Introduction to electronics

Objectives: At the end of this lesson you shall be able to
- **describe about electronics**
- **explain the types of resistors and induction**
- **explain the active components**
- **state the coding of semiconductors devices.**

Electronics is the discipline dealing with the development and application of devices and systems involving the flow of electrons in a vacuum, in gaseous media, and in semiconductors. Electronics deals with electrical circuits that involve active electrical components such as vacuum tues, transistors, diodes, integrated circuits, optoelectronics, and sensors, associated passive electrical components, and interconnection technologies. Commonly, electronic devices contain circuitry consisting promarily or exclusively of active semiconductors supllemented with passive elements; such a circuit is described as an electronic circuit.

Electronics is considered to be a branch of physics and electrical engineering.

The nonlinear behavious of active components and their ability to control electron flows makes amplification of weak signals possible. Electronics is widely used in information processing, telecomunication, and signal processing. The ability of electronic devices to act as switches makes digital information proccessing possible. Interconnection technologies such as circuit boards, electronics packaging technology and varied forms of communication infrastructure complete circuit functionality and transform the mixed components into a regular working system.

This Electronic sensors and signals are very much useful in Refrigeration & Air conditioning process.

Electrical and electro-mechanical science and technolgy deals with the generation, distribution, switching, storage and conversion of electrical energy to and from other energy forms (using wires, motors, generators, batteries, switches, relays, transformers, resistors and other passive components). This distinction started around 1906 with the invention by Lee De Forest of the triode, which made electrical amplification of weak radio signals and audio signals possible with a non-mechanical device. Until 1950 this field was called “radio technology” because its principal application was the design and theory of radio transmitters, receivers and vacuum tubes.

Today, most electronic devices use semiconductor components to perform electron control. The study of semiconductor devices and related technology is considered a branch of solid-state physics, whereas the design and construction of electronic circuits to solve practical problems come under electronics engineering. This article focuses on engineering aspects of electronics.

Branches of electronics

Electronics has branches as follows:

1 Digital electronics	2 Analogue electronics
3 Microelectronics	4 Circuit design
5 Integrated circuits	6 Optoelectronics
7 Semiconductor devices	8 Embedded systems

Resistors : The Components used in electronic circuits can broadly grouped under two headings.

– passive components – active components

Passive components : Components like resistors, capacitors, and inductors used in electronic circuit are called as passive components. These components by themselves are not capable of amplifying or processing an electrical signal. However these components are equally important in electronic circuit as that of active components, without the aid of passive components, a transistor (active components) cannot be made to amplify electrical signal.

Circuits formed with passive components obey the electrical circuits laws such as ohm’s law, Kirchoff’s Laws etc.,

Active components : In electronic circuit, the components, other than passive are known as active components. Namely, transistors, diodes, SCRs Vacuum tubes etc.,

Resistors : The components whose purpose to introduce resistance in the circuit is called as resistors. Other details of resistors are dealt in earlier lessons.

Capacitor : The components whose purpose to introduce capacitance in the circuit is called as capacitor. The unit of capacitance is ‘FARAD’. Commercially capacitors are available in micro farad (mF), nanofarad (nf) & pico farads (pf).

The colour coding of capacitors and resistors are same. Where as, in the case of fixed capacitors, the colour coded unit shall be in pico farads.

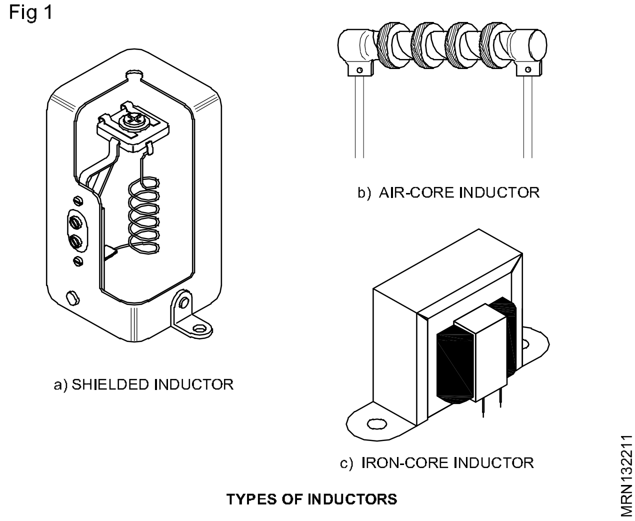
For letter coding, incase of capacitor, the letter ‘p’, ‘n’, ‘m’ shall be used as multipliers. Where p = 10^{-12}, n= 10^{-9} and m = 10^{-6} farads, and letter code for tolerance on capacitor is the same as in resistor.

Other details about the capacitors are already dealt in 1st year trade theory.

INDUCTOR : The ability of the conductor to induce voltage in itself, when the current changes in it is called as self inductance (or) simply inductance. A coil introduced in a circuit to have inductance is called as inductor.

Different type of inductors are shown in Fig 1. The unit of inductance is “Henry”. Commercially a coil may have inductance in milli henry (10^{-3}H), or in micro henry (10^{-6}H).

Fig 1



TYPES OF INDUCTORS

While specifying the inductance the following factors to be considered

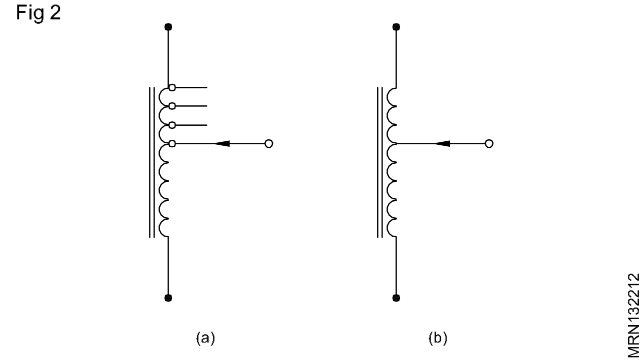
- nominal value of inductance in Henry / millihenry / micro (m) henry
- tolerance in percentage (±5/10/20%)
- type of winding like single layer, double layer, multilayer and pie (p) etc.
- type of core like air core, iron core, ferrite core
- type of application like audio frequency (AF), Radio frequency (RF) coupling coil, filter coil etc.,

In an electronic circuit some time, it is also required to vary the inductance.

The inductance of a coil can be varied by:-

– providing tapped inductive coil, as shown in Fig 2 or

Fig 2

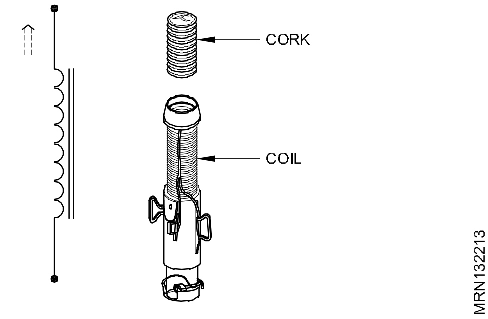


– adjusting the core of a coil as shown in Fig 3.

