GOVERNMENT OF TAMIL NADU

HIGHER SECONDARY FIRST YEAR

VOCATIONAL EDUCATION

Basic Electronics Engineering

THEORY & PRACTICAL

A publication under Free Textbook Programme of Government of Tamil Nadu

Department of School Education

Untouchability is Inhuman and a Crime

Government of Tamil Nadu

First Edition - 2018

Revised Edition - 2019

(Published under New Syllabus)

NOT FOR SALE

Content Creation

State Council of Educational Research and Training

Printing & Publishing

Tamil Nadu Textbook and Educational Services Corporation

PREFACE

This book is written in accordance with the new guidelines formulated by Tamilnadu Government Curriculum Framework (TNCF-2017) Committee to strengthen the higher secondary education on par with the Global Standards by providing different kinds of learning opportunities to promote holistic approach to education. The objectives of this book on Electronics Equipment is not only for knowledge upgradation but also for providing basic skills viz., hands-on-experience with electronic circuits, trouble shooting of minor problems in electronic equipment, handling of test and measuring equipment.

This book covers the up-to-date curriculum in the area of Electronics and related fields to encourage the multidisciplinary approach and discourage rote learning of Electronics with different subject areas. Each Chapter has been designed and written in such a way to inculcate the basic knowledge of the Electronics to the students and also to give opportunity to the stakeholders to provide a platform for exhibiting their creativity.

Each Chapter starts with the introduction of the concerned topic and covers the contribution from different domains such as brief history of scientists and their related inventions, proverbs or Tamil literature quotes related to the particular scientific concept, learning objectives, learning outcomes and detailed description of the concepts with the related figures, equations for the easy and deep understanding of the subject matter. Further, several solved problems and self-evaluation exercises are given in each Chapter to motivate the students for self-learning and to develop self-confidence in the subject matter.

We appreciate the initiatives, encouragement and guidance extended by the Tamilnadu Curriculum Development committee headed by Prof. M. Anandakrishnan, who is responsible for shaping this book to this higher level. We are indebted to the institutions and organisations, which have generously permitted us to draw upon their resources, material and personnel. We are especially grateful to the members of the Tamilnadu State Council for Education Research and Training (SCERT) for their valuable support. For the systemic reform and continuous improvement in the standard of this book, we welcome critical comments and valuable suggestions, which will enable us to undertake further revision and refinement of the subject matters covered in this book.

We hope this book will bring an appreciable change in the teaching-learning process. We wish all the stakeholders to make use of this book effectively, to get the intended outcomes and benefits.

With Wishes

Dr. Damodaran Nedumaran

Chair Person

HOW TO USE THE BOOK

Learning Objectives	Learning objectives briefly describe the contents of the unit. It also outlines the knowledge gained by the students.
DO YOU KNOW?	Interesting facts to motivate students to gain more information regarding the unit.
Infographics	Visual representations of the unit for better understanding.
Concept Figures	Conceptual diagrams that potrays the technique of drafting and sewing.
	To facilitate reading at anytime, anywhere.
Activity	Skill oriented activities based on the units for better understanding.
Evaluation	Access students under the category of understanding, reproducing and application oriented.
Glossary	Explanation of significant terms.
Model Question Paper	A model question paper to help students to face examinations.
References	List of related books for further reading.
Case Study	Brief note on successful students who have pioneers in the field.
Career Guidance	List of job opportunities on successful completion of course

CAREER GUIDANCE AFTER COMPLETION OF 12TH STANDARD

After completion of Higher Secondary (+2) Vocational Engineering (EE) course, students can pursue the following courses / Jobs / Self-employment as detailed below:

Vocational Stream

The Vocational Engineering students are blessed with two major opportunities after completing their +2.

Vertical Mobility	Job / Self Employment
1. Lateral Entry for DIPLOMA in Engineering (DECE, DEEE, DE&I)	1. Job opportunities offered by few industries like TVS, Leyland, Lucas, TI-cycles, TITAN watches.
2. Separate allocation given for Vocational (Engg & Tech) students in Engineering (B.E.,) Courses (ECE, EEE, E&I). Even first 2 days counseling is allotted for Engineering Vocational students.	2. Audio/Video Equipment Service Centre. Computer Hardware service
3. B.Sc., (Eletronics), B.Voc (NSQF)	3. They can register their names in the "Board of Apprenticeship Training", 4th Cross street, CIT Campus, Tharamani, Chennai – 600013 for employment opportunities.
4. Lateral entry opportunities (for B.E./B.Tech.,) after completing Diploma.	4. The students who need for employment opportunities and career guidance, including counselling both in Government, Private and Public sector can see the website for further details.

CONTENTS

T23IFG
E-book

T2CEH4
Assessment

B194_11_ELE.E_EM
DIGI-Links

TN_QR_ENG

Lets use the QR code in the text books ! How ?
- Download the QR code scanner from the Google PlayStore/ Apple App Store into your smartphone
- Open the QR code scanner application
- Once the scanner button in the application is clicked, camera opens and then bring it closer to the QR code in the text book.
- Once the camera detects the QR code, a url appears in the screen.Click the url and goto the content page.

BASIC ELECTRICAL PRINCIPLES

CHAPTER 1

T2LAIR

CONTENT

LEARNING OBJECTIVES

A student can understand the following in this Chapter

1. Basics of electricity
2. Electrical parameters and its definitions
3. Ohm's law and its verification
4. Kirchhoff's law
5. Working of Resistors
6. Working of Capacitors

1.1 INTRODUCTION TO ELECTRICITY

Electricity is the integral part of human lives like water, space, land, fire and air. Today's technological era, all the activities and functions of the human beings are pervaded/controlled/facilitated by electrical and electronic gadgets. For example, a person awakening from sleep and during sleep, the environment, work, routine physiological activities, etc., have been pervaded by electrical or electronics equipment like fan, computer, cell phone, etc. Presently, all fields of science, engineering, technology, humanities and arts mostly rely on electrical and electronic gadgets for their sustenance. Further, our body activities are initiated and controlled by movement of ions across the cell wall, which is called as bioelectricity. Currently, in medical diagnosis, the measurement of bioelectric potential on the surface of the human body such as Electrocardiogram (ECG), Electroencephalograph (EEG), Electromyogram (EMG), Electroculogram (EOG), etc., play a vital role in understanding the functioning of the body organs and their disease condition. In automobiles, most of the mechanical parts are controlled by electronic controls. Additionally, the identification of human beings is based on biometrics measurements, which completely depends on electronic gadgets. As a result, the human life is dominated by electrical and electronic gadgets, hence, the learning and understanding of their working principle is well advised for proper handling, maintenance and troubleshooting of those devices. Hence, we will discuss the history and basic principles of electricity in this Chapter.

1.1.1 History of Electricity

In June 1752, American Scientist Benjamin Franklin, tried to prove that lightning is a phenomenon of electricity by flying a kite with conductive rods to attract lightning to a Leyden jar, which was an early form of a capacitor. When kite was flying at a certain height, he observed an electric spark and felt electric shock slightly, which proved that lightning is electric in nature.

In 1800, in Paris (France), Italian scientist Alessandro Volta proved that his invention, "Voltaic Pile" produced electricity.

DO YOU KNOW?

Later days, The Voltaic Pile was called as Voltaic cell

1.1.2 Generation of Electricity

In 1831-32, a British scientist Michael Faraday invented electromagnetic generator using Faraday's laws of electro magnetism which produced Alternating current. Nikola Tesla, Serbian-American inventor contributed the design of modern A.C supply system.

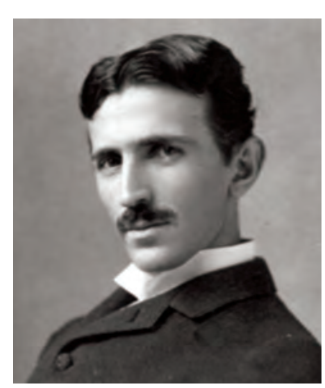
1.1.2 (a) Types of Power Generation

Important types of power generation are

1. Hydroelectric power station
2. Thermal power station
3. Atomic power station
4. Wind Power station
5. Solar power station (D.C)
6. Gas power station

Benjamin Franklin

Benjamin Franklin Trying to Draw Electricity from Lightning



Nikola Tesla

1.1.3 Electricity

It is a kind of energy that one cannot see as like air. It's existence can only be known through the working of electrical appliances. Also its existence can be found using line tester and multimeter.

DO YOU KNOW? **Initially, electricity was known as electric fluid.**

1.2 TYPES OF ELECTRICITY

Generally there are two types of Electricity. They are:

1. Alternating Current (AC)
2. Direct Current (DC)

1.2.1 Alternating Current

The direction of current varies with time is called as alternating current. It has two terminals viz., phase and Neutral. If the phase terminal acts as '+VE', then neutral terminal acts as '-VE' terminal. If phase terminal acts as '-VE', then neutral terminal acts as '+VE' terminal.

If you test the phase terminal with a line tester, you may see the tester shows light indication. Neutral shows no indication. Neutral is a common terminal used as a return path current flowing from phase to neutral through the connected device. It is neither '+VE' nor –VE.

1.2.2.1 Voltage and Frequency of Household AC Supply

In our country, the voltage and frequency of single phase supply is maintained as 220V/50Hz. In Foreign Countries, particularly in U.S.A, it is maintained as 110V/60Hz AC. Figure 1.1 shows the waveform of the alternating current.

1.2.2.2 Waveform

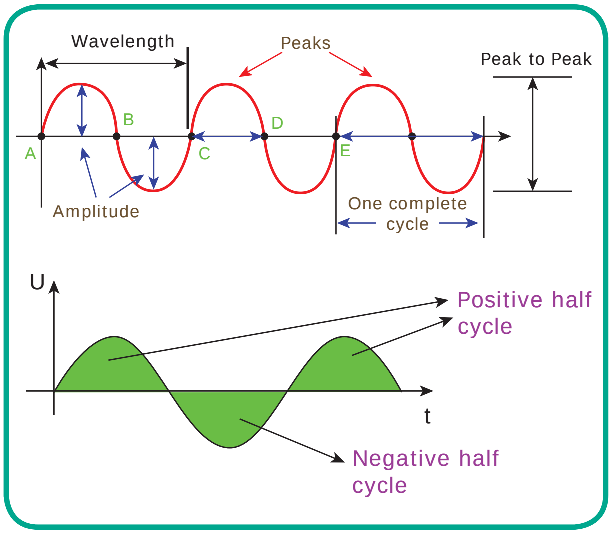


Figure 1.1 AC sine waveform

1.2.2.3 Amplitude

Amplitude is the distance from the X-axis to the vertex or peak of the any one half cycle of the AC waveform. Its unit is volts.

1.2.2.4 Polarities

The top half cycle is positive half cycle and the bottom half cycle is negative half cycle. Both half cycles combined together to form the one complete full cycle.

1.2.2.5 Wavelength

The length from starting point of the wave to the finishing point, which includes one positive half cycle and one negative half cycle, is called wavelength. Its unit is meter.

1.2.2.6 Peak to Peak Value

The distance between positive peak and negative peak is referred as peak to peak value. Its unit is volt.

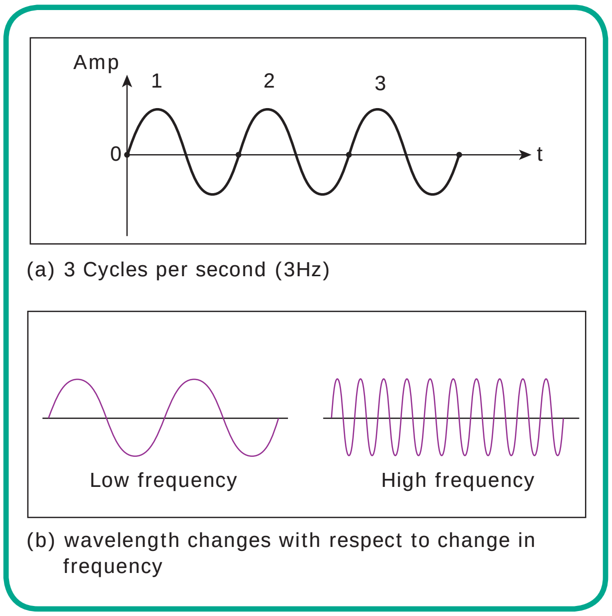
1.2.2.7 Angles

The starting point of the wave is 0°, +VE peak is 90°, the end of positive half cycle is 180°, peak of negative half cycle is 270°

and the end of negative half cycle is 360°. The wave consists of four quadrants like a circle.

1.2.2.8 Frequency

The number of complete cycles per second is called Frequency. Its unit is Hertz (Hz). Higher value units are kilo-Hertz (kHz), Mega-hertz (MHz), Gigahertz(GHz) and so on.



(a) 3 Cycles per second (3Hz)

(b) wavelength changes with respect to change in frequency

Figure 1.2 **Frequency of the AC waveform**

If there are 3 full cycles occur in one second, then its frequency is 3Hertz.It is shown in Fig 1.2 (a)

Low frequency has long wavelength and high frequency has short wavelength. It is shown in Fig 1.2 (b)

$$\text{Wavelength } (\lambda) = \frac{\text{Velocity of light or Electromagnetic waves (C)}}{\text{Frequency (F)}}$$

$\lambda = C / F$

(Unit of wavelength in meter, velocity of light - constant - 3×10^8 meter/sec and unit of frequency in Hertz)

> **DO YOU KNOW?** **The unit of frequency was named after German scientist Heinrich Hertz.**

1.2.3 Direct Current

The direction of current does not vary with time. Therefore, it is called as Direct Current. We can get DC from battery or by converting AC into DC using rectifier circuits. Figure 1.3 represents the direct current.

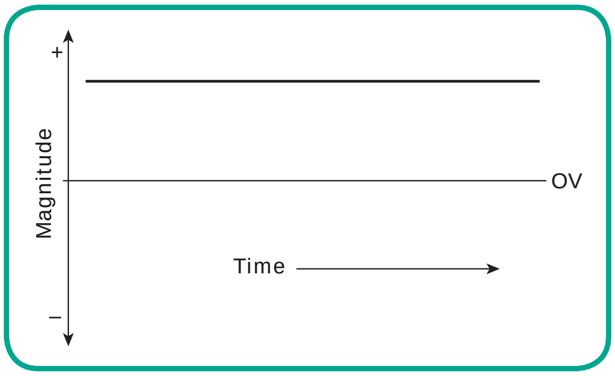


Figure 1.3 **Representation of direct current**

ACTIVITY 1.1

- Take a cycle dynamo.
- Connect the output of it with a multi-meter in DC voltage range.
- Rotate the dynamo.
- Observe the voltage reading in the meter.
- Connect an LED in series with 1 kΩ with the output of the dynamo.

  You will see the bulb glowing.

DC has two terminals namely +ve and –ve and hence battery symbol is used to denote DC.

1.3 ELECTRICAL PROPERTIES

Basic Electrical properties are Voltage, Current and Resistance.

1.3.1 Voltage

Let us see an example to understand about voltage. In our home, water is filled in the overhead tank using electrical motor pump. Due to atmospheric air pressure and gravitational force, tank water is at the higher pressure. The pressure of the water in the tank is assumed as the supply voltage as shown in Figure 1.4.

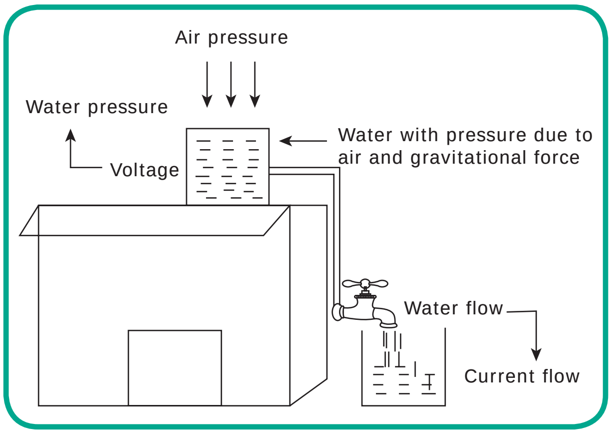


Figure 1.4 Comparison of voltage with pressure of water

The amount of electrical pressure required to pass the current in a conductor is known as voltage. It is represented by the letter V or E and measured by the unit Volt. Highest unit value is kilo-Volt (kV). Lower value units are milli-Volt (mV) and micro-Volt (μV).

The quantity of one volt is defined as the voltage needed to send one ampere of current through one ohm resistance in a circuit.

As we designed weighing stone to measure rice, wheat etc., we defined one volt in the above paragraph.

1.3.2 Electric Current

Let us try to understand current through an example. If we open a tap in our home, water flows quickly because it gets a path to flow from tank where water is under pressure.

Likewise, if we connect an electrical load through proper conducting wires, Electrons will flow from higher density point to lower density point as shown in Figure 1.5. This is called Electric Current.

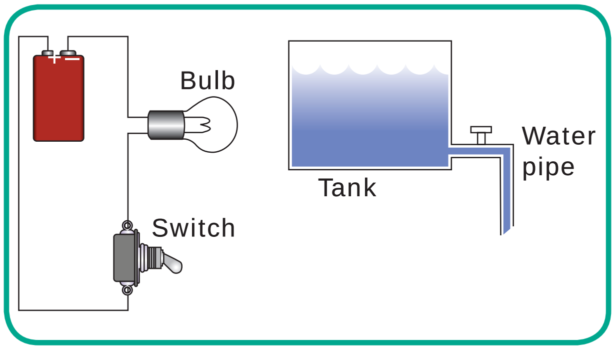


Figure 1.5 Comparison of electric current with flow of water

The flow of current can be measured as 'the number of electrons crossing the particular cross section of a conductor in a second". It is represented by the letter 'I'. Its unit is Ampere. It is the highest value. Lower values are milli-Ampere (mA) and micro-Ampere (μA).

1.3.3 Resistance

The property of a material which opposes the flow of current is known as resistance. An electrical component which has the resistance property is said to be resistor. It is denoted by the letter R and measured by the unit ohm. (The units used to measure higher value resistance are kilo ohm (kΩ) and mega ohm (MΩ).

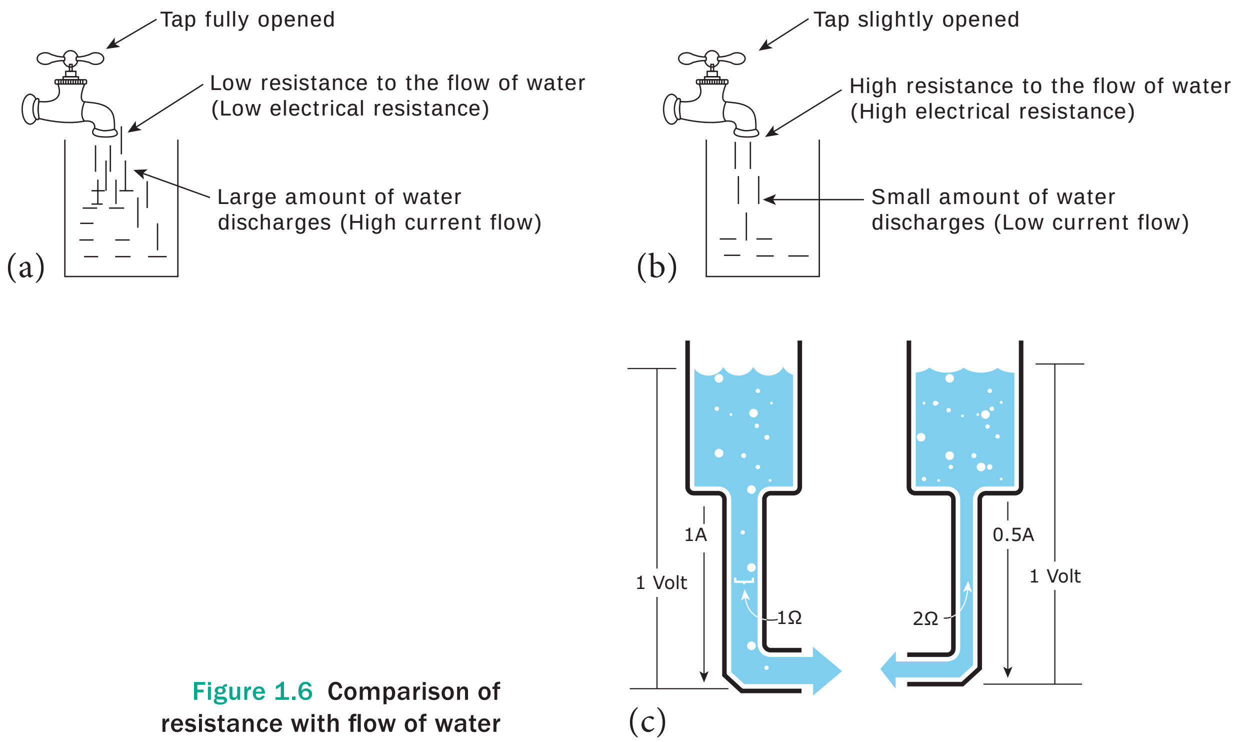


Figure 1.6 Comparison of resistance with flow of water

To understand "what is resistance", an analogy between the water-tap and the resistance is the simplest way. For example, if the tap is fully opened, maximum water flows through the tap, otherwise if a water tap is partially opened, then the amount of water flow through the tap is less.

> *Similarly, if the resistance offered to an electrical circuit is less, the amount of current flows in the circuit is maximum and vice versa.*

In other words, the current depends upon the resistance offered by the circuit. This is shown in Figure 1.6(c).

1.3.3.1 Laws of resistance

The resistance of a conductor may vary according to the following factors.

1. It is directly proportional to the length of the conductor.
2. Inversely proportional to the cross sectional area of the conductor.
3. Directly proportional to the specific resistance or resistivity of the conductor.

$$R=\rho\frac{l}{A}$$

Where R is the resistance, l is the length, A is the area of cross-section, and ρ is the specific resistivity of the conductor as shown in Figure 1.7.

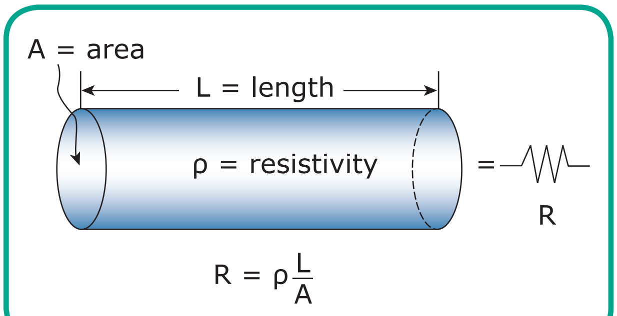


Figure 1.7 Factors affecting the resistance of a conductor

DO YOU KNOW?

The following units were named after the scientists, as given below.

Volt	Italian scientist Alessandro volta
Ampere	French scientist André-Marie Ampere
Ohm	German physicist George simon ohm.

1.4 OHM'S LAW

German physicist George Simon Ohm found that "voltage, current and resistance" are related to each other and derived a law. This is called Ohm's law. Let us try to understand ohm's law through the example shown in Figure 1.8.

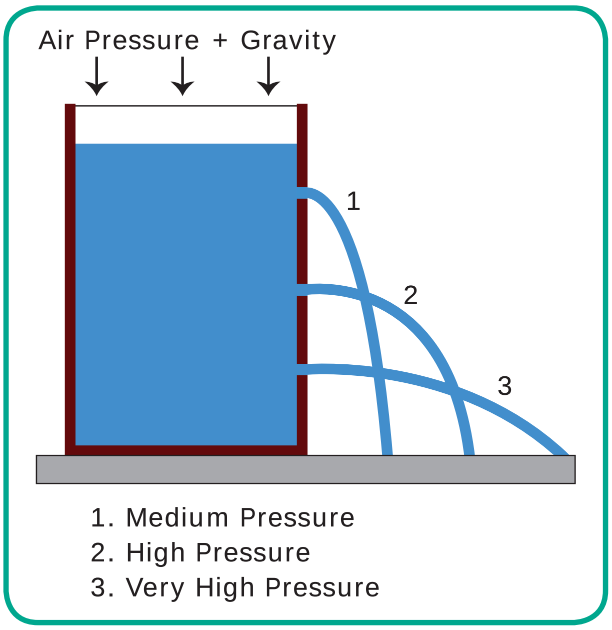


Figure 1.8 Demonstration of Ohm's law

Take a plastic bottle and make three equal sizes of holes viz. (i) Top (ii) centre and (iii) bottom and fill up the bottle with water.

What will happen?

There are air pressure and gravitational force always around us. Due to this, water in that bottle is under pressure.

1. From top hole, water flows with a low speed. Because, only air pressure and gravity act on it.
2. Water from the *middle hole* flows with increasing speed than in the top hole, because pressure increases due to water in the top portion of the bottle along with air and gravity.
3. Water from the *bottom hole* flows with high speed than in the first and middle, because pressure increases due to water in the top and middle parts along with air and gravity.

Likewise, in a circuit, if the supply voltage increases, the electric current increases. If the supply voltage decreases, current also decreases (Resistance value should be constant in both the conditions)

$$I \propto V$$

Therefore, the current in a circuit can be represented as,

$$I \, \alpha \, \frac{V}{R}$$

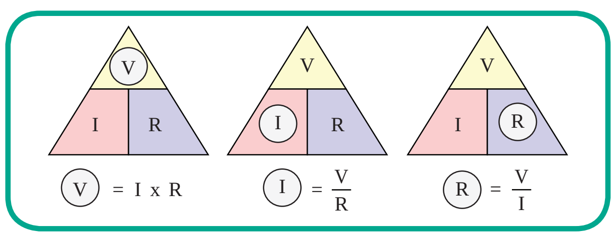
DO YOU KNOW?

Ohm's law states that at constant temperature, the current flows in a circuit is directly proportional to the voltage and inversely proportional to the resistance in the circuit.

$$\text{Current (Ampere)} = \frac{\text{Voltage (Volt)}}{\text{Resistance (ohm}}$$

$$I = \frac{V}{R}$$

The other forms of Ohm's law are given below:



Theoretical Verification of Ohm's Law

Example 1: Let V=100 V, R=10Ω,Find the value of I. Assume that the resistance value is kept constant.

$$I = \frac{V}{R} = \frac{100}{10} = 10\,A$$

Example 2: Let V=10 V, R=10Ω, Find the value of I. Assume that the resistance value is kept constant.

$$I = \frac{V}{R} = \frac{10}{10} = 1A$$

From these two examples, we can conclude that the voltage increases (100 V) the current increases (10 A), and voltage decreases (10 V) current decreases (1 A). That is, current *I* is directly proportional to voltage V, proved theoretically.

Example 3: Let V=100 V, R=100 Ω, find the value of I.

$$I = \frac{V}{R} = \frac{100}{100} = 1A$$

Comparing Examples 1 and 3, in both the examples the voltage is kept constant and the resistance is varied. From these, it is proved that the resistance value decreases (10Ω), current increases (10A), whereas resistance value increases (100Ω), current decreases(1 A), As a result, we prove that I is inversely proportional to R.

Example 4: Let I=2 A, R=10Ω, find the value of V.

To find the value of V, the respective quantities are substituted in Ohm's law 2.

$$V = I \cdot R = 2 \times 10 = 20V$$

Example 5: Let I = 5 A, V=25 V, find the value of R.

Using Ohm's Law 3: $R = \frac{V}{I} = \frac{25}{5} = 5\Omega$

1.4.1 Power

The Electrical work done during a specific time interval is known as power.

$$Power\,(P) = \frac{Work\ done}{Time} = \frac{W}{T}$$

$$P = \frac{V \times I \times t}{t}$$

$$P = V \times I \quad or\ Power = Voltage \times Current$$

Power (P) is measured using the unit called watt. To represent high power values, kilo-watt or mega-watt is used.

