1

Fundamentals of Electronics

1·1. Introduction

The term *electronics* may be defined as the field of science and engineering that deals with electron devices, *i.e.* devices in which operation takes place due to flow of electrons through vacuum, gas or a semi-conductor material. An electronic device is named as a vacuum tube or a gas tube if the electrons are made to flow vacuum or a gas. If the movement of electrons takes place through a semi-conductor medium, the device is termed a semi conductor device. The word 'electronics' in fact stands for 'Electron Mechanics' and refers to the study of the behaviour of electrons under different conditions of applied electric and magnetic fields. Since the flow of electrons results in flow of electric current, electronics engineering was previously treated as an integral part of electrical engineering with separate branches of electrical power engineering and electrical communication engineering but with tremendous development and expansion, electronics have become a vast field in itself. Electronics devices now play a major role in all spheres of our daily life.

Some of the major fields of applications of electronics are listed below.

1·1·1. Communication Systems

A cheap and fast communication system is the backbone to the progress of a country. Electronics Engineering has revolutionized the communication systems so much so that modern communications are usually termed as electronic communication systems. Electronics engineering provides different forms of communications such as telegraphy, telephony, telex FAX and data communication which utilize a pair of conducting lines for transmitting messages from one point to another. It is now possible to see your near and dear ones on a small screen while you are talking to him on a device called videophone. Another important form of electronic communications utilizes propagation of telegraphy, telephony or telex messages from one place to another through free space. This is termed as *wireless or radio* communication and is capable of providing communication over distances of thousands of kilometres. Microwave communication systems and communication through satellites are the latest additions in international communication networks. Optical fibres are now in common use. They are capable of carrying a large volume of information. It is now possible to talk to a person going in a car, bus, train etc. from a far-off place with mobile phones.

1·1·2. Entertainment Systems

Electronic equipments provide a variety of entertainment to the masses. Radio and television programmes are transmitted as means of mass entertainment. Tape recorders, record players, stereo systems, film projectors are common forms of entertainment used in homes. Video cassette recorders, laser disks and Video games are the latest additions in the field of entertainment electronics. With cable TV, a perosn is able to select a TV programme of his choice out of a number of TV channels available over cable transmission.

1·1·3. Defence Applications

Most of the advancement in the field of electronics has taken place because of its impact on the defence of different nations. RADAR (which is the short form of Radio Detection And Ranging) was the most important development that took place during the second World War. It became possible not only to detect but also to find the exact location of aeroplanes with the help of RADAR. Enemy aeroplanes can be easily differentiated from friendly aeroplanes. It is also possible to use a RADAR for accurately controlling Anti-Aircraft Guns thereby destroying enemy aircrafts. Radar controlled guided missiles, pilotless aeroplanes are the latest developments in defence oriented electronic engineering. LASER beams are now used for guiding missiles as well as weapons. Electronic equipments are used to provide a fast communication between different organs of defence. Modern warfare is essentially an electronic warfare with weapons like guided missiles, smart bombs, pilotless planes etc.

1·1·4. Medical Electronic Equipments

Electronic equipments are finding an ever-increasing use in the medical field. These equipments are used for diagnosis and treatment of various diseases. Among the diagnostic systems are X-ray machines, Infra red screening, gamma camera, ultrasonic diagnostic systems, Electro cardiography (ECG), Electro Encephalo Graphy (EEG), Oscillographs, Computer Aided Topology (CAT), scanning etc. Eletronic pace makers for heart patients, hearing aids for the deaf, short wave diathermy treatment for healing sprains and fractures, electronic shock treatment equipments, radiation treatment for cancer patients are the important biomedical electronic equipments used for treatment of patients. Laser knife is now commonly used for performing bloodless operations by surgeons.

1·1·5. Industrial Applications

Electronic equipments find important applications as automatic control systems in various industries. These equipments can be used for accurate control of thickness, weight, numbers, quality etc., of the finished products and while processing. Electronic equipments are used as automatic temperature controllers, speed controllers, timers, automatic safety alarm systems etc. Calculators and computers are in common use for computation of industrial and business data. Computer aided design of industrial products is now very common. Microprocessor controlled Robots are now replacing industrial workers in several industries resulting in a high quality and large industrial production.

1·1·6. Electronic Instrumentation Systems

These systems provide an accurate and precise measurement of different parameters and play an important role in industrial organisations and research laboratories. It has become possible to analyze various problems with the help of these instruments and design systems accordingly in these research and development laboratories. Among the important electronic instruments are electronic and digital multimeters. VTVM. Cathode Ray Osoilloscopes, Frequency counters, Signal generators, Strain gauges, pH meters etc.

1·1·7. Computer Applications

One of the most important advances in the electronics field is the digital computers. Computers are now used everywhere-offices, factories, railway stations, aerodromes, hospitals, banks, telephone exchanges etc. to perform different types of operations. In fact, a computer can process any information. In the meteorological department, it can be used to accurately predict weather conditions, rainfall storms etc. warning the farmers and sailors. In hospitals, computers are used to monitor and analyze the condition of a patient thereby helping the doctors in deciding the line of treatment. In railways and airlines, they are used in booking and reservation of seats, traffic control etc. Computers are used to prepare water, telephone and electric bills. In fact, computers have given birth to a new technology — Information technology. Government has now set up computer networks at all the 439 districts of the country, state capitals, union territories and four regional centres. There are several other important computer networks like BANKNET, COALNET, SAILNET, VIKRAM etc. operating in the country.

1·1·8. Electronics in Education

Electronics have provided various forms of teaching aids. Film projectors have been in use as a teaching aid for a long time. Then came the TV and VCR. Television is used in mass education through a countrywide classroom programme run by University Grants Commission. Another important mass education programme is the 'Turning Point' which aims at awakening scientific knowledge in the Indian masses. The use of computers in education is becoming common.

The computer is different from other educational aids because of its interactive nature. It has emerged as a general purpose, adaptable educational tool that can be used by students of different disciplines. It can act as a custom-built teacher of sorts.

A student can have an ongoing dialogue with a computer. It provides a self learning tool under each students control. The expertise of an outstanding teacher may be used in as many classrooms or students as desired by use of computers. Interaction of each student may be stored and studied deeply by the teacher and shortcomings in the students can be pointed out. The teaching-learning processes are likely to undergo a radical change with the use of computers.

1·2. Modern Electronic Developments

Modern electronic systems are to a very large extent based upon solid-state devices—commonly termed as semi-conductor devices. The development of these devices started with the invention of the *transistor—the solid state equivalent of a vacuum triode* by John Bardeen ; Walter Brattain and William Shockley in 1948. This started the process of miniaturization of electronic equipments. In an effort for further miniaturization of these equipments, steps were taken to fabricate the complete circuits in the form of the single standard packages. Such circuits were termed as *Integrated Circuits* (ICs). ICs are now available freely in the market for various applications such as amplifiers, modulators, signal processors, gates, counters etc. Further miniaturization took place when density of components in the packages were increased. Such ICs are accordingly termed as small scale integration (SSI), medium scale integration (MSI), large scale integration (LSI) and very large scale integration (VLSI) depending upon the density of components. It has now become the standard electronic design practice to make use of these ICs.

This micro miniaturization of electronic equipments has made possible exploration of outer space. It has become a major factor for cost reduction. Power requirement of such equipments is very small. All these factors have resulted in rapid spread of these devices. Digital watches, quartz clocks, television receivers, pocket calculators are now well in the reach of common people.

Electronic equipments have practically intruded every sphere of life. It is, therefore, essential that students studying various disciplines of engineering acquire a basic knowledge about this branch of engineering.

1·3. Atomic Structure of Matter

According to modern theory, every matter is composed of *molecules*—the smallest divisible particle of matter retaining all physical properties of the matter. By special methods, a molecule may be further broken up into atoms but these atoms may or may not have the same physical properties. For example, a water molecule when broken results in one oxygen and two hydrogen atoms but none of these atoms has the properties of water. On the other hand, a copper atom has all the physical properties of copper. Thus, an atom may be considered as the most fundamental unit of matter which is capable of existing independently. Accordingly, an atom is sometimes referred to as the basic natural building block over which the entire universe has been built. It must be mentioned here that all atoms corresponding to an element have same properties.

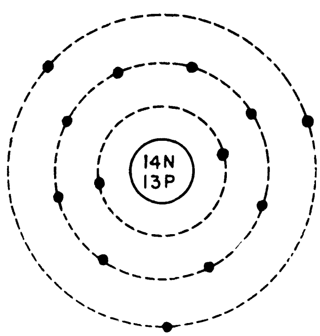
An atom comprises of two parts—the *central part or nucleus* and *orbiting electrons.*

1·3·1. Nucleus

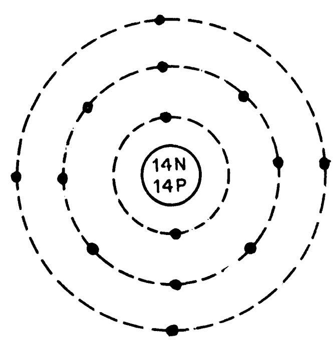
The central body or nucleus of atoms in general consists of *protons* and *neutrons.* A proton is a positively charged particle whereas a neutron does not have any electrical charge. Both these particles have the same mass however. The presence of protons in the nucleus makes it positively charged. The nucleus constitutes almost entire weight of an atom and this weight is termed as the *atomic weight of the element.* Different elements have different number of protons and neutrons in the nuclei of their atoms.