However, all inductor coils have inherent resistance due to the resistance of the winding wire in the coil. Further the maximum current that can be safely carried by an inductor depends upon the size of the winding wire used.

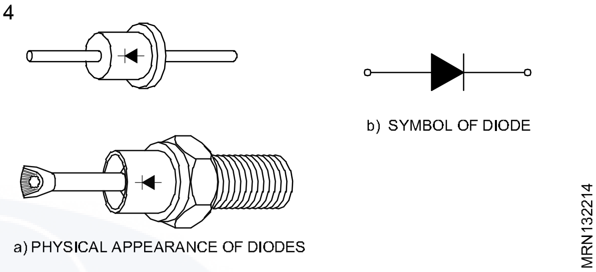
Active components : In electronic circuits, components other than resistors, capacitors and inductors are also used. Namely, transistors, diodes, vacuum tubes, SCRs, diacs, zener-diode etc. The application of electrical circuit laws (Ohm’s law etc.) in the circuit containing the above components will not give correct results. i.e. these components do not obey. Ohm’s law, Kirchoff’s law etc. These components are called active components.

Fig 3



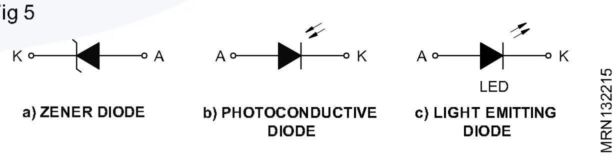
The different active components and the method of representing them by symbols in the circuit diagram are given below. (Fig 4)

Fig 4



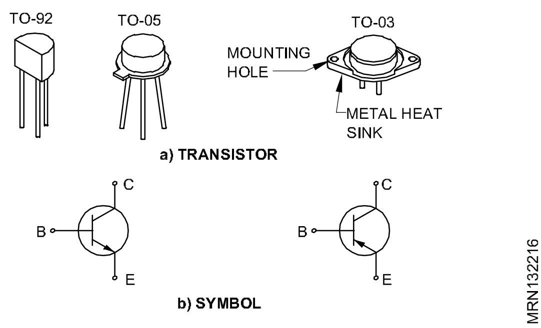
The different types of diodes (Fig 5) used for specific purposes are represented by the symbols given.

Fig 5



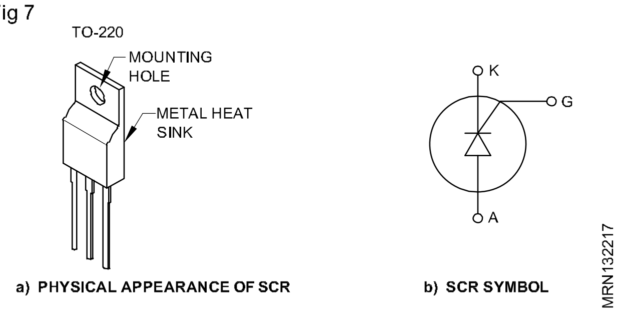
Transistor : Figure 6a shows the physical appearance of transistors. There are two symbols to represent a transistor. (Fig 6b). The selection of a symbol is based on either the NPN or the PNP type of transistor.

Fig 6



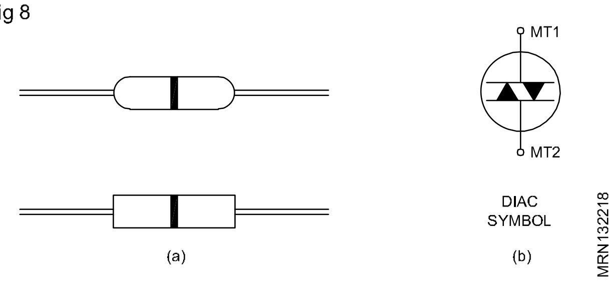
SCR (Silicon controlled rectifier) : Figure 7a shows the physical appearance of one type of SCR and the symbol is shown in Fig 7b. SCRs are also called thyristors and used as switching devices.

Fig 7



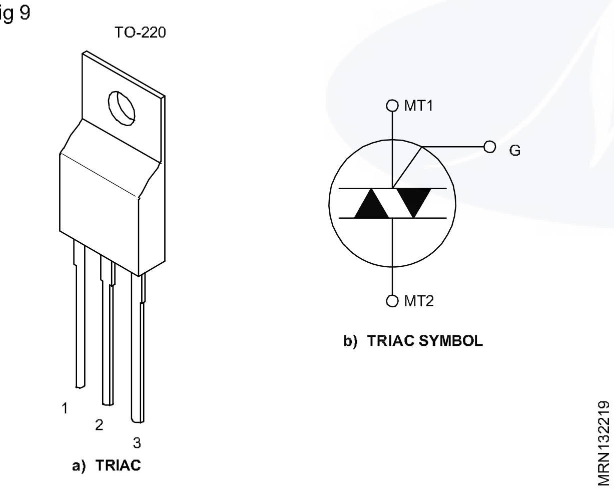
Diac : A diac (Fig 8a) is a two-lead device like a diode. It is a bidirectional switching device. Its symbol is shown in Fig 8b.

Fig 8



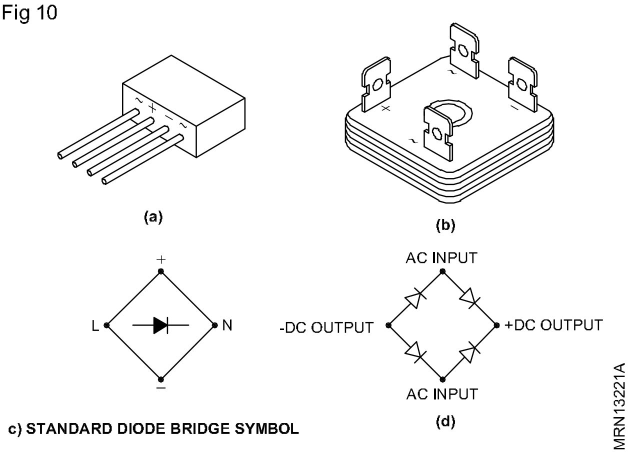
Triac : A triac is also a semiconductor device with three leads like two SCRs in parallel. The triac can control the circuit in either direction. (Fig 9)

Fig 9



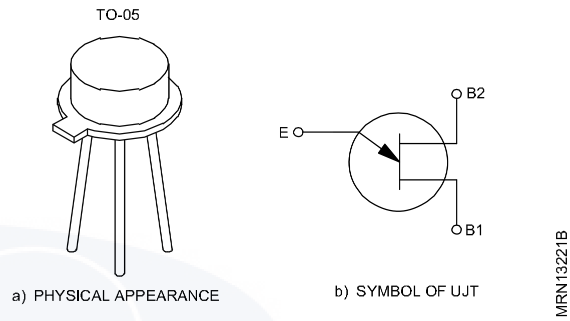
Bridge rectifier or diode bridge : It is a single package of four semiconductor diodes connected in bridge circuit. The input AC and the output DC leads are marked and terminated as shown in the Figure 10.