DO YOU KNOW?

The unit of Power is 'Watt'., named after Scotland scientist James Watt.

1 kilowatt = 1000 watt

i.e. 1 kw = 1,000 watt

1 Mw = 10,00,000 watt

To find and measure the power, the following formula is used

$$P = V \times I \quad \text{.....................} \quad 1$$

According to ohm's law, ($V = I\ R$). Substitute this in the equation..1

$$P = I \times R \times I = I^2 R \quad \text{..................} \, 2$$

And also substitute $I = \frac{V}{R}$ in equation 1,

we get $P = V \times \frac{V}{R} = \frac{V^2}{R}$

Therefore, power can be calculated by following three formulae.

1. $P = V \times I$
2. $P = I^2 R$
3. $P = \frac{V^2}{R}$

Example 1: Let V = 10 V,
I=2 A, find the value of P.

$$P = V \times I = 10 \times 2 = 20 \textit{ watt}$$

Example 2: Let I = 2A, R=15Ω, find the value of P.

$$P = I^2 R = 2 \times 2 \times 15 = 60 \textit{ watt}$$

Example 3: Let V = 6 V, R=12Ω, find the value of P.

$$P = \frac{V^2}{R} = \frac{6 \times 6}{12} = 3 \textit{ watt}$$

1.4.2 Electromotive Force (E.M.F)

The force exerted by the density of the electrons in a point is referred as Electromotive Force (E.M.F). Also, it is the voltage developed by any source of electrical energy such as battery or dynamo. Its unit is Volt.

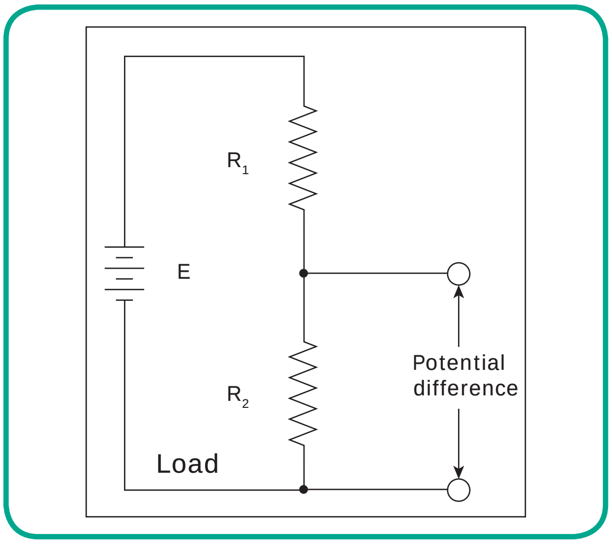


Figure 1.9 **Potential difference across the load**

1.4.3 Potential Difference

It is the voltage across any two terminals of a load in a circuit as shown in Figure 1.9. It is measured in Volt.

1.4.4 Electrical Load

If electrical energy is supplied to an electrical appliance, it starts operating using that energy. For example, an electrical fan supplied with electrical energy starts rotating and gives air circulation. In this phenomenon, fan is a load, consuming the electrical energy. Similarly, electric lamp offers light using electrical energy. Here, lamp acts as a load by consuming the electrical energy. From this we come to know that

An object that consumes electrical energy is called electrical load. e.g., electrical lamp, fan, mixie, radio, television, etc.

1.4.5 Electrical Circuit

If two terminals of an electrical supply is connected to a load, which enable to pass current through the electrical devices is called electrical circuit as shown in Figure 1.10.

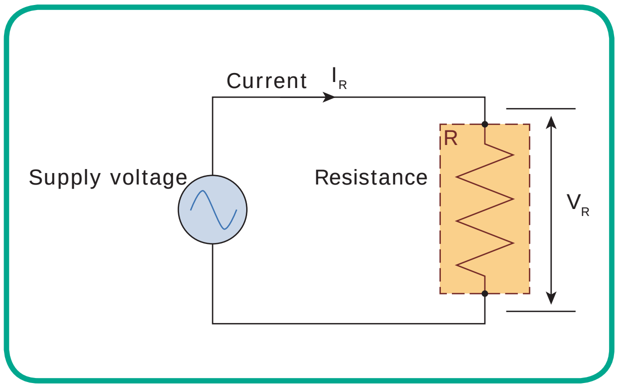


Figure 1.10 **Electrical circuit**

1.4.6 Symbols

One cannot draw the actual appearance of electrical connections and loads. Hence, simplified symbols are allotted to electrical connections, loads, appliances and devices. For example, few symbols are given in Figure 1.11.

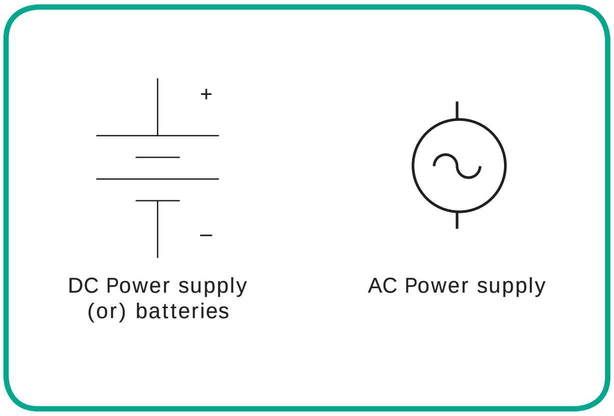


Figure 1.11 **Electrical symbols**

1.4.7 Circuit Diagram

An electrical technician can easily draw electrical connections if simplified symbols are used. Figure 1.12 shows a sample electrical circuit diagram.

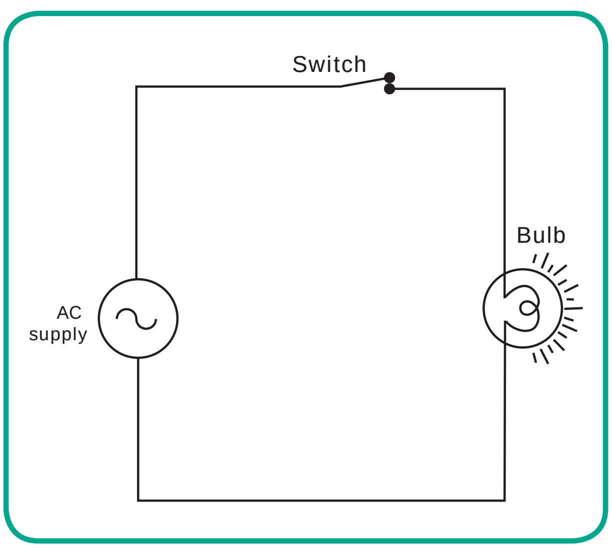


Figure 1.12 **Example of a circuit diagram**

> **A method of drawing electrical connections with simplified symbols is called circuit diagram.**

1.4.8 Closed Circuit

A circuit connected in such a way to allow current flow through one or more loads with respect to the electrical supply. In a closed circuit, current will flow in the circuit as shown in Figure 1.13.

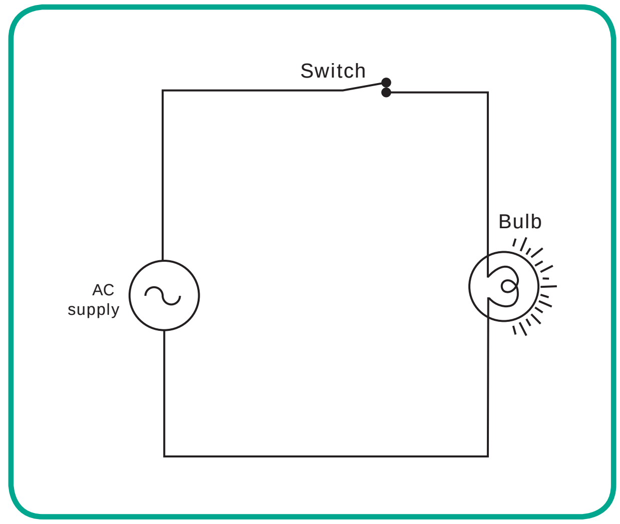


Figure 1.13 **Closed circuit**

1.4.9 Open Circuit

In a circuit, if there is no current flow due to disconnection of wire or switched-off condition, then the circuit is said to be open circuit. In an open circuit, no current flow in the circuit. Figure 1.14 shows a sample open circuit.

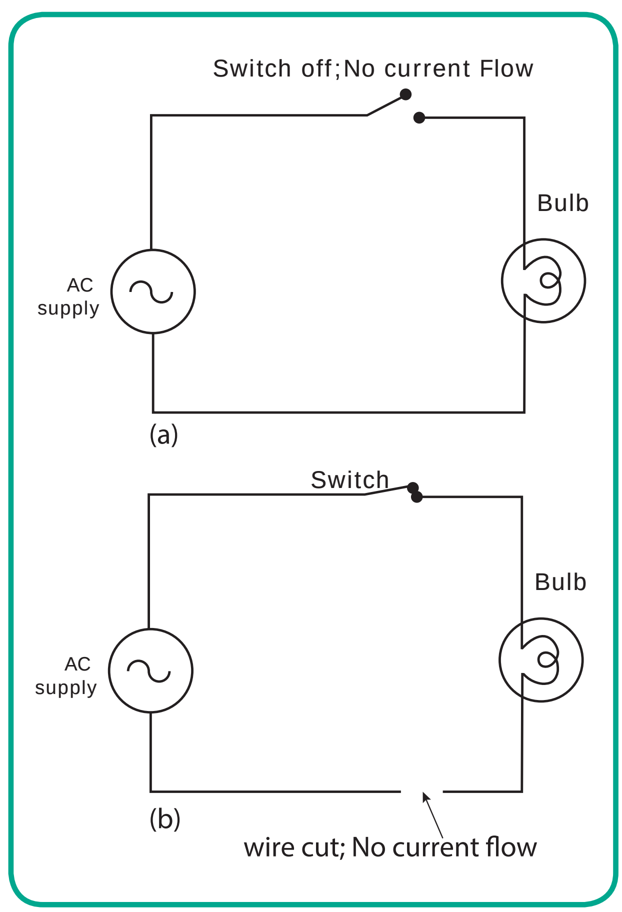


Figure 1.14 **Open circuit**

1.4.10 Short Circuit

In a circuit, if the two terminals of a supply are connected directly without load, then the circuit is said to be short circuit. Figure 1.15 shows a circuit in a short circuit condition.

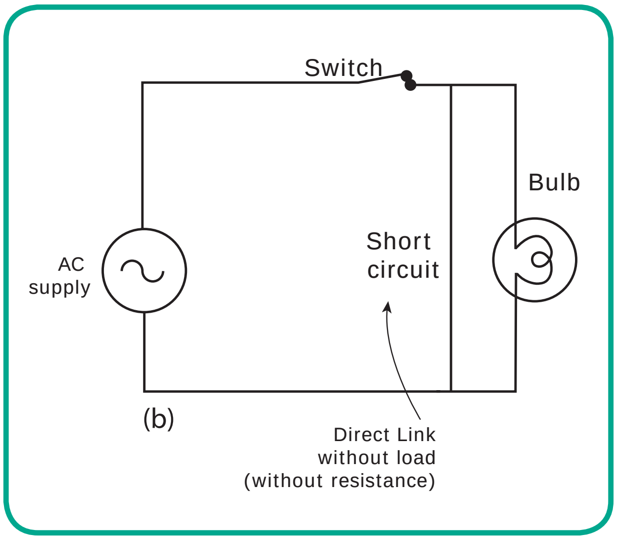


Figure 1.15 **Short circuit**

In this circuit, the flow of current is infinite $I = \frac{V}{0} = \infty A$. When short-circuit occurs, enormous amount of heat will be produced and heavy spark will occur. This will cause electrical fire accidents. Hence, it is very dangerous. To avoid this, fuse wire, main circuit breakers (MCB) and Earth leakage circuit breakers (ELCB) are used in electrical circuits.

1.4.11 Fuse Wire

To avoid fire accidents due to short circuit, thin tin coated copper wires with low melting point is used in series with the circuit. If short-circuit or overload occurs, heat increases in the wires and fuse wire is blown within a second. So, the short-circuit becomes open-circuit, no further current flow and thus avoids fire accident. Figure 1.16 shows the fuse wire connected in an electrical circuit.

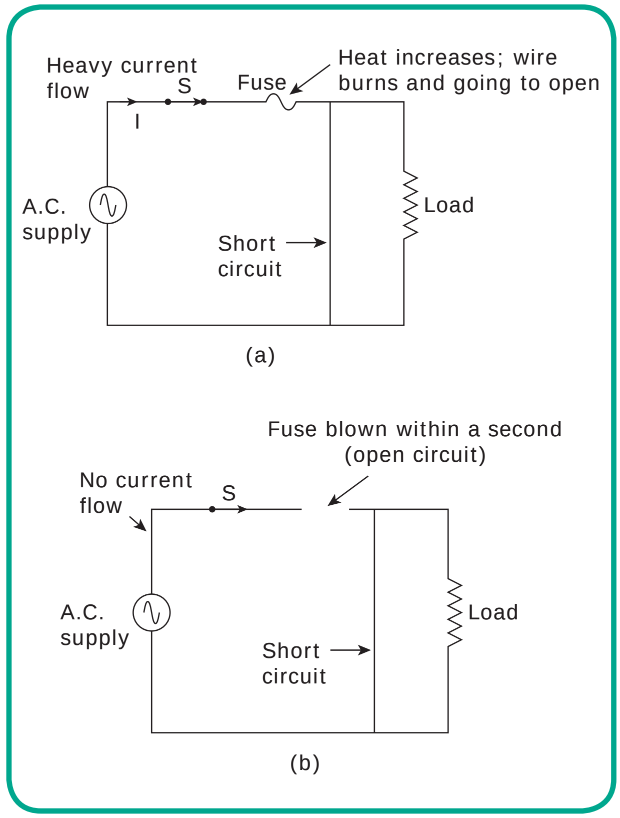


Figure 1.16 **Circuit using fuse wire**

Fuse wires are available in amperes such as 1A, 2A, 5A and 10A in the market. Presently, fuse wires are substituted with mains circuit breaker and Earth leakage circuit breaker (ELCB).

Thiruvalluvar referred regarding over load in Thirukkural well before 2000 years.

பீலிபெய் சாகாடும் அச்சிறும் அப்பண்டஞ்
சால மிகுத்துப் பெயின் #குறள்:475

பொழிப்புரை : மயிலிறகு ஏற்றிய வண்டியே ஆனாலும், அந்தப்பண்டமும்அளவோடு ஏற்றாமல் அளவுகடந்து மிகுதியாக ஏற்றினால்அச்சு முறியும்.

With peacock feathers light, you load the wain;

Yet, heaped too high, the axle snaps in twain.

The axle tree of a bandy, loaded only with peacocks' feathers will break, if it be greatly overloaded.

1.4.12 Partial Short Circuit

If short-circuit occurs in few windings of a coil or a transformer, it is called partial short-circuit. Due to this phenomenon, overload occurs. This defect cannot be found even by multimeter testing. It can be rectified only by replacing the existing transformer with a new one. Partial short-circuit may result in minor fire accidents. Partial short- circuit may occur in Line Output Transformer (LOT), which is used in CRT model television circuit. Figure 1.17 shows an example for partial short-circuit.

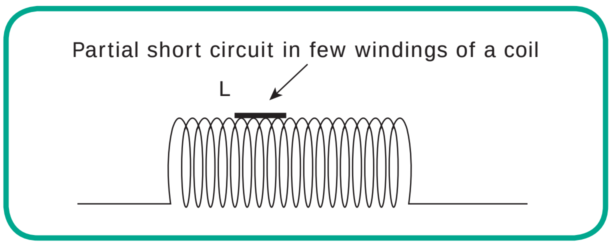


Figure 1.17 Coil showing partial short-circuit

1.4.13 Series Circuit

A circuit which has current flow in only one path through more than one load connected in serial manner (one after another load) with a power supply is said to be series circuit. Figure 1.18 shows a series circuit.

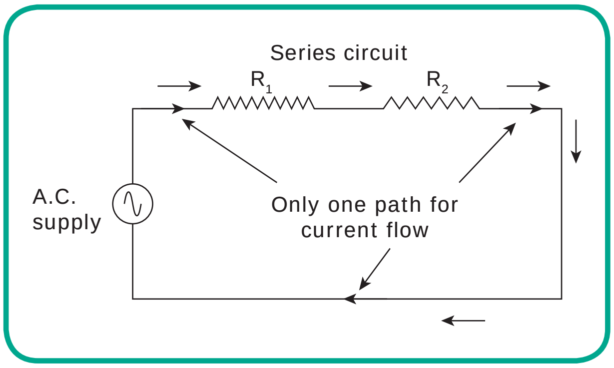


Figure 1.18 Series circuit

1.4.14 Parallel Circuit

A circuit, in which all the loads connected, have individual path for current flow, then it is said to be parallel circuit. Figure 1.19 shows the parallel circuit.

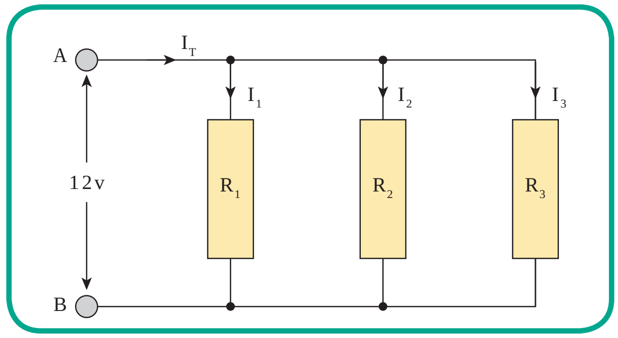


Figure 1.19 Parallel circuit

1.5 RESISTORS CONNECTED IN SERIES

Figure 1.20 shows three resistors R_1, R2 and R_3connected in series. When the voltage (V) is applied to the circuit, the current flow through the circuit and the following important points are to be noted.

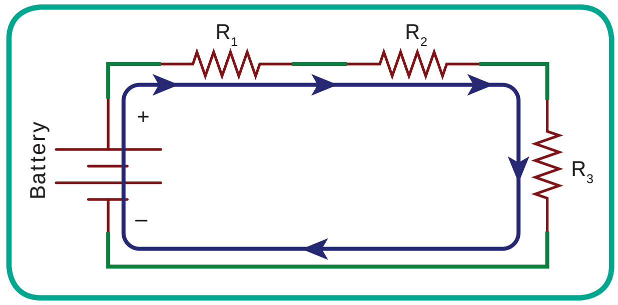


Figure 1.20 Resistors in series

1. The current I is equal in all the resistors.
2. The voltage drop across each resistor depends upon their resistance value i.e.,

$$V_1 = I.\ R$$
$$V_2 = I.\ R$$
$$V_3 = I.\ R$$

3. The EMF applied to the circuit is equal to the sum of the voltage drops across all resistors (Kirchhoff's voltage law). Hence $V = V_1 + V_2 + V_3$
   We can derive formula for Total resistance of a series circuit from the above equation.

As per ohm's law $V = IR_1+IR_2+IR_3$

$V=I(R_1+R_2+R_3)$

$$\frac{V}{I} = R_1 + R_2 + R_3$$

$$R = R_1 + R_2 + R_3$$

$$R = \frac{V}{I}$$

Where R is the total resistance of the series circuit

That is total resistance R is the sum individual resistors present in the series circuit.

4. The current flows in the individual resistors will be $I = \dfrac{V}{R}$
5. The current cannot flow through the circuit, if there is any disconnection in any one point of the circuit.

1.5.1 Uses of Series Connection

1. Series connection is used in serial sets as decorative lamps which are used in festivals and functions.
2. It is used to find out the defect in electrical appliances such as tube light, mixie, electric stove and fans.

Problems

Two resistors of values 100 Ω and 200Ω are connected in series with a 300 volts supply. Prove that the sum of the voltage drops in the circuit is equal to the supply voltage.

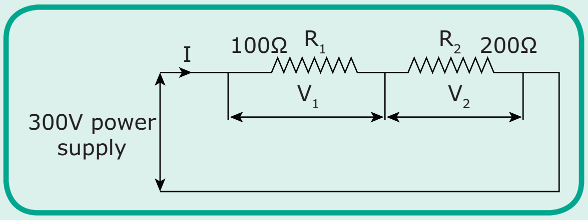


Figure 1.21

Total Resistance R = R1+R2

= 100+200

R = 300Ω

$$\text{Current } I = \frac{V}{R} = \frac{300}{300} = 1A$$

Voltage drop $V_1 = \text{I} \times R_1 = 1 \times 100 = 100V$

Voltage drop $V_2 = \text{I} \times R_2 = 1 \times 200 = 200V$

V = V1 + V2

300 V = 100V + 200 V

300 V = 300 V

The sum of the voltage drops in the circuit is equal to the given supply voltage. Hence, it is proved.

1.6 RESISTORS CONNECTED IN PARALLEL

When two resistors are connected one after the other as shown in the Figure 1.22 (the first ends and last ends are connected separately), the number of current flowing paths (two) is equal to the number of resistors present in the circuit.

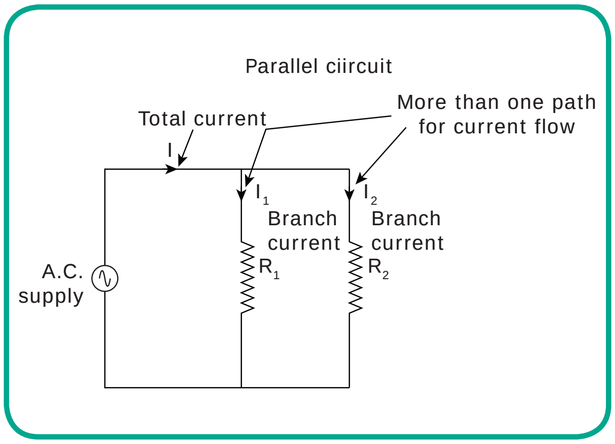


Figure 1.22

Figure 1.22 shows R_1 and R_2 are connected in parallel. When the voltage 'V' is applied in between the ends of the circuit, the following points are to be noted.

1. The potential difference across all the resistors is equal to the EMF applied.
2. The current flows through resistors will differ according to the value of the resistor.

   The current flows through resistor R_1 is referred as I_1, whereas the current flows through resistor R_2, is referred as I_2.

$$I_1 = \frac{V}{R_1} \qquad I_2 = \frac{V}{R_2}$$

3. Hence, the sum of the currents flows through the individual resistor is equal to the flow of total current in the circuit. Using this, we can derive the formula for the total resistance *(R)*.

$$I = I_1 + I_2$$

As per ohm's law, $\frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2}$

$$\frac{V}{R} = V\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$

Cancelling 'V' on both sides,

$$\frac{1}{R} = \left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$

Again simplifying the above formula by taking LCM,

$$\frac{1}{R} = \left(\frac{R_2 + R_1}{R_1 R_2}\right)$$

Cross multiplying: $R(R_1 + R_2) = R_1 \cdot R_2$

$$R = \frac{R_1 R_2}{R_1 + R_2}$$

4. There will be current flow in other paths, even if any of the paths is disconnected. It is shown in Figure 1.23

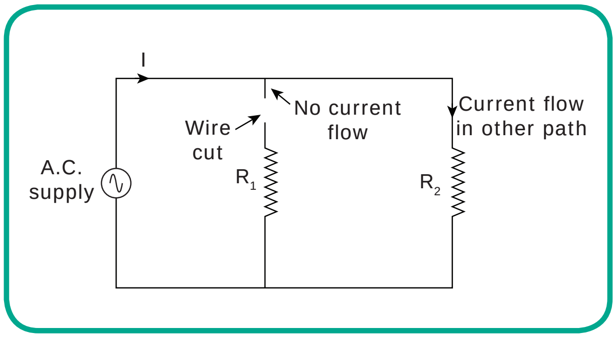


Figure 1.23

5. The current in this circuit takes two or more branch paths from main path. The current takes branch path (i.e. flows through each resistor) is called branch current.

1.6.1 Uses of Parallel Connection

At homes and industries, this type of connection is used.

Problems

1. Two resistors of values 10Ω and 15Ω are connected in parallel with 60V power supply. Prove that the sum of the branch currents is equal to the total current.

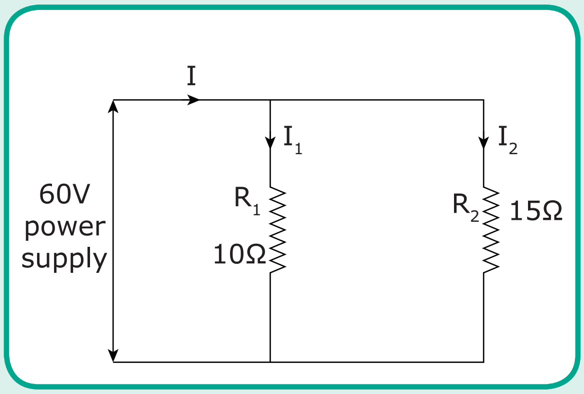


Figure 1.24

Total Resistance

$$R = \frac{R_1 R_2}{R_1 + R_2} = \frac{10 \times 15}{10 + 15} = \frac{150}{25} = 6\Omega$$

$$R = 6\ \Omega$$

(continued)

Total current $I = \frac{V}{R} = \frac{60}{6}$

$I = 10\ A$

Branch current $I_1 = \frac{V}{R_1} = \frac{60}{10}$

$I_1 = 6\ A$

Branch current $I_2 = \frac{V}{R_2} = \frac{60}{15}$

$I_2 = 4\ A$

$I = I_1 + I_2$

$10A = 6A + 4A$

$10\ A = 10\ A$

The sum of the branch currents is equal to the total current in a parallel circuit. Hence, the theorem is proved.

DO YOU KNOW?

In parallel connection, the total resistance is always lower than the lowest resistance connected in the circuit.

Ex., If two resistors 10Ω and 15Ω,are connected in parallel circuit, the total resistance is lower than 10 Ω. R = 10 X 15 /25 = 6 Ω. Notice that the total resistance (6 Ω) is lower than the lowest resistance (10 Ω). (Here, 10 Ω is the lowest resistance connected in the circuit).

2 Two resistors of values 50 Ω and 50Ω are connected in parallel with 250 V power supply. Prove that the sum of the branch currents is equal to the total current.

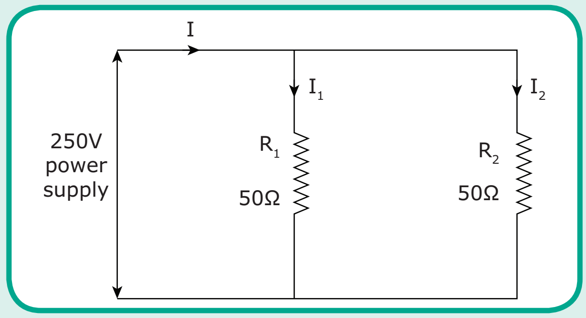


Figure 1.25

Total Resistance

$$R = \frac{R_1 R_2}{R_1 + R_2} = \frac{50 \times 50}{50 + 50} = \frac{2500}{100} = 25\Omega$$

$R = 25\ \Omega$

Total current $I = \frac{V}{R} = \frac{250}{25} = 10A$

$I = 10\ A$

Branch current $I_1 = \frac{V}{R_1} = \frac{250}{50} = 5A$

$I_1 = 5\ A$

Branch current $I_2 = \frac{V}{R_2} = \frac{250}{50} = 5A$

$I_2 = 5\ A$

$I = I_1 + I_2$

$10A = 5A + 5A$

$10A = 10A$

The sum of the branch currents is equal to the total current in a parallel circuit. Hence the theorem is proved.

