistor (JFET), inductor (L), Liquid crystal display (LCD), light dependent resistor (LDR, light emitting diode (LED), Metal oxide semiconductor field effect transistor (MOSFET), transistor

Consumer Electronics include products like – Audio Systems, Video Systems, TV (Television), Computer, Laptop, Digital Camera, DVD Players, Home and Kitchen Appliances, GPS, Mobiles Phones etc.

Communication. Electronic communication systems connect people around the world. Using telephones, Internet and computers, people in different countries communicate almost instantly. Radios transmit sounds and televisions transmit sounds and pictures great distances. Cellular telephones enable a person to call another person. Within seconds, fax machines send and receive copies of documents over telephone lines/Satellite.

Information processing. Scientists, artists, students, government and business workers, and hobbyists at home all rely on computers, Internet to handle huge amounts of information quickly and accurately. Computers solve difficult mathematical problems, maintain vast amounts of data, create complex simulations, and perform a multitude of other tasks that help people in their everyday lives.

Medicine and research. Include product like X-ray machines ECG (Electrocardiogram) use radiation to take images of bones and internal organs. Radiation therapy, or radiotherapy, uses X-rays and other forms of radiation to fight cancer. Many hearing-impaired people depend on hearing aids to electrically amplify sound waves.

Computers and other electronic instruments provide scientists and other researchers with powerful tools to better understand their area of study. Computers, for example, help scientists design new drug molecules, track weather systems, and test theories about how galaxies and stars develop. Electron microscopes use electrons rather than visible light to magnify specimens 1 million times or more.

Automation. Electronic components enable many common home appliances, such as refrigerators, washing machines, and toasters, to function smoothly and efficiently. People can electronically program coffeemakers, lawn sprinklers, and many other products to turn on and off automatically. Microwave ovens heat food quickly by penetrating it with short radio waves produced by a vacuum tube.

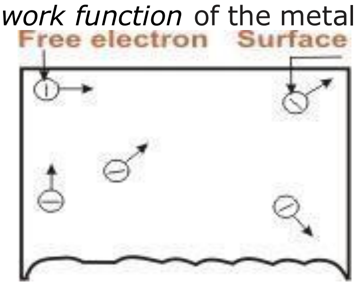
Instrumentation. Measuring Instruments like CRO, Multimeter, ph-meter, strain gauge, VTVM, Frequency Counter are used in different Laboratory/organisations.

Many automobiles have electronic controls in their engines and fuel systems. Electronic devices also control air bags, which inflate to protect a driver and passengers in a collision.

Define Electronic Emission & different types of Emission.

The Electronics devices depends the movements of free Electrons in an evacuated space. *The liberation of electrons from the surface of a metal is known as* ***Electron Emission.***

- For electron emission, metals are used because they have many free electrons.
- The electrons are free only to transfer from one atom to another within the metal but they cannot leave the metal surface to provide electron emission.
- Thus at the surface of the metal, a free electron encounters forces that prevent it to leave the metal.
- In other words, the metallic surface offer a barrier to free electrons, their kinetic energy increases and is known as surface barrier.
- However, if sufficient energy is given to the free electrons, their kinetic energy increases and thus the electrons will cross over the surface barrier to leave the metal.
- This additional energy required by an electron to overcome the surface barrier of the metal is called *work function* of the metal.



The metallic surface offers a barrier to free electrons and is known as *surface barrier*.

Work function (W_0): *The amount of additional energy*(such as heat energy, energy stored in electric field, light energy or kinetic energy of the electric charges bombarding the metal surface) *required to emit an electron from a metallic surface is known as* work function *of that metal*. The minimum energy required by an electron to just escape (i.e. with zero velocity) from metal's surface is called **Work function (W_0)** of the metal. The work function of pure metals varies (roughly) from 2eV to 6eV. Its value depends upon the nature of the metal, its purity and the conditions of the surface.