Fig 10



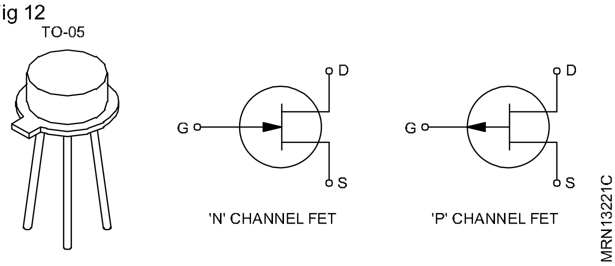
UJT (Uni-junction transistor) : It has two doped regions with three leads and has one emitter and two bases. (Fig 11)

Fig 11



FET (Field effect transistor) : Fig 12a give a pictorial view of the component, and the related symbol to represent the field effect transistor is shown in Fig 12b. The selection of the symbol is based on whether the FET is a 'N' channel or a 'P' channel one.

Fig 12



Note:- The devices like transistor, SCR triac, UJT & FET may look alike due to similarity in encapsulation. They can be identified only by the code numbers and relevant data books.

Coding of semiconductor devices

Objectives: At the end of this lesson you shall be able to
- **state the purpose of letters used in the old systems of coding semiconductors, by referring to the manual**
- **describe the meaning of 1N, 2N, 3N in semiconductor coding.**

Old system : Some earlier semiconductor diodes and transistors have type numbers, consisting of two or three letters followed by group of one, two or three figures. The first letter is always 'O', indicating a semiconduct device.

The second (and third) letter(s) indicate the general class of the device.

A – diode or rectifier

AP – photo-diode

AZ – voltage regulator diode

C – transistor

CP – phototransistor

The group of figures in a serial number indicating a particular design or development.

Present system : This system consists of two letters followed by a serial number. The serial number may consists of three figures of one letter and two figures depending on the main application of the device.

The first letter indicates the semiconductor material used.

A Germanium

B Silion

C Compound materials such as gallium arsenide

R Compound materials such as cadmium sulphide

The second letter indicates the general function of the device.

A detection diode, high speed diode, mixer diode

B variable capacitance diode

C transistor for I.F. applications (not power types)

D power transistor for A.F. applications (not power types)

E tunnel diode

F transistor for A.F. applications (not power types)

G multiple of dissimilar devices, miscellaneous devices

L power transistor for a.f. applications

N photo-coupler

P radiation sensitive device such as photo-diode, photo-transistor, photo-conducive cell, or radiation detector diode

Q radiation generating device such as light-emitting diode

R controlling and switching devices (e.g. thyristor) having a specified breakdown characteristic (not power types)

S transistor for switching applications (not power types)

T controlling and switching power device (e.g. thyristor) having a specified breakdown characteristic.

U power transistor for switching applications

X multiplier diode such as varactor or step recovery diode

Y rectifier diode, booster diode, efficiency diode

Z voltage reference or voltage regulator diode, transient suppressor diode.

The remainder of the type number is a serial number indicating a particular design or development, and is in one of the following two groups.

a Devices intended primarily for use in consumer applications (radio and television receivers, audio-amplifiers, tape recorders, domestic appliances, etc.) The **serial number** consists of three figures.

b Devices intended mainly for applications other than (a) e.g. industrial, professional and transmitting equipments.

The serial number consists of one letter (Z,Y,X,W etc) followed by two numbers (digits)

The international system follows letters 1N, 2N, 3N etc followed by four numbers.

1N indicates single junction

2N indicates two junction

3N indicates three junctions.

The number indicates internationally agreed manufacturer's code e.g. 1N 4007, 2N 3055, 3N 2000.

Again, manufacturers use their own codes for semiconductor devices. Manufacturers in Japan use 2SA, 2SB, 2SC, 2SD etc. followed by a group of numbers e.g. 2SC 1061, 2SA 934, 2SB 77. Indian manufacturers have their own codes too.

Resistors

Objectives : At the end of this lesson you shall be able to
- **state the function of a resistor in a circuit and unit of resistance**
- **name and list the classifications of resistors**
- **brief constructional details of important resistor types**
- **state the meaning of tolerance in resistor and power rating.**

Resistors

Resistors are electronic components, used to reduce, or limit, or resist the flow of current in any electrical or electronic circuit.

Resistors are made of materials whose conductivity fall in-between that of conductors and insulators. This means, the materials used for making resistors have free electrons, but not as many as in conductors. Carbon is one such material used most commonly for making resistors.

When a large number of electrons are made to flow through a resistor, there is opposition to the free flow of electrons. This opposition results in generation of heat.

Unit of resistance

The property of the resistor to limit the flow of current is known as *resistance*. The value, or quantity of *resistance* is measured in units called **ohms** denoted by the symbol Ω.

Resistors are called *passive devices* because, their resistance value does not change even when the level of applied voltage or current to it is changed. Also, the resistance value remains same when the applied voltage is AC or DC.

Resistors can be made to have very small or very large resistance. Very large values of resistances can be represented as given below;

1000 Ω	= 1 x 1000 Ω	= 1 x kiloΩ	= 1 K Ω
10,000 Ω	= 10 x 1000 Ω	= 10 x kiloΩ	= 10 K Ω
100,000 Ω	= 100 x 1000 Ω	= 100 x kilo Ω	= 100 K Ω
1000,000 Ω	= 1000 x 1000Ω	= 1000 x kiloΩ	= 1000 KΩ
		= 1000kΩ	= 1MΩ

Classification of resistors

Fixed value resistors

Its ohmic value is fixed. This value cannot be changed by the user. Resistors of standard fixed values are manufactured for use in majority of applications.

Fixed resistors are manufactured using different materials and by different methods. Based on the material used and their manufacturing method/process, resistors carry different names.

Fixed value resistors can be classified based on the type of material used and the process of making as follows.

Physical appearance of some types of fixed value resistors is shown in Chart 1 at the end of this lesson.

Power rating

As already discussed, when current flows through a resistor, heat is generated. The heat generated in a resistor will be proportional to the product of applied voltage (V) across the resistor and the resultant current (I) through the resistor. This product VI is known as *power*. The unit of measurement of power is *watts*.