1·3·2. Electrons

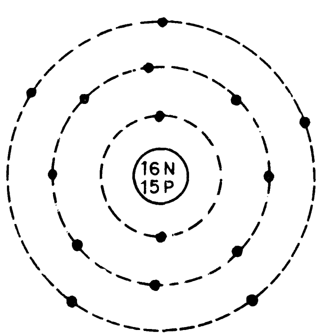
A number of electrons revolve around the nucleus of an atom in approximately elliptical orbits or shells. An electron has the same magnitude but opposite type of charge as compared to positive charge of a proton. However, electrons are very light in weight as compared to protons. The mass of an electron is 1/1850th of the mass of a proton. The electrons belonging to a gold atom are in no way different than the electrons belonging to an iron atom. The number of electrons in an atom (or the number of protons) is termed as the *atomic number* of the element.



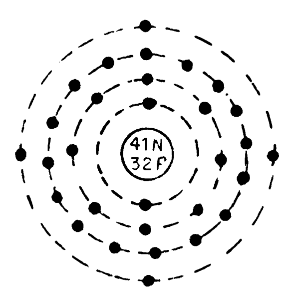
Aluminium atom (N = 13)
Conductor (Trivalent)



Silicon atom (N = 14)
Semi-conductor (Tetravalent)



Phosphorus atom (N = 15)
Pentavalent



Germanium atom (N = 32)
Semi-conductor (Tetravalent)

Fig. 1·1. Schematic representation of some atoms.

All the electrons in an atom do not revolve in the same orbit. These electrons on the other hand move in different *orbits or shells*. The distribution of electrons in different shells may in general be determined from the expression $2n^2$ where n is the number of the shell as counted from nucleus. The maximum number of electrons that different orbits can contain is thus given as $2n^2$ where n is the order of the orbit counted from nucleus.

Maximum number of electrons in different shells or orbits :-

I orbit $= 2 \times 1^2 = 2$

II orbit $= 2 \times 2^2 = 8$

III orbit $= 2 \times 3^3 = 18$

IV orbit $= 2 \times 4^4 = 32$

The outermost shell in an atom cannot have more than eight electrons. The outermost shell is termed as the *valence shell* and the electrons contained in this shell are termed as the *valence electrons*. The electrons carry large charge as compared to their mass *i.e.* the charge/mass ratio equals $1{\cdot}77 \times 10^{11}$ coloumbs/kg. Figure 1·1 gives the atomic structure of materials commonly used in electronic devices.

1·3·3. Atomic Number

The atomic number of an element gives the number of electrons revolving around the nuclei of its atoms. An aluminium atom shown in Fig. 1·1 has 13 electrons revolving around its nucleus. So its atomic number is 13. Similarly, all the known electrons are identified by their atomic numbers and a Table known as the *Periodic Table* is obtained. Within this Table-different elements are grouped according to the number of *valence electrons* contained. Thus there are nine groups formed—Group I to Group VIII and Group 0. The elements belonging to a particular group exhibit similar property. Consider copper, gold and silver. They belong to group I and are good conductors of heat and electricity. Some of the elements that are commonly used in the fabrication of electronic devices are listed below in Table 1·1.

Table 1·1. Elements Commonly Used in Electronic Devices

Periodic Group	*Element*	*Symbol*	*Atomic Number*	*Periodic Group*	*Element*	*Symbol*	*Atomic Number*
I	Copper	Cu	29	IV	Carbon	C	6
	Silver	Ag	47		Silicon	Si	14
	Gold	Au	79		Germanium	Ge	32
III	Boron	B	5	V	Phosphorus	P	15
	Aluminium	Al	13		Arsenic	As	33
	Gallium	Ga	31		Antimony	Sb	51
	Indium	In	49				

Elements belonging to Group I exhibit good electrical conductivity and are used as *conductors*. Elements belonging to periodic group IV behave neither as good conductors nor as good insulators. They are called semi-conductors. Since all semiconductors have four valence electrons ; they are called *tetravalent* materials. Elements belonging to periodic group III are known as *trivalent* materials because all these materials possess three valence electrons. Phosphorus, Arsenic and Antimony have 5 valence electrons and are called *pentavalent* materials.

1·3·4. Valence Electrons

Electrons revolving in the outermost shell of an element are called valence electrons *e.g.* silicon has four electrons in the outermost shell and is said to have a valency of four or is *tetravalent.* The chemical and electrical behaviour of an element depends upon the number of valence electrons.

The orbiting electron experience a force of attraction towards nucleus. The farther an electron from the nucleus, the less this force of attraction. Thus, the valence electrons are relatively less tied up with the nucleus as compared to inner-orbit electrons. The valence-electrons therefore, require a smaller amount of energy to overcome the force of attraction towards nucleus and become detached from their orbits. As compared to this, there is a large force of attraction between nucleus and the electrons of the inner shells and large energy is required to free such an electron. Due to this reason, the valence electrons play a key role in deciding its electrical and chemical behaviour.

1·3·5. The Electron Volt (eV)

Joule (J) is the standard unit of energy in SI system. In some energy problems this unit is very small while in some other problems this unit is found to be very large magnitudes of energy involved in electronic devices are usually so small that even the smallest unit of energy (erg = 10^{-7} J) is too large. For such applications the unit of energy *electron volt* (eV) is used. It is defined as the kinetic energy gained by an electron when it falls through a potential of one volt. This gain in kinetic energy is equal to the loss in its potential energy.

$$1\text{eV} = \text{Charge of an electron} \times 1 \text{ volt} = 1{\cdot}602 \times 10^{-19} \text{ C} \times 1 \text{ volt.}$$
$$= 1{\cdot}602 \times 10^{-19} \text{ J}$$

If an electron or proton is accelerated through a potential rise of 10 volts, kinetic energy gained by it is 10 eV. Though, the energy carried by each electron is very small, the total energy involved is large because a very large number of electrons are involved in electronic devices. The use of eV unit of energy can be extended to any problems involving such minute magnitude of energies.

1·3·6. Energy Levels

Assume an isolated atom. In this atom electrons move in fixed orbits. Each revolving electron carries certain energy. Thus, the two electrons revolving in the first orbit have the

(*a*) Electron orbits (*b*) Energy levels of electrons in different orbits.

Fig. 1·2. Energy levels in atoms.

same energy. This energy level can be represented by a line as shown and marked as $n = 1$ in Fig. 1·2. Similarly, all the eight electrons revolving in the second orbit will have same magnitude of energy. This energy is represented in the figure by the line marked as $n = 2$. Similarly, the line marked as $n = 3$ represents energy level of electrons of the third orbit.

It should be noted that the total energy of an electron comprises of two parts kinetic energy and potential energy. Kinetic energy is directly proportional to the electron mass and its velocity and hence the order of the orbit. Potential energy is directly proportional to the magnitude of the electric charge and inversely proportional to the square of the distance of the orbit from the nucleus. As the order of the orbit increases, the total electron energy also increases. The valence electrons thus have the highest amount of energy. If an additional amount of energy is imparted to these electrons to overcome the force of attraction between the nucleus and the electrons they become detached from their nucleus and move away. Such electrons are termed as *free electrons*. The energy so imparted to these electrons must be sufficient to move the valence electrons away from the region of influence of the nucleus. If the energy is less than this, then the electrons are attracted back to the nucleus and cannot move away. The free electrons conduct current very easily. The materials which have large number of free electrons are called good conductors of electricity.

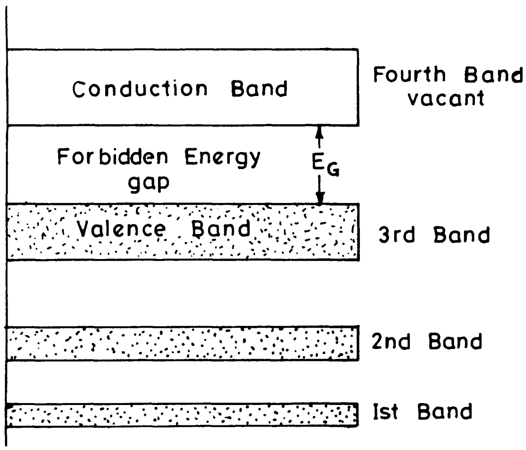


Fig. 1·3. (*a*) Energy band representation of solids.