Different types of Emission:

There are following four principal method of obtaining electron emission from the surface of a metal:

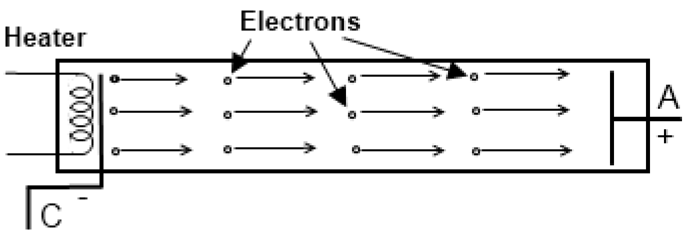
1. Thermionic Emission - (Due to Thermal energy)
2. Field Emission - (*Due to application of strong electric field)*
3. Secondary Emission – (***due to bombardment of high-speed electrons)***
4. Photo Electric Emission – (*by the application of light)*

1. Thermionic Emission

The process of electron emission from a metal surface by supplying thermal energy to it is known as **Thermionic emission**.

In this type of emission the electron emission is achieved by heating the electrode to a sufficient temperature (about 2500°C) to enable the free electrons to leave the metal surface. Due to heating the electrons get enough energy that they emit from the surface of that material heat energy is converted into kinetic energy, causing accelerated motion of free electrons and electrons acquire additional energy equal to the work function of the metal. An electron emitted from a hot cathode comes out with a velocity that presents different between the kinetic energy possessed by electron just before emission usually used in cathode of diode, triode, pentode, CRT and many other. The higher the temperature, the greater is the emission of electrons. The commonly used materials for electron emission are *tungsten, thoriated tungsten* and *metallic oxides of barium and strontium*.

S.No.	Emitter	Work Function	Operating Temperature
1	*Tungsten*	4.52 eV	2327ºC
2	*Thoriated tungsten*	2.63 eV	1700ºC
3	*Oxide-coated*	1.1 eV	750ºC



2. Field Emission

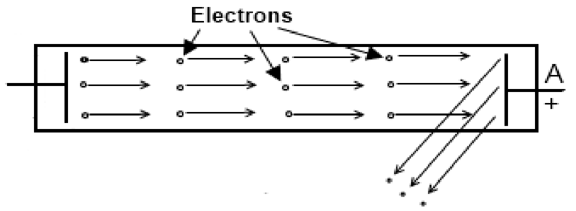
The process of electron emission by the application of strong electric field at the surface of a metal is known as **field emission.**

When metal surface is placed in an electric field, the electron rotating in their orbits experience a force due to electrostatic field. Hence the process of electron emission by application of strong electric field at the surface of a metal is called field emission. It is also called *cold cathode emission* or *auto- electronic emission*.

3. Secondary Emission

Electron emission from a metallic surface by the bombardment of high-speed electrons or other particles is known as secondary emission.

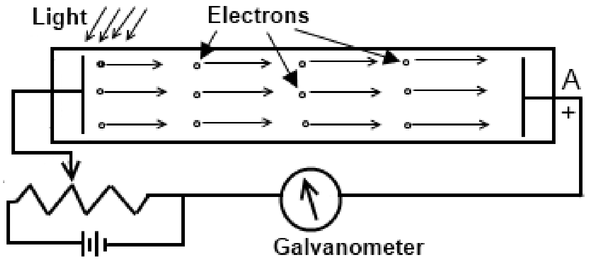
When high-speed electrons suddenly strike a metallic surface, they may give some or all of their kinetic energy to the free electrons in the metal. If the energy of the striking electrons is sufficient, it may cause free electrons to escape from the metal surface. This phenomenon is called secondary emission. The electrons that strike the metal are called primary electrons while the emitted electrons are known as secondary electrons. The intensity of secondary emission depends upon the emitter material, mass and energy of the bombarding particles.



4. Photo Electric Emission

Electron emission from a metallic surface by the application of light is known as photo electric emission.

When a beam of light strikes the surface of cathode normally made of potassium, Sodium the energy of photons of light is transfer to the free electrons of cathode. In this method, the energy of light falling upon the metal surface is transferred to the free electrons within the metal to enable them to leave the surface. The greater the intensity of light beam falling on the metal surface, the greater is the photoelectric emission. The emitted electrons are known as *photo electrons* and the phenomenon is known as *photoelectric emission*. Photo-electric emission is utilised in photo tubes which form the basis of television and sound films.



Classification of solid according to electrical conductivity (Conductor, Semiconductor & Insulator) with respect to energy band diagram only.