Resistor values - coding schemes

For using resistors in circuits, depending upon the type of circuit in which it is to be used, a particular type, value and wattage of resistor is to be chosen. Hence before using a resistor in any circuit, it is absolutely necessary to identify the resistor's type, value and power rating.

Selection of a particular type of resistor is possible based on its physical appearance. The resistance value of a resistor will generally be printed on the body of the resistor either directly in ohms or using a typographic code or using a colour code.

Colour band coding of resistors

Colour band coding is most commonly used for carbon composition resistors. This is because the physical size of carbon composition resistor is generally small, and hence, printing resistance values directly on the resistor body is difficult.

Tolerance

In bulk production/ manufacturing of resistors, it is difficult and expensive to manufacture resistors of particular exact values. Hence the manufacturer indicates a possible variation from the standard value for which it is manufactured.

This variation will be specified in percentage tolerance. Tolerance is the range(max -to- min) within which the resistance value of the resistor will exist.

Typo graphical coding of resistors

In the typographical coding scheme of indicating resistance values, the ohmic value of the resistor is printed on the body of the resistor using a alpha-numeric coding scheme.

NOTE: Some resistance manufacturers use a coding scheme of their own. In such cases it will be necessary to refer to the manufacturer's guide.

FIXED VALUE RESISTORS

- Carbon composition resistors
- Wire-wound resistors
- Film resistors
  - Carbon - film resistors
  - Metal film resistors
  - Metal oxide film resistors
  - Cermet film resistors
  - Integrated resistors
- Printed resistors

Applications

Carbon composition, fixed value resistors are the most widely used resistors in general purpose electronic circuits such as radio, tape recorder, television etc. More than 50% of the resistors used in electronic industry are carbon resistors.

Brief constructional details of a few important types of fixed value reistors is given in Chart-2 at the end of this lesson.

Measuring ohmic value of resistors

It is not possible to read the *exact ohmic value* of a resistor from colour/other coding schemes due to manufacturing tolerance built into the resistors. To find the exact ohmic value of resistors *ohmmeters* are used. When a resistor is placed between the test prods of an ohmmeter as shown in Fig 6A, the meter shows nearest to the exact resistance of the resistor directly on the graduated meter scale. Multimeters are also used to measure the value of resistors as shown in Fig 6B.

When a multimeter is used for resistance measurement, the resistance range switch on the meter should be put to the most suitable resistance range, depending upon the value of resistance being measured.

Appendix D suggest the meter ranges for measuring different resistor values accurately.

Wire-wound Resistors

Resistors, in addition to having a required ohmic value, should also be capable of dissipating the heat produced. Carbon by its nature has a limitation in the maximum heat it can dissipate. Carbon resistors become too hot when high current flows through them. This increased heat in carbon resistors changes the ohmic value of the resistors. Sometimes the resistors may even burn open due to excessive heat. Hence carbon resistors are suited only in low power circuits safely up to 2 watts.

This limitation in carbon resistors can be overcome by using wires of resistive materials like Nichrome, Manganin etc., instead of carbon. Resistors made using wires of resistive materials are known as *wire-wound* resistors. These resistors can withstand high temperature, and still maintain the exact ohmic values. In addition, wire-wound resistors can also be made to have fractional ohmic values which is not possible in carbon composition resistors.

Resistor values

Wire-wound resistors are available from a fraction of an ohm to 100's of Kilo ohms, with a power ratings of 1 watt to several 100s of watts. The higher the power rating, the thicker the resistive wire used, and bigger will be the physical size of the wire-wound resistor.

Applications

Wire-wound resistors are commonly used in electronic circuits where small values, precision values, high wattage ratings are required. A few applications are : regulated power supplies, amplifiers, motor controls, servo control circuits, TV receivers etc.

Special types of fixed value wire wound resistors

In applications where more than one fixed value wire-wound resistor is required to be used, a tapped wire wound resistor with more than one value, made in a single unit as in Fig 7 can be used.

Tapped resistors, whose tapings can be adjusted by adjusting the position of the sliding collar are also available as shown in Fig 8. This gives the flexibility of varying the resistance value between the tapings.

Ohm's law - Resistors - Measurement of resistance - Laws of resistance

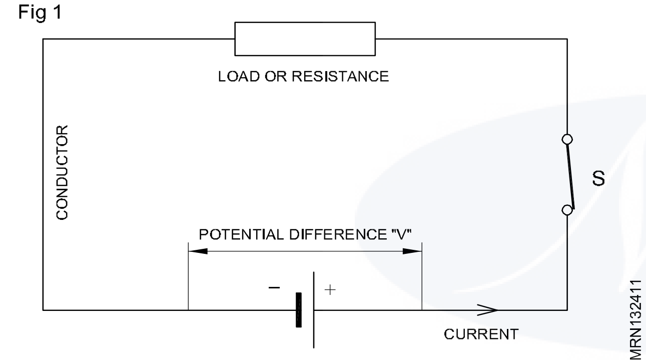
Objectives: At the end of this lesson you shall be able to
- **describe the essential factors in an electrical circuit**
- **state the relation between circuit factors through Ohm's law**
- **apply Ohm's law in an electric circuit**
- **explain the working of semi conductors**
- **state the classification of diodes**
- **check the diode with multimeter**
- **state the use of voltmeter amphere meter and multimeter.**

Simple electric circuit

In the simple electric circuit shown in Fig 1, the current completes its path from the positive terminal of the battery via the switch and the load back to the negative terminal of the battery.

The circuit shown in Fig 1 is a closed circuit. In order to make a circuit to function normally the following three factors are essential.

Fig 1



- Electromotive force to drive the electrons through the circuit
- Current, the flow of electrons
- Resistance - the opposition to limit the flow of electrons.

Electromotive force (Symbol E)

An electromotive force is essential to drive the electrons in a circuit.

This force is obtained from the source of supply i.e. Torch cells, dynamo.

Systems International (SI) unit of electromotive force is volts (symbol V).

Potential difference (Symbol V)

The difference of voltage across two points in a circuit is called a potential difference and is measured in volts.

In a circuit, when a current flows, there will be a potential difference across the terminals of the resistor/load. In the circuit shown in Fig 1, when the switch is in the open condition, the voltage across the terminals of the cell is called electromotive force (E) whereas when the switch is in the closed position, the voltage across the cell is called potential difference which will be lesser in value than the electromotive force earlier measured. This is due to the fact that the internal resistance of the cell drops a few volts when the cell supplies current to the load.

Current (Symbol I)

The flow of current through a circuit is essential for energy conversion.

Example

Heat produced in electric kettles/heaters.

Light produced in electric lamps.

Mechanical force produced in electric motors.

The SI unit of electric current is ampere (symbol A).