ACTIVITY 1.2

If two equal value resistors are connected in parallel circuit, the total resistance of the circuit will be half of any one of resistance value.

Ex., If 100 Ω and 100 Ω are connected in parallel, the total resistance is (100 X 100) / (100+100) = 10,000/200 = 50 Ω.

Shortly, 100/2 = 50 Ω.

Check it through various examples on your own.

1.7 RESISTORS IN SERIES-PARALLEL CIRCUIT

In a circuit, some resistors may be connected in series and some may be connected in parallel. In this, both series and parallel connection resistors are calculated separately and then the total resistance (Equivalent Resistance) can be calculated. Figure 1.26 shows R1& R2 are in parallel to each other and R3is series to R1 and R2.

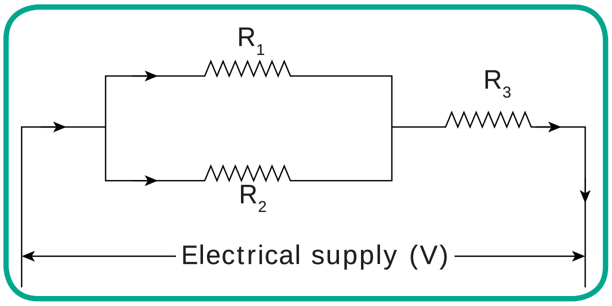


Figure 1.26 **Resistors in series-parallel circuit**

To find out the total parallel resistance Rp (the total resistance of parallel resistance only), the circuit is simplified as shown in Figure 1.27.

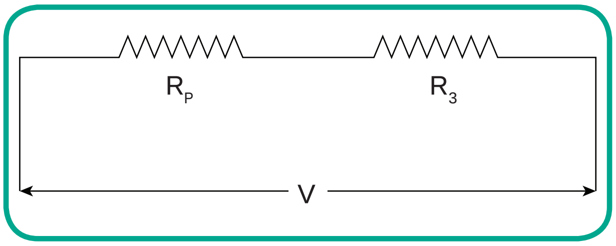


Figure 1.27

$$\frac{1}{Rp} = \left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$

$$Rp = \frac{R_1R_2}{R_1 + R_2}$$

Now, R_p and R_3 are series as shown in Figure 1.27 for estimating the total resistance $R_T = R_p + R_3$.

Example: Find out the total resistance of the circuit given in Figure 1.28.

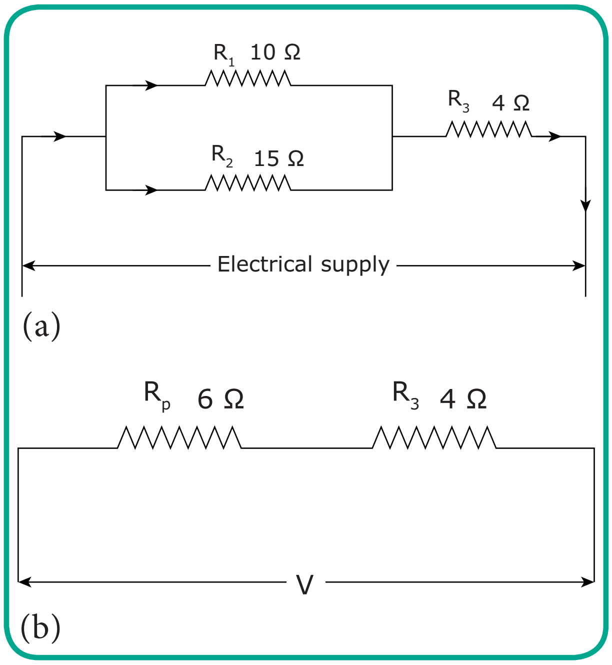


Figure 1.28

In the circuit shown in Figure 1.28,R_1 (10 Ω) andR_2 (15Ω) are parallel and R_3(4Ω) is series with the resistors R_1 and R_2.

$$Rp = \frac{R_1 R_2}{R_1 + R_2} = \frac{10 \times 15}{25} = \frac{150}{25} = 6\Omega$$

$$R_p = 6\ \Omega$$

$$R_T = R_p + R_3$$

$$R_T = 6+4$$

$$R_T = 10\ \Omega$$

Total resistance of the circuit is 10Ω

1.8 CLASSIFICATION OF RESISTORS

Resistors are broadly classified into two categories.

1. Fixed Resistor
2. Variable Resistor

1.8.1 Fixed Resistors

The value of fixed type of resistors cannot be changed. Hence, these resistors are called as fixed resistors as shown in Figure 1.29. Its symbol is shown in Figure 1.30.

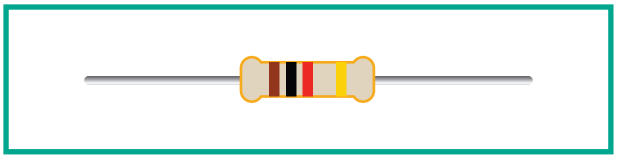


Figure 1.29 Fixed Resistor

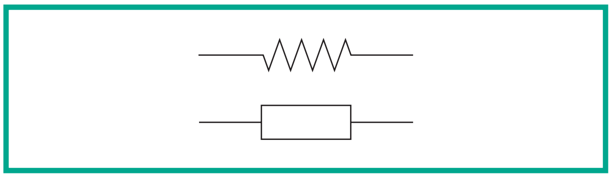


Figure 1.30 Symbols of fixed resistor

The classification of resistors depends upon their materialsand fabrication methods used.

1. Carbon resistors
2. Wire wound resistors
3. Metal oxide resistors
4. Metal film resistors
5. Printed resistors
6. SMD type (Surface Mount Device).

In modern circuits, Printed resistors and SMD type resistors are used.

Special Type of Resistors

7. Positive Temperature Coefficient Resistor (PTC)
8. Negative Temperature Coefficient Resistor (NTC)

1.8.2 Carbon Resistor

It is made up of carbon paste and burnt clay with connecting leads, which is heated and kept under high pressure. The resistor is formed as small sticks. It can handle small amount of current through it. If high current flows through this type of resistor, it will burn. Figure 1.31 shows the internal construction of a carbon resistor.

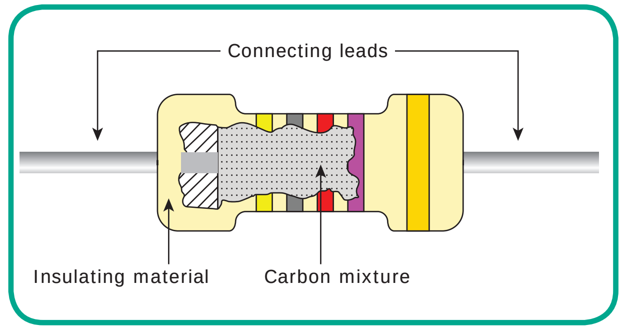


Figure 1.31 Carbon resistor

Uses

1. It is widely used in low current flowing circuits like Radio, DVD players and television etc.

1.8.3 Wire Wound Resistors

Figure 1.32 shows the cut away view of a wire wound resistor. Particular length of Nichrome is wound on a small Porcelain cylinder. The two terminals of the nichrome are connected to the copper legs. The surface is given a protective coating with glass and enamel. These types of resistors are manufactured with high precision.

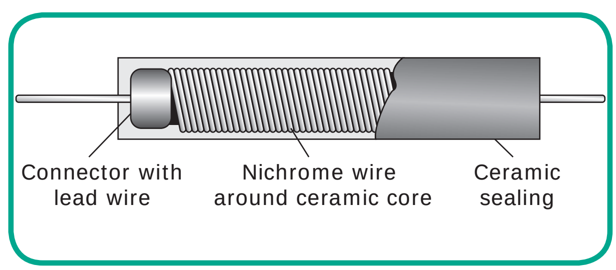


Figure 1.32 Wire wound resistor

Uses

1. Regulated power supplies in television, inverters etc.
2. Also used in Public Address system amplifiers.

DO YOU KNOW?

Nichrome is an alloy made of Nickel and chromium.

1.8.4 Metal Oxide Resistors

It is manufactured by coating tin oxide and antimony on a glass strip. It withstands high temperature and moisture. It is rolled and cut to get desired value. Figure 1.33 shows a metal oxide resistor

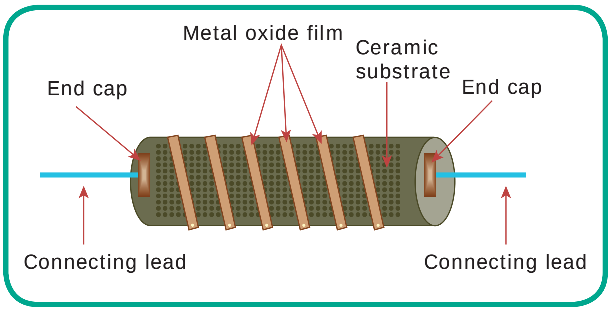


Figure 1.33 Metal oxide resistor

Special Features

1. It has long life
2. It operates at high frequency
3. It is not affected by moisture
4. It can withstand temperature up to 450°C

1.8.5 Metal Film Resistors

There are two types of metal film resistors, viz. Thick film resistor and thin film resistor.

1.8.5.1 Thick Film Resistor

This type of resistor is in the form of cylinder (or) plate shape. Inside the cylinder, there is nichrome metal film as shown in Figure 1.34. It has more physical strength.

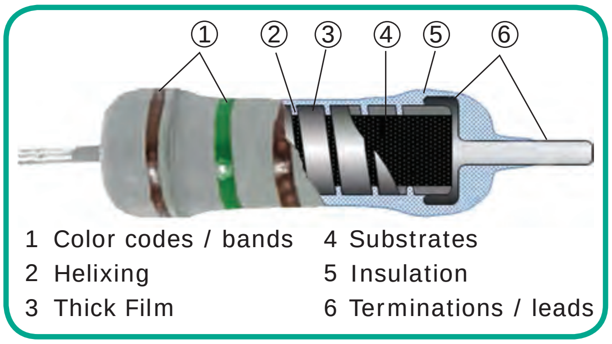


Figure 1.34 Cross-sectional view of thick film resistor

Uses

1. Used in high frequency circuits such as mobile phone transmitters.
2. Used in computers.
3. Used in motor controlled circuits.
4. Used in radar systems.

1.8.5.2 Thin Film Resistor

This type of resistor is manufactured on high quality ceramic (or) glass tube in which nichrome metallic vapour is coated. It was heated to high temperature and slowly cooled down (called annealing). Depending on the thickness and materials of the thin film, desired values of resistors can be produced. Figure 1.35 shows a thin film resistor.

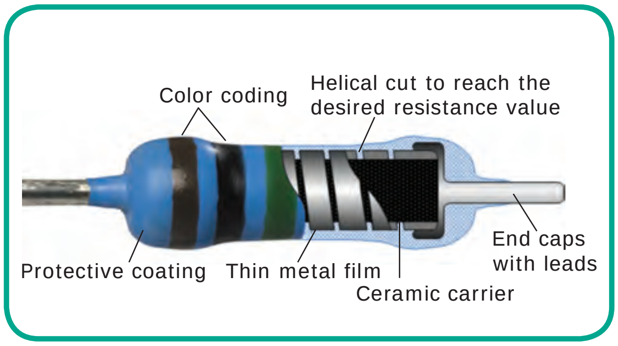


Figure 1.35 Cross sectional view of the thin film resistor

1.8.6 Printed Resistors

A carbon resistor which is printed directly on a Printed Circuit Board (PCB) is called as printed resistor. It is shown in Figure 1.36.

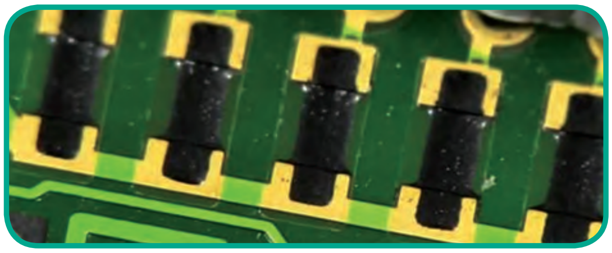


Figure 1.36 Printed resistor

Advantages of Printed Resistors

1. Low cost
2. It takes small space

Disadvantages

1. Replacement of faulty printed resistors is complicated and resulting in damage to the PCBs.

1.8.7 SMD Resistors

SMD stands for Surface Mounted Device. This type of resistor is directly soldered on copper solder points in the surface of the board and therefore they are called SMD resistors. They are smaller in size than their traditional carbon resistors. They are square, rectangular or oval in shape. The SMD resistor is shown in Figure 1.37 (a) and (b).

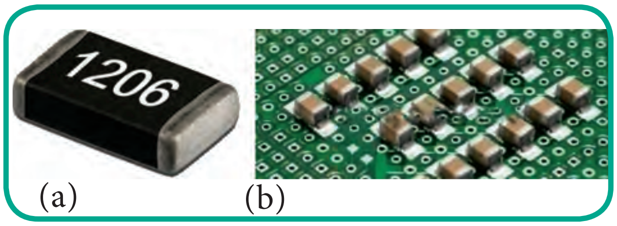


Figure 1.37 SMD resistors

Advantages

1. This type of resistor has small leads or points that are soldered on copper solder points in the surface of the board. This eliminates the need for holes in the PCB and we can utilize both sides of the PCB.
2. Once the PCB is manufactured, SMDs can be placed on it using a special machine called a pick and place machine.

Disadvantages

1. Replacement of faulty resistors is complicated.

1.8.8 Variable Resistor

The resistor which value can be changed is called as variable resistors.

Its symbol is shown in Figure 1.37 (a)

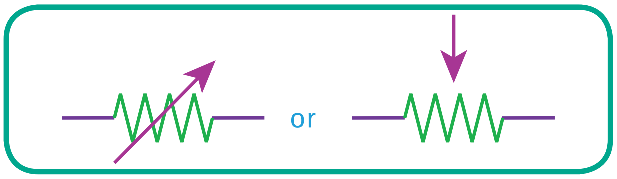


Figure 1.37(a) Symbol of variable resistor

Variable resistors are also called as potentiometers. In this, base is like a washer type with carbon coating. There is a rotary setup having slip-ring to the resistor and have three electrical contacts as shown in Figure 1.38. Between the first terminal T_1 and last terminal T_3, the value of resistance is fixed, i.e., cannot be altered. But centre terminal T_2 is a variable terminal with respect to T_1 and T_3.You can check this using a multimeter. A plastic or metal shaft attached to T_2 is used to change the value of the resistance.

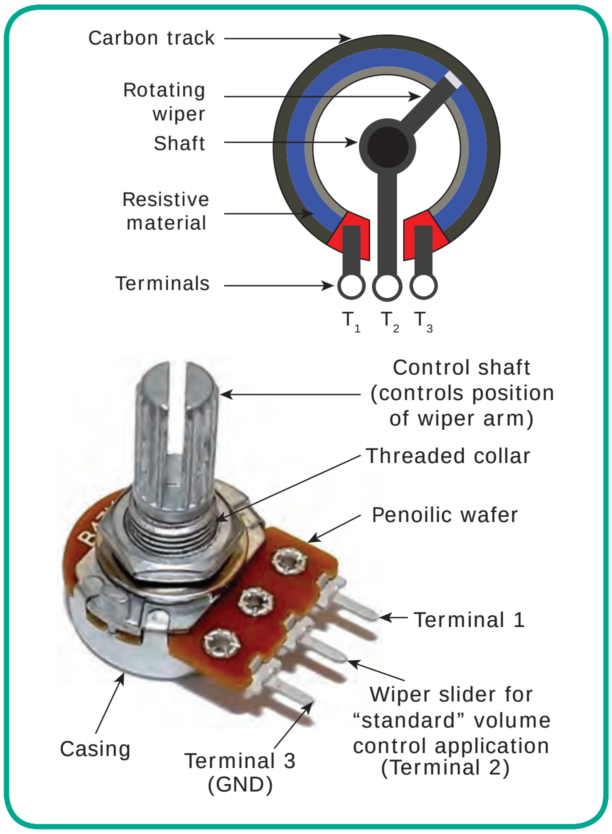


Figure 1.38 Variable resistor

Uses

1. Used as volume control in television and radio sets.
2. Used as a variable control in amplifiers as bass and treble controls.

Semi Variable Resistors

It is nothing but preset type resistors. It is used in CRT based TV receivers and voltage stabilizers. Its value can be altered if needed. The preset type resistor is shown in Figure 1.39.

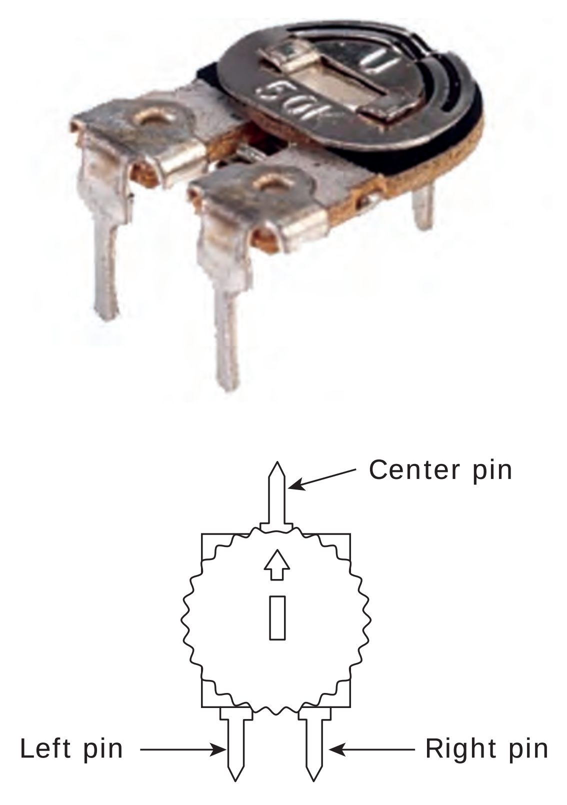


Figure 1.39 Semi variable resistors

Uses

1. Used in CRT type television receivers
2. Used in stabilizers and inverters.

Special Type Resistors

Now, we are going to study about special type resistors. They have special characteristics.

They are:

1. Positive Resistors (PTC)
2. Negative Resistors (NTC)

1.8.9 Positive Temperature Coefficient Resistor (PTC)

If the temperature of this resistor increases, its resistance value increases. Hence, the resistor is known as Positive Temperature Coefficient (PTC) resistor. It is also called as Posistor and is shown in Figure 1.40. It is used in automatic degaussing circuit in CRT type televisions.

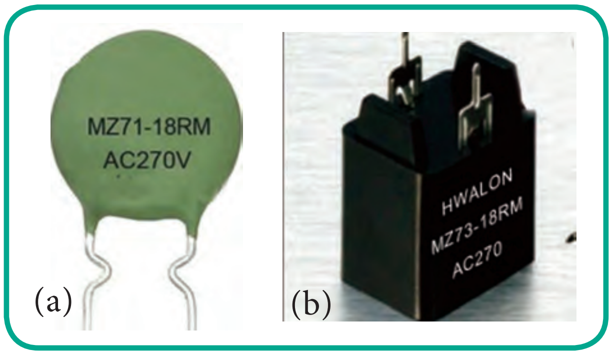


Figure 1.40 Posistors

1.8.10 Negative Temperature Coefficient resistor (NTC)

If the temperature of this resistor increases, its resistance value decreases. Hence it is known as Negative Temperature Coefficient (NTC) resistor. It is also called as Thermistor. To avoid the surge current while switching on a power supply, the NTC type of resistors is used. It is shown in Figure 1.41.

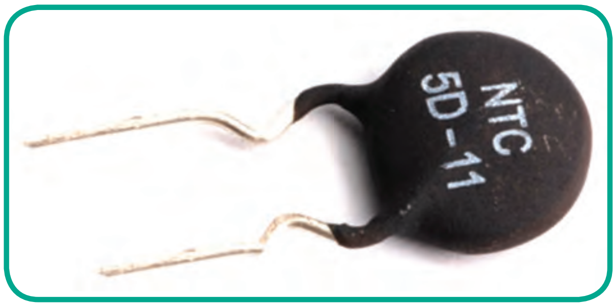


Figure 1.41 Thermistor

1.9 COLOUR CODING OF RESISTORS

Printing values in small resistors cannot be viewed clearly. So, in small rating resistors, colour is coated on the body of resistors in circular shape. Each colour is allotted a number. This is called as colour coding.

Figure 1.42(a) **Color coding in a resistor**

The first colour denotes the value of first digit, second colour denotes the value of second digit and the third colour (called as multiplier) denotes the number of zeros followed by the two digit. The fourth colour denotes tolerance level. If it is gold, the tolerance value of the resistor is 5% and if it is silver the tolerance is 10% of the value. Figure 1.42(a) shows the resistor with colour code. Table 1.1 shows the colour coding of the resistor.

Table 1.1 Colour Coding of Resistors

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

ACTIVITY 1.3

Make a colour circle showing Resistor values using colour codes as shown in the Figure 1.42(b).

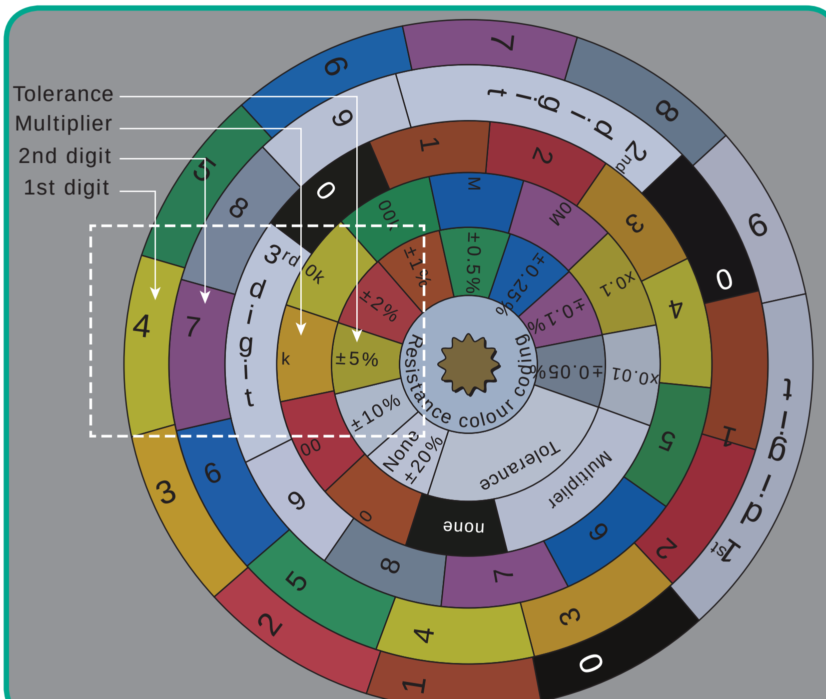


Figure 1.42(b) **Colour circle for colour coding of resistors**

1.9.1 Tolerance

It is impossible to manufacture resistors to the exact values. For example, if we want to manufacture a resistor to the value of 100 ohms , after the production, the value may be a bit higher or lower. This is due to unavoidable manufacturing process. Hence, there is some lenience in production of resistors. It is referred as tolerance. Fourth colour code is the tolerance code. If it is gold, tolerance is 5%. If it is silver, tolerance is 10%.

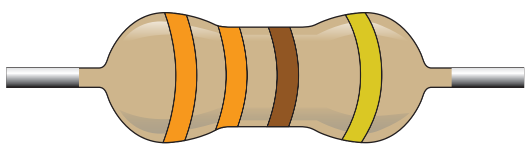
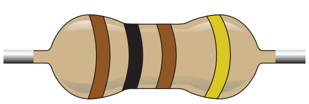


Figure 1.43 Tolerance code – 4th colour from left

Finding the values of resistors using colour codes

Example 1: Brown Black Brown



1 0 $\times 10^1$

10 $\times$10

100 Ω

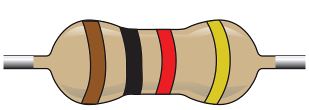
Example 2: Brown Red Black

1 2 $\times 10^0$

12 $\times$ 1

12 Ω

Example 3: Brown Black Red

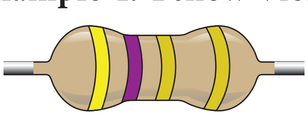


1 0 $\times 10^2$

10 $\times$100

1,000Ω = 1k Ω

Example 4: Yellow Violet Gold

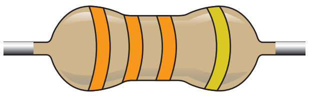


47×10^{-1}

$\frac{47}{10}$

= 4.7 Ω

Example 5: Orange Orange Orange

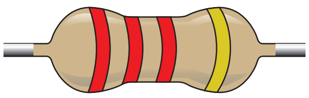


3 3 $\times 10^3$

33,000Ω

33 kΩ

Example 6: Red Red Red

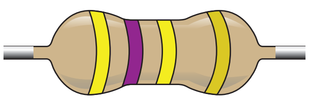


2 2 $\times10^2$

2200Ω

2.2kΩ

Example7: Yellow Violet Yellow

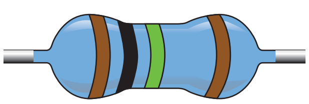


4 7 $\times 10^4$

4,70,000Ω

470 kΩ

Example 8: Brown Black Green



10 $\times 10^5$

10,00,000Ω

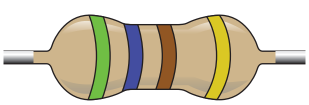
= 1 MΩ

Example 9: Brown Black Black

1 0 $\times 10^0$

10 $\times$ 1 = 10Ω

Example 10: Green Blue Brown



5 6$\times 10^1$

560Ω

Figure 1.44 Finding the values of the resistors using colour coding

Tolerance Calculation

1. Find the tolerance value of the resistor given below

   Brown Black Brown Gold

   100Ω ± 5% = 100Ω ± 5Ω

Tolerance value of 100Ω = 95Ω to 105 Ω

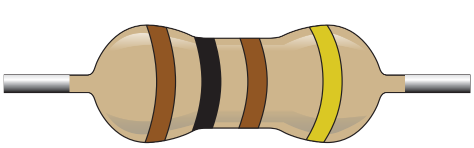


Figure 1.45(a) Calculating tolerance code

2. Find the tolerance value of the resistor given below

   Green Blue Red Silver

   5 6 X 10^2 ± 10%

   5600 Ω ± 10% i.e., 560 Ω

Tolerance value of 5.6 kΩ = 5040 Ω to 6160 Ω

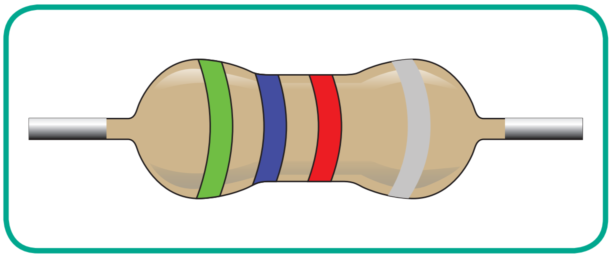


Figure 1.45(b) **Calculating tolerance code**

1.9.2 Faults in Resistors

1. Resistors may get opened because of overheat due to excess current flow.
2. Resistance value becomes higher than the original value.
3. Faulty resistors cannot be used in circuits.

1.9.3 Testing of resistors

1. Using multimeter, test a resistor, If the dial remains unmoved, then the resistor is open
2. If meter shows higher value than that of the actual value of the resistor, the resistor becomes high value.

1.10 KIRCHHOFF'S LAWS

It is used to find out the current flow in the network circuits easily where it is not easy to find values using ohm's law. It is applicable for both DC and AC circuits. There are two types of law viz.

1. Current law
2. Voltage law

DO YOU KNOW?