Pre-Knowledge:

(i) Valence band. *The range of energies (i.e. band) possessed by valence electrons is known as* **valence band.** The electrons in the outermost orbit of an atom are known as valence electrons. This band may be completely or partially filled.

(ii) Conduction band.

The range of energies (i.e. band) possessed by conduction band electrons is known as **conduction band.** Generally, insulators have empty conduction band. On the other hand, it is partially filled for conductors. The free electrons which are responsible for the conduction of current in a conductor are called *conduction electrons*.

(iii) Forbidden energy gap. *The separation between conduction band and valence band on the energy level diagram is known as* **forbidden energy gap.**

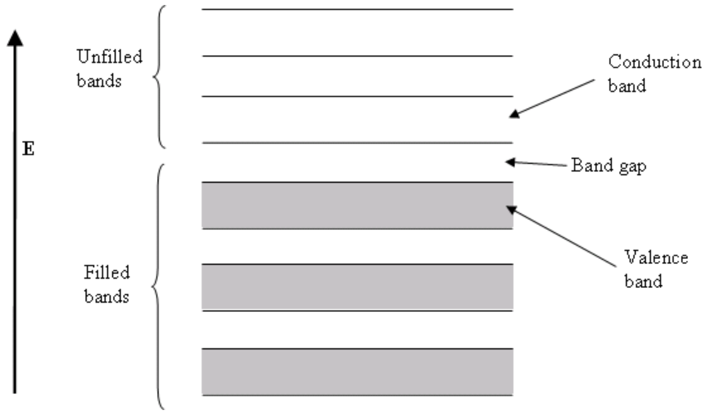


Fig 1. Energy band diagram

Classification:

Solid-state materials According to electrical conductivity can be classified into three groups. Such as:

1. Insulators - Insulators are materials having an electrical conductivity $\sigma < 10^{-8} S/cm$ (like diamond: 10-14S/cm);
2. Semiconductors - semiconductors have a conductivity $10^{-8} S/cm < \sigma < 10^{3} S/cm$ (for silicon it can range from 10-5S/cm to 103S/cm)
3. Conductors - at last conductors are materials with high conductivities: $10^{3} S/cm < \sigma$ (like silver: 106S/cm.)

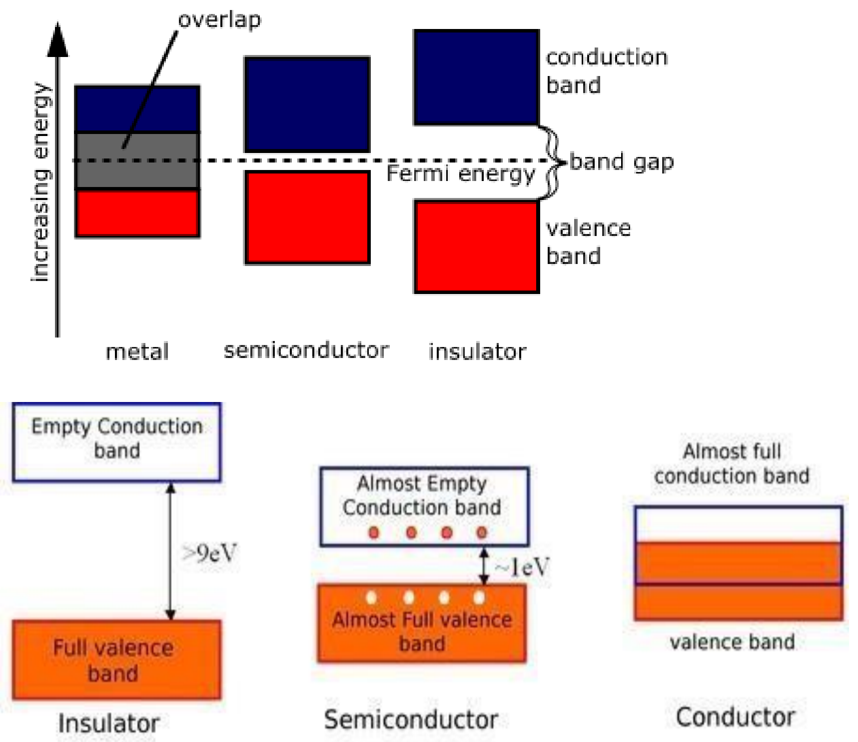


Figure 2 : Representation of energy bands

(i) **Insulators.** Insulators (*e.g.* wood, glass, plastics,rubber etc.) are those substances which do not allow the passage of electric current through them. In terms of energy band, the valence band is full while the conduction band is empty as shown in Fig 2. Further, the energy gap between valence and conduction bands is very large (***15 eV***). Therefore, a very high electric field is required to push the valence electrons to the conduction band. For this reason, the electrical conductivity of such materials is extremely small. At room