Resistance- (Symbol R)

The resistance offered by the circuit elements like resistance of the conductor or load is essential to limit the flow of current.

In the absence of resistance in a circuit, the current will reach an abnormally high value endangering the circuit itself.

Example

Filament of a lamp, heater coil of a kettle, winding of a motor.

The SI unit of electrical resistance is ohm. (symbol ý)

Ohm's law

The relation between the electromotive force, current and resistance of a circuit is given by Ohm's law.

Ohm's law states that the ratio of the voltage (V) across any two points of a circuit to the current (I) flowing through is constant provided physical conditions, namely temperature etc. remain constant. This constant is denoted as resistance (R) of the circuit.

Thus $\frac{V}{I} = \text{Constant}$

or we can say $\frac{V}{I} = R$

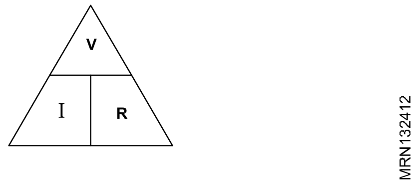
V = Voltage applied to the circuit

I = Current flowing through the circuit

R = Resistance of the circuit

The above relationship can be referred to in a **triangle** as shown in Fig 2. In this triangle whatever the value you want to find out, place the thumb on it then the position of the other factors will give you the required value.

Fig 2



For example for finding 'V' close the value 'V' then readable values are IR, so V = IR.

Again for finding 'R', close the value R, then readable values are V/I so R = V/I, like that $I = \frac{V}{R}$

Application of Ohm's law in circuits

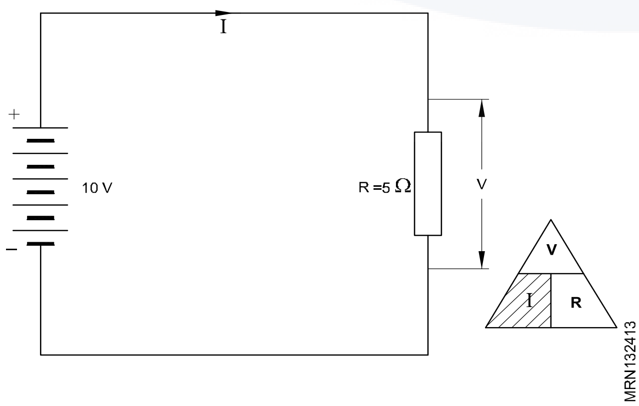
Example 1

Let us take a circuit shown in Fig 3 having a source of 10V battery and a load of 5 ohms resistance. Now we can find out the current through the conductor.

$I = \frac{V}{R}$, applying the value

$I = \frac{10}{5}$ = 2 amperes.

Fig 3



Problem

Find the value of voltage across a10 ohms resistor in the circuit shown (Fig 4) when the current of 2 amps flows through the 10 ohms resistor.

Solution

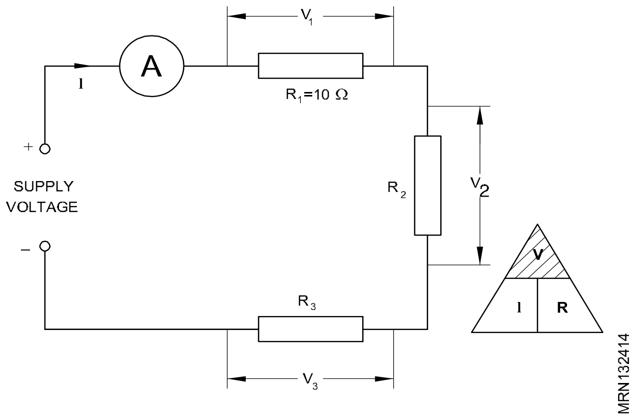
Voltage across 10 ohms

V = I x R

= 2 x 10 = 20 volts.

Similarly if the value of the other resistance is known we can find the voltage drop across them.

Fig 4



Extreme circuit conditions

Two important extreme conditions can occur in a circuit.

Open circuit

In an open circuit, there is an infinitely high resistance in the circuit. This condition can happen in a circuit when the switch is open. Therefore, no current of flow.

For example, a generator is said to be in an open circuit when the switch is open and running without supplying current to the circuit. A wall socket, too, is an open circuit if the control switch of the wall socket is 'OFF'or 'ON' position provided there is no appliance plugged to the wall socket.

Short circuit

The other important extreme condition is the short circuit. A short circuit will occur, for example, when the two terminals of a cell are joined. A short circuit may also occur if the insulation between the two cores of a cable is defective. The resulting low resistance will cause large currents which can become a hazard.

Identification of rectifier diodes

Semiconductor

Semiconductors are materials whose electrical property lies between that of Conductors and Insulators. Because of this fact, these materials are termed as semiconductors. In conductors the valence electrons are always free. In an insulator the valence electrons are always bound. Whereas in a semiconductor the valence electrons are normally bound but can be set free by supplying a small amount of energy. Several electronic devices are made using semiconductor materials. One such device is known as Diode.

Semiconductor theory

Basic semiconductor materials like other materials have crystal structure. The atoms of this structure, are bonded to each other. This bonding is known as covalent bonding. In such a bonding, the valence electrons of the atoms are shared to form a stable structure.

Intrinsic semiconductors

The most important of the several semiconductor materials are Silicon (Si) and Germanium (Ge). Both these semiconductor materials have four valence electrons per atom. These valence electrons, unlike in conductors, are not normally free to move. Hence, semiconductors in their pure form, known as Intrinsic semiconductors, behave as insulators.

However, the valence electrons of a semiconductor can be set free by applying external energy. This energy will tear-off the bound electrons from their bond and make them available as free electrons. The simplest method of turning bonded valence electrons into free electrons is by heating the semiconductor.

The higher the temperature to which the semiconductor is heated, more the bound electrons becoming free and will be able to conduct electric current. This type of conduction in an intrinsic semiconductor (pure semiconductor) as a result of heating is called intrinsic conduction.

From the above said phenomena, it is important to note that semiconductors are temperature-sensitive materials.

Extrinsic semiconductor

The number of free electrons set free by heating a pure semiconductor is comparatively small to be used for any useful purpose. It is found experimentally that, when a small quantity of some other materials such as Arsenic, Indium, Gallium etc. is added to pure conductor material, more number of electrons become free in the mixed material. This enables the semiconductor to have higher conductivity.

These foreign materials added to the pure semiconductor are referred to as impurity materials.