German scientist Robert Kirchchoff created these laws and hence called as Kirchhoff's laws.

1.10.1 Current law

The sum of the currents flowing towards a junction is equal to the sum of the currents flowing away from it. This is called Kirchhoff's current law.

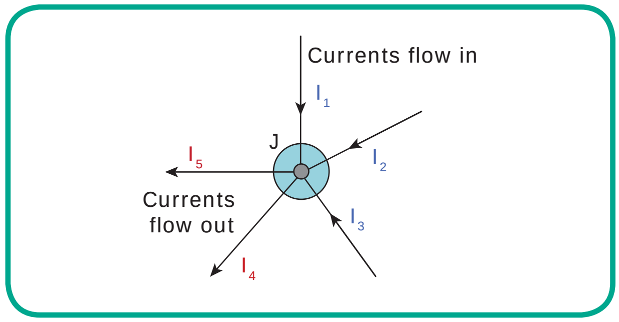


Figure 1.46 **Kirchhoff's current law**

In the Figure 1.46, J is the junction (or node) formed by five conductors. The current in these conductors are I_1, I_2, I_3, I_4 and I_5. Here, I_1, I_2 *and* I_3 flow towards the junction and I_4 *and* I_5 flow away from the junction. According to Kirchhoff's current law,

$$I_1 + I_2 + I_3 = I_4 + I_5$$

i.e. currents flow towards junction = currents flow away from junction.

On the other hand, $I_1 + I_2 + I_3 - I_4 - I_5 = 0$. This is known as Kirchhoff's current law equation.

1.10.2 Voltage law

At any closed circuit, the sum of potential drops across each resistor in a series circuit is equal to the supply voltage given to the circuit. The circuit representing the voltage law is shown in Figure 1.47.

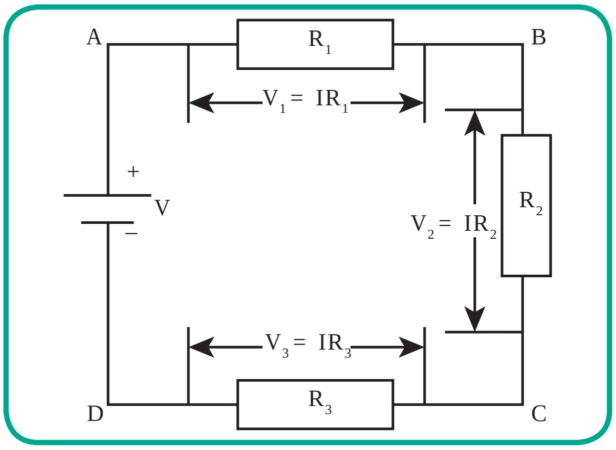


Figure 1.47 Kirchhoff's voltage law

In a closed circuit, the sum of the voltage drops is equal to the sum of the potential applied. This is called Kirchhoff's voltage law (shortly KVL)

i.e., $V = IR_1 + IR_2 + IR_3$

As per ohm's law

$V = V_1 + V_2 + V_3$

Example 1

Find the current flow through each resistor in the circuit shown in Figure 1.48, using Kirchhoff's law.

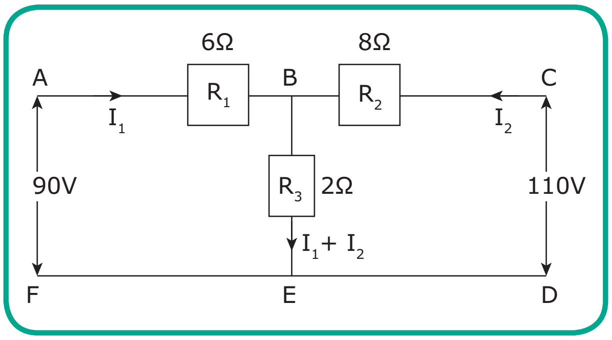


Figure 1.48

Solution

According to Kirchhoff's current law, the direction of current flow towards the junction is noted. According to voltage law, write down the KVL equation in the closed circuits.

1. ABEFA forms a closed circuit

$6I_1+2(I_1+I_2) = 90$

$8I_1 + 2I_2 = 90$ Eqn.. 1.1

2. CBEDC forms another closed circuit

$8I_2+2(I_1+I_2) = 110$

$2I_1 + 10I_2 = 110$ Eqn.. 1.2

To solve this, multiply Equation 1.2 by 4 on both sides, Therefore,

$8I_1+40I_2 = 440$ Eqn.. 1.3

Subtract Eq.1.3 from Eqn.1.1.

$$\begin{array}{r} 8I_1 + 40I_2 = 440 \\ 8I_1 + 2I_2 \;=\; 90\ (-) \\ \hline 38I_2 = 350 \\ \hline \end{array}$$

$$I_2 = \frac{350}{38}$$

$$I_2 = 9.21\ A$$

By putting the value of I_2 in Eq.1.1, we can get the value of I_1

$$8I_1 + (2 X 9.21) = 90$$

$$8I_1 = 90 - 18.42$$

$$I_1 = \frac{71.58}{8}$$

$$I_1 = 8.95\ A$$

From this, we found that

1. The current flows through resistor 6Ω is 8.95 A.
2. The current flows through 8Ω resistor is 9.21 A.
3. The current flows through 2Ω resistor is 8.95 + 9.21 = 18.16 A.

Example 2

By using Kirchhoff's law, calculate the current flowing through each resistor shown in the circuit diagram (Figure 1.49).

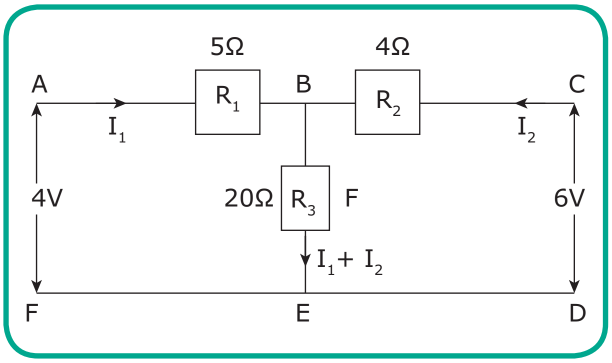


Figure 1.49

By applying Kirchhoff's second law (voltage law)

In circuit *ABEFA*,

$$5I_1 + 20(I_1 + I_2) = 4$$

$$25I_1 + 20I_2 = 4 \qquad \text{Eqn.. 1}$$

In circuit CBEDC,

$$4I_2 + 20(I_1 + I_2) = 6$$

$$20I_1 + 24I_2 = 6 \qquad \text{Eqn.. 2}$$

To solve this, multiply Eqn.1 by 4 on both sides, we get,

$$100I_1 + 80I_2 = 16 \qquad \text{Eqn.. 3}$$

Multiply Eqn.2 by 5 on both sides, we get,

$$100I_1 + 120I_2 = 30 \qquad \text{Eqn.. 4}$$

Subtracting Eqn.3 from 4, we get,

$$\begin{array}{r} 100I_1 + 120I_2 = 30 \\ 100I_1 + \ \ 80I_2 = 16(-) \\ \hline 40I_2 = 14 \\ \hline \end{array}$$

$$I_2 = \frac{14}{40}$$

$$I_2 = 0.35 \text{ A}$$

Substitute the value of I_2 in Eqn. 1, we get,

$$25I_1 + 20(0.35) = 4$$

$$25I_1 = 4 - 7 = -3$$

$$I_1 = \frac{-3}{25}$$

$$I_1 = -0.12 \text{ A}$$

The minus symbol shows the current flows in the opposite direction.

1.11 CAPACITOR

A component which stores electrical energy and discharges when needed is called capacitor.

The unit for measuring capacitance is Farad, which is used to measure higher values.

Other smaller value capacitors are measured using micro-Farad (µ*F*) shortly *µF*, pico-Farad (*pF*), and nano-Farad (*nF*).

The ability to store electrical energy is called as capacitance. Figure 1.50 shows the internal construction of a capacitor. The capacity to store electrical energy is termed as capacitance and the electric device to store it is termed as Capacitor. Like resistors, capacitors are also manufactured with admissible tolerance of 5% - 20%.

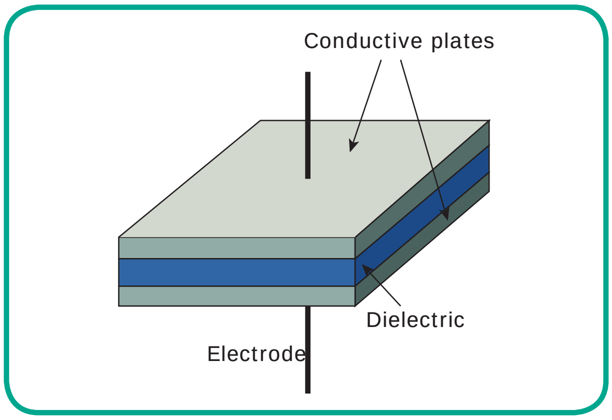
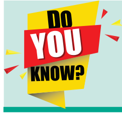


Figure 1.50 Capacitor



Unit Farad was named after the British scientist Michael Faraday.

1.11.1 History

Figure 1.51 is the earliest version of a capacitor, called Leyden jar. It is a device that stores static electricity between two electrodes on the inside and outside of a glass jar. It was the initial form of a capacitor. It was invented independently by German scientist Cleric Ewald Georg Von Kleist and by Dutch Scientist Pieter Van Musschenbroek of Leyden city. The invention was named after the city.

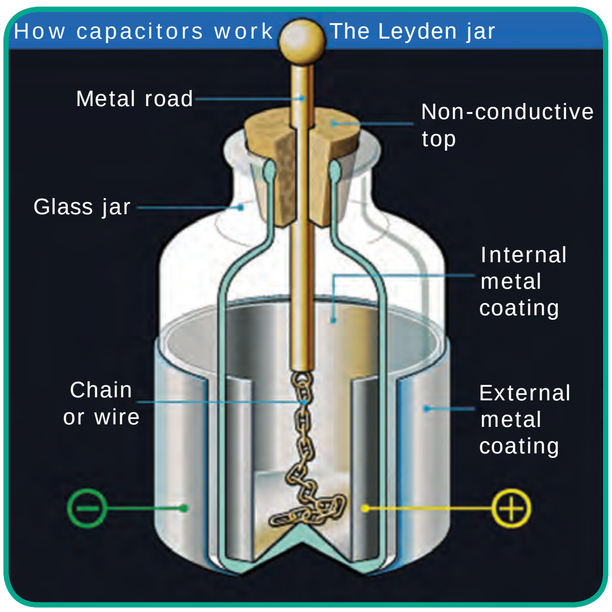


Figure 1.51 Leyden jar

> **DO YOU KNOW?** Capacitor was initially known as condenser

1.11.2 Construction

Figure 1.52 shows the parts of the capacitor. In this, an insulator placed between two parallel conducting plates is termed as a dielectric medium. The two parallel plates are termed as electrodes. Based on the insulator used in the capacitors, they are named as paper, ceramic, mica, and polyester capacitors.

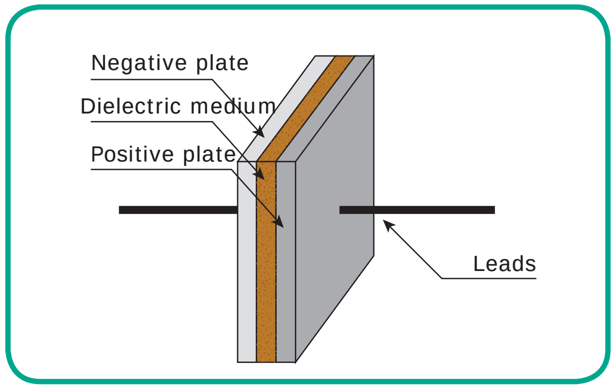


Figure 1.52 Parts of a capacitor

1.11.3 Working of a capacitor

Figure 1.53 shows a capacitor connected in an electrical circuit.

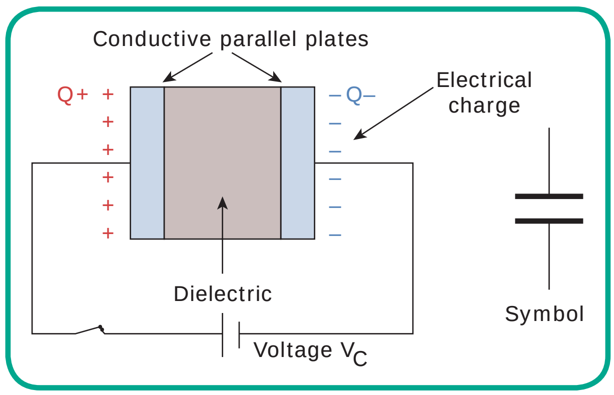


Figure 1.53 Capacitor connected in a circuit.

Charging

When switch *S* is on, current flows through the capacitor. Due to this, the plate *A* of the capacitor gets +ve charge and plate *B* gets –ve charge. Thus, electric field forms across the plates. After complete charging , the current flow will stop. The amount of charge between the plates depends upon the dielectric material and also the distance between the electrodes. The charging limit depends upon the E.M.F. of the battery.

Discharging

If a load is connected to that charged capacitor after removing from the circuit, the electrical energy will discharge. This is known as discharging of capacitor.

Dielectric strength

The maximum point at which the dielectric field withstands the potential difference, without damage is known as di-electric strength.

1.11.4 Functions of a Capacitor

1. It stores electrical energy particularly DC when connected in parallel.
2. It blocks DC supply when connected in series with DC.
3. It couples AC to the next circuit and blocks DC to that next circuit.
4. It discharges while connected to a load.
5. It bypasses unwanted signals to earth.
6. It filters ripples in the pulsating dc to get pure dc while connected in parallel.
7. It decouples the unwanted signals.
8. It helps in producing signals of various frequencies in oscillator circuits.
9. Presently, very high value ultra capacitors are used in place of batteries for quick charging.
10. In a circuit, if an insulator is accidentally placed in between two conductors, it also works as a capacitor. It is called as stray or parasitic capacitance. While designing circuits, the design engineers take care of this fact.
11. Now a days, capacitive type touch screens are widely used.

1.11.5 Capacitive Reactance(X_c)

It is the property of a capacitor which opposes alternating current, is known as Capacitive Reactance. It is represented by the letter $X_{c.}$ Capacitive reactance is inversely proportional to the frequency applied to the capacitor and the capacitance value of the capacitor. Its unit is also ohm.

$$X_C = \frac{1}{2\pi fc}$$

where f is the frequency and C is the capacitance of the capacitor.

High value capacitor offers low reactance to low frequency, but offers high reactance to high frequency.

Low value capacitor offers low reactance to high frequency signals but offers high reactance to low frequency signals.

Ex: High value capacitors such as 1000 µF, 2200 µF and 4700 µF are used for filtering low frequency 50 Hz ripples in power supplies.

1.11.6 Capacitance

The capacitance (C) is derived from the ratio between charge (Q - Coulomb) and the potential difference between the two plates(V).

$$C = \frac{Q}{V}$$

$$\text{Capacitance (C)} = \frac{\text{Charge (Q)}}{\text{Voltage (V)}}$$

(C in farad, charge in coulombs, V in volts.)

1.11.7 Classification of Capacitors

These are two main classifications

1. Fixed capacitor
2. Variable capacitor

Fixed capacitor

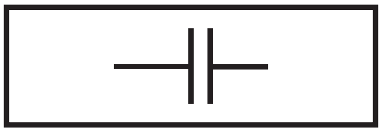


Figure 1.54 (a)

In fixed capacitor, capacitance value cannot be changed.

Its symbol is shown in Figure 1.54 (a).

1.11.7.1 Types of fixed Capacitors

1. Paper capacitor
2. Mica capacitor
3. Polyester capacitor
4. Ceramic capacitor
5. Electrolytic capacitor (polarized and non-polarized)
6. Bipolar Electrolytic Capacitor
7. Tantalum capacitors (metal film capacitors)
8. SMD capacitor
9. Ultra capacitor (or) super capacitor

1.11.7.1.1 Paper capacitor

Figure 1.54(b) shows a paper capacitor. In this, wax paper is rolled in the form of cylinder and dipped in wax solution in order to exhaust the air. Then, it is placed in between two thin aluminium plates.

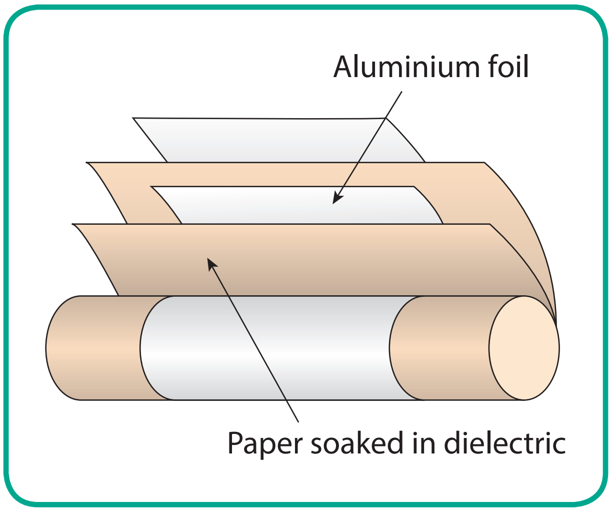


Figure 1.54 (b) Paper Capacitor

Available capacitor values are from 0.001 µF. Voltage rating from 100 V to 1500 V.

Uses

Paper capacitor is used for the following purposes.

1. Blocking
2. Coupling
3. Decoupling
4. Filtering
5. Bypassing

1.11.7.1.2 Mica Capacitor

Figure 1.55 shows a mica capacitor. In this type, mica is used as the dielectric medium. Silver coated on the mica acts as electrodes.

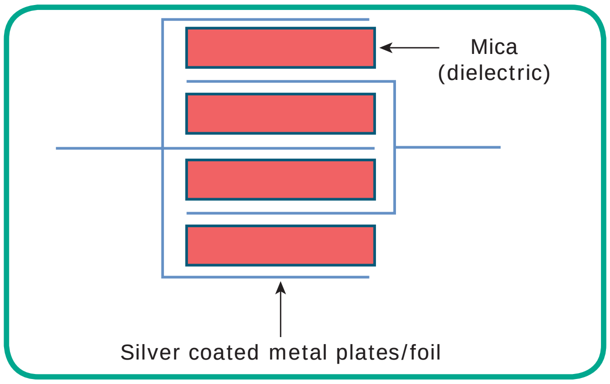


Figure 1.55 Mica Capacitor

This type of capacitor's values are available from 2 pF to 1000 pF and voltage rating from 6V to 500V.

Uses

1. Used in high frequency coupling circuits.
2. Used in tuning circuits.

1.11.7.1.3 Polyester capacitors

Figure 1.56 shows a Polyester capacitor.

It uses polyester film as a dielectric medium and aluminium foils as conducting plates.

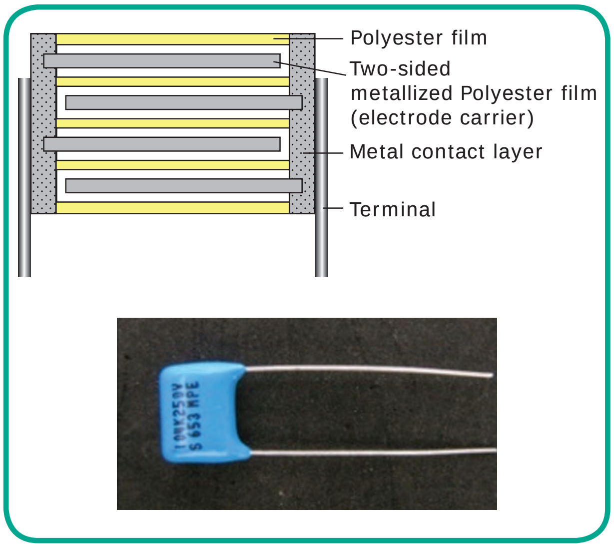


Figure 1.56 **Polyester Capacitor**

Advantage

It can be used in high voltage applications having voltage rating up to 2 kV.

Uses

1. Coupling
2. Decoupling

1.11.7.1.4 Ceramic capacitor

Figure 1.57 shows the Ceramic capacitor.

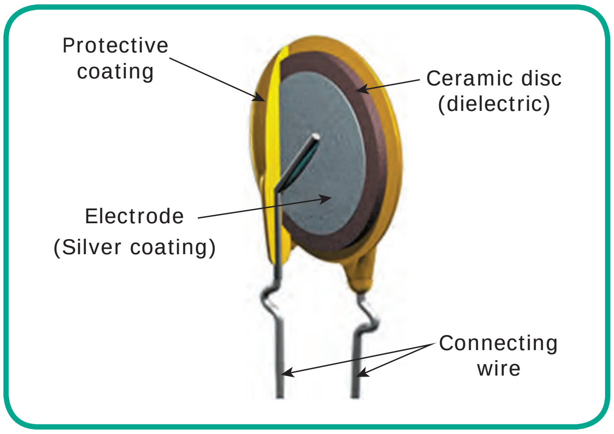


Figure 1.57 **Ceramic Capacitor**

In this, ceramic is used as dielectric medium. Silver coating is made on both sides of the ceramic. It is also called as Disc Capacitor, because it looks like a small disc.

Available capacitor values are from 100 pF to low value μF. Voltage rating from 16V to 200V.

Uses

1. Blocking.
2. Coupling.
3. Decoupling.
4. High frequency filtering.

Identifying the values

Figure 1.58

Figure 1.58 shows the values of capacitors as 102 and 103.

102 means 10 X 10^2= 1000pF

= 1kilo pico Farad = 1kpF

103 means 10×10^3=10,000pF

= 10 kilo pico Farad = 10kpF

1.11.7.1.5 Electrolytic capacitor

Figure 1.59 shows the electrolytic capacitor. In this, aluminium oxide is used as dielectric medium. Pure aluminium foils are used as anode (+). Aluminium paste is coated in the dielectric and it is used as cathode (-).

Precautions

Since it has polarities (+ and -), it has to be connected with DC supply only with correct polarities. Only –ve polarity is printed in the capacitor. The other terminal is taken as +ve terminal. Care must be taken while connecting an electrolytic capacitor in a circuit,

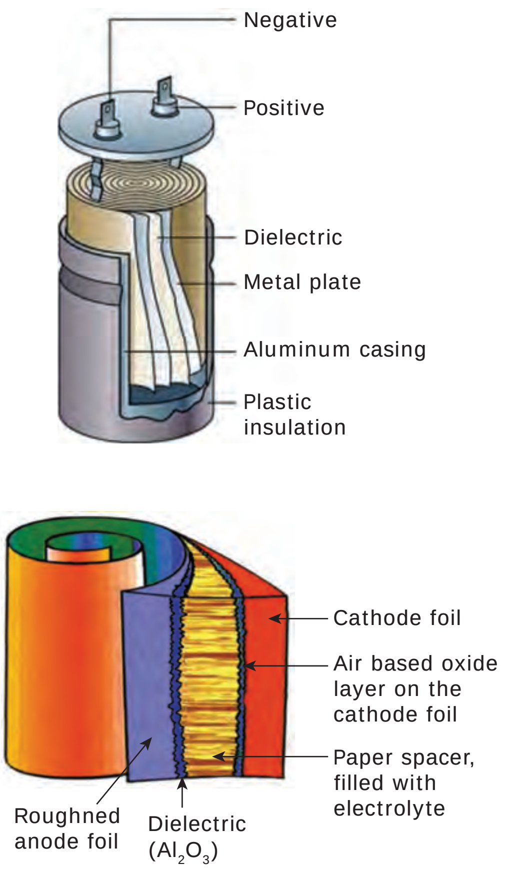


Figure 1.59 **Electrolytic capacitor**

i.e., +ve terminal should be connected with +ve terminal of DC and – terminal of capacitor should be connected with – ve terminal of DC supply.

Electrolytic capacitors should be connected in correct polarities.

Otherwise the capacitor will burst out which is very dangerous.

Available capacitor values are from 0.47μF to 4700μF and voltage rating from 3V to 500V.

Uses

1. Filtering
2. Used in inverters
3. Used for photo flash

1.11.7.1.6 Bipolar Electrolytic Capacitor

Figure 1.60 shows a bipolar electrolytic capacitor.

Figure 1.60 **Bipolar electrolytic capacitor**

This type has two oxide coated anodes. Hence, it has no polarity and can be connected in an AC supply without looking polarities.

Uses

1. Used in starting the AC motors.
2. Used in CRT model TV receivers.

1.11.7.1.7 Tantalum Capacitors

Figure 1.61 shows a tantalum capacitor.

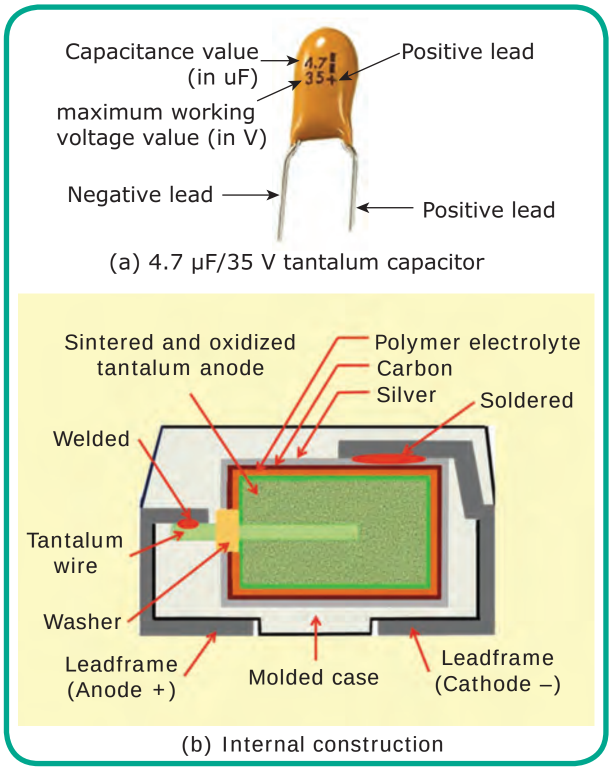


Figure 1.61 **Tantalum capacitor**

In this type, tantalum foil acts as an anode. Using electro-chemical process, thin tantalum oxide layer is deposited on anode. This oxide layer acts as a dielectric medium. Cathode is also a tantalum foil. The total setup is placed in a sealed package.

Advantages

1. Smaller in size
2. Long term stability
3. Long shelf-life
4. Low leakage
5. Can be used in SMD form.

Disadvantages

It cannot be used in the circuits where voltage spikes are more.

Uses: It is used in

1. Cell phones.
2. Computer circuits.
3. LED Television circuits.

1.11.7.1.8 SMD Capacitor

It is directly soldered on the copper solder points of the surface of the PCB and is called as SMD capacitor. It is shown in figure 1.62

Figure 1.62 SMD capacitor

1.11.7.1.9 Ultra Capacitor

It is a type of capacitor which has higher capacitance value in farad with low voltage rating. It is an electric double layer capacitor. It is also called as super capacitors. It uses carbon as electrodes. Figure 1.63 shows an ultra-capacitor.

They can store 10 to 100 times more electrical energy than electrolytic capacitors.They can accept and deliver charge much faster than batteries, and long lasting many more charge and discharge cycles than rechargeable batteries.

Uses: It is used in DC operated cars, buses, trains, cranes and elevators and static RAM in computers.