temperature, the valence electrons of the insulators do not have enough energy to cross over to the conduction band. However, when the temperature is raised, some of the valence electrons may acquire enough energy to cross over to the conduction band. Hence, the resistance of an insulator decreases with the increase in temperature *i.e.* an insulator has negative temperature coefficient of resistance.

(ii) **Conductors.** Conductors (*e.g.* copper, aluminum) are those substances which easily allow the passage of electric current through them. It is because there are a large number of free electrons available in a conductor. In terms of energy band as in Fig 2, the valence and conduction bands overlap each other due to this overlapping; a slight potential difference across a conductor causes the free electrons to constitute electric current.

(iii) **Semicondutors.** Semiconductors (*e.g. germanium, silicon etc*.) are those substances whose electrical conductivity lies in between conductors and insulators. In terms of energy band, the valence band is almost filled and conduction band is almost empty in fig 2. Further, the energy gap between valence and conduction bands is very small. The semiconductor has :

(a) Filled valence band
(b) Empty conduction band
(c) Small energy gap or forbidden gap (1 eV) between valence and conduction bands.
(d) Semiconductor virtually behaves as an insulator at low temperatures. However, even at room temperature, some electrons cross over to the conduction band, imparting little conductivity (i.e. conductor).

Discuss Intrinsic & Extrinsic Semiconductor.

Intrinsic Semiconductor

A semiconductor in an extremely pure form is known as an **intrinsic semiconductor**.

In this case the holes in the valence band are vacancies created by electrons that have been thermally excited to the conduction band and hole-electron pairs are created. When electric field is applied across an intrinsic semiconductor, the current conduction takes place by two processes, namely; by *free electrons* and *holes* as shown in Fig 3. The free electrons are produced due to the breaking up of some covalent bonds by thermal energy. At the same time, holes are created in the covalent bonds. Under the influence of electric field, conduction through the semiconductor is by both free electrons and holes. Therefore, the total current inside the semiconductor is the sum of currents due to free electrons and holes. This creates new holes near the positive terminal which again drift towards the negative terminal.

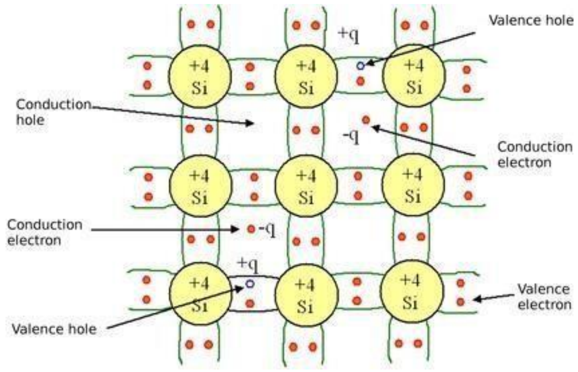


Figure 3 : Diagram showing the electronic bonds in an intrinsic semiconductor (Si)

Extrinsic Semiconductor

An extrinsic semiconductor is a semiconductor doped by addition of small amount impurity which is able to change its electrical properties (conduction), making it suitable for electronic applications (diodes, transistors, etc.) or optoelectronic applications (light emitters and detectors). This is achieved by adding a small amount of suitable impurity (having 3 or 5 valence electron) to a semiconductor (having 4 valence electron). It is then called impurity or extrinsic semiconductor.