The process of adding impurity to an Intrinsic semiconductor material is known as Doping. Since the doped semiconductor materials are no longer pure, they are called impure or **extrinsic semiconductors.**

Depending upon the type of impurity used, extrinsic semiconductors can be classified into two types;

1 N-type semiconductors

When a pentavalent material like Arsenic (As) is added to a pure Germanium or pure Silicon crystal, one free electron results per bond. As every arsenic atom donates one free electron, arsenic is called the donor impurity. Since a free electron is available and since the electron is of a Negative charge, the material so formed by mixing is known as **N type material.**

When a N-type material is connected across a battery, current flows due to the availability of free electrons. As this current is due to the flow of free electrons, the current is called electron current.

2 P-type semiconductors

When a trivalent material like Gallium(Ga) is added to a pure Germanium or pure Silicon crystal, one vacancy or deficit of electron results per bond. As every gallium atom creates one deficit of electron or hole, the material is ready to accept electrons when supplied. Hence gallium is called acceptor impurity. Since vacancy for an electron is available, and as this vacancy is a hole which is of Positive charge, the material so formed is known as **P-type material**.

When a P-type material is connected across a battery as shown in Fig 4b, current flows due to the availability of free holes. As this current is due to flow of holes, the current is called hole current.

P-N junction

When a P-type and a N-type semiconductors are joined, a contact surface between the two materials called PN-junction is formed. This junction has a unique characteristic. This junction, has the ability to pass current in one direction and stop current flow in the other direction. To make use of this unique property of the PN junction, two terminals one on the P side and the other on the N side are attached. Such a PN junction with terminals attached is called a **Diode.** The typical symbol of a PN-junction diode.

When a P and N material is put together, at the junction of P and N materials, some electrons from the N-material jump across the boundary and recombine with the hole near the boundary of the P-material. This process is called diffusion. This recombination makes atoms near the junction of the P-material gaining electrons and become negative ions, and the atoms near the junction of the N-material, after losing electrons, become positive ions. The layers of negative and positive ions so formed behave like a small battery. This layer is called the depletion layer because there are neither free electrons nor holes present (depleted of free carriers). This depletion region prevents further the movement of electrons from the N-material to the P material, and thus an equilibrium is reached.

The internal voltage set up due to +ve and -ve ions at the junction is called barrier potential. If any more electrons have to go over from the N side to the P side, they have to overcome this barrier potential. This means, only when the electrons on the N side are supplied with energy to overcome the barrier potential, they can go over to the P side.

In terms of voltage applied across the terminals of the PN junction diode, a potential difference of 0.7V is required across the terminals in the case of silicon diode and 0.3V in the case of Germanium diode for the electrons, in order to cancel off the barrier potential and cross over the barrier. Once the barrier potential gets canceled due to external voltage application, current flows through the junction freely. In this condition the diode is said to be forward biased.

Types of diodes

The PN junction diodes discussed so far are commonly referred to as rectifier diodes. This is because these diodes are used mostly in the application of rectifying AC to DC.

Classification of Diodes

1 Based on their current carrying capacity/power handling capacity, diodes can be classified as

- **low power diodes**
  can handle power of the order of several milliwatts only

– **medium power diodes**
can handle power of the order of several watts only

– **high power diodes**
can handle power of the order of several 100's of watts.

2 Based on their principal application, diodes can be classified as,

– **Signal diodes**
low power diodes used in communication circuits such as radio receivers etc. for signal detection and mixing

– **Switching diodes**
low power diodes used in switching circuits such as digital electronics etc. for fast switching ON/OFF of circuits

– **Rectifier diodes**
medium to high power used in power supplies for electronic circuits for converting AC voltage to DC.

3 Based on the manufacturing techniques used, diodes can be classified as,

– **Point contact diodes**
a metal needle connected with pressure on to a small germanium(Ge) or silicon(Si) tip.

– **Junction diodes**
made by alloying or growing or diffusing P and N materials on a semiconductor substrate.

Types of diode packaging

The type of packaging given to diodes is mainly based on the current carrying capacity of the diode. Low power diodes have either glass or plastic packaging. Medium power diodes have either plastic or metal can packaging. High power diodes will invariably have either metal can or ceramic packaging. High power diodes are generally of stud-mounting type.

Testing rectifier diodes using ohmmeter

A simple ohmmeter can be used to quickly test the condition of diodes. In this testing method, the resistance of the diode in forward and reverse bias conditions is checked to confirm its condition.

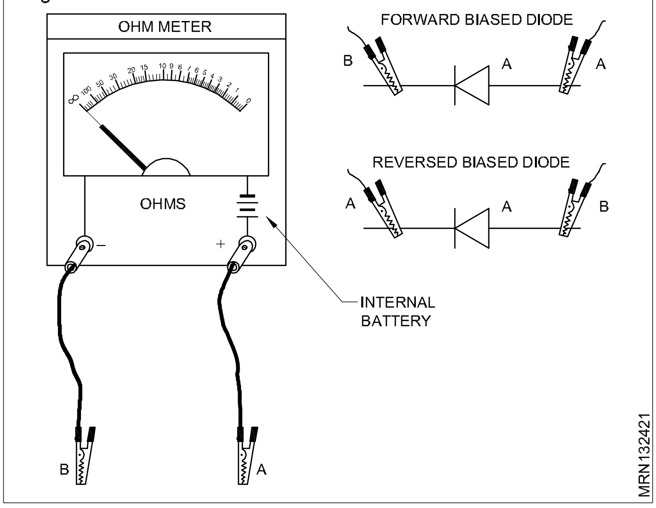
Recall that there will be a battery inside an ohmmeter or a multimeter in the resistance range. This battery voltage comes in series with the leads of the meter terminals. In FIg 10, the lead A is positive, lead B negative.

NOTE: If the polarity of the meter leads are not known at first, the polarity of the meter leads can be determined using a voltmeter across the ohm meter terminals.

If the positive lead of the ohmmeter, lead A in the Fig 1, is connected to the anode of a diode, and the negative (lead B) to the cathode, the diode will be forward-biased. Current will flow, and the meter will indicate low resistance.

On the other hand, if the meter leads are reversed, the diode will be reverse-biased. Very little current will flow because a good diode will have very high resistance when reverse biased, and the meter will indicate a very high resistance.

Fig 1



While doing the above test, if a diode shows a very low resistance in both the forward and reverse biased conditions, then, the diode under test must have got damaged or more specifically shorted. On the other hand, a diode is said to be open if the meter shows very high resistance both in the forward and reverse biased conditions.

Polarity marking on the diodes

The cathode end of a diode is usually marked by a circular band or by a dot or by plus (+) sign as shown in Chart 1. In some diodes the symbol of the diode, which itself indicates the polarities, is printed on the body of the diode.