Working Voltage

In the Figure 1.63(a), the voltage mentioned in the capacitor is the maximum voltage to be applied to a capacitor. But it

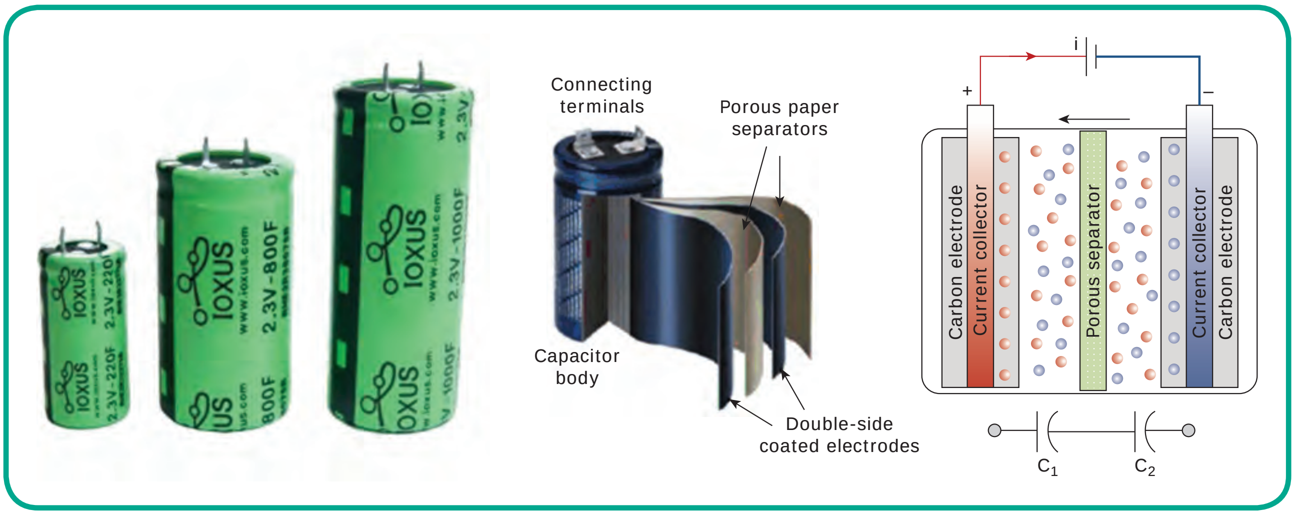


Figure 1.63 Ultra capacitor

should be connected to two-third of the voltage of the maximum voltage.

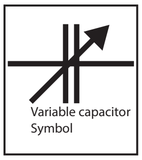
Figure 1.63(a) **Working voltage**

In the Figure 1.63(a), 1,000 micro farad / 25volts is mentioned in the capacitor. 25 V is the maximum voltage to be applied. Two third of 25 V, that is 16 V should be normally applied to this capacitor.

1.11.8 Variable Capacitor

In variable capacitor, the capacitance value can be changed within a particular limit.

In this section, different types of variable capacitors used in electronics circuit are discussed.



1.11.8.1 Ganged Capacitor

Two variable capacitors are arranged in a setup and can be varied through a common shaft is called Ganged capacitor.

It is of two types:

1. Metal gang
2. PVC gang

1.11.8.1.1 Metal Gang

Figure 1.64 shows a ganged capacitor.In this, there are two sets of plates and air acts as dielectric medium. One is static (stator) and another set is kept rotating (rotor). Rotor is connected to a shaft. When the shaft is rotated, metal plates mounted on the shaft, moves between fixed metal plates. This varies the value of the capacitance.

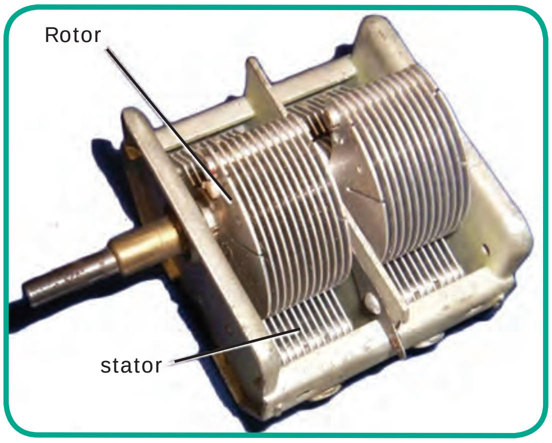


Figure 1.64 **Ganged capacitor (Metal)**

If rotor moves outward, the area between stator and rotor is less, capacitance also becomes low value. If rotor moves inside the stator, the area becomes large. Hence capacitance value also becomes high. The minimum capacitance is 49 pF and maximum is 500pF. It consists of two variable capacitors as shown in the Figure 1.64.

1.11.8.1.2 PVC Gang

In this type of gang, thin layer of PVC acts as a dielectric medium.

Rotor is connected with chassis. Its value depends upon the area of plates. It is shown in figure 1.65.

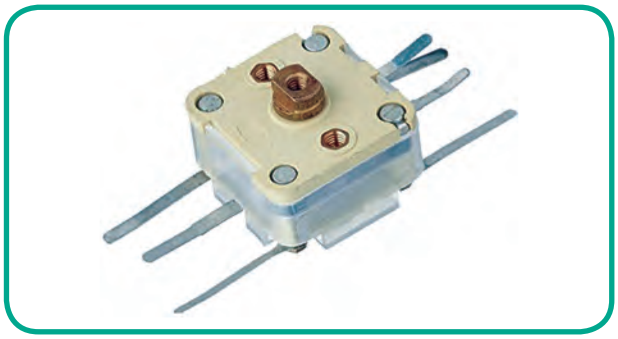


Figure 1.65 **PVC gang**

Uses

It is used in tuning circuits of the radio receivers for selecting a desired radio station.

1.11.8.2 Semi-Variable capacitor

Trimmer is a semi-variable capacitor as shown in Figure 1.66.

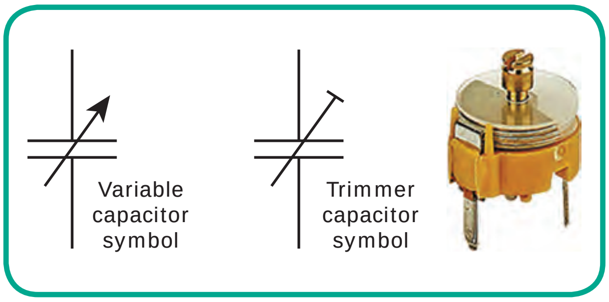


Figure 1.66 Trimmer

In this, a plate is kept static (unmoved) and another plate is placed at a distance and it is in such a way that the second plate can be moved little by little towards the first plate. The second plate is attached with the screw for comfortable movement.

When the plates are nearer, the capacitance is high and when it is at a distance the capacitance is low. This type of capacitor is said to be Trimmer. It is also called as button trimmer. It is available in values from 4pF to 70pF.

Uses

It is used in pre-tuning circuits of the radio receivers.

1.11.9 Capacitor in series

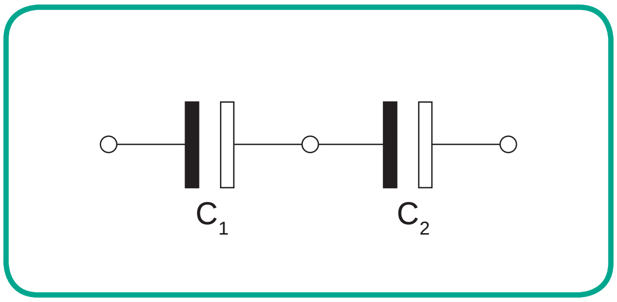


Figure 1.67 Capacitors in series

Figure 1.67 shows the capacitors connected in series.

When the capacitors are connected in series as shown in Figure 1.67, the total capacitance is

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}$$

$$C = \frac{C_1 C_2}{C_1 + C_2}$$

Problems

Find out the total capacitance, when two capacitors of values 10 µF, 15 µF are connected in series.

Total capacitance

$$C = \frac{C_1 C_2}{C_1 + C_2}$$

$$C = \frac{10 \times 15}{25}$$

Total capacitance C = 6 µF

1.11.10 Capacitors in Parallel

Figure 1.68 shows a circuit in which the capacitors are connected in parallel.

When the capacitors are connected in parallel as shown in Figure 1.68, the total capacitance is $C = C_1 + C_2$

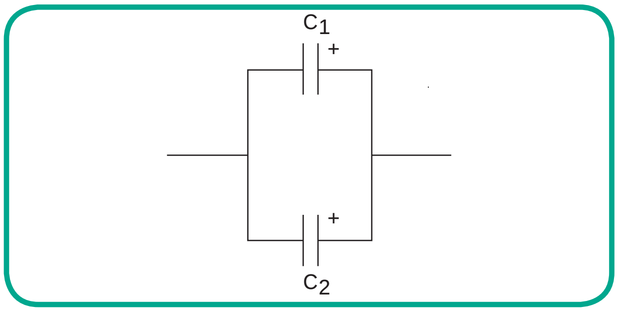


Figure 1.68 Capacitors in parallel

Problems

Find the total capacitance when two capacitors of values 1000μF and 470μF connected in parallel.

Total capacitance $C = C_1 + C_2$

$C = 1000 + 470$

$C = 1470 \mu F.$

1.11.11 Action of a Capacitor in DC Circuit

Figure 1.69 shows a capacitor connected in a DC circuit.

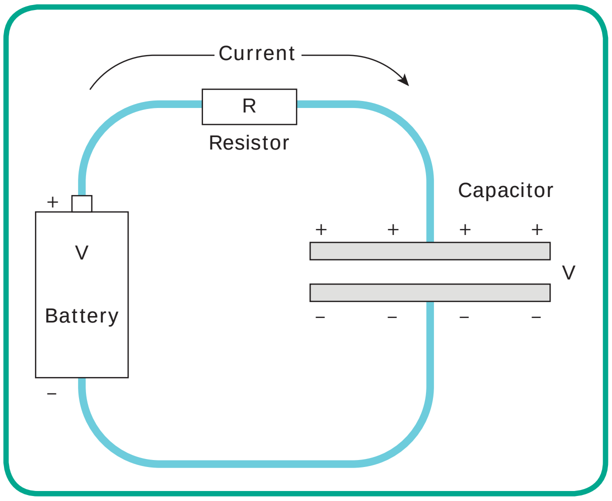


Figure 1.69 Action of a capacitor in DC circuit

When a capacitor is connected in DC circuit, the current flow will be high until it is charged fully.

When it is charged completely, the flow of current will be stopped and the voltage in the capacitor will be equal to the EMF in the battery. When a capacitor is connected in series with DC, it blocks the supply.

1.11.12 Action of a Capacitor in AC Circuit

Figure 1.70 shows a capacitor connected in an AC circuit.

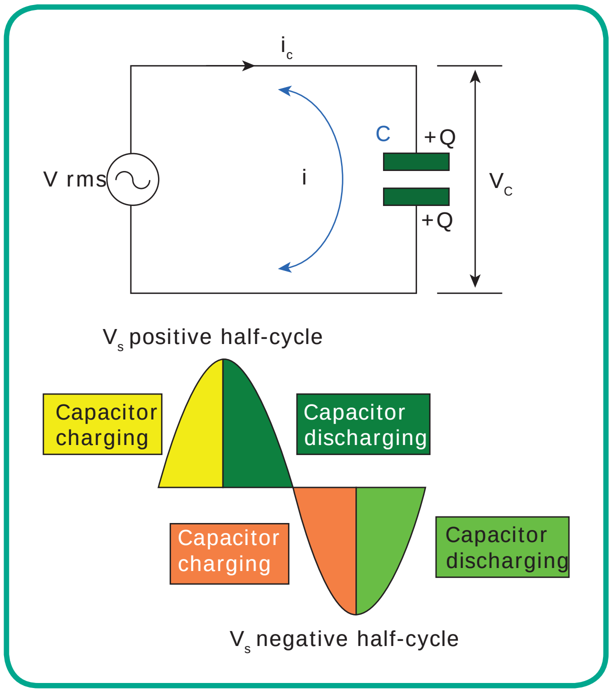


Figure 1.70 Action of capacitor in AC circuit

When a capacitor is used in AC circuit, it will be charged and gets discharged for every quarter cycle, since polarity is changed for every quarter cycle (i.e., 90°).

LEARNING OUTCOMES

After studying this Chapter, a student can understand the following

1. Basics of electricity
2. Electrical parameters
3. Ohm's law
4. Kirchhoff's law
5. Working of Resistors
6. Working of Capacitors

GLOSSARY

S. No	Terms	Explanation
1	**Ampere**	The unit of electrical current
2	**Volt**	The unit of voltage (potential difference)
3	**Ohm**	The unit of resistance
4	**Hertz**	The unit of frequency
5	**Watt**	The unit of power which equals one joule per second
6	**Anode**	Positive current flows in while AC supply given
7	**Cathode**	Negative current flows in while AC supply given
8	**Direct current**	Electric current flowing in one direction only
9	**Fuse**	A device that protects an electric circuit from excessive current
10	**Alternating current**	An electric current that reverses direction in a circuit at regular intervals

T2HH8K

QUESTIONS

I. Choose the best answer from the given four options. **Each question carries one mark**

1. The unit of current is

   a) Volt b) Ampere c) Ohms d) None of these

2. The power can be calculated by

   a) P = I - R b) P = V. I c) P = V/I d) P = V/R

3. Two resistors are connected in series, the total resistance value is calculated by

   a) $R = R_1 + R_2$ b) $R = R_1 / R_2$ c) $R = R_1 \times R_2$ d) $R = R_1 + R_2/R_1$

4. If two resistors 150Ω and 150Ω are connected in parallel, the total resistance is

   a) 50 Ω b) 100 Ω c) 200 Ω d) 75 Ω

5. What is the colour coding of a resistor which resistance value is 10,00,000 Ω ?

   a) Brown Black Brown b) Brown Black yellow

   c) Brown Black Green d) Brown Black Gold

Continued on next page

6. The unit of wavelength is

   a) Micro Farad   b) Ampere   c) Ohm   d) Meter

7. Which of the following is not true?

   a) Current Increases while voltage increases   b) Power increases while resistance increases

   c) Current decreases while voltage decreases   d) Current increases while resistance decreases

8. The unit of capacitance is

   a) Ampere   b) Ohms   c) Farad   d) Watt

9. When two capacitors are connected in parallel, the total capacitance value is

   a) $C = C_1 + C_2 / C_1 + C_2$ b) $C = C_1 + C_2$

   c) $C = C_1 + C_2 / C_1.C_2$ d) $C = C_1 - C_2$

10. Write the odd one

    a) Ohm   b) kilo ohm   c) megawatt   d) mega ohm

II. Answer in few sentences. Each question carries three marks. (3 marks)

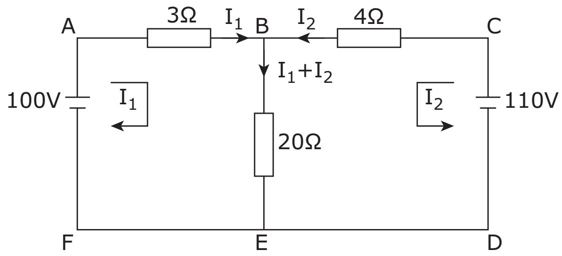
1. Define Ohm's law.
2. Define open-circuit and short-circuit.
3. Draw symbols for i) AC supply ii) DC supply iii) Resistor
4. What is meant by a resistor?
5. What is meant by tolerance in resistors?
6. If 100 Ohms and 150 Ohms are connected in parallel in a circuit , calculate the total resistance of the circuit.
7. If 15 Ohms and 10 Ohms are connected in series with 50Volts, Calculate the current flow in this circuit.
8. Write the expansion for i) NTC ii) PTC iii) PCB
9. Write short notes on i) SMD capacitor and ii) Ultra capacitor
10. State any three advantages of tantalum capacitors.
11. Define capacitive reactance.
12. What is meant by variable capacitor? Draw its symbol.

III. Explain in a paragraph. Each question carries five marks. (5 marks)

1. Draw and explain about wire wound resistors.
2. Draw and explain about carbon resistors.
3. What is meant by Kirchhoff's laws? Explain the same.
4. Draw and explain about electrolytic capacitors.
5. Write any five names of the types of capacitors.

IV. Explain in about a Page. Each question carries ten marks.

1. Using Kirchhoff's law, find the value of current flow through all resistors in the given circuit



2. In a series circuit, two resistors 50Ω and 100Ω are connected with 300 V supply. Prove that the sum of the voltage drops across the resistors is equal to the EMF applied in the circuit.
3. In a parallel circuit, two resistors 100 Ω and 150Ω are connected with 240V supply. Prove that the sum of branch currents is equal to the Total current of the circuit.
4. List out the functions of a capacitor.

Answers

1) **b**	2) **b**	3) **a**	4) **d**	5) **c**
6) **d**	7) **b**	8) **c**	9) **b**	10) **c**

CHAPTER 2

ELECTRICAL DEVICES

T2V6KE

அருவினை யென்ப உளவோ கருவியான்
காலம் அறிந்து செயின் #குறள் 483

விளக்கம்:
செய்யும் செயலை முடிப்பதற்கு வேண்டிய கருவிகளுடன், ஏற்றக் காலத்தையும் அறிந்து செய்தால், அரிய செயல்கள் என்பது இல்லை.

"True wisdom wards off woes, A circling fortress high; Its inner strength man's eager foes Unshaken will defy". #kural 421

Meaning: Wisdom is a weapon to ward off destruction; it is an inner fortress which enemies cannot destroy.

CONTENT

LEARNING OBJECTIVES

After the completion of this chapter, the students can

1. Understand the basic working principles of electrical devices viz., cell, inductors, transformers, switches and fuses.
2. Understand the functions of microphone and loudspeaker.
3. Be aware of electrical hazards and able to implement basic actions to avoid unsafe work conditions.

Confidence and hard work is the best medicine to kill the disease called failure. It will make you successful person.

–A.P.J Abdul Kalam

INTRODUCTION

In our day-today life, we are supposed to use many electrical appliances such as water pump, iron box, mixie, grinder, washing machine, UPS, TV etc. In order to understand the basic working principle of these appliances, it is better to know about some of the important electrical devices which are used in the appliances.

In this, we are going to read about

1. Cells
2. Inductors
3. Transformers
4. Switches and Fuses

2.1. CELLS

A device which converts chemical energy into electrical energy is called as a cell. A group of cells connected together is called battery.

In electric and electronic circuits, an electrical cell is denoted by the following symbol as shown in Figure 2.1.

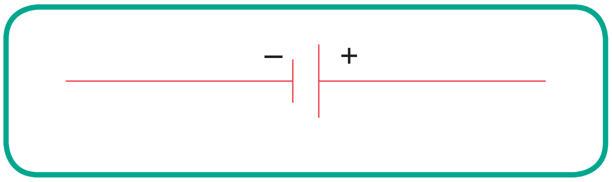


Figure 2.1 **Symbol for Cell**

When two dissimilar metals or electrodes are immersed in an electrolyte, there will be a potential difference produced between these metals or electrodes. In this, one electrode acts as positive terminal and another electrode acts as negative terminal.

History

In 1800, "Alessandro Volta" invented the 'Voltaic Pile' and discovered the first practical method of generating electricity, as we already discussed in the Chapter 1. This 'Voltaic pile' was the first 'wet cell' that produced a reliable, steady current of electricity.

2.1.1. Types of Cells

The cells are classified into two categories. They are,

1. Primary cells
2. Secondary cells

Primary Cells

Primary cells are widely used in clocks, watches, remote controls and calculators.

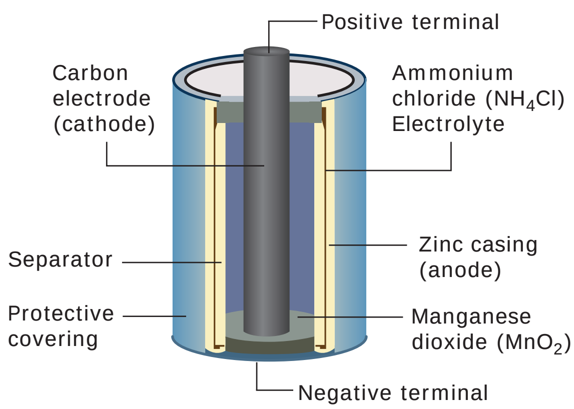


Figure 2.2(a) **Structure of Primary Cell**

The cells that cannot be recharged are called as 'primary cells'. Some of the primary cells are Alkaline cell, Lithium cell, Zinc-Carbon cell or dry cell.

Generally, primary cells (figure 2.2a) are available in the voltage rating of 1.5 V, 3 V, 9 V and 12 V and the current rating of 0.2 A, 0.5 A, 1 A and 2 A. AA and AAA type of cells (1.5V) are used in clocks and remote controls. 1.5 V, 3 V button cells are used in watches and computers, respectively. 9 V cell is used in multimeter and cordless microphone.

Secondary Cells

The cells that can be recharged are called as 'secondary cells'. Some of the secondary cells are lead-acid cell, Lithium ion cell and Nickel Cadmium cell.

Figure 2.2(b) shows the structure of secondary cell. Lead-acid cell is widely used in two-wheel and four-wheel vehicles. Lithium ion cells are used in laptops and cell phones. Nickel cadmium cells are used in flash lights, emergency lights and toys.

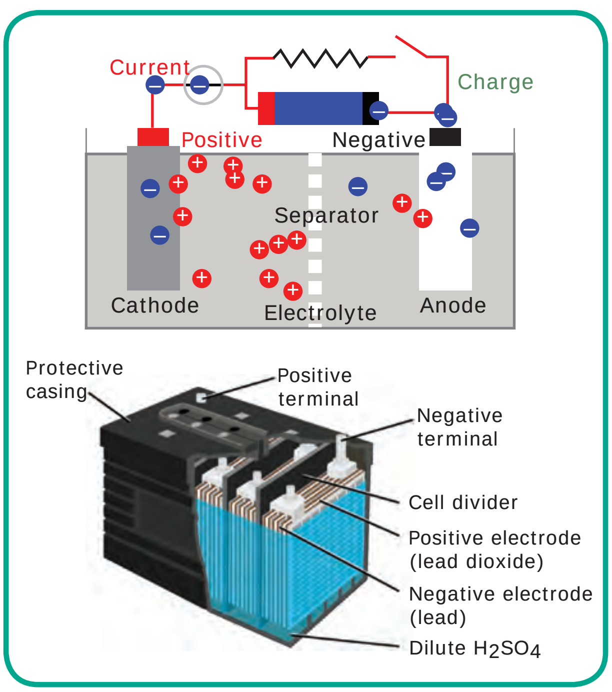


Figure 2.2(b) **Structure of Secondary Cell**

2.1.2. Capacity of Cells

The capacity of the cells is termed in Ampere-hour (Ah). This denotes the supply of current based on time.

For example, if a cell has a capacity of 2 Ah, it could supply the current of one Ampere in 2 hours or 2 Amperes in 1 hour.

2.1.3 Cell Arrangements

Cell arrangement determines the voltage and current. For that, the cells are connected in series and parallel.

2.1.3.1 Cells in Series

In this method, the positive (+) terminal of one cell is connected with the negative (-) terminal of next cell and so on.

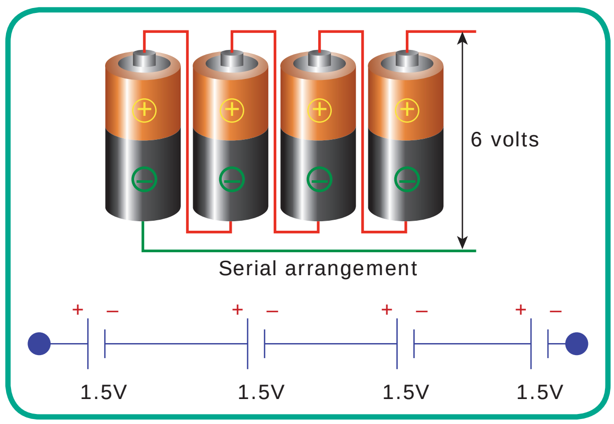


Figure 2.3 **Cells Connected in Series**

Figure 2.3 shows the series connection of cells. Cells have a particular potential difference (Eg.1.2 V, 1.5 V, etc.). If higher voltage is needed (E.g. 6 V, 9 V, 12 V) cells are connected in series. The current flow through in each cell is equal and same.

If four cells are connected in series (1.5 V each) the total EMF is,

$$E_T = n \times e$$

$$= 4 \times 1.5 = 6 \text{ V}$$

where '*n*' is number of cells and '*e*' is the voltage of the cell.

2.1.3.2 Cells in Parallel

In this method, the positive terminal of each cell is connected simultaneously and taken as a single positive output and the negative terminals are connected simultaneously and taken as a single negative output.

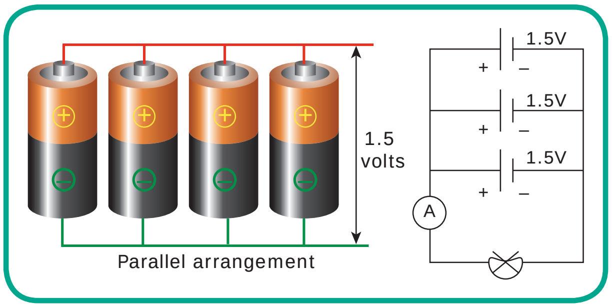
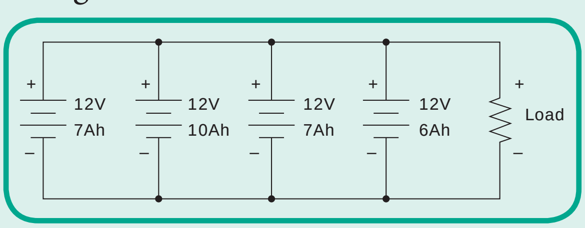


Figure 2.4 Cells Connected in Parallel

Figure 2.4 shows parallel connection of cells. If higher current is needed (having same EMF), cells are connected in parallel. The total EMF is equal to the EMF of individual cells.

Problems

Let four batteries are connected in parallel having a voltage and current rating of 12V/7Ah, 12V/10Ah, 12V/7Ah and 12V/6Ah. Calculate the total current rating of the circuit.



Total current rating of the circuit

= 7 + 10 + 7 + 6

= 30 Ah

Activity 2.1

- **Take few lemons**
- **Connect the lemons in parallel connection with LED through copper wire**
- **You can see that LED will glow.**

2.2. INDUCTOR OR COIL

Inductor is the passive component used in electronic circuits. It stores energy in the form of magnetic field and delivers it as and when required. An inductor is usually a coil of copper wire wound around a core of ferromagnetic material. Figure 2.5 shows an inductor coil.

DO YOU KNOW?

Who invented the inductor coil?

"Rev.Nicholas Calland" of Ireland invented the inductor coil.

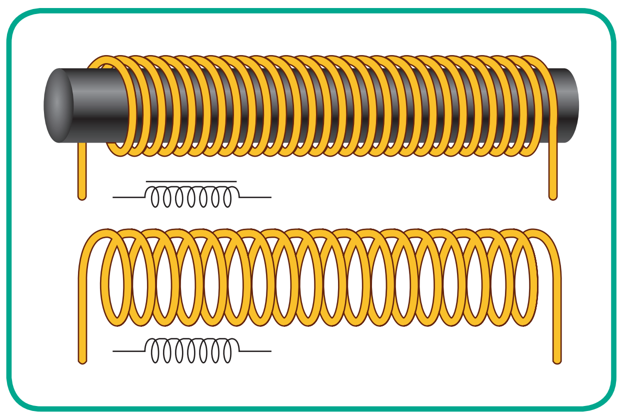


Figure 2.5 Inductors

2.2.1 Inductance

Whenever current passes through a coil, magnetic flux is generated around it. This magnetic flux opposes any change in current due to the induced EMF. The opposition to the change in current is known as inductance. The unit of inductance is Henry.

2.2.2 EMF (Electro Magnetic Force)

Figure 2.6 shows the force acts between the charged particles and the combination of all electrical and magnetic forces. It can be in attractive or repulsive.