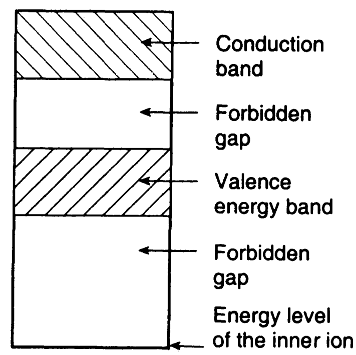


Fig. 1·3. (*b*) Energy band diagram.

So far, the discussion of electron energies has been limited to an isolated atom. However, in solid materials, the atoms bond together and the valence electrons not only experience forces of attraction towards their own nucleus, but also experience certain forces from other nuclei. As a result, different electrons will have different energy levels and representation of Fig. 1·2 cannot be used. Figure 1·3 (*a*) gives the energy band representation of a solid. The inner orbit electrons are not greatly affected by inter-atomic forces. As a result, their energy bands are narrow. Valence electrons experience maximum amount of such forces and different valence electrons have widely different energies. These energies are represented by the valence band.

When electrons in the valence energy band acquire an additional amount of energy equal to or greater than E_G, these electrons overcome the force of attraction towards the nucleus and cross over to the *Conduction Band* and become free to conduct current. If the energy given is less than E_G, the electrons fall back into the valence band. The electrons, thus, cannot remain indefinitely between conduction and valence bands. E_G is accordingly termed as *Forbidden Energy Gap*. Different forbidden energy gaps exist between different energy bands. Since only valence band electrons are of any practical use in electronics engineering, the lower energy bands are not therefore shown in energy band representations and we use energy band diagram shown in Fig. 1·3 (*b*).

Fermi Level. Fermi level represents the energy state in the energy band representation which has a 50% probability of being filled with electrons from the valence band. From the definition, it is clear that fermi level (E_f) will lie mid-way between valence and conduction bands as shall be seen later. Fermi level (E_f) lies in the centre of the forbidden energy gap in pure semi-conductors.

1·4. Conductors, Semi-Conductors and Insulators

A material having free electrons (*i.e.*, electrons in the conduction band) is capable of conducting current when an external source of e.m.f. is connected. Since different materials have different value of E_G, it follows that they will have different number of free electrons in the conduction band. As a result, under given physical conditions, different materials will pass different magnitudes of current.

Materials may be classified as conductors, semi-conductors or insulators depending upon forbidden energy gaps, between the valence and the conduction bands in the energy band diagram.

1·4·1. Insulators

A material with large forbidden energy gap may be termed as an insulator. Such a material may be represented by the energy level diagram of Fig. 1·4 (*a*). The forbidden energy

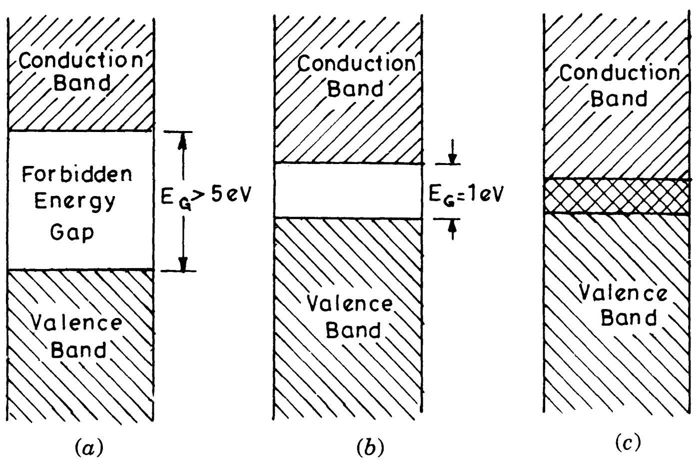


Fig. 1·4. Energy band diagram of (*a*) insulators (*b*) semi-conductors and (*c*) conductors.

gap is of the order of 5 eV or more in such materials. At room temperature, thermal energy imparted to the valence electrons of such materials is insufficient and is not able to cause these electrons to cross to the conduction band. As a result, current conduction is not possible in these materials. Only at very high temperatures or when a high electric field is created across these materials, the valence electrons may attain sufficiently high additional energy and jump to the conduction band. Under these conditions, current flow through these materials may take place. This condition is referred to *insulation breakdown.* Under normal working conditions, however, the material does not allow any current flow.

1·4·2. Conductors

In most of the metals, the forbidden energy gap is very small. At room temperature, the energy imparted to the valence electrons is so large that most of the valence electrons cross the narrow forbidden energy gap and become free for conduction of current. In fact, there is no energy gap and the conduction band overlaps the valence band as shown in Fig. 1·4 (*c*).

To understand this phenomenon, consider the example of good conductors such as copper, sodium or silver. All these materials have a valency of *one*. The inner core of the atoms in these materials has a force of attraction towards this electron corresponding to one unit positive charge. Even this force is partly neutralized by the screening effect of inner orbit electrons. As a result, these valence electrons are very loosely bound to their nuclei. At room temperatures, these electrons acquire sufficient thermal energy and jump to conduction band. These electrons become free to move from one atom to another and allow an easy flow of electric current. Such materials are accordingly termed as good conductors.

1·4·3. Semi-conductors

A semi-conductor is a material with a relatively narrow forbidden energy gap. Such materials act as perfect insulators at low temperatures, but at room temperature, some of the valence electrons acquire sufficient thermal energy and move to the conduction band leaving behind vacant places (deficiency of electrons called holes). As a result, these materials allow some flow of current even at room temperatures. This current is lower than conductors but higher than insulators. Thus, the conductivity of these materials lies between conductors and insulators. Energy level diagram of such a material is shown in Fig. 1·4 (*b*). Semi-conductor materials have forbidden energy gap of the order of 1 eV. Silicon and germanium are the most popular semi-conductor materials.

1·5. Conduction in metals

In metals, atoms are very close to one another in a regular pattern. Due to close spacing between the nuclei, there are various inter-atomic forces present. These forces give great physical strength to a metal. Due to these forces, energy levels of valence electrons are split into a large number of energy levels. Thus valence energy band is increased to overlap the forbidden energy gap. Therefore forbidden energy gap E_g becomes negligible. The valence electrons are very loosely attached to their nuclei. At room temperatures, these electrons acquire additional energy to overcome the force of attraction between the nuclei. They become free and move away from their orbits. As such, the forbidden energy gap is completely overlapped. The electrons can cross over to the conduction band. These electrons are free to move from one atom of the metal to the other and are known as *free electrons*. The motion of these electrons is random as can be seen from Fig. 1·5 which depicts the motion of an electron without an external field. Consider any cross section *AA*' of the metal. The charges crossing *AA*' leftwards equals the charges moving across *AA*' rightwards. Therefore net flow of current due to this electron motion is zero.

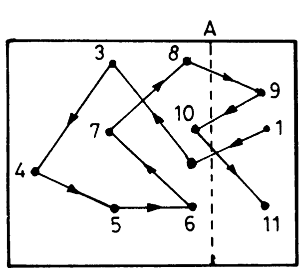


Fig. 1·5. Random motion of electrons in a metal with applied electric field.

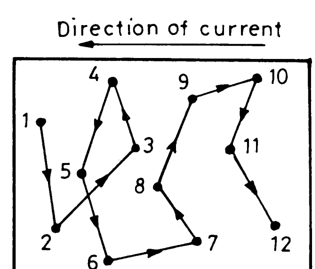


Fig. 1·6. Drift of electrons in a metal with applied electric field.

Now let us apply an e.m.f. across the metal. The field causes the electron to drift rightwards resulting in a net current as shown in Fig. 1·6. Direction of current is also marked in the diagram.

The drift current density (commonly called electric current density) is given by the relation

$$J = n.e.\mu.E$$

$$= \sigma\ E \text{ Amp/m}^2 \quad ...(1\cdot1)$$

where n is the concentration of free electrons/m^3, e is the charge on an electron, μ is the mobility of electrons in m^2/volt-second and E is the intensity of electric field in volts/metre.

σ is termed as the conductivity of the metal.

$$\sigma = n.e.\mu. \quad ...(1\cdot2)$$

1·5·1. Surface Barrier

Whenever a metal solidifies its atoms arrange themselves in a particular form called the *space lattice structure.* The complete set-up of this structure is three dimensional and difficult to visualize. Thus, for simplicity the behaviour is generally illustrated in two dimensional representations.

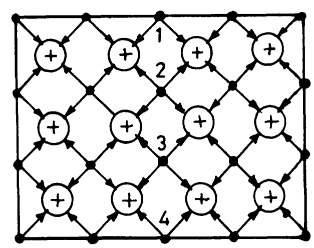


Fig. 1·7. Sectional view of a metallic crystal.

Fig. 1·7 shows the cross-section of a metallic crystal. The atoms in the crystal have a heavy mass and remain fixed in the space lattice structure whereas the valence electrons have a light mass and are free to move within the crystal. As an electron moves away from its orbit, the atom becomes a positive ion. These positive ions are shown by circles with a positive sign in them. The electrons are represented by solid dots.