Type number or diode code number

Unlike resistors, capacitors or inductors, the diodes do not have any value that can be printed or coded on its body. The other reason for this is, there are almost innumerable types of diodes with varied current handling and other specifications. Hence, instead of printing its specifications on its body, all diodes will have a type number printed on their body. This type number carries a set of specifications which can be found out by referring to a diode data manual. Diode data manuals give data of several thousands of diodes from different manufacturers. Some of the popular type numbers of diodes are

OAxx,	xx - from 70 to 95.	examples: OA79, OA85 etc.,
BYxxx,	xxx- from 100 onwards,	examples: BY127, BY128 etc.
DRxxx,	xxx- from 25 onwards.	examples: DR25, DR150 etc.,
1Nxxxx	examples: 1N917	1N4001, 1N4007 etc.

Voltmeter

A voltmeter is an instrument used for meauring electrical potential difference between two points in an electric circuit. Analog voltmeters move a pointer across a scale in proportion to the voltage of the circuit; digital voltmeters give a numerical display of voltage by use of an anolog to digital converter.

Ampere meter

An ammeter (from ampere meter) is a measuring instrument used to measure the current in a circuit. Electric currents are measured in amperes (A), hence the name. Instruments used to meaure smaller currents, in the milliampere or microampere range, are designated as milliameters of microammeters.

Multimeter

A multimeter or a multitester, also known as a VOM (volt-ohm-milliammeter), is an electronic measuring instrument that combines several measurement functions in one unit. A typical multimeter can measure voltage, current, and resistance. Analog multimeters use a mucroammeter with a moving pointer to display readings.

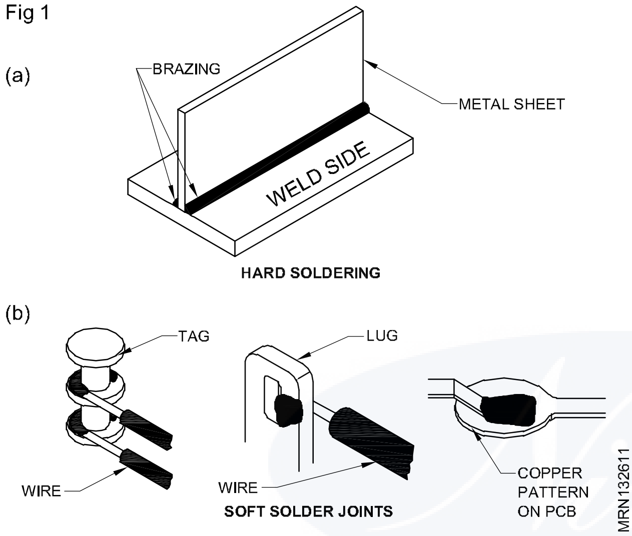
Tinning and soldering of wires

Objectives : At the end of this exercise you shall be able to
- **state the meaning of soldering**
- **list two main types of soldering and its uses**
- **state the soldering technique.**

Solering

Soldering is a process of connecting any two metallic surfaces such as copper, brass and alloys of these metals. Some types of solder joints are shown in Fig 1

Fig 1



There are two types of soldering,

1 **Hard soldering or brazing** used for joining large metal parts as shown in Fig 1a.

2 **Soft soldering** used to form good electrical joints/ connections between electrical/electronic parts as shown in Fig 1b.

Soft soldering is used extensively for electronic circuit wiring. In this lesson only soft soldering is discussed. Hard soldering or brazing is out of scope of this lesson.

From now on in this book, soldering means soft soldering.

Need for soldering

Requirements of an electrical joint

1 The electrical joint must provide ideally zero resistance or at least a very low resistance path, for the flow of current.

2 The electrical joint made should be strong enough to withstand vibrations, physical shock, bumps etc, without causing any deterioration to the quality and strength of the joint.

3 The electrical joint should be able to withstand corrosion and oxidation due to adverse atmospheric conditions.

All the above requirements of an electrical joint can be achieved by making a solder joints.

Solder

In a soldered joint, the solder is a mixture of metals, generally TIN and LEAD. It is made to melt at a certain temperature. It acts as a filler between the parts of the connection/joint to form a continuous, low resistance metallic path for conduction of electricity.

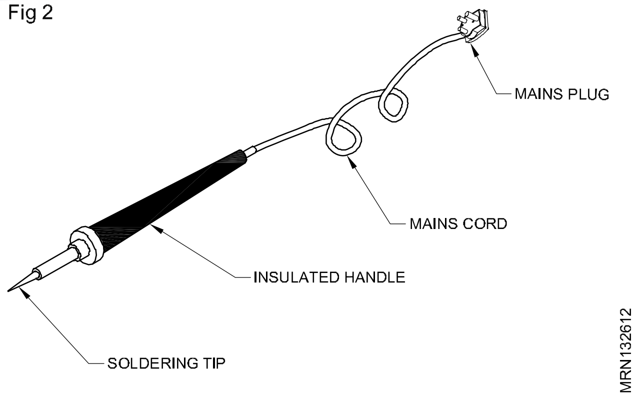
In soldering, as the metal surface is wetted (free flow of liquid solder over a surface) by the solder, a complex chemical reaction, bonds the solder to the metal surface.

The tin content of the solder diffuses with the metal surface to form a layer of a completely new alloy. The alloy so formed will have the same structure as the constituent metals and retain their metallic properties and strength.

Soldering and soldering irons

While soldering, the solder is made to melt between the metallic surfaces of the joint, using a soldering iron, as shown in Fig 2. A **soldering iron** is an instrument used to produce the required heat to carry out soldering.

Fig 2



Soldering irons of different wattage ratings starting from 10 watts to more than 150 watts are available commercially. Depending on the type, size and heat sensitivity of the components being soldered, the most suitable wattage soldering iron should be chosen. Most of these soldering iron work on 240V, 50Hz ac mains supply. There are special type irons which work on dc supply also. For soldering delicate components, soldering irons with temperature controlling facility are used. These are known as soldering stations.

Soldering iron tips

Soldering irons are designed to take, a variety of tip sizes and shapes. The choice of the iron and the tip to use depends on, the nature of the joint to be soldered. A proper selection of the soldering iron and tip is important for obtaining good quality soldered joint. To solder effectively, the tip of the soldering iron must be kept clean all times.

Types of solders

Solders are available in many forms. The type to be chosen depends on, the type of soldering to be carried out. The wire type solder is the most commonly used solder for hand soldering work, using low wattage soldering iron.

Solders available in the market may have different tin-lead proportion in it. For general electronic circuit soldering work, solder with 60% tin and 40% lead is most suited. This solder is commonly called 60/40 solder. This solder has been specially developed to possess superior properties required for electronic circuit work.

Soldering FLUX

A protective oxide layer forms on the exposed surface of most metals. The rate at which the oxide layer is formed varies from metal to metal. The layer forms quickly on newly exposed metal, and over time, the layer slowly become quite thick.