- The process of adding impurities to a semiconductor is known as *doping*. The purpose of adding impurity is to increase either the number of free electrons or holes in the semiconductor crystal.
- If a penta valent impurity (having 5 valence electrons) is added to the semiconductor, a large number of free electrons are produced in the semiconductor.
- If a trivalent impurity (having 3 valence electrons) is added to the semiconductor, large number of holes are produced in the semiconductor crystal.
- Depending upon the type of impurity added, extrinsic semiconductors are classified into:
  (i) *n*-type semiconductor
  (ii) *p*-type semiconductor

(i) *n*-type Semiconductor

When a small amount of pentavalent impurity is added to a pure semiconductor, it is known as **n-type semiconductor.**

The addition of pentavalent impurity pro-vides a large number of free electrons in the semiconductor crystal. Typical examples of pentavalent impurities are *arsenic , antimony,Bismuth and Phosphorous etc*. Such impurities which produce *n*-type semiconductor are known as *donor impurities* because they donate or provide free electrons to the semiconductor crystal.

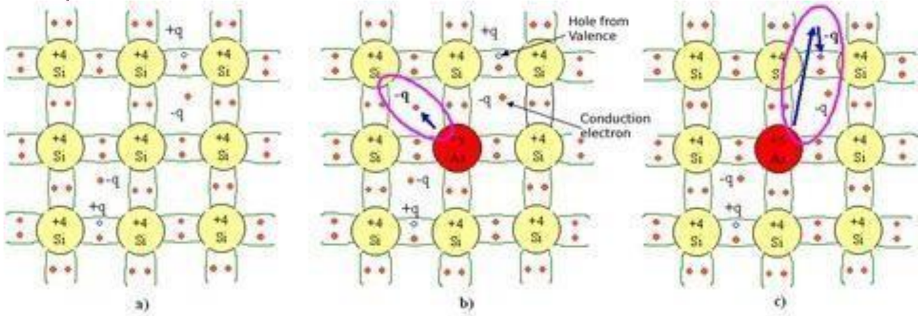


Figure 4 : Schematic representation of electronic bonds in a Silicon crystal doped with Arsenic As (n doping)

- Electrons are said to be the majority carriers whereas holes are the minority carriers.

(ii) *p*-type Semiconductor

When a small amount of trivalent impurity is added to a pure semiconductor, it is called **p-type Semiconductor.**

The addition of trivalent impurity provides a large number of holes in the semiconductor. Typical examples of trivalent impurities are *gallium , indium, boron etc*. Such impurities which produce *p*-type semiconductor are known as *acceptor impurities* because the holes created can accept the electrons fig 5.

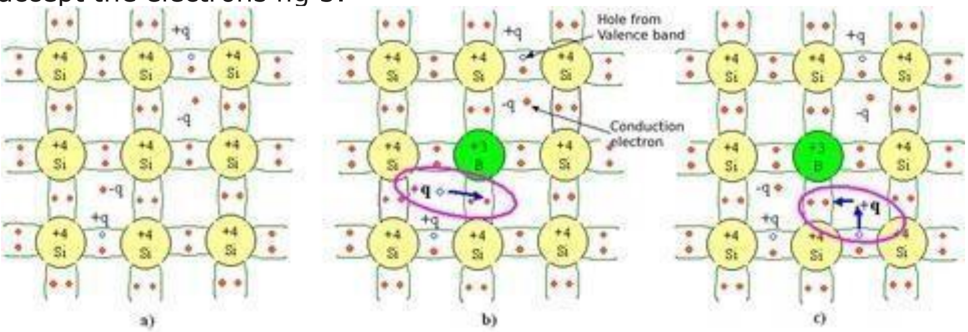


Figure 5 : schematic representation of a Si crystal doped with boron (B)

Electrons are said to be the minority carriers whereas holes are the majority carriers.

Explain the difference between vacuum tube & semiconductor.

Figure 6: Vacuum tubes

Vacuum Tubes:

Advantages

1. Superior sound quality.
2. Can handle large currents
3. Tolerant of large overloads and voltage spikes.
4. Characteristics highly independent of temperature, greatly simplifying biasing.
5. Wider dynamic range than transistors circuits, due to higher operating voltages and overload tolerance.
6. Capacitive coupling can be done with small, high-quality film capacitors, due to inherently high-impedances of tube circuits.
7. Operation is usually in Class A or Class AB, minimizing crossover notch distortion.
8. Tubes can be relatively easily replaced by user.