Since the electrons are not attached to any atom, they are free to move in the crystal. Can these electrons leave the metal surface and move away from it ? If not, what prohibits them from doing so ? To answer this question let us consider the sectional view of the metal shown in Fig. 1·7. Each electron in this sectional view experiences forces of attraction from the adjoining positively charged ions. The electrons inside the crystal such as 2 and 3 experience forces from four neighbouring atoms as shown by arrows. The attracting froces on these electrons are such as to neutralize each other so that the net force acting on these electrons is almost zero. These electrons are therefore free to move away randomly from their positions. Now consider the electrons such as 1 and 4 on the surface of metal. These electrons experience forces of attraction such that these electrons are not permitted to leave the metal boundary. This can be seen by referring to the arrows which point inwards. This phenomenon is known as the *surface barrier*. Therefore it can be concluded that the electrons are free to move about within the metal surface but are not permitted to leave the metal boundary.

1·5·2. Work Function

In order to make an electron leave a metallic surface, an energy from some external source must be supplied to the electron, so that it overcomes the surface barrier. This additional energy required to liberate an electron from the metallic surface is called the work function of the metal and is measured in electron volts (eV). The work function of a metal depends upon the nature of the metal and its surface conditions and may lie between 1·0 to 10·0 eV. The work function of some of the important metals is given in Table 1·2.

Table 1·2. Work function of some metals

Metal	*Work Function* *eV*	*Metal*	*Work Function* *eV*
Calcium	3·2	Tantalum	4·1
Carbon	4·7	Thorium	3·4
Copper	4·1	Tungston	4·52
Molybdenum	4·3	Thoriated Tungston	2·63
Nickel	5·0	Oxide coated emitter	1·0

1·6. Units of Measurements

Different units of measurements will be used throughout the text. These units are given in Table 1·3 below.

Table 1·3. Common units of measurements

Physical quantity	*Unit used*	*Symbol*
Electric potential	Volt	V = W/A
Electric charge	Coulomb	$C = As$
Electric current	Ampere	A
Electric capacitance	farad	$F = As/V$
Electric conductance	siemens	$S = A/V$
Electric resistance	ohm	$\Omega = V/A$
Force	newton	N = kg m/s^2
Frequency	hertz	Hz = cycles/s = 1/s
Power	watt	W = J/s
Work, energy, quantity of heat	joule	J = Nm
Inductance	henry	H = Vs/A

Some of these units of measurements are not of a convenient size ; so their multiples and submultiples have to be used. A list of these multiples and submultiples is given in Table 1·4 below.

Table 1·4. Decimal multiples and submultiples

Factor	*Prefix*	*Symbol*	*Factor*	*Prefix*	*Symbol*
10^1	deca	da	10^{-1}	deci	d
10^2	hecto	h	10^{-2}	centi	c
10^3	kilo	k	10^{-3}	milli	m
10^6	mega	M	10^{-6}	micro	µ
10^9	giga	G	10^{-9}	nano	n
10^{12}	tera	T	10^{-12}	pico	p
10^{15}	peta	P	10^{-15}	femto	f
10^{18}	exa	E	10^{-18}	atto	a

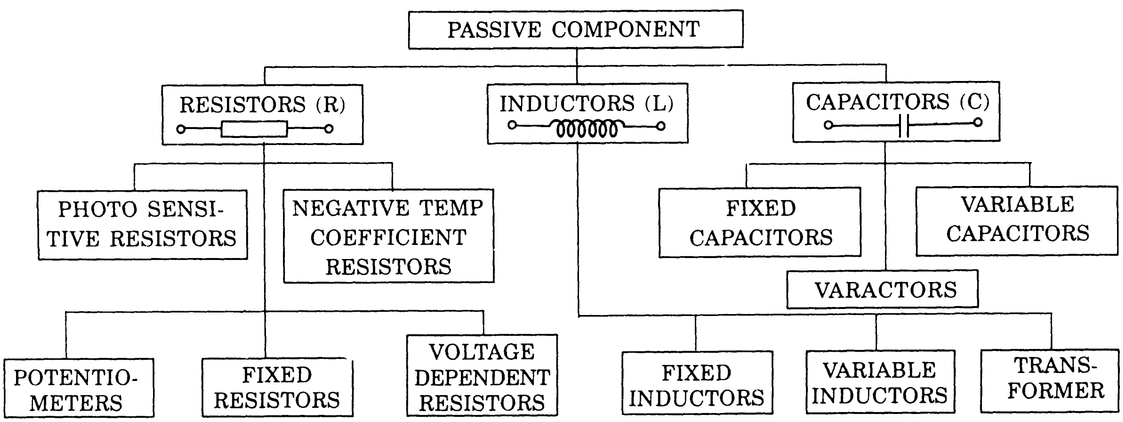
1·7. Electronic Components

Electronic equipments may contain a large and complicated circuitry capable of perform-ing different functions but a close study reveals that all such circuits contain a few basic components. These components may be broadly classified into *passive components* and *active components.* The active components are those which are capable of performing important signal processing functions like amplification rectification, signal generation etc. The passive components cannot perform the above mentioned functions by themselves but are used in conjunction with active components to perform above functions. Thus passive components are employed along with active components so that the latter perform the desired function.

1·7·1. Passive Components

Resistors, inductors and capacitors are the three basic passive components but each of these components may be divided into different types. Table 1·5 outlines different passive components.

Table 1·5. Outlines of electric passive components



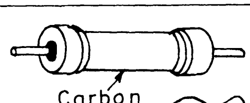
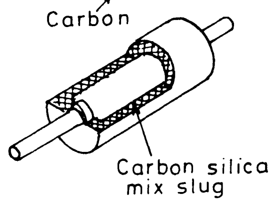
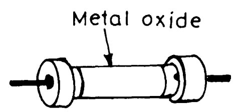
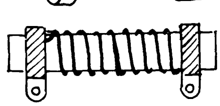
Resistor Type	*Constructional Feature*
1. Carbon composition	
2. Carbon film	
3. Metal Film	
4. Wirewound	

Fig. 1·8. Constructional details of fixed resistors.

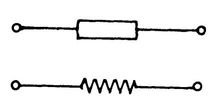


Fig. 1·9. Circuit symbol of fixed resistors (*a*) ISI symbol (*b*) Conventional symbol.

Resistors. A resistor is a component that reduces the flow of current in a circuit in a manner that is similar to mechanical friction. The amount of opposition offered to flow of current by a component is termed the *resistance* of the component and is measured in *ohms*. The greek letter omega (Ω) is used as a symbol for the resistance. There are basically two types of resistors—fixed and variable.

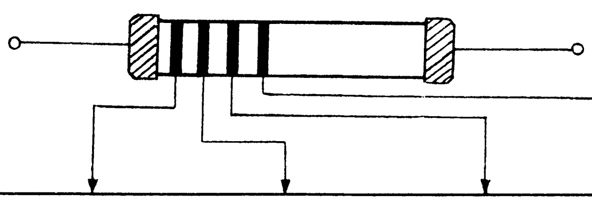
Fixed resistors. Four types of fixed resistors are available in the market. They are (*i*) moulded carbon composition, carbon film, metal oxide and wire wound. Fig. 1·8 gives the constructional details of these resistors.

Fixed resistors are available with values as low as 0·1 ohm to a value as high as 100 mega ohms. Resistors with power rating lying between 1/8 watt and 100 watts are readily available. These resistors have extremely small associated inductance and capacitance and can be selected with tolerance between 1% to 20%. They are relatively cheap. Circuit symbol of fixed resistors is given in Fig. 1·9.

Colour Coding. Size of resistors is very small and it is generally not possible to print the value of the resistor on its body. So the value of the resistor is coded and printed in the form of four coloured circles on the body of the resistor. The colour bands are read from left to right starting from the band. The colour band near the resistor end is always treated as the first band. The first and second bands represent the first and second significant digits respectively. The third band is the multiplier while the fourth represents the tolerance. Table 1·5 gives the colour coding scheme used for fixed resistors.

In potentiometers and wire wound resistors, value of the resistance is printed on the body of the resistor but in carbon and metal film resistors, colour coding scheme is used to indicate the resistor value. Table 1·6 shows the colour coding scheme used in resistors.

Table 1·6. Colour coding in resistors



Colour	*I Digit*	*II Digit*	*Multiplier*	*Tolerance*
Black	0	0	10^0	±20%
Brown	1	1	10^1	–
Red	2	2	10^2	±2%
Orange	3	3	10^3	–
Yellow	4	4	10^4	–
Green	5	5	10^5	±5%
Blue	6	6	10^6	–
Violet	7	7	10^7	–
Grey	8	8	10^{-2}	
White	9	9	10^{-1}	±10%
Gold	–	–	10^{-1}	±5%
Silver	–	–	10^{-2}	±10%
No colour	–	–	–	±20%

Note. (1) Some manufacturers print resistor values on to the body *e.g.* 4K7 means a resistor of 4·7 K ohms, 4E7 means a resistor of 4-7Ω.