This oxide layer on metals interferes with soldering. Hence, it must be removed before a soldered joint can be made.

The purpose of flux is to first dissolve the thin layer of oxide from the surface of the metals to be joined, and then form a protective blanket over them until the solder can flow over the joint surfaces to form the joint.

However, thick layers of oxide must be removed using an abrasive method as all types of flux are not capable of dissolving their oxide layers.

Types of flux

There are several types of fluxes used in different types of soldering. The type of flux used for soldering electronic components is called **rosin**. Rosin is made from a resin obtained from the sap of trees.

Rosin flux is ideal for soldering electronic components because, it become active at the soldering temperature, but revert to an inactive state when cooled again. An additional advantage is that it is non-conductive.

The rosin has activators or halides added to it. The activators used in rosins are mild acids that become very active at soldering temperatures. These acids dissolve the oxide layer on the metals to be soldered.

Organic and inorganic acid fluxes are available. These fluxes are not suitable for soldering electronic circuits.

For further details on the different types of rosin fluxes refer reference books listed at the end of this book.

Common forms of flux

Flux is available in a variety of forms to suit various types of application. Flux is available as a liquid, paste or a solid block. For most applications flux is often put in the solder itself during manufacture.

Not all flux types are available in all forms. For hand soldering work on electronic circuits, the best form for the flux is either as a liquid or a paste.

Rosin cored solder

Several manufacturers produce solder wire with the flux already included in one or more cores running along its length. This is known as **cored solder**.

The most popular type of cored solder for electronic hand soldering contains rosin type flux. Such solder is known as **rosin cored solder**.

When the solder is heated, the rosin flux melts before the solder. The rosin then flows out over the surface to be soldered ahead of the solder.

The amount of flux contained in the core is carefully controlled by the manufacturer and for most applications it will be sufficient. However, it is a common practice to apply additional liquid flux or flux paste to the joint, just prior to making the joint. This additional flux ensures that, sufficient flux available while the joint is being made. When the soldering has been completed, excess flux if any has to be removed.

Rosin-cored solder is available in different gauges as shown in Fig 5. It is important to choose a size suitable for the job at hand as given below;

– use 22 gauge for small joints

– use 18 gauge for medium joints

– use 16 gauge for large joints.

Tinning wires

When wires are to be connected to lugs or any other type of terminations, after skinning the wire, it is preferred to apply a thin coating of solder using a soldering iron. This process is known as **tinning** the wire.

When tinned, the solder penetrates the wire strands and holds them together. This holding of strands prevents the strands from becoming separate while soldering the wire onto terminations.

Tinning of the wire is advised to be done soon after stripping of the wire end, so that the wire strands do not tarnish.

Care must be taken when tinning a wire to ensure that capillary action does not draw the solder under the unstriped insulation. This action is called **wicking**. A special tool known as **anti-wicking tweezers** can be used to help prevent wicking. A wire that has wicked under the insulation must be cut off and the tinning process repeated.

Inspecting tinned wires

When a wire has been tinned, it is necessary to inspect the tinned wire to ensure that:

– the solder has not wicked under the insulation

– the insulation on the wire is not melted or burnt

– the wire strands are visible beneath the solder

– the tinned surface is smooth and shiny.

If tghe tinned wires does not meet these standards that portionof the wire must be cut. The wire must be reskinned and cut

If the tinned wire does not meet these standards, that portion of the wire must be cut. The wire must be re-skinned and tinned.

Soldering technique

Soldering a joint

Selection and preparation of the soldering materials is the most time consuming phase of making a solder joint. Heating the joint and applying solder is the least time consuming but, it is the most important part of the soldering process.

Critical factors during soldering

1 Controlling the temperature of the workpiece

2 Limiting of time that a workpiece is held at soldering temperature.

These factors are specially critical while soldering electronic components like resistors, capacitors, transistors, ICs etc., Failure to correctly time and coordinate the heating of the joint and add solder, will result in a poor quality joint and may even damage the components.

Stages in soldering

The soldering process can be divided into several distinct stages or phases as given below:

1 Selection and preparation of materials.

2 Heating the joint and adding solder.

3 Cooling the joint.

4 Cleaning the joint.

5 Inspecting the joint.

1 Selection and preparation of materials

1.1 Selection of soldering iron wattage

Soldering irons are available in different wattage ratings starting from 10 watts to several 100 watts. The wattage of a soldering iron specifies the amount of heat it can produce. As a thumb rule, higher the physical dimension of the workpiece, higher should be the wattage rating of the soldering iron. Some of the suggested wattage choices are given below:

i For soldering less temperature sensitive components such as, resistors on lug boards, tag boards, use 25 to 60W iron. For soldering on printed circuit boards, use 10 to 25 W iron.

ii For soldering highly temperature sensitive components such as, diodes, transistors and integrated circuits, use 10 to 25 watts iron.

1.2 Selection of soldering iron tip

To ensure that the joint is heated to the required temperature ideally,

– the area of the tip face should be approximately equal to the area of the joint to be soldered

– the tip should be long enough to allow easy access to the joint.

– the tip should not be too long, as this may result in too low temperature at the tips working face.

In most soldering irons, the tip can be easily removed and replaced.

Selection of tip temperature

Good quality soldering iron tips have numbers punched on them. These numbers indicate the temperature to which the tip can be heated, as shown in table in the next page.

Selection of tip shape

Suggested soldering tip shapes selection table is given below;

Tip No.	Temperature °C	Temperature °F
5	260	500
6	316	600
7	371	700
8	427	800

1.3 Selection of solder and flux

There are several sizes of the cored solders whose choice depends on the size of the joints to be soldered. Also the tin and lead percentage of the solder should be checked before using the solder. Different tin and lead combinations of solder need different temperatures for it to melt and reach the liquid state.

Type of soldering work	Soldering tip shape to choose
Wires, resistors and other passive components on to lug/tag boards	CHISEL TIP
All miniature electronic components except ICs on to lug boards and printed circuit boards (PCB)	BEVEL TIP
Integrated circuits (ICs) on to printed circuit boards (PCBs)	CONICAL TIP

For electronic soldering applications, solder of tin and lead of 60/40 proportion is used. This solder proportion has a melting point of 200°C which is the required temperature for general purpose soldering irons.

While soldering to make a strong solder joint the flux should melt first, and then the solder. Therefore, while using rosin cored solder, cut off the first 5 to 10mm of the solder using a side cutter, so that any earlier melted portion of the solder blocking the rosin core is removed.

For ease of application, the flux used in addition to the cored flux in solder should be of paste form.

Flux is a chemical substance which has acidic properties. Therefore, it is advised not to touch flux by hand. Use a stick or a thin stiff brush to apply flux on workpieces. Hands should be washed after soldering work.

Fig 3