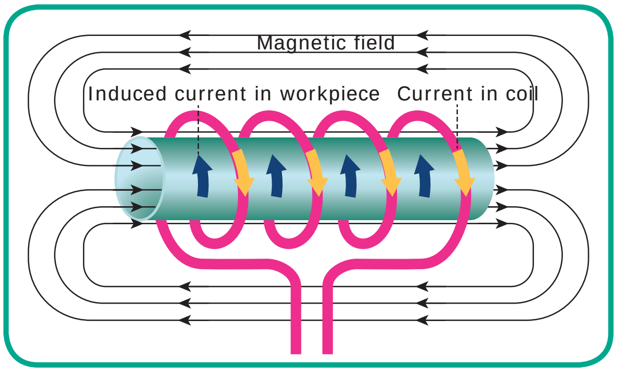


Figure 2.6 **Electro Magnetic Force**

2.2.3 Types of Inductor

Inductor can be divided in two categories.

1. Fixed inductors
2. Variable inductors

2.2.3.1 Fixed Inductor

The symbol of fixed inductor is shown in Figure 2.7 and can be further divided into 3 categories depending on the type of cores.

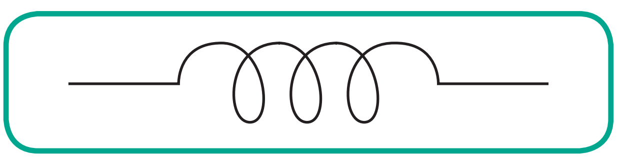


Figure 2.7 **Fixed Inductor**

They are,

1. Air Core Inductors
2. Iron Core Inductors
3. Ferrite Core Inductors

Air Core Inductors: Air core inductors consist of a few turns of wire wound on a hollow former. In radio frequency applications, where a very low value of inductance is required, air core inductors are generally used. It is shown in Figure 2.8.

Iron Core Inductors: In this, the former is generally made up of silicon steel in the form of thin laminated sheets. These are used in low frequency applications such as filter circuits in power supplies, chokes in fluorescent tubes. The iron core inductor is shown in Figure 2.9.

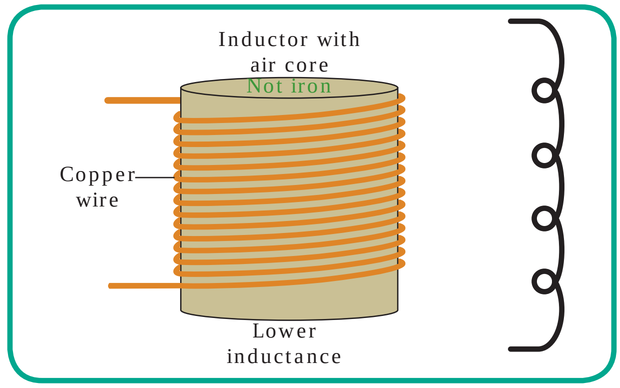


Figure 2.8 **Air Core Inductors**

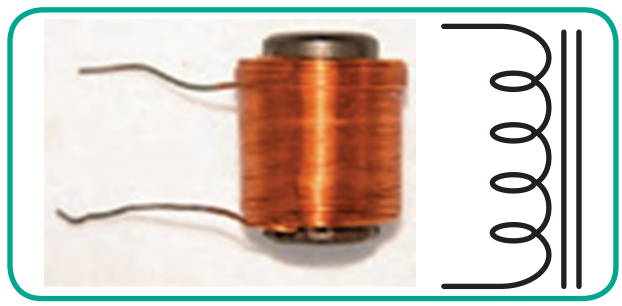


Figure 2.9 **Iron Core Inductors**

Ferrite Core Inductors: Ferrite core inductors consist of a few turns of wire wound on a ferrite materials. A ferrite is basically an insulator having very high permeability. Ferrite core inductor is suitable for high frequency applications and is shown in Figure 2.10.

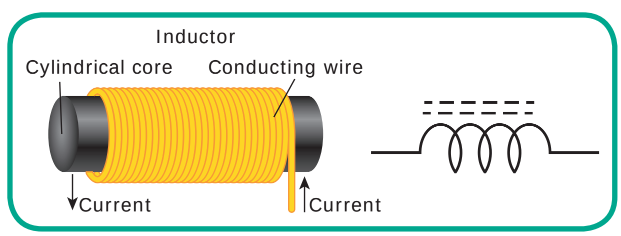


Figure 2.10 **Ferrite Core Inductors**

2.2.3.2. Variable inductors

In certain application such as tuned circuits, it is required to vary the inductance from minimum value to a maximum value. Ferrite core variable inductors are generally used for this purpose. The variable inductors are shown in Figure 2.11.

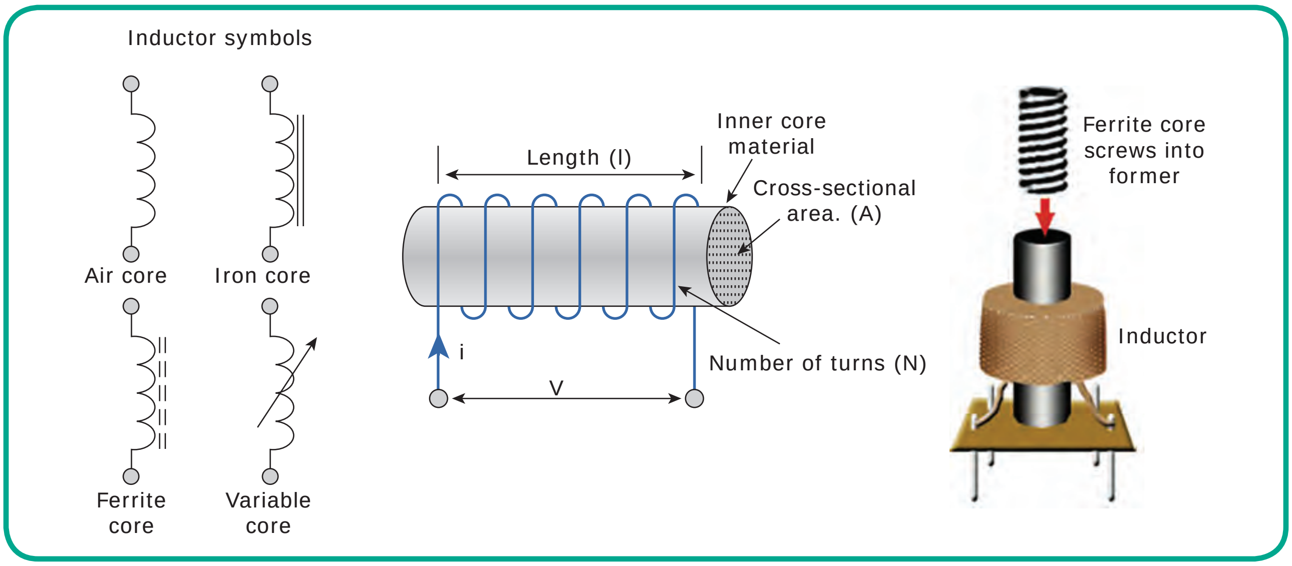


Figure 2.11 Variable Inductors

2.2.4. 'Q' factor (Quality factor) of an inductor

The ratio of the inductive reactance to the effective resistance is known as the 'Q' of an inductor.

$$Q = \frac{2\pi fL}{R}$$

where f is the AC frequency, L is the inductance and R is the resistance.

2.2.5 Chokes

A choke is an inductor that is designed to block unwanted high frequency ac in an electrical circuit. But it allows low frequency and dc.

There are two classes of chokes.

1. Power Chokes
2. RF Chokes

Power and audio frequency chokes typically have an iron core to increase their inductance and make them more effective filters. RF chokes use ferrite core, which operate effectively at high frequencies and is shown in Figure 2.12.

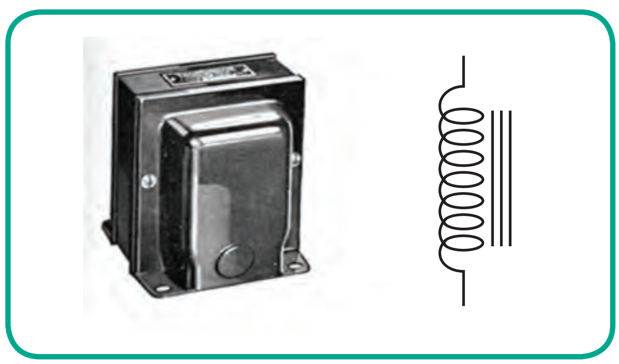


Figure 2.12 Chokes

2.2.6 Relay

A relay is an electrically operated switch and is shown in Figure 2.13. The current flowing through the coil of a relay creates a magnetic field which attracts the lever and changes the switch contacts. Relay is used in applications to turn ON and OFF a circuit by a low power signal.

Uses: Relays are used in stabilizers, UPS (Uninterrupted power supply) and three phase change over switches.

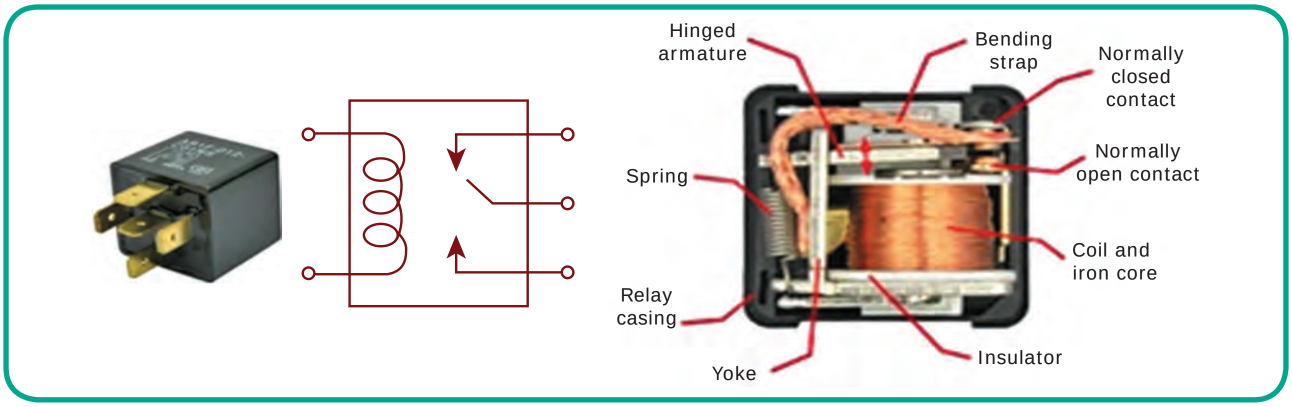


Figure 2.13 Relay

2.2.7 Action of Coils in AC and DC Circuits

2.2.7.1 AC Circuits

Since the phase is alternatively changed in AC circuits, the back EMF continuously presents in the coil. This back EMF depends upon the frequency and the core of the coil. Hence, the coils in AC circuits have resistance carried by back EMF along with normal resistance. These two resistances combined together is known as inductive reactance.

$$\text{Inductive Reactance } X_L = 2\pi f L$$

where $\pi = 3.14$, f is the frequency of AC and L is the inductance. In AC circuits, the current flows in the coil lag 90˚ with reference to the voltage.

2.2.7.2 DC Circuits

When the switch is ON, the back EMF generated opposes the flow of current. The back EMF will get vanished when constant magnetic field is produced, i.e. the back EMF persists only to the fraction of switching on the circuit. When the circuit is switched ON, automatically the back EMF becomes zero. In DC circuits, coils would have only normal resistance. Hence, it may not be taken into consideration.

2.3. TRANSFORMERS

A device which has two or more coils wound on a core is termed as transformer. The electrical energy is transformed from one coil to other through mutual inductance in it.

The symbol of Transformer is shown in Figure 2.14

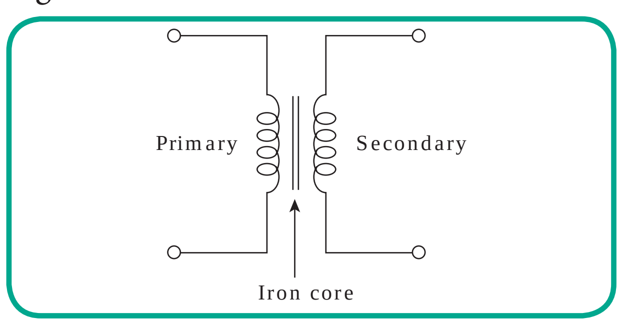


Figure 2.14 Symbol of Transformer

History

In 1880s, the first commercially-used transformer was built by William Stanley, working under George Westinghouse that was wound to form a core of E-shaped plates in step-up and step-down variations.

2.3.1 Principle of Transformer Construction

Transformer is a static device which contains one primary and one or more secondary coils. The electrical energy in primary coil produces a magnetic field (flux).This magnetic strength induces an EMF in the secondary coil. Normally, this happen only in AC circuits. Figure 2.15 shows the parts of the transformer.

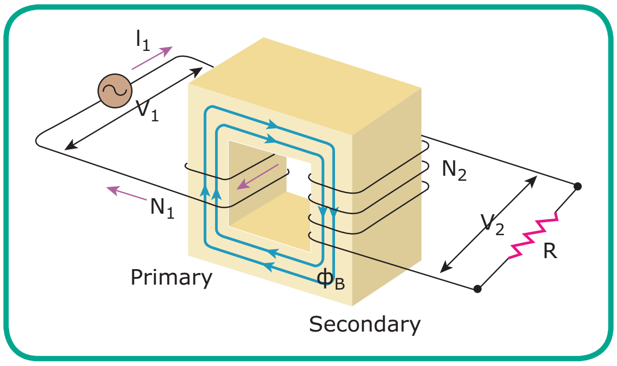


Figure 2.15 **Transformer**

The AC current flowing through the primary induces an alternating magnetic field. This magnetic field creates an EMF in the secondary. If we are giving DC in the primary, it won't induce any EMF, hence the phase does not get changed. Therefore, the transformer can be used only in AC Circuits.

2.3.2 Turns Ratio

The strength of current induced in the secondary depends upon the number of turns in the secondary coil. That is, the induced EMF is directly proportional to the turns in the coil. The voltage ratio between the primary and secondary is equal to the ratio between the number of turns in the primary and secondary.

$$\frac{E_P}{E_S} = \frac{N_P}{N_S}$$

$E_P \rightarrow$ primary coil voltage

$E_S \rightarrow$ Secondary coil voltage

$N_p \rightarrow$ Number of turns in primary coil

$N_S \rightarrow$ Number of turns in secondary coil

2.3.3 Types of Transformer

Based on the turns ratio, type of the core and the type of application, the transformers are classified as given below.

Transformers

Turns Ratio
- Step-up Transformer
- Step-down Transformer
- Isolating Transformer

Core Type
- Air Core Transformer
- Iron Core Transformer
- Ferrite Core Transformer

Application
- Power Transformer
- R.F Transformer
- I.F Transformer

2.3.3.1 Step-up Transformer

In this type, the number of turns in secondary coil must be more than the turns in the primary coil. These types of transformers are used in power generating plants, where the electricity is carried over a long distance and also in Television. The step up transformer is shown in Figure 2.16 and its turns ratio is given in Table 2.1.

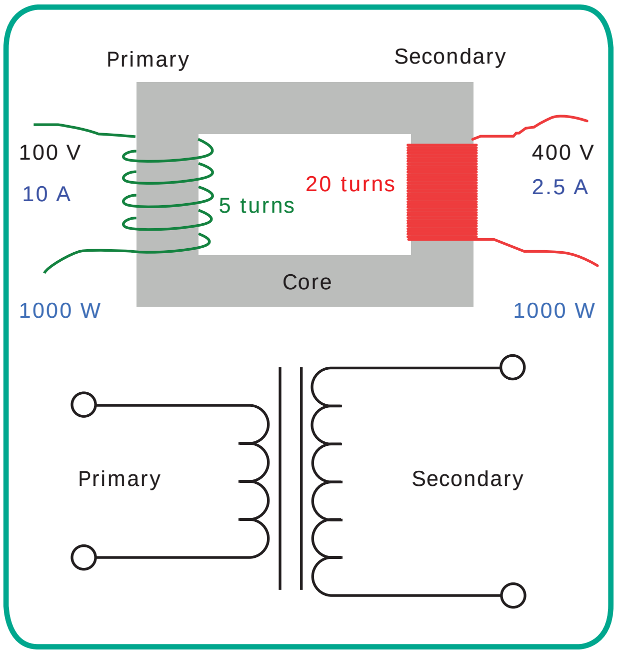


Figure 2.16 Step-up Transformer

Table 2.1 Turns ratio of step-up transformer

	Primary	Secondary
Turns ratio	*1*	*2*
Voltage ratio	*1*	*2*

2.3.3.2 Step-down Transformer

In this type, the number of turns in the secondary coil must be less than the number of turns in the primary coil. This type of transformer is used in Radio and TV receivers, eliminators and other video equipment. Figure 2.17 shows a step-down transformer. Table 2.2 summarizes the turns ratio of step-down transformer.

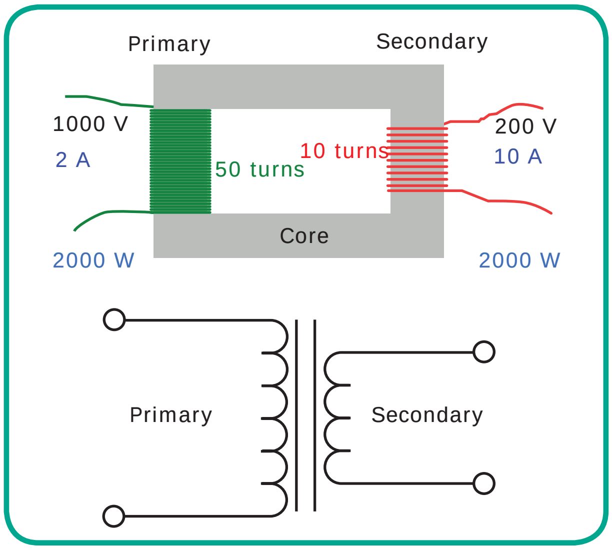


Figure 2.17 Step-down Transformer

Table 2.2 Turns ratio of step-down transformer

	Primary	Secondary
Turns ratio	*2*	*1*
Voltage ratio	*2*	*1*

2.3.3.3 Isolating Transformer

This type of transformer has 1:1 ratio of winding. These types of transformer are used mainly in fault finding places. This transformer is used to avoid materials to have direct contact with main supply. Figure 2.18 shows an isolation transformer.

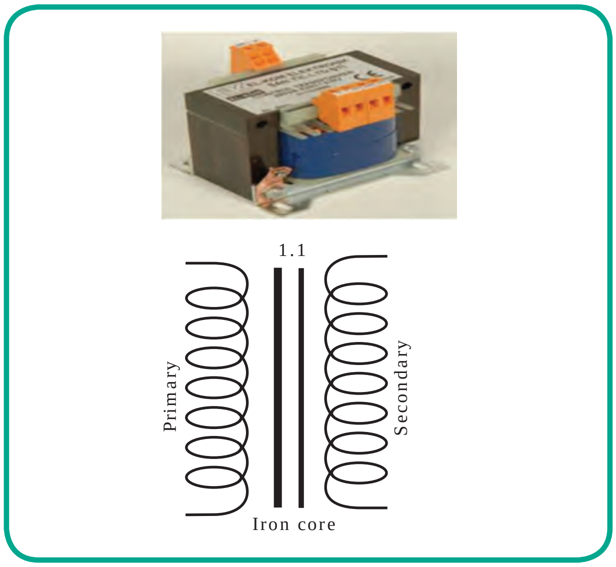


Figure 2.18 Isolating Transformer

2.3.3.4 Air-core Transformer

This type of transformer coils are wound on plastic sheets placed on thick paper as shown in Figure 2.19. This is used in Antenna coil and R.F. Transformer.

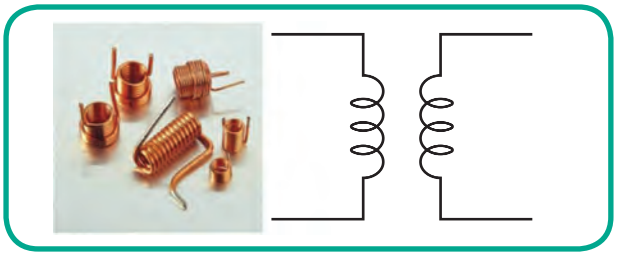


Figure 2.19 **Air Core Transformer**

2.3.3.5 Iron-core Transformer

In this type of transformer, two coils are wound on thin laminated iron plates as shown in Figure 2.20. Thin plates are used in order to avoid eddy current loss. They are used as eliminator transformer and output transformer.

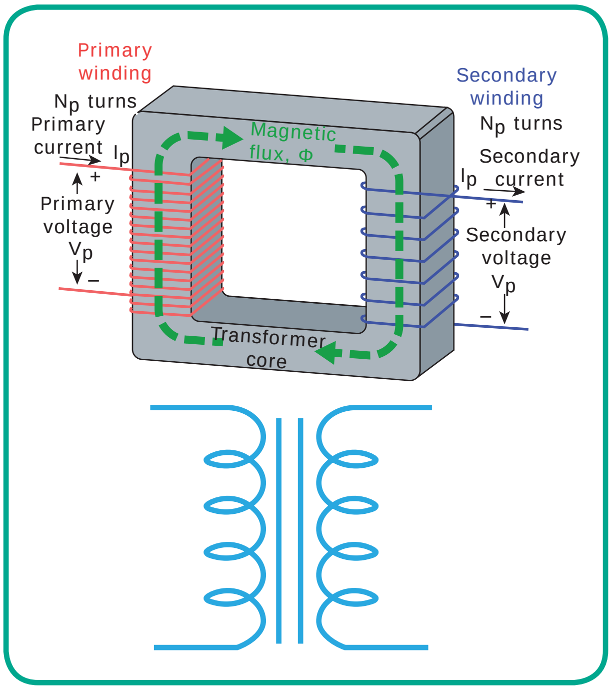


Figure 2.20 **Iron Core Transformer**

2.3.3.6. Ferrite-core Transformer

In this type of transformer, coils are wound on ferrite rod. Figure 2.21 shows the ferrite-core SMPS transformer.

Example: EHT transformer, SMPS transformer and Antenna coil.

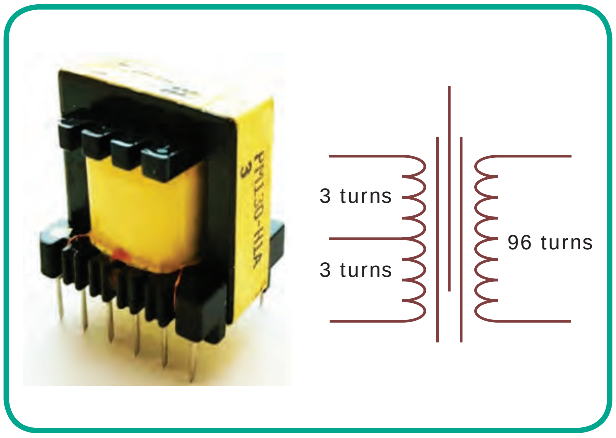


Figure 2.21 **Ferrite Core SMPS Transformer**

2.3.3.7. IF Transformer

In radio receivers, IF Transformers are connected in the input and output of the IF amplifier. It is shown in Figure 2.22.

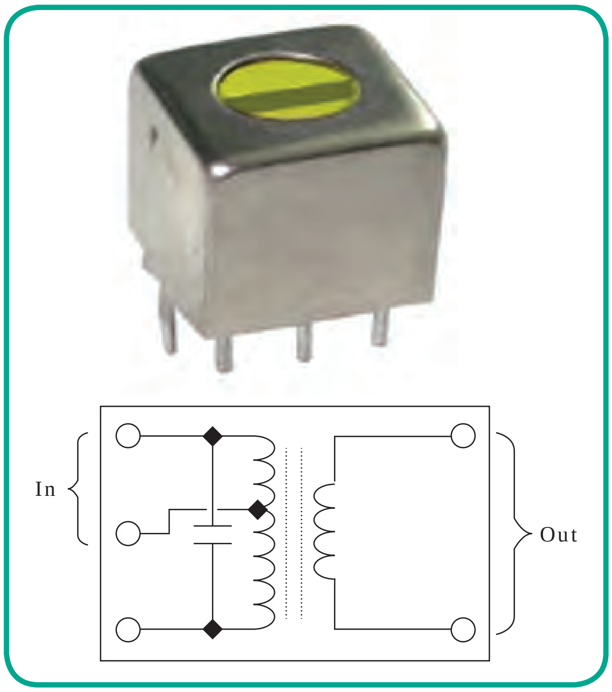


Figure 2.22 **I.F. Transformer**

2.3.3.8 Power Transformer

Generally, in Radio receivers, power transformer is used to match the input impedance of the receiver and the output impedance of speaker. The Power transformer is as shown in Figure 2.23. The power transformer is a step-down transformer.

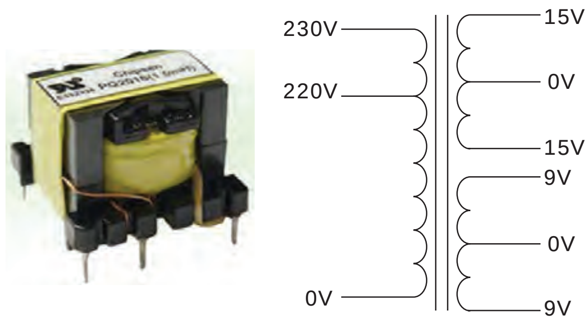


Figure 2.23 Power Transformer

DO YOU KNOW?

What is the difference between electrical and electronics devices?

The devices that work on AC (Alternating Current) are called Electrical devices and the ones that work on DC (Direct Current) are called Electronic devices.

2.3.4 Transformer Losses

Even in best transformers, unavoidable losses are occurred. These losses may be reduced using quality materials and cannot be totally nullified. The losses are of three types.

Copper Loss: The loss appeared because of the resistivity of copper string in the coil.

Hysteresis Loss: When AC changes its phase, the magnetic phase also gets changed. This causes some loss in the strength of the current. This is known as Hysteresis loss.

Eddy Current Loss: When current flows in an iron, it will get heated. This heat creates some loss. This loss is said to be Eddy current loss. To minimize this loss, the core should be laminated.

2.4. MICROPHONES AND LOUD SPEAKERS

In this Section, we are going to study about Microphones and loud speakers. They may also be called as transducers, because they are converting one form of energy into another form.

2.4.1 Microphone

A device, which converts sound waves into electrical waves, is called as microphone. There are few types based on the construction.

Types of microphone

1. Carbon microphone
2. Ribbon microphone
3. Dynamic microphone
4. Condenser microphone

Let us see some of the important microphones.

2.4.1.1 Dynamic Microphone

The dynamic microphone can also be called as moving coil microphone, which is shown in Figure 2.24. It is working under the principle of electromagnetic induction. This works on the basis of the following principle which states that "in a magnetic field a conductor is placed in such a way that it cuts the magnetic field and then inducing an electrical field in it".

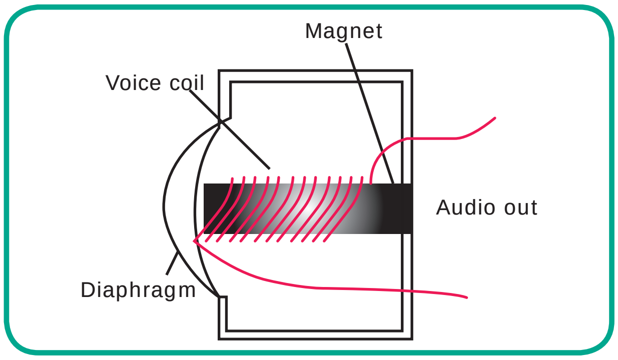


Figure 2.24 Dynamic Microphone

In dynamic microphone, between the two-strong magnetic ends a coil spring is placed. A diaphragm is attached along with this coil spring. The diaphragm is firmly attached to the body of the microphone. The coil spring laminated so it won't have any contact with other parts. This total setup is fixed in a case.