(2) Some resistors have a fifth colour band which gives reliability level in per cent change in value per thousand hours of operation. The colour code for fifth band is

Brown = 1%	Orange = 0·01%
Red = 1%	Yellow = 0·01%

Example 1·1. *Give the colour code of the following resistors (a) 3·9 K ± 5% (b) 6·8 M ± 20% (c) 4·7 Ω ± 10% (d) 390 K ± 20%.*

Solution.

Resistor	*Colour band I*	*Colour band II*	*Colour band III*	*Colour band IV*
(*a*) 3·9 K ± 5%	Orange	White	Red	Gold or green
(*b*) 6·8 M ± 20%	Blue	Grey	Green	Black or no colour
(*c*) 4·7 Ω ± 10%	Yellow	Violet	White or Gold	Silver or white
(*d*) 390 K ± 20%	Orange	White	Yellow	Black or no colour

Example 1·2. *A resistor has the following colour coding sequence—Band A—Orange, Band B—White, Band C—Red and Band D—Gold. Find the range of values within which its value will be.*

Solution. From the colour coding table, we obtain the following value

Ist Band	IInd Band	IIIrd Band	IVth Band
Orange	White	Red	Gold
3	9	10^2	± 5%

∴ Resistor value = 3·9 K ± 5% = 3·9 K ± 195 Ω = 3705 ohms or 4095 ohms.

In electronic circuits, the values of resistors required may differ very widely from one another. Except for some applications where precise values of resistors are required it is not necessary to use exact values in most of the circuits. A resistor may in general differ from its expected value by as much as 20%, yet the circuit in which it is connected may work quite satisfactorily. Thus resistor manufacturers market their products as *standard values.* Values of resistors available in standard values are given below in Table 1·7.

Table 1·7. Standard Values of Resistors

5%—10, 11, 12, 13, 15, 16, 18, 20, 22, 24, 27, 30, 33, 36, 39, 43, 47, 51, 56, 62, 68, 75, 82, 91

10%—10, 12, 15, 18, 22, 27, 33, 47, 56, 68, 82

20%—15, 22, 33, 47, 68

Note. These values are multiplied by appropriate power of 10 to get the desired value and resistors are available in these values.

Variable resistors. In several circuits applications, there is a need to adjust the values of voltages and currents. Variable resistors are used in such applications. Common examples of the use of variable resistors are : adjusting sound levels in radio/TV receivers ; adjusting brightness, colour or contrast in TV receivers, adjusting voltage output of a power supply unit.

Variable resistors are commonly called *potentiometers* and abbreviated as 'pots'. Variable resistors used in electrical circuits are named *rheostats.* Rheostats generally use wire wound resistors. On the other hand, a potentiometer may use carbon or wire wound resistor elements. Fig. 1·10 shows the circuit symbol of a potentiometer.

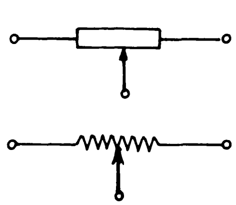


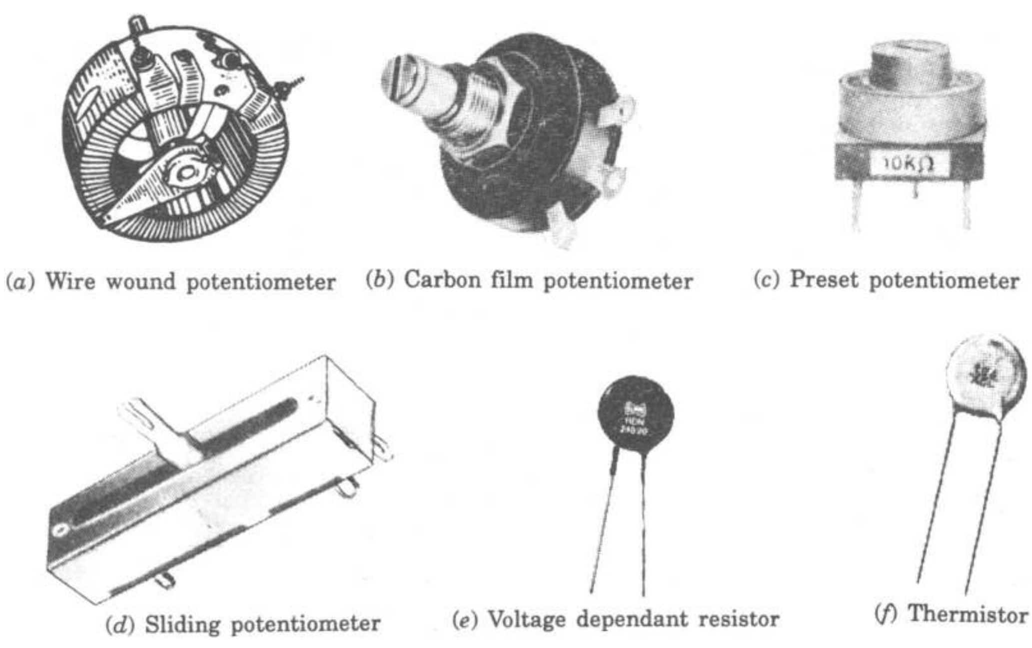
Fig. 1·10. Potentiometer symbols (*a*) ISI symbol (*b*) Conventional symbol.

Wire wound potentiometers are suitable for low value of resistances. When a variable resistor with high resistance is needed, carbon film is used as the resistive element. Wire wound potentiometers employ a dough-shaped core of ceramic or bakelite over which is wound a resistive (nichrome) wire. In carbon film potentiometers, a carbon film is deposited in the form of an open ring and the two ends of the film act as two fixed points of the potentiometer. A shaft with a moving contact and terminal is used to vary the resistance.

Various types of potentiometers are in use. A few of them are shown in Fig. 1·11. Wire wound potentiometer is shown in Fig. 1·11 (*a*) followed by carbon film potentiometers shown in Fig. 1·11 (*b*), (*c*) and (*d*). The potentiometer shown in Fig. 1·11 (*c*) can be varied with the help of a screw driver and is meant to be preset by a technician. This type of potentiometer is called a *preset potentiometer.*

The potentiometer of Fig. 1·11 (*d*) can be varied by moving the sliding arm. This type of potentiometer is commonly used as a volume control in radio/TV receivers.

Fig. 1·11 (*e*) and (*f*) show resistors whose value can be changed by changing the voltage across the resistor or by changing the temperature of the resistor. The former type is called *voltage dependant resistor* (VDR) and is also known as a *varistor* while the latter is known as thermistor. Another type of resistor whose value is dependant upon the light intensity falling on it is used in several applications and is known as a photo resistor.



(*a*) Wire wound potentiometer (*b*) Carbon film potentiometer (*c*) Preset potentiometer

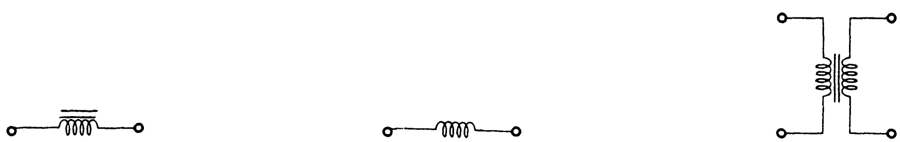
(*d*) Sliding potentiometer (*e*) Voltage dependant resistor (*f*) Thermistor

Fig. 1·11.

Inductors. An electric current flowing through a coil of wire produces a magnetic field. This magnetic field tends to oppose any change in the current thereby trying to maintain the current steady. This phenomenon is termed as the *inductance* and the coil is called the inductor. While a resistor resists (opposes) direct as well as alternating current equally, an inductor allows the direct current unopposed but offers opposition (resistance) to alternating currents. This property is measured in terms of *inductive reactance* of the coil and is denoted by the symbol X_L. X_L is given by the expression $X_L = 2\pi f.L$, where f is the frequency of the AC signal and L is inductance of the coil. Inductance is measured in henries (H).

Inductors find several important uses. They can be used in circuits where alternating signals of a particular frequency are to be reduced or eliminated in the output. Such chokes are referred as *filter chokes*. When such chokes are to be used at the supply frequency (50 Hz), the value required is large (5 to 20 H). These chokes are termed as *power chokes* and use laminated iron cores. For AF application, *Audio frequency chokes* are used. These chokes also employ laminated core but are smaller in size than power chokes. At radio frequencies, small values of inductors are used as *radio frequency chokes*. These chokes do not use any core normally and have values lying between a few milli henries (mH) and a few micro henries (μH).