Disadvantages

1. Bulky(Larger in Size), hence not suitable for portable products
2. Higher operating voltages required.
3. High power consumption; needs heater supply that generates waste heat and yields lower efficiency, notably for small-signal circuits.
4. Glass tubes are fragile, compared to metal transistors.
5. Cathode electron-emitting materials are used up in operation.
6. High-impedance devices that need impedance matching transformer for low-impedance loads, like speakers; however, the magnetic cushion provided by an output transformer prevents the output tubes from blowing up.
7. Sometimes higher cost than equivalently powered transistors.
8. Complicated in manufacturing process.

Transistors:

Advantages

1. Usually smaller size, lower cost and longer life.
2. Can handle small current
3. Can be combined in the millions on one cheap die to make an integrated circuit, whereas tubes are limited to at most three functional units per glass bulb.
4. Lower power consumption, less waste heat, and high efficiency than equivalent tubes, especially in small-signal circuits.
5. Can operate on lower-voltage supplies for greater safety, lower costs, tighter clearances.
6. Usually more physical ruggedness than tubes (depends upon construction).

Disadvantages

1. Tendency toward higher distortion
2. Complex circuits and considerable negative feedback required for low distortion.
3. Large unit-to-unit manufacturing tolerances and unreliable variations in key parameters, such as gain and threshold voltage.
4. Device parameters vary considerably with temperature, complicating biasing and increasing likelihood of thermal runaway.
5. Cooling is less efficient than with tubes, because lower operating temperature is required for reliability. Tubes prefer hot; transistors do not. Massive, expensive and unwieldy heat sinks are always required for power transistors, yet they are not always effective

(power output transistors still blow up; whereas, tubes fade down gracefully over time with warning.)

6. Less tolerant of overloads and voltage spikes than tubes.
7. Capacitive coupling usually requires high-value electrolytic capacitors, which give audibly and measurably inferior performance at audio frequency extremes.
8. Greater tendency to pick up radio frequency interference and self-oscillate to the point of self-destruction, due to rectification by low-voltage diode junctions or slew-rate effects.
9. Maintenance more difficult; devices are not easily replaced by user.

State basic concept of Integrated Circuits (I.C) & its use.

Figure 7: Integrated Circuits

An integrated circuit (IC), sometimes called a *chip* or microchip, is a semiconductor wafer on which thousands or millions of tiny resistors, capacitors, and transistors are fabricated. An IC can function as an amplifier, oscillator, timer, counter, computer memory, or microprocessor. A particular IC is categorized as either linear analog or digital, depending on its intended application. IC's are are of Linear , digital and mixed types

Linear ICs have continuously variable output (theoretically capable of attaining an infinite number of states) that depends on the input signal level. As the term implies, the output signal level is a linear function of the input signal level. Linear ICs are used as audio-frequency **(**AF**)** and radio-frequency **(**RF**)** amplifiers. The *operational amplifier* (op amp) is a common device in these applications.

Digital ICs operate at only a few defined levels or states, rather than over a continuous range of signal amplitudes. These devices are used in computers, computer networks, modems, and frequency counters. The fundamental building blocks of digital ICs are logic gates, which work with binary data, that is, signals that have only two different states, called low (logic 0) and high (logic 1).

Applications and Uses of Integrated Circuits

The advantages of Integrated Circuits are:

1. Very small size: Hundred times smaller than the discrete circuits.
2. Lesser weight: As large number of components can be packed into a single chip, weight is reduced
3. Reduced cost: The mass production technique has helped to reduce the price,
4. High reliability: Due to absence of soldered connection, few interconnections and small temperature rise failure rate is low.
5. Low power requirement: As the size is small power consumption is less.
6. Easy replacement: In case of failure chip can easily be replaced.

Linear IC's also known as analog Integrated circuits are:

1. Power amplifiers
2. Small-signal amplifiers
3. Operational amplifiers
4. Microwave amplifiers
5. RF and IF amplifiers
6. Voltage comparators

7. Multipliers
8. Radio receivers
9. Voltage regulators

Digital IC's are mostly used in computers. They are also referred as switching circuits because their input and output voltages are limited to two levels - high and low i.e. binary. They include:

1. Flip-flops
2. Logic gates
3. Timers
4. Counters
5. Multiplexers
6. Calculator chips
7. Memory chips
8. Clock chips
9. Microprocessors
10. Microcontrollers
11. Temperature sensors