When sound waves strike the diaphragm, the coil attached to it will vibrate front and back. Due to this, the coil cuts the magnetic field and creating electrical signal. The strength of this electrical signal and frequency decides the true deflection of vibration occurred in the diaphragm. This electrical signal is the output of the microphone. The dynamic microphone will give equal frequency response for the sound waves in the range of 50 Hz to 10000 Hz. It is made up of low impedance material.

2.4.1.2 Condenser Microphone

When the distance between the electrodes of a capacitor gets changed the capacitance also varies. The condenser microphone is working under this principle. A condenser microphone is shown in Figure 2.25. The construction of this microphone is also similar to the construction of a capacitor. In this, one plate is kept static and another plate can vibrate on receiving the sound wave.

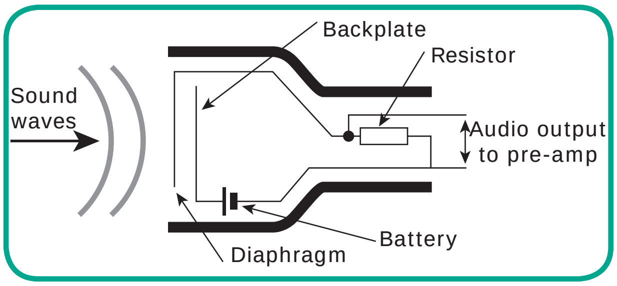


Figure 2.25 Condenser Microphone

The vibrating plate will act as diaphragm. When the sound signal strikes the microphone, the vibrating plate starts slight movement (vibration) in front and back. Due to this, the gap between the two plates gets changed and in turn there is a change in capacitance occurs. The change in capacitance depends upon the sound waves. Hence, the electrical signal produced also gets changed and is taken as output. The condenser microphone is a high impedance microphone.

2.4.2 Loud Speaker

A material which converts electrical energy into mechanical energy and converting such energy into sound energy is known as loud speaker. Simply to say, the part that converts amplified audio frequency signals back to the original sound is the speaker.

2.4.2.1 Dynamic Loudspeaker

Figure 2.26 shows a cross sectional view of a Dynamic Loudspeaker.

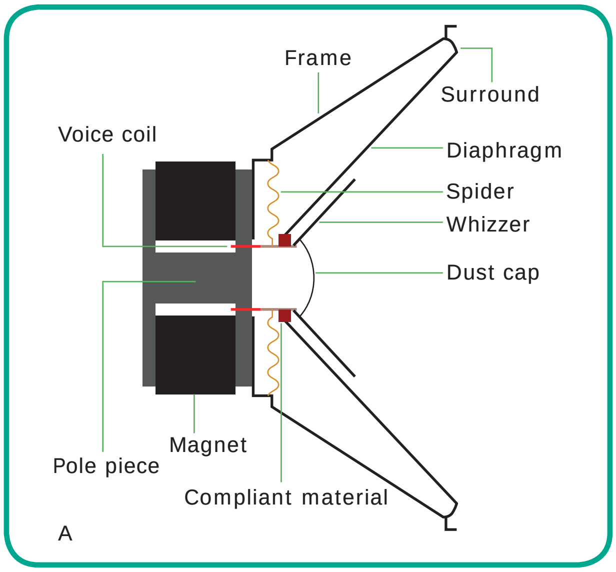


Figure 2.26 Dynamic Loudspeaker

Voice coil is placed in between the strong magnetic ends in order to fill the air gap. Spider is placed on the voice coil.

Spider helps the voice coil to fill the air gap. Paper cone is used to connect the voice coil with the frame of the speaker and so as vibration will be proper.

When the amplified audio signal is given to the voice coil, it will create variable magnetic field. The force develops in between the static and dynamic magnetic field move the voice coil front and back. Due to this the paper cone gets vibrated.

2.4.2.2 Impedence of the Speaker

Speakers are classified (as 4 ohms, 8 ohms ,16 ohms) based on their impedence rating. The impedence rating is depends upon the thickness and numbers of turns of the voice coil. For proper matching the audio frequency amplifier output must be equal to the voice coil Impedence. If it is not equal, then it is said to be improper matching. This improper matching affects the sensitivity of the audio output.

2.4.2.3 Frequency Handling of Speakers

Speakers are classified as per the frequencies handled by them. They are

1. Woofer
2. Squawker
3. Tweeter

Figure 2.27
Types of Speakers
A Woofer
B Squawker
C Tweeter

Woofer (Low-Frequency range): The speaker which functions efficiently in the low frequency (20 Hz to 1000 Hz) audio signal range is called as Woofer and is shown in Figure 2.27(a). Since a large amount of power is needed to deliver this range, these types of speakers are designed as big in size and diameter. Presently, sub-woofer with frequency range of 20-200 Hz is also widely used.

Squawker (Mid-Frequency range): The speaker which functions efficiently in the mid frequency (2 to 8 kHz) audio signal range is called as Squawker or mid-range speaker and is shown in Figure 2.27(b).

Tweeter (High-Frequency range): The speaker which functions efficiently in the high frequency (8 to 20 kHz) audio signal range is called as Tweeter. It has less weight and small in size. Now, Piezo tweeters are also used. Tweeter is shown in Figure 2.27(c).

2.4.2.4 Two Way and Three-way Speaker System

A single speaker cannot deliver the full range of the audio signal (20 Hz to 20 kHz) with good quality and required fidelity. So, by using cross-over network with Woofer, Squawker and Tweeter, the full audio range can be delivered with good quality and fidelity. This is done in two channels (ways), for that, two speaker boxes are used. This is called as stereophonic system. If all the three speakers are used in one speaker box, it is said to be monophonic system (one channel).

2.4.3 Wattage Rating of Speakers

Wattage rating of speakers is nothing but the capability of voice coil which delivers the power of sound signal. Speaker having high wattage rating deliver high volume of sound and also it avoids the burn-out of voice coil and torn-out of cone paper. Manufactures determine the wattage rating of amplifiers and speakers. It is noted in the label pasted in the speakers. The wattage rating of speakers used in radio and TV receivers is from 0.5 watts to 15 watts approximately.

2.4.4 Column Loudspeakers

Many Dynamic Loudspeakers (in same wattage rating) used in single system are termed as Column Loudspeakers. They are placed vertically and closely to each other in a box. This system is placed in such a way that the most of the sound delivered from this box is towards audience. Since only a little amount of sound goes towards the wall and ceiling, echo is not produced. This system is used in auditorium and theaters. Figure 2.28 shows a Column loudspeaker.

Figure 2.28 Column Loudspeaker

2.4.5 Horn type Loudspeaker

This type of speakers is extensively used in Public meeting. It is designed in tube type funnel. It is more suitable than cone paper type speakers for delivering very high volume. It has very good frequency response in medium and high frequency audio range and less response in low frequency. A horn type loudspeaker is shown in Figure 2.29.

Figure 2.29 Horn Type Loudspeaker

2.4.6 Cross Over Network of Speakers

The method of connection needed when a woofer and tweeter are used in the audio system is called cross over network, since tweeters perform very well only in high frequencies and not in low frequencies. A simple cross over network with a capacitor connected in series with tweeter is shown in Figure 2.30. If the audio frequency decreases, the capacitive reactance of the capacitor increases. In a particular frequency, the capacitive reactance and the impedance of the tweeter will become equal. That frequency is referred as the 'cross over frequency' of the system.

A filter circuit is used to give the respective audio range of frequencies to the woofer and tweeter separately. This filter circuit has a coil and capacitor. Capacitor blocks the low frequency audio signal whereas coil prevents the entry of high frequency audio signal to the tweeter and woofer, respectively.

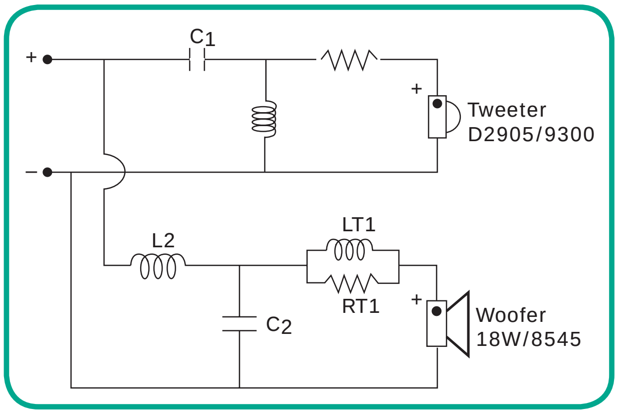


Figure 2.30 Cross Over Networks of Speakers

How the bat identify the object?

Bat emits the ultra sound frequency (more than 20 KHz) and send towards the particular object. This frequency hits the object and returns to it as echoes. The bat will calculate the location of the object by measuring the time it takes for an echo to return from it.

2.5. FUSE

A fuse is made up of a piece of metal that melts when over-heated. It should be connected in series with the load. Fuse is made up of 37% of lead and 67% of iron. Most common sizes having maximum working voltages are 32 V, 125 V, 600 V to 25000 V. Electronic fuses having a current rating of 0.1 A, 0.5 A, 1 A, 2 A, 3 A, 5 A, 10 A, 100 A and 500 A.

2.5.1 Types of fuse

Fuses can be divided into two main categories, according to the type of input supply voltage. They are,

1. AC fuses
2. DC fuses

There is a little difference between AC and DC fuses in size.

2.5.2 Other Types of Fuse

1. Cartridge Fuse
2. Blade Type Fuse
3. Surface Mount Device (SMD) Fuse
4. Axial Type Fuse
5. Thermal Type Fuse
6. HRC Type Fuse
7. Resettable Type Fuse

2.5.2.1 Cartridge Fuse

Cartridge fuses are used to protect electrical appliances such as motors, air conditioners, refrigerators, pumps etc., where high voltage rating and current rating are required. Cartridge fuse is shown in Figure 2.31

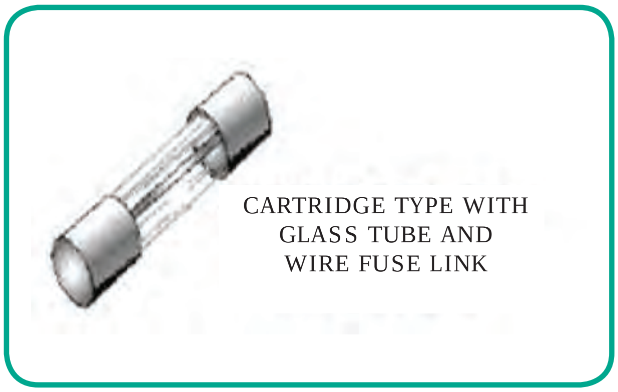


Figure 2.31 Cartridge Fuse

2.5.2.2 Blade Type Fuse

This type (also known as plug in fuses) comes in plastic body and two metal caps to fit in a socket. Mostly, they used in auto mobiles for wiring and short-circuit protection. A typical blade type fuse is shown in Figure 2.32.

Figure 2.32 Knife Blade Cartridge

2.5.2.3 Surface Mount Device (SMD) fuse

This type of fuses directly soldered in the printed circuit board. These fuses are available in low-voltage and low-current ratings. It is the latest method of fuse and also no need to pierce on the PCB. The SMD fuse is shown in Figure 2.33.

Figure 2.33 SMD Fuse

2.5.2.4 Axial Type Fuse

In this type of fuses, the fuse element is enclosed in a glass chamber directly soldered in the PCB board and available in low-voltage and current ratings. These are used in robotics, power supplies etc. The axial type fuse is shown in Figure 2.34.

Figure 2.34 Axial Fuse

2.5.2.5 Thermal Type Fuse

The thermal type fuse is used to protect electrical appliances from the damages caused due to over-heating. Thermal fuses are used in coffee makers, refrigerators etc., in the form of thermostats. Figure 2.35 shows the thermal fuse.

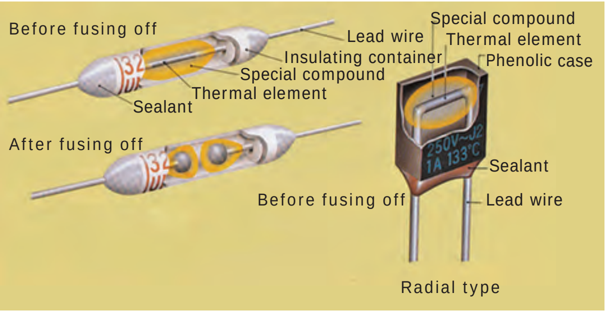


Figure 2.35 Thermal Fuse

2.5.2.6 HRC (High Rupturing Capacity) Type Fuse

This type of fuse is available in the current rating of 2 A to 800 A as shown in Figure 2.36. An HRC fuse is a type of cartridge fuse, in which the fuse element is enclosed with in a transparent ceramic material. These are used for protection of power transformers, motors, automobiles etc.

Figure 2.36 HRC

2.5.2.7 Resettable Type Fuse

A resettable fuse is a polymeric positive temperature co-efficient (PPTC) device that is used to protect against over-current faults in electronic circuits. This device is also known as poly-fuse or poly-switch. It is used in audio-amplifier, computer power supplies etc. It is shown in Figure 2.37.

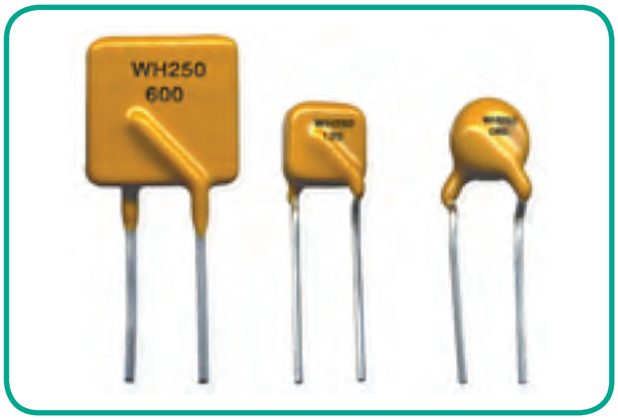


Figure 2.37 Resettable Fuse

2.6 CIRCUIT BREAKER

A circuit breaker is an automobile operated electrical switch designed to protect an electrical circuit from damage caused due to excess current, typically resulting from an over-load or short-circuit. Its basic function is to stop current flow after short-circuit or over-load is detected. There are different types of circuit breakers and are summarized below:

2.6.1 MCB (Miniature Circuit Breaker)

Presently, we use MCB in low-voltage electrical network instead of fuse. MCB is an electromechanical device which protects an electrical circuit from over-current. An MCB is better alternative to fuse, since it does not require replacement once an over-load is detected. Unlike fuse, an MCB can easily reset and thus offers improved operational safety.

Working principle

MCBs are either electromagnetic or a bi-metallic strip. In either case, when turned on, the breaker allows electrical current to pass from a bottom to an upper terminal across the solenoid or strip. When the current reaches un-safe levels, the magnetic force of the solenoid becomes so strong, that a metal lever within the switch mechanism is thrown and the current gets cut-off. Alternatively, the metal strip bends throwing the switch and disconnecting the connection. To reset the flow of electricity after the problem is resolved, the switch can simply be tuned back to on, thus reconnecting the circuit. Figure 2.38 shows a layout of MCB.

Figure 2.38 Layout of Miniature Circuit Breaker

Difference between Fuse and MCB

The difference between MCB and Fuse is summarized in Table 2.3.

Table 2.3: Difference between Fuse and MCB

Fuse	MCB
Fuse is usually made up of a fuse wire. It is an alloy which has a no melting point	MCB has a tripping circuit
Fuse works on the electrical and thermal properties of the conducting materials.	MCB works on the electromagnetism and switching principle
Fuses can be used only once	MCB can be used a number of times
Fuse cannot be used as an ON/OFF switch	MCB can be used as an ON/OFF switch
Operating time of Fuse is Very less (0.002 sec)	Operating time is comparatively more than that of fuse (0.02-0.05 sec)
Cost of fuse is low	Cost of MCB is high

2.6.2 ELCB (Earth Leak Circuit Breakers)

An ELCB is a safety device, used in electrical installations with high earth impedance to prevent even minor shock. It detects even small stray voltages on any electrical equipment enclosures and terminates the supply to them. An ELCB is a specialized type of a latching relay that has a provision for incoming mains power connected through its switching contacts. So, the ELCB disconnects the power when earth leakage is detected.

Figure 2.39 Earth Leak Circuit Breakers

The ELCB detects fault currents from live to earth (ground) within the installation and protect the circuit. If sufficient voltage appears across the ELCB's sense coil, it will switch off the power and remain off until manually reset. A voltage sensing ELCB does not sense fault currents from live to any other earthed body. A typical ELCB is shown in Figure 2.39.

2.7 SWITCH

These are designed depends upon the contact points (pole) and number of connections (ways).

A device which is used to connect supply from one point to another point (load) is called a switch.

There are few type of switches based on requirements.

1. Single Pole Single Way
2. Single Pole Two Way
3. Single Pole Multi Way
4. Double Pole Single Way
5. Double Pole Two Way
6. Double Pole Multi Way
7. Multi Pole Multi Way

Switches are classified based on their voltage and current ratings. In some places separate switches are used for AC and DC. Switches are available based on the following ratings1 A, 2 A, 5 A, 10 A, 15 A, 32 A, 64 A, 100 A and even above. The different types of switches are shown in Figures 2.40(a-g).

We can use switches depends upon our equipment.

1. Normally open
2. Normally closed

Rotary type and slide type switches are also available.

Yet another type called push button switch is available, which makes contact temporarily. This will disconnect the contact while withdrawing the pressure

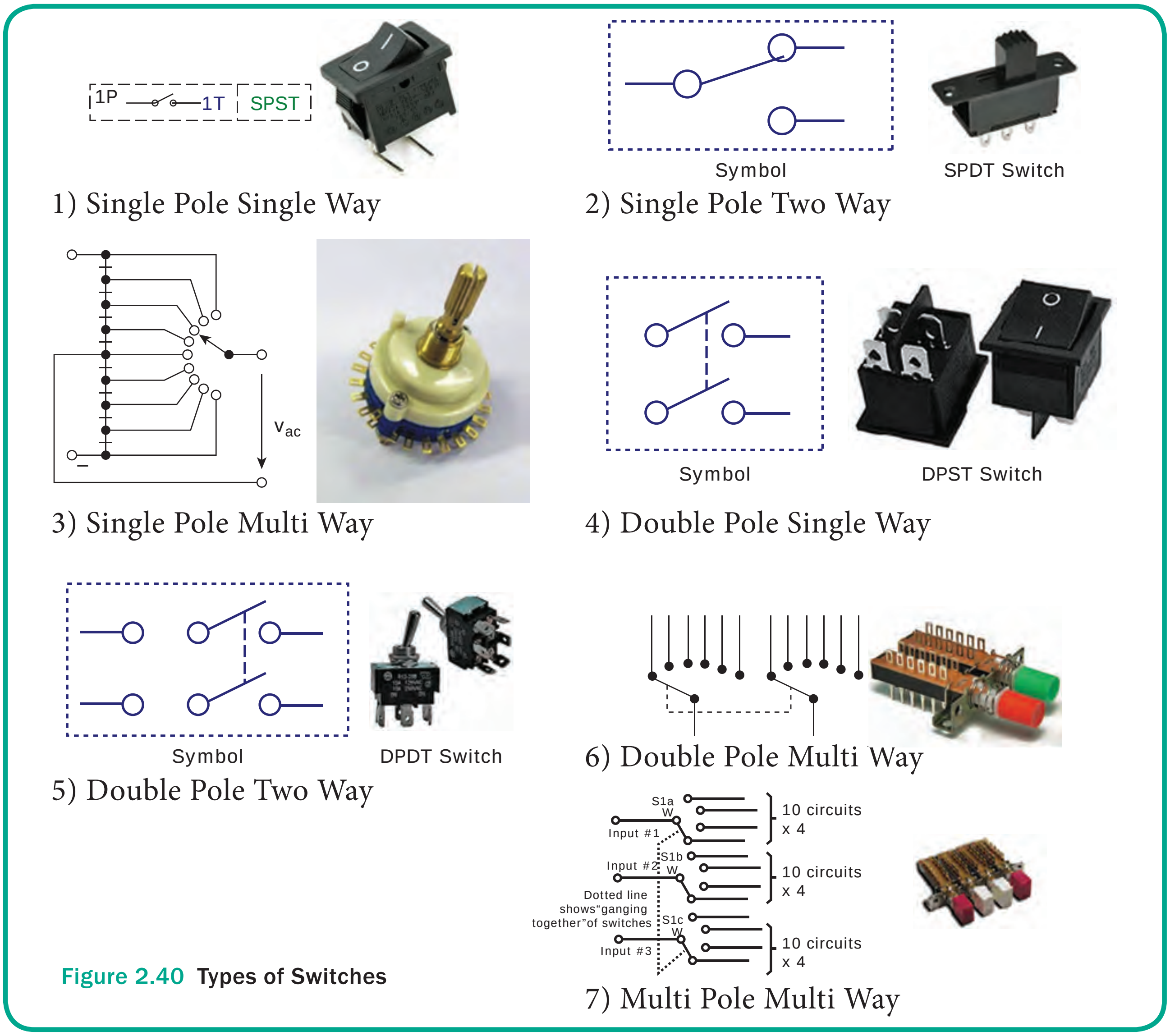


Figure 2.40 Types of Switches

applied in the switch. This type of switch is used in computer keyboard, digital circuits for reset, etc.

2.8 ELECTRONIC SERVICING - SAFETY PRECAUTIONS

An electronic technician must carefully handle the work without any damage to the equipment. He must know all the operations of electronic equipment. Electrical accident may occur only due to carelessness. To avoid this, electronic technician must follow the rules and regulations when working.

1. Before using the equipment, the technician must know the operation of that equipment and made proper electrical connections.
2. If any fault occurs in the electronic equipment, it will be checked and repaired after the equipment is totally disconnected from the supply. E.g. TV, DVD players
3. While removing the plug-point pin from the socket, it should be done properly. We should not pull the wire.

4. If fire occurs in the circuit, immediately the main switch must be turned OFF. Water should not be used to extinguish the fire because it conducts electricity.
5. If any person getting electric shock on touching the electric wire, immediately the supply should be disconnected. The person should be removed from the wire by beating with dry stick.
6. Sweating hand should not be used to switch ON or OFF.
7. During servicing, one must sit in a wooden chair to avoid electric shock.
8. Before to turn ON the switch, check if anybody is working in the electronic circuit.
9. While working with SMPS troubleshooting, the main switch must be switched OFF before troubleshooting.
10. Before troubleshooting, the technician should inspect the circuit through visualization by identifying the symptoms like burst, missed and damaged electronic components. Only after visual inspection, the technician should start the troubleshooting of circuits.
11. It is recommended to wear the rubber shoes to avoid accidental shock.

LEARNING OUTCOMES

1. **Remembering the concept of primary cells and secondary cells.**
2. **Acquiring depth knowledge about working principles of cells, inductors and transformers.**
3. **Knowing the importance of safety precautions while electronic servicing.**
4. **Designing and testing of the circuit breakers.**

GLOSSARY

S. No	Terms	Explanation
1	Auto transformer	Transformer that uses a common winding for both primary and secondary windings
2	Electromotive Force	Measured in volts, a force that exists between positive and negative charges
3	Inductors	A device for introducing inductance into a circuit
4	Electrostatic	Relating to stationary electric charges or fields as opposed to electric currents
5	Troubleshoot	Trace and correct faults in an electronic system

6	Echo	A sound or sounds caused by the reflection of sound waves from a surface back to the listener
7	Transducer	Device that converts energy from one form to another
8	Electromagnetism	Relates to the magnetic field generated around a conductor when current is passed through it
9	Choke	Inductor used to oppose the flow of alternating current
10	Magnetic field	Magnetic lines of force traveling from the north pole to the south pole of a magnet

QUESTIONS

I Choose the best answer — 1 Mark

1. A device which converts chemical energy into electrical energy.
   a) Capacitor b) Cell c) Resistor d) Transformer

2. Voltaic pile was invented by……………..
   a) Graham Bell b) Michael Faraday c) Alessandra Volta d) Marconi

3. The unit of an inductor is ………………
   a) Ohms b) Farad c) Hertz d) Henry

4. Which of the following is a transducer
   a) Resistor b) Condenser c) Transformer d) Microphone

5. Electrical signal can be converted into audio signal by …………
   a) Microphone b) Speaker c) Condenser d) Cell

6. Audio signal can be converted into electrical signal by ……………..
   a) Transformer b) Microphone c) Speaker d) None of these

7. The formula for inductive reactance is
   a) $X_L=2\Pi fL$ b) $X_L = \frac{1}{2\pi L}$ c) $X_L = 2\Pi\sqrt{fL}$ d) $X_L = \frac{1}{2\pi LC}$

8. Which speaker works efficiently in the low frequency audio range?
   a) Tweeter b) Woofer c) Squawker d) Horn type speaker

9. The ratio of winding in isolating transformer is
   a) 1:2 b) 1:1 c) 2:1 d) 2:2

10. Which among these is the least expensive protection for over-current in low-voltage system
    a) Rewirable fuse b) Isolator c) Circuit Breaker d) Air Breaker switch

II Answer in Few Sentences — 3 Marks

1. What is meant by a cell?
2. What is meant by secondary cell? Give the examples.
3. What is meant by ampere hour capacity in a battery?
4. Define Electromagnetic force.
5. What is 'Q factor' of the inductor?
6. What is meant by an inductive reactance?
7. What is a transformer?
8. What is meant by turns ratio in the transformer?
9. How transformers are classified depending upon the core?
10. Write down the faults occurred in transformers?
11. What is meant by transducers?
12. What is the function of microphone?
13. Write down the function of loudspeaker?
14. What is a switch?
15. What is the function of circuit breaker?

III Explain the following questions — 5 Marks

1. A 100 ohms bulb is connected with 6 volts battery. Find out the current flows in the bulb?
2. How the inductors are classified? Explain.
3. How speakers are classified as per the frequencies handled by them?
4. Explain the cross over network.
5. Explain about the losses occurred in the transformer.

IV Briefly explains the following questions — 10 Marks

1. Explain the series and parallel connection of cells with necessary diagram.
2. Explain the working of a transformer with neat diagram.
3. What are the precautions to be followed while on servicing?

Answers

1) **b**	2) **c**	3) **d**	4) **d**	5) **b**
6) **b**	7) **a**	8) **b**	9) **b**	10) **a**

CHAPTER 3

BASIC PRINCIPLES OF ELECTRONICS

T36NBV

"அணுவைத் துளைத்து ஏழ்கடலைப் புகட்டி
குறுகத் தரித்த குறள்". – ஔவையார்

Well before 2000 years, one of our women tamil poet and scholar "Avvaiyar" used the word 'அணு' i.e.atom, in her appreciation towards the universal religious book "Thirukkural". She used the word 'அணு' even before a single literal science or scientific word was derived. This proves the language Tamil and Tamilians were forerunners in deriving science, from basic to astronomy.

CONTENT

LEARNING OBJECTIVES

From this chapter the students would learn about the following:

1. Knowledge about basic electronic principles
2. Atomic structure of elements
3. Classification of Elements
4. Detailed knowledge of Semiconductors and its working
5. Working of PN-junction

INTRODUCTION

In this fast developing world, "Electronic" is the most important branch of engineering. Electronic devices are used in day to day common man life to big industrial activities. At its peak now robot are replacing human in areas where criticality and safety of human become risk.