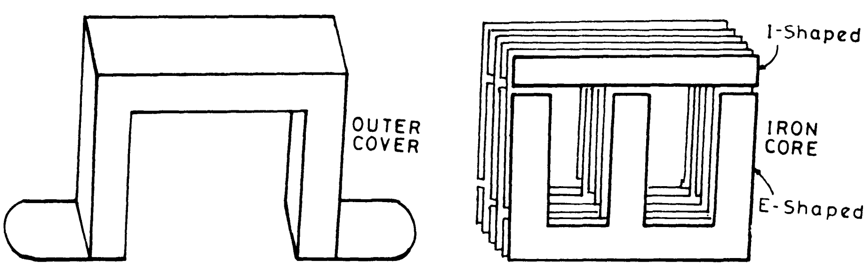
Another important application of inductors is in transformers which consists of two inductors placed close to one another. Alternating energy applied at one winding called the primary winding is transferred to the other winding called the secondary—symbols of different types of inductors are given in Fig. 1·12.



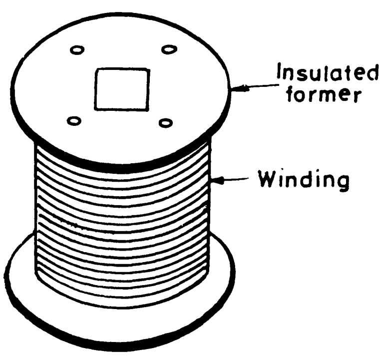
(*a*) A power choke or AF choke with iron core (*b*) An RF choke (air core) (*c*) A low frequency transformer

Fig. 1·12. Symbols of inductors and transformers.

Fig. 1·13 shows the constructional details of a low frequency transformer. It consists of an insulated former over which are wound two inductors—*primary* and *secondary*. Insulation is provided between different layers of windings as well as between the primary and secondary windings. The wound coil is fitted with the laminated iron core which consists of E-shaped and I-shaped laminations. The outer cover is then fixed over the laminations.



(*a*) (*b*)



(*c*)

Fig. 1·13. Constructional details of a low frequency transformer.

Constructional details of high frequency inductors is shown in Fig. 1·14. These inductors are wound on a paper former and fixed with an adhesive. They may have a ferrite core to adjust the value of the inductor as shown in Fig. 1·14 (*a*) or may not use any core. These inductors are called radio frequency chokes or RFC and have values lying in the range of a few μH to a few mH.

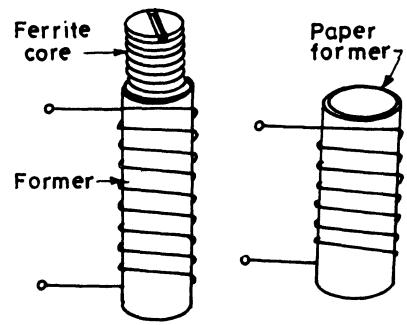


Fig. 1·14. Radio frequency chokes (*a*) with and (*b*) without ferrite core.

Capacitors. A capacitor is another important passive component that is commonly used in electronic circuits. The basic property of capacitors is that they store electric energy in the form of electric charge. The capability of a capacitor to store electrical energy is measured in terms of *capacitance,* the unit of measurement is *Farad* (F). A Farad is too big a unit and in practice, capacitors with capacitances lying in the range of a few pico-farads (10^{-12}F) to a few micro farads (10^{-6}F) are used.

The behaviour of a capacitor is just opposite to that an inductance. While an inductor opposes the flow of alternating current but does not oppose the direct current, a capacitor gives the strongest opposition to direct currents. For alternating currents, the opposition offered is inversely proportional to the frequency. This opposition is termed as *capacitive reactance* (X_C) and measured in ohms. X_C is numerically gives as $X_C = \frac{1}{2\pi fC}$.

Two most important applications of capacitors are as *series coupling capacitors,* where they allow alternating signals from the output points of one stage to pass to the next stage but prohibit DC voltage and as *shunt pass capacitors,* where they are connected across a resistor to shunt away the AC currents and allow only DC voltages to develop across the resistor.

Like resistors and inductors, a capacitor may either be fixed or variable. Variable capacitors are indicated by an arrow similar to resistors in capacitor symbols. Figure 1·15 shows the symbol of fixed and variable capacitors.

A capacitor comprises of two conducting plates separated by an insulating medium called *dielectric.* Capacitors are usually named after the material used as dielectric.

A *paper* or *polyster capacitor* is fabricated by using thin layers of paper or polyster between two metallic foils. The complete assembly is rolled to form a compact capacitor with capacitances ranging from 0·0005 μF to several μF with voltage rating lying between 100 volts to several hundred volts. These capacitors have leakage resistances of the order of 100 MΩ.

Mica Capacitors employ mica as dielectric. These capacitors give stable characteristics against wide temperature variations as compared to paper or polyster capacitors and have extremely low leakage currents (leakage resistance is of the order of 1000 MΩ). Since mica cannot be rolled, mica capacitors have low capacitances ranging from 5 PF to 10 KPF. These capacitors have a working voltage of about 500 volts.

Ceramic Capacitors comprise of ceramic dielectric of various shapes and sizes which is coated on both sides with a good conductor like copper or silver. The two metallic coatings act as capacitor plates. The assembly is covered with a protective plastic coating and capacitor value is marked on the body either by printing the capacitor value or by using a colour coding scheme similar to that employed in resistors. This colour coding scheme is given in Table 1·8. The colour coding scheme also indicates the temperature coefficient of the capacitor in addition to the capacitor value and tolerance. These capacitors are very versatile in nature. They can be fabricated with capacitances ranging from a few picofarads to a few microfarads with working voltages lying in the range of a few volts to several kilovolts. These capacitors have leakage resistance that is approximately same as mica capacitors. Shapes of different types of fixed capacitors are shown in Fig. 1·16.

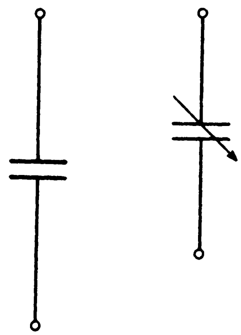
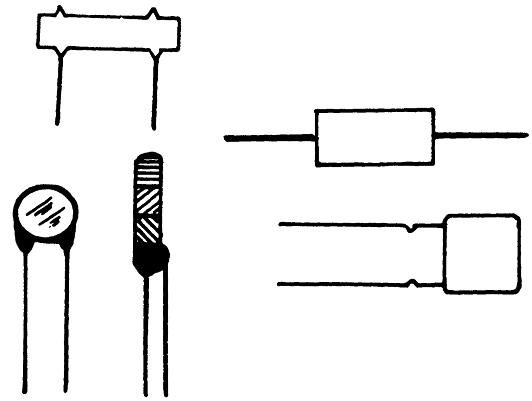


Fig. 1·15. Capacitor Symbols for fixed and variable capacitors.



(a) (b)

Fig. 1·16. Commonly used fixed capacitors. (a) ceramic capacitors (b) Paper capacitors.

Electrolytic Capacitors. These capacitors consist of an aluminium foil which is coated with an aluminium oxide film on one side. The aluminium plate acts as the positive plate while the aluminium oxide acts as the dielectric. The oxide film is so arranged as to make contact with a paper or gauze that is impregnated with an *electrolyte.* This electrolyte acts as the second plate (negative) for the capacitor. Another aluminium foil is introduced in the electrolyte to provide electrical connections for the second plate. In most of the cases, this foil is connected to the aluminium container internally which then acts as the negative plate, but in some case, the connections are brought separately. Since the capacitors have separate positive and negative plates, they cannot be used for alternating currents. In contrast to this, the capacitors previously discussed can be used both for AC and DC. Since the oxide layer which acts as dielectric is very thin, the capacitor has a large capacitance compared to its volume, *i.e.* it has a high *capacitance to size ratio.* Electrolytic capacitors with capacitance ranging from 1 microfarad to several thousand microfarads are available with DC working voltages in the range of about 1 to 500 volts. These capacitors are used in DC circuits where large capacitances are required. However, there are available capacitors with a special oil acting as dielectric and these capacitors can be used in AC circuits *e.g.*, starting of motors etc. Figure 1·17 gives the symbol and outlines of electrolytic capacitors. A recently developed electrolytic capacitor uses tantalum as dielectric and has an excellent *capacitance to size ratio.*

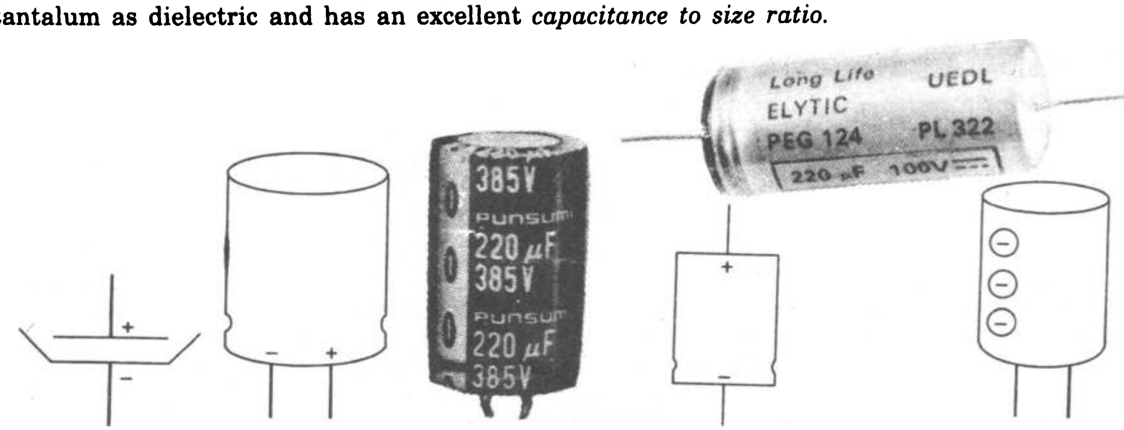
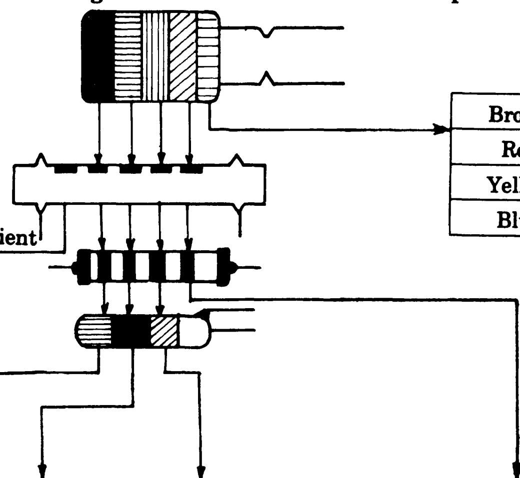


Fig. 1·17. Electrolytic capacitor symbol and shapes.

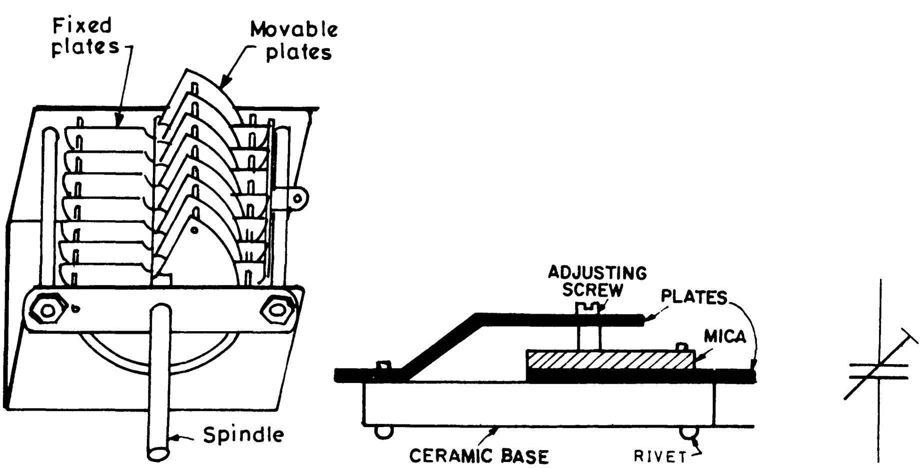
Table 1·8. Colour coding scheme for resistors and capacitors



Black	0×10^{-6}	Temp. Coefficient
Orange	-150×10^{-6}	
Violet	-750×10^{-6}	

	V_{DC}
Brown	100
Red	250
Yellow	400
Blue	600

Colour	*I-Digit*	*II-Digit*	*Multiplexer*	*Tolerance*		
Black	0	0	× 1 Ω/pF	(resistor)	Gold	± 50%
Brown	1	1	× 10		Red	±2%
Red	2	2	× 100			
Orange	3	3	× 1K	C > 10pF	Black	± 20%
Yellow	4	4	× 10K		White	±10%
Green	5	5	× 100K		Green	±5%
Blue	6	6	× 1M		Red	±2%
Violet	7	7	–		Brown	±10%
Gray	8	8	× 0·01 pF	C < 10pF	Green	±0·5 pF
White	9	9	× 0·01 pF		Red	±0·25 pF
Gold	–	–	× 0·1 Ω			



(*a*) Variable capacitor (*b*) Trimmer (*c*) Symbol

Fig. 1·18.

Variable Capacitors are used in circuits where an adjustment in its capacitance is desired. The most common application of these capacitors is in resonant circuits. A widely used variable capacitor in radio receivers is the *ganged capacitor* that is used to tune different radio stations. Capacitance of these capacitors can be changed by mounting a set of conducting plates on a shaft and movement of the shaft gives the change in its capacitance. The other set of plates is kept fixed. Figure 1·18 (*a*) shows the basic construction of a variable capacitor.

In some applications, adjustment of capacitance is not frequently required. In such cases, variable capacitors commonly termed as *trimmers* or *padders* are commonly employed. Construction of this type of capacitors is also shown in Fig. 1·18 (*b*) and Symbol for variable capacitors is given in Fig. 1·18 (*c*).

1·7·2. Active Components

As already explained, active components are used for signal processing like signal amplification, signal generation, conversion, rectification etc. There are two basic types of active devices in use—tubes and solid state devices.

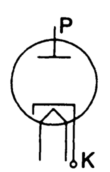
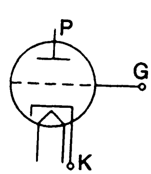
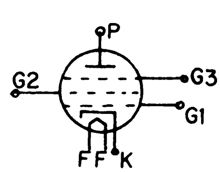
(*i*) **Tubes.** These devices utilize for their operation, removal or emission of electrons from a metal called cathode by overcoming its surface barrier, their flow through vacuum or a gas and subsequent control and/or collection of these electrons.

(*ii*) **Solid State Devices.** These devices utilise flow of electrons or other carriers of current within the surface of a metal. The subsequent control and/or collection of these carriers results in the desired characteristic of these devices.

Detailed discussion of the active devices is carried out in the following chapters but Table 1·9 gives the broad outlines of the active devices currently in use.

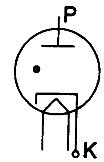
Table 1·9. Symbols of Active Devices and their uses

Vacuum Tubes

(*i*) Diodes		Rectifiers, detectors
(*ii*) Triodes		Amplifiers, Oscillators, mixers
(*iii*) Pentodes		Amplifiers, Oscillators, mixers, modulators, limiters

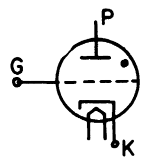
Gas Tubes

(*i*) Gas diodes



Voltage regulators, Neon signs

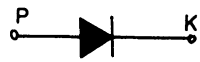
(*ii*) Thyratrons



Controlled rectifiers

Semi-conductor Devices

(*i*) PN junction diodes

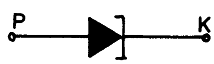


Rectifiers, Detectors

(*ii*) Zener diode

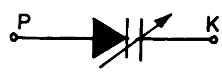
Voltage Regulation

(*iii*) Tunnel diodes



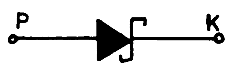
Oscillators, Amplifiers

(*iv*) Varactor diodes



Amplifiers, Oscillator tuning

(*v*) Schottkey diode

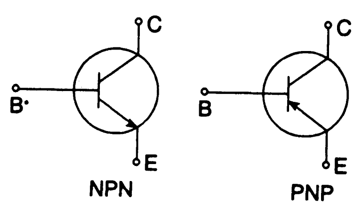


Switching circuits

(*vi*) PNPN diode

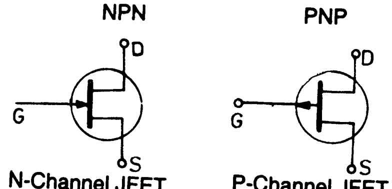
Switching (high voltage)

(*vii*) Transistors (BJT)



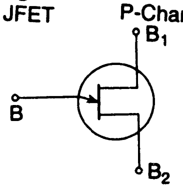
Amplifiers, Oscillators, Mixers, Modulators

(*viii*) Transistor (FET)



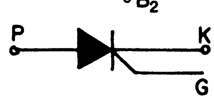
Amplifiers, Oscillators

(*ix*) Transistor (UJT)



Oscillators, Power control

(*x*) Silicon Controlled Rectifiers (SCR)



Controlled rectifier, motor speed control

1·7. Coding of Semi-conductor Devices and Tubes

Electronic circuits usually consist of active devices such as diodes, tubes, transistors and passive components such as resistors, capacitors, chokes, etc. These components may be mounted on a chassis and interconnected by means of necessary wirings or directly mounted on printed circuit boards which also provide interconnections. This section deals with coding, symbols and identification of pin connections of various components.

1·7·1. Semi-Conductors (BEL Code)

The code consists of two or three letters followed by two or three figures. The specification of various letters and figures is given below :

The first letter indicates the semi-conductor material used.

A—Devices made of germanium.

B—Devices made of silicon.

The second letter indicates the main applications of the device.

A—Detector diode, high speed diode.

B—Variable capacitance diode.

C—Transistor for AF use.

D—Power transistor for AF use.

E—Tunnel diode.

F—Transistor for RF use.

L—Power transistor for RF use.

S—Transistor for switching applications.

U—Power transistor for switching applications.

Y—Rectifier diode, booster diode, efficiency diode,

Z—Zener diode.

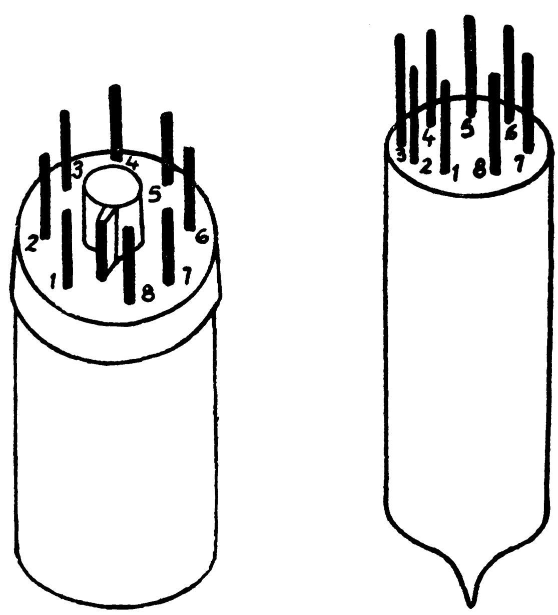


Fig. 1·19. Pin identification of vacuum tubes.

The serial number consists of

(*a*) Three figures for devices designed for commercial or entertainment purposes.

(*b*) One letter followed by two figures for devices designed for professional or industrial use.

Examples

(1) AF 139—Germanium RF transistor for entertainment use.

(2) *BYX* 27—Silicon rectifying diode for industrial use.

(3) ASZ 18—Germanium switching transistor for professional use.

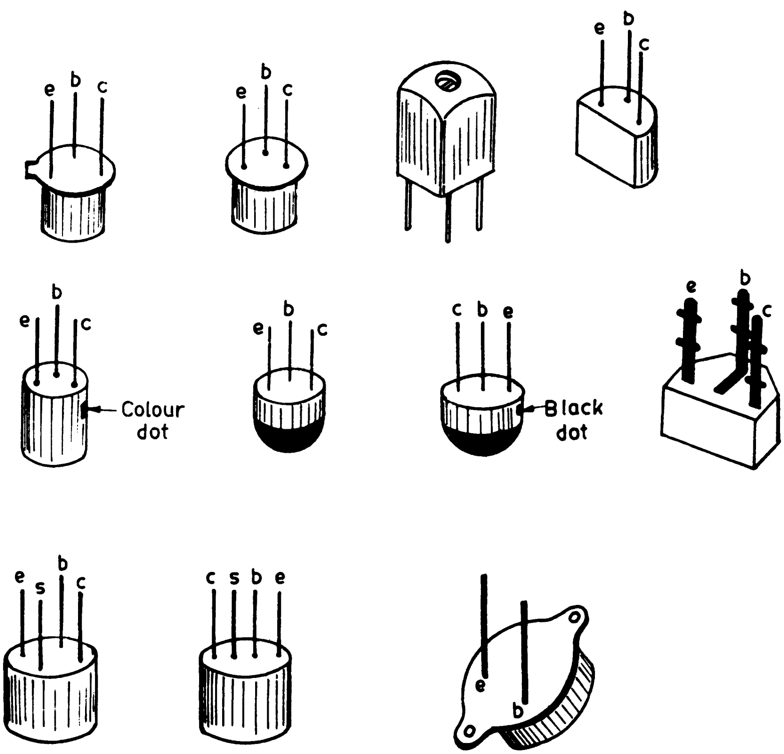


Fig. 1·20. Pin identification of transistors.

OBJECTIVE TYPE QUESTIONS

1·1. In the statements given below, select the correct answer from the alternatives given :

(*a*) One of the following is not an active device :

(*i*) Transistors (*ii*) Thyratrons

(*iii*) Transformer (*iv*) SCR.

(*b*) Most of the advancement in electronics have taken place because of

(*i*) defence applications

(*ii*) communication applications

(*iii*) power control engineering.

(*c*) An integrated circuit is an example of

(*i*) active device (*ii*) passive device.

(*d*) A resistor with colour bands Red, Violet, Green and Black will have a value

(*i*) 27 K ± 10% K (*ii*) 2·7 M ± 20% K (*iii*) 270 K ± 5% K

(*e*) An alternating signal with a frequency of 10 KHz is to be passed from one stage to another. If at the first stage the DC is also present, the stages will be coupled by

(*i*) an inductor (*ii*) a capacitor (*iii*) a diode.

(*f*) A circuit requires a capacitor of 100 μF, 25 V. The capacitor can be a

(*i*) paper capacitor (*ii*) electrolytic capacitor (*iii*) ceramic capacitor.

(*g*) A resistor with negative temperature coefficient is called a

(*i*) potentiometer (*ii*) thermistor (*iii*) photo resistor.

(*h*) A material has a forbidden energy gap of 1 eV between valence and conduction bands. The material will behave as

(*i*) a good conductor (*ii*) an insulator (*iii*) a semi-conductor.

(*i*) The sound of radio receiver is to be increased. The control used for this purpose is a

(*i*) a variable capacitor (*ii*) a variable inductor (*iii*) a variable resistor.

(*j*) A resistor of 39 K ± 2% is to be purchased. Its colour code will be

(*i*) Orange, white orange, red (*ii*) Green, blue, yellow, gold

(*iii*) Orange, violet, orange, red.

(*k*) In tubes, the excess energy given to the cathode for electron emission corresponds to

(*i*) potential barrier (*ii*) work function.

(*l*) A circuit offers large opposition to a 1 KHz signal and low opposition to a 100 Hz signal. The circuit comprises of

(*i*) an inductor (*ii*) a capacitor (*iii*) a resistor.

(*m*) In a germanium atom, highest energy is carried by electrons in the

(*i*) innermost shell (*ii*) outermost shell

(*iii*) second shell (*iv*) third shell.

1·2. Fill up the blanks in the given statements :

(*a*) The chemical and electrical behaviour of a metal depends upon its ....

(*b*) Work function of a metal is defined as ....

(*c*) Solid state devices are different than tubes in that while the former employs .... for their operation, the latter works on the principle of ....

(*d*) The number of electron that a given atom can have, is given by the .... of the metal.

(*e*) The maximum number of electrons in a given orbit is given by the relation ....

(*f*) Electrons in the outermost orbit of an atom are called ....

(*g*) If an electron moves away from its orbit, the remaining atom is called a ....

(*h*) Removal of electrons from a metallic surface is called ....

REVIEW QUESTIONS

1·1. List important applications of electronics.

1·2. Explain with the help of a diagram, the phenomenon of surface barrier in metals and hence define work function.

1·3. Draw the atomic structure of the following materials and mark the valence electrons in each

(*a*) Boron, (*b*) Antimony, (*c*) Arsenic, (*d*) Aluminium.

1·4. From the periodic table of elements, make a list of

(*a*) Trivalent, (*b*) Tetravalent, (*c*) Pentavalent materials.

1·5. Explain the terms

(*a*) Valence electrons, (*b*) Free electrons

(*c*) Atomic weight, (*d*) Atomic number

1·6. Define Work function. Can it be changed ? If so, how ?

1·7. Define the unit of energy that is used for measuring electron energy in an atom. Draw the energy level diagram of an isolated atom. How is this affected by presence of other electrons ? On the basis of energy level diagrams, how will you classify materials into conductors, semi conductors and insulators ?

1·8. What do you understand by active and passive components ? Explain different types of active components available.

1·9. Give a brief description of different. types of fixed capacitors available. Compare their important characteristics. What type of capacitor will you use to filter out AC ripples from the DC supply.

1·10. Give the constructional details of a low frequency transformer.

1·11. Give the colour coding scheme used in ceramic capacitors. Given colour coding for

(*a*) 100 pF ± 5% (*b*) ·001 μF 400 VDC ± 10%

1·12. Define Fermi level and Forbidden energy gap. Where does the fermi level lie in pure semi conductors.

1·13. What do you understand by the coding of semi-conductor devices ? What type of devices do these code numbers represent ?

(*a*) BC 148 (*b*) AC 127 (*c*) BYX 27 (*d*) ASZ 18

1·14. Give symbols of the following devices

(*a*) UJT (*b*) *P* channel JFET (*c*) PNP transistor

(*d*) Zener diode (*e*) Silicon controlled rectifier

(*f*) Varactor (*g*) PNPN diode (*h*) gas diode.