The fast growth of this electronic technology offers a great challenge to the beginner, who likes to learn about electronics. This fundamental knowledge about electronics can make easy and simple learning process. The purpose of this chapter is to give basic elementary knowledge in order to understand the following chapters.

DO YOU KNOW?

What is meant by electronics..?

The branch of engineering which deals with current conduction through a vacuum or gas or semiconductor is known as electronics.

Few important activities of electronic devices are

1. Rectification
2. Amplification
3. Control
4. Oscillations
5. Conversion of light into electricity and
6. Conversion of electricity into light etc.

The first step to understand the principles of electronics starts from knowing about an atom, since everything is made up of atom.

3.1. ATOMIC STRUCTURE

According to modern theory, matter is electrical in nature. All the materials are composed of very tiny particles called atoms. The atoms are the root cause for all the matter or material existing in this world.

The atom consists of a central nucleus, contains protons and neutrons as shown in Figure 3.1. A proton is a positively charged particle, where neutron does not have any charge. There is yet another particle called electrons which is negative in charge and it is not reside inside the nucleus rather revolving around the nucleus. This is termed as extra nucleus.

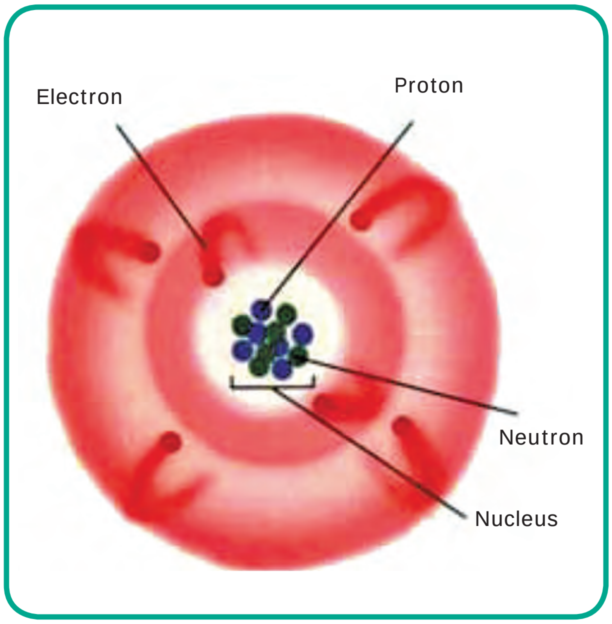


Figure 3.1 Atomic structure

The character of any atoms can be defined by three factors.

1. Atomic number
2. Atomic weight
3. Electrical charge

3.1.1 Nucleus

It is a central part of an atom, which contains protons and neutrons. A proton is a positively charged particle, while the neutron has the same 'mass' as the proton , but has no charge. Therefore the nucleus of an atom is positively charged. The sum of protons and neutrons decides the entire weight of an atom. Because, the particle in the extra nucleus (i.e., electrons) have negligible weight as compared to protons and neutrons.

Extra Nucleus

It is the outer part of an atom which contains electrons only. An electron is a negatively charged particle having negligible mass. The charge of an electron is equal but opposite to that of a proton. Also the number of electrons are equal to the number of protons in an atom under ordinary conditions. Therefore an atom is neutral as a 'whole'. The number of electrons or protons in an atom is called atomic number.

3.1.2 Atomic Number

Normally at ordinary conditions the number of electrons in the extra nucleus (i.e, orbits) are equal to number of protons present in the nucleus.

Therefore, an atom is neutral as a whole. The number of electrons or protons in an atom is called atomic number.

∴ Atomic Number = No. of Protons (or) No. of Electrons in an atom.

3.1.3 Atomic Weight

The sum of the protons and neutrons decides the entire weight of an atom and is called atomic weight. The electrons are not taken for consideration because it is having negligible mass as compared to protons or neutrons.

Atomic Weight = No. of Protons + No. of Neutrons

The electrons present in the atom is root cause for the action of any type of conduction (say electricity, heat etc).The electrons in an atom revolve around the nucleus in different orbit or paths. The number and arrangement of electrons in any orbit is determined by the following rules.

1. The number of electron in any orbit is given by $2n^2$ where n is the number of orbit.

For Example:

First orbit contains	$2x1^2$ = 2 electrons
Second orbit contains	$2x2^2$ = 8 electrons
Third orbit contains	$2x3^2$ = 18 electrons and so on

2. The last orbit cannot have more than 8 electrons.
3. The last but one orbit cannot have more than 18 electrons.

3.2. STRUCTURE OF ELEMENTS

We have seen all atoms are made up of protons, neutrons and electrons. The difference between types of elements is due to the different number and arrangement of these particles within their atoms. The structure of copper atom is different from carbon atom and hence the two elements have different properties.

The atomic structure can be easily drawn if we know the atomic weight and atomic number of an element.

For example:

We take copper atom,

Atomic weight = 64
Atomic number = 29
No. of Protons = No of Electrons = 29 and
No of Neutrons = 64-29=35.

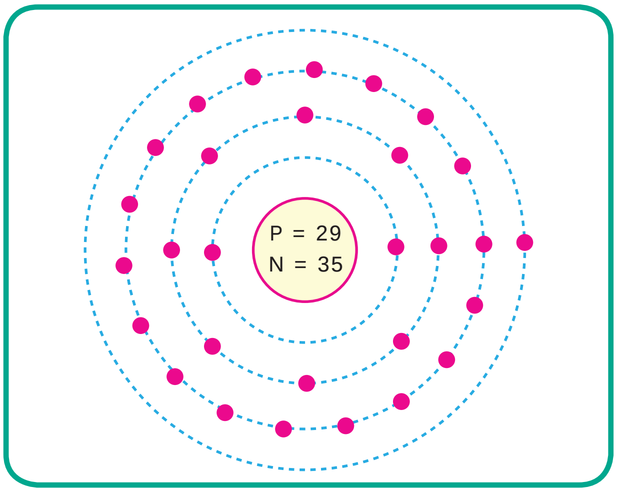


Figure 3.2 Atomic structure of copper

The Figure 3.2 shows the structure of copper atom. It has 29 electrons which are arranged in different orbits as follows. The first orbit will have 2 electrons, the second 8 electrons, the third 18 electrons and fourth orbit will have 1 electron. The atomic structure of all known elements can be shown in this way and we can refer few elements.

3.2.1 Electron

Since electronics deals with tiny particles called electrons, these small particles require detailed study. *An electron is a negatively charged particle having negligible mass.* Some of the important properties of an electron are:

1. Charge of an electron,
   $e= 1.602x10^{-19}$ coulomb
2. Mass of an electron,
   $n=9.0x10^{-31}$ kg
3. Radius of an electron,
   $r = 1.9x10^{-15}$ meter

3.2.2 Energy of an Electron

An electron moving around nucleus possesses two types of energies, viz.

Kinetic Energy -due to its motion (relativity)

Potential Energy - due to the charge in the nucleus

The total energy of the electron is the sum of these two energies. The total energy of the electron increases as its distance from the nucleus increases. Hence, the electron in the last orbit possesses high energy than the electrons in the previous orbits. The last orbit electron plays important role in determining the physical, chemical and electrical properties of a material.

Valence Electron

The electrons in the outermost orbit of an atom are known as valence electrons.

The outermost orbit can have maximum of 8 electrons. i.e., the maximum number of valence electrons can be 8. The valence electron determines the physical, chemical and electrical properties of material.

3.2.3 Atomic Structure of Materials

On the basis of electrical conductivity, materials are generally classified into conductors, insulators and semi-conductors. In general one can determine the electrical behaviour of a material from the number of valence electron as under.

i. Conductor:

When the number of valence electron of an atom is less than 4 (i.e., half of the maximum of 8 electron) the material is usually a metal and a conductor. Examples are sodium, magnesium and aluminium which have 1,2 and 3 valence electrons respectively. Is shown in Figure 3.3.

ii. Insulator:

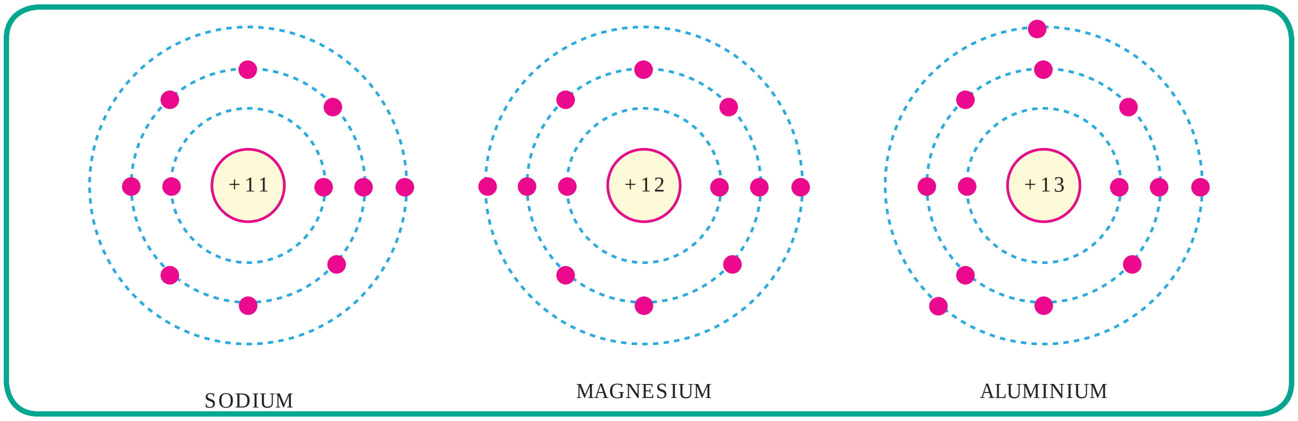


Figure 3.3 Atomic structure of sodium, magnesium and aluminium

When number of valence electron of an atom is more than 4, the material is usually a non-metal and an insulator.

Examples are nitrogen, sulphur and neon which have 5, 6 and 8 valence electrons respectively as shown in Figure3.4.

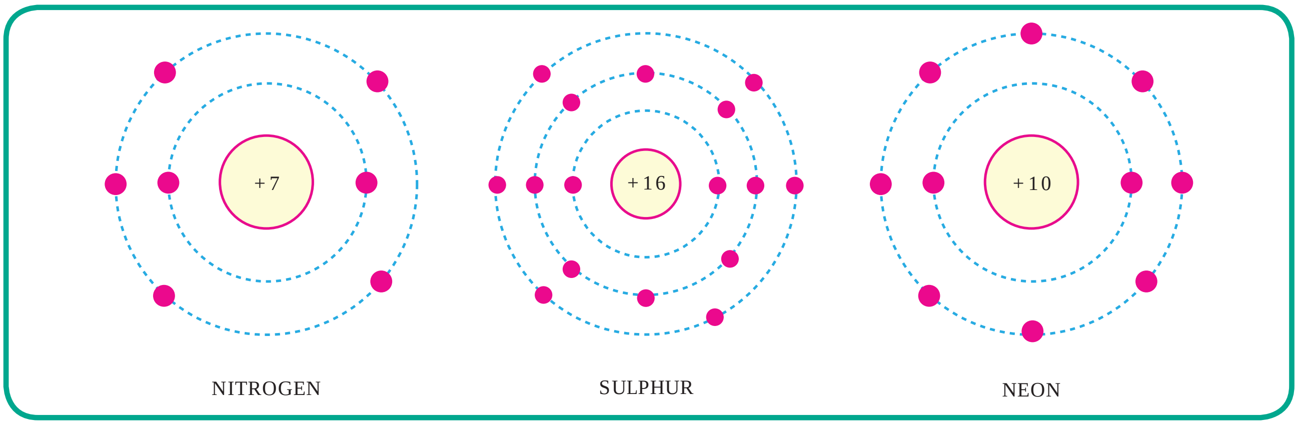


Figure 3.4 Atomic structure of nitrogen, sulphur and neon

iii. Semiconductor:

When the number of valence electrons of an atoms is 4 (i.e., exactly one-half of the maximum of 8 electron), the material has both metal and non-metal properties and is usually a semiconductor. Examples are carbon, silicon and germanium as shown in below Figure3.5.

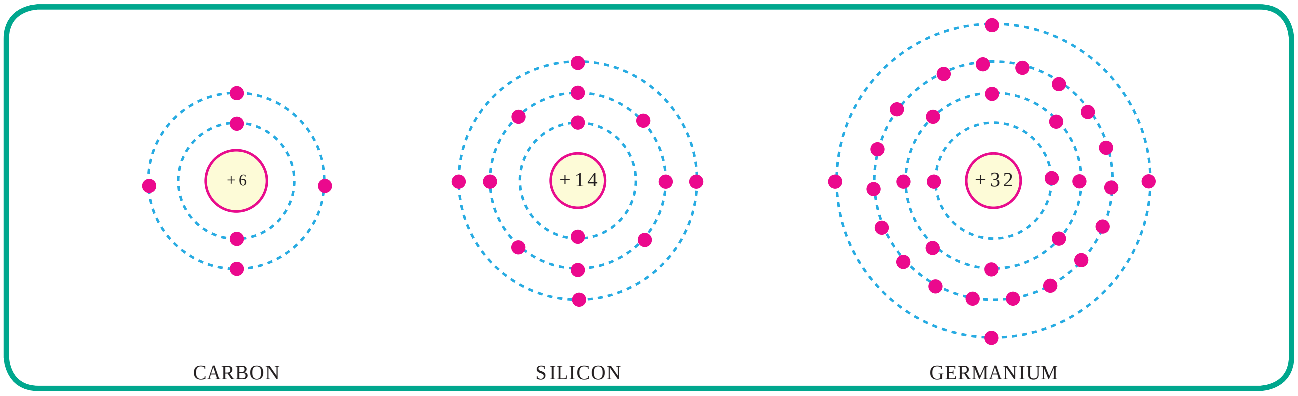


Figure 3.5 Atomic structure of carbon, silicon and germanium

3.2.4 Free Electrons

The valence electron of different material possesses different energies. The greater the energy of a valence electron, the lesser it is bound to the nucleus. In certain substance, particularly metals, the valence electron possess so much energy that they are very loosely attached to nucleus. These loosely attached valence electron move at random within the material and are called free electrons.

The valence electrons which are very loosely attached to the nucleus are known as free electron.

The free electrons can be easily removed or detached by applying a small amount of external energy. As a matter of fact, these free electrons which determine the electrical conductivity of the material. On the basis of free electron concept, the conductors, insulators and semiconductors can be defined as under:

1. A conductor is a substance which has a large number of free electrons. When potential difference is applied across a conductor, the free electron move towards positive terminal of supply constituting electric current.
2. An insulator is a substance which has practically no free electrons at ordinary temperature. Therefore an insulator does not conduct current under the influence of potential difference.
3. A semiconductor is a substance which has very few free electrons at room temperature. Under the influence of potential difference, a semi-conductor practically conducts no current.

3.3 ELECTRON EMISSION

The liberation of electron from the surface of a substance is known as electron emission.

For electron emission metals are used because they have many free electrons as shown in Figure 3.6. When sufficient energy is given to the free electron, its kinetic energy is increased and thus electron will cross over the surface barrier to leave the metal.

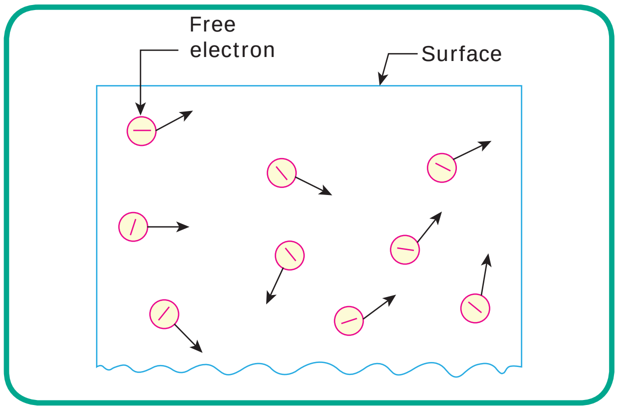


Figure 3.6 **Free electron on the surface of the atom**

Types of Electron Emission

There are four principle methods of obtaining electron emission from the surface of a metal.

a) Thermal Energy   b) Light Energy

c) Secondary Electron   d) Electric Field

1. **Thermionic Emission:** In this method, the metal is heated to sufficient temperature (about 2500°C) to enable the electron to leave the metal surface. The number of electrons emitted depends upon the temperature. The higher the temperature, the greater is the emission of electron. This type of the emission is employed in vacuum tubes and CRTS as shown in Figure 3.7.

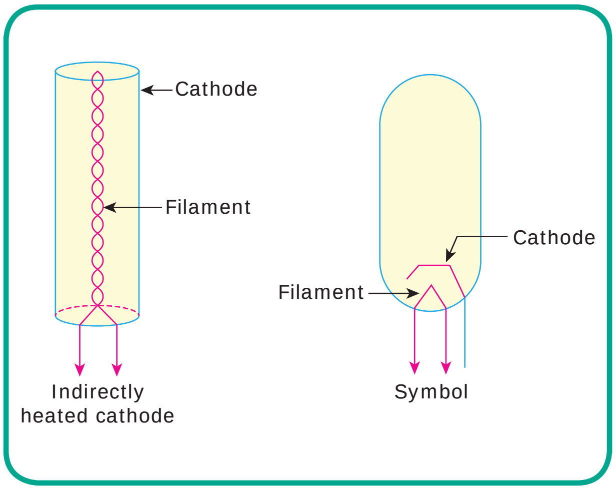


Figure 3.7 **Thermionic emission**

2. **Photo electric emission:** In this method, energy of light is falling upon the metal surface is transferred to the free electrons within the metal to enable them to leave the surface as shown in Figure 3.8. The greater the intensity (i.e., brightness) of light beam falling on the metal surface, the greater is the photoelectric emission.

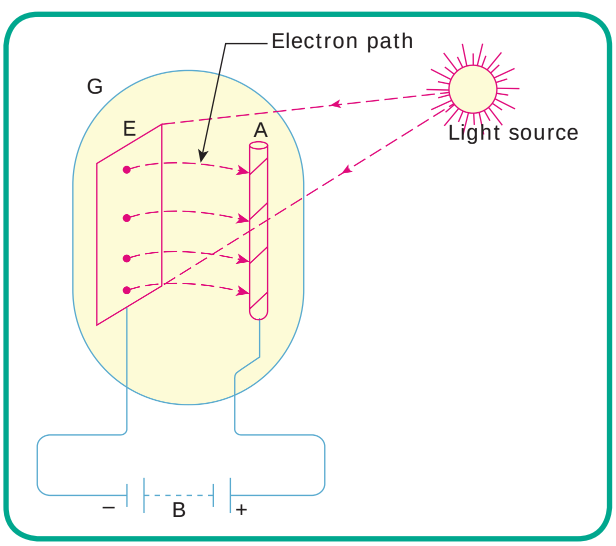


Figure 3.8 **Photo electric emission**

3. **Secondary Emission:** In this method, a high velocity beam of electrons strike the metal surface and causes the electron emission out of the surface as shown in Figure 3.9.

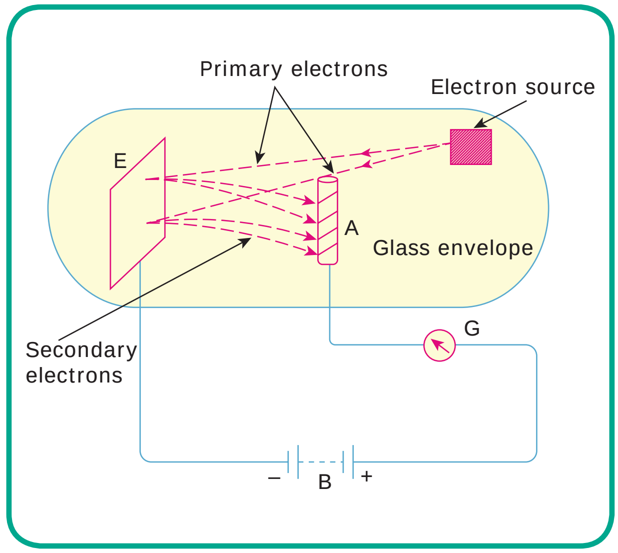


Figure 3.9 **Secondary emission**

4. **Field Emission:** In this method, a strong electric field (i.e., high positive voltage)is applied at the metal surface which pulls the electrons out of metal surface because of the attraction of positive field. The stronger the electric field, the greater is the electron emission as shown in Figure 3.10.

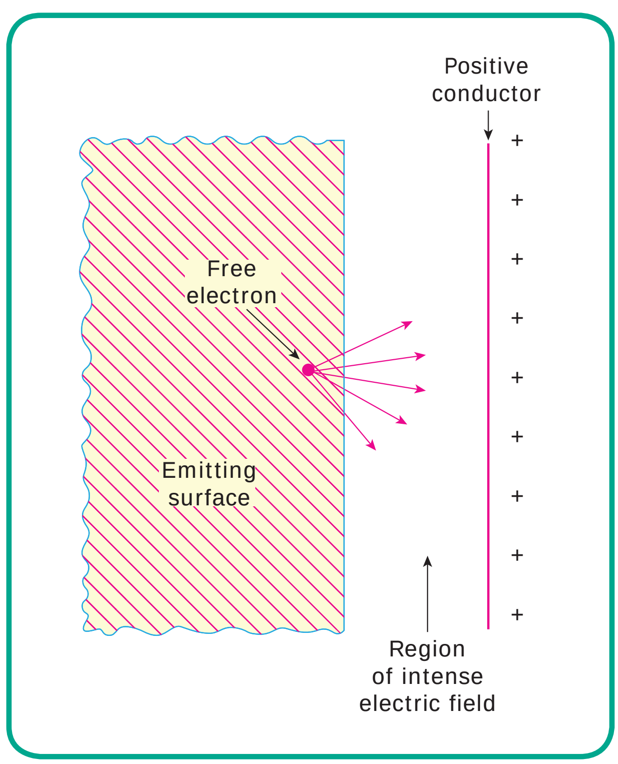


Figure 3.10 **Field emission**

3.4. VACUUM TUBES

Early days of electronics made successful strides by the introduction and working efficiency of the vacuum tubes. During 20th century, a new branch of engineering called "electronics" originated from the electrical engineering, due to the arrival of the vacuum tubes. These tubes have been finding wide applications in radio, television, long distance telephones, sound motion pictures, radar and electronic computers. A typical vacuum tube having three electrodes called triode is shown in Figure 3.11

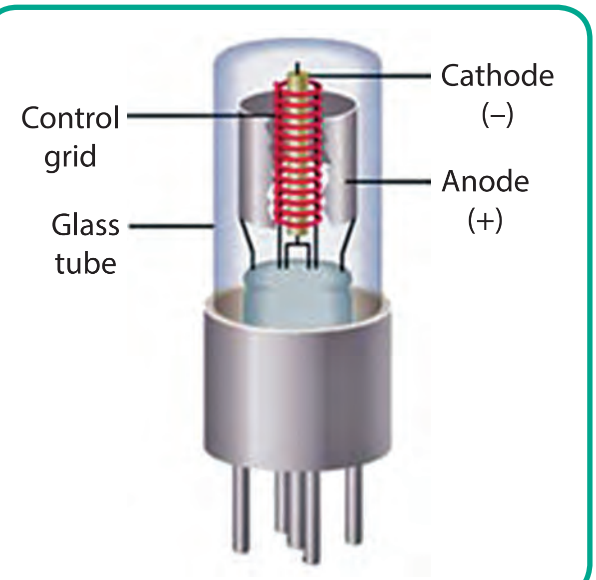


Figure 3.11 Parts of the vacuum tube

Due to its size, slowness in working-speed, cost of production, and above all the emission of heat while on working reduced the life of many electronic instruments.

Continuous research was going on, which paves the way for arrival of semiconductors.

Before studying about semiconductor, it would be better to know about the structure of atom and characteristics of electrons.

3.5 ATOMIC MODEL

The study of atomic structure is very important for electronics engineering. The size of an atom is so small that it is virtually impossible to see it even through the most powerful microscope. Therefore, we have to employ indirect method for the study of its structure. Though many scientists derived atomic theories, Bohr's atomic model is adequate to understand the electronics.

3.5.1. Bohr's Atomic Model

In 1913, Neil Bohr, Danish Physicist gave clear explanation of atomic structure. Bohr postulated the following points about the structure of the atom:

Neil Bohr
(1885 – 1962)

1. An atom consists of positively charged nucleus around which negatively charged electrons revolve in different circular orbits.
2. The electrons can revolve around the nucleus only in certain permitted orbits i.e., orbits of certain radii are allowed.
3. The electrons in each permitted orbit have a certain fixed amount of energy. The larger the orbit (i.e., larger radius), the greater is the energy of electrons.
4. If an electron is given additional energy (e.g., heat, light, etc.), it is lifted to the higher orbit. The atom is said to be in a state of excitation. This state does not lost long, because the electron soon falls back to the original lower orbit. As it falls, it gives back the acquired energy in the form of heat, light or other radiations.

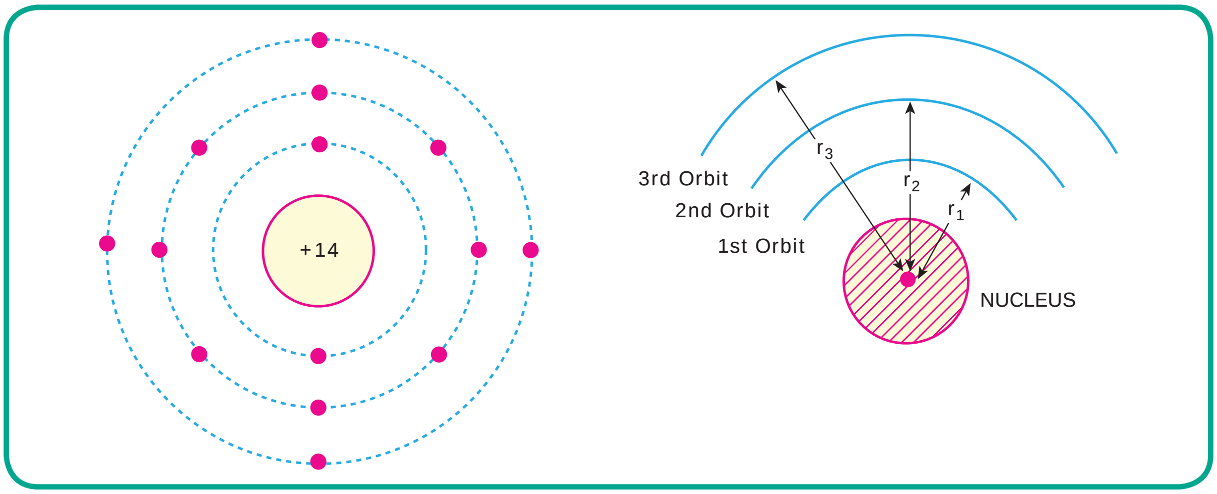


Figure3.12 **Structure of silicon atom**

Figure 3.12 shows the structure of silicon atom. It has 14 electrons, 2 in the first, 8 in the second and remaining 4 electrons in third orbit. The first, second, third orbits are also known as K, L and M orbits, respectively.

These electron can revolve only in permitted orbits (i.e., orbits of radii r_1, r_2 and r_3) and not in any orbit. Thus, all radii between r_1 and r_2 or between r_2 and r_3 are forbidden. Each orbit has fixed amount of energy associated with it. If an electron in the first orbit is to be lifted to the second orbit, just the right amount of energy should be supplied to it. When this electron jumps from second orbit to first, it gives back the acquired energy in the form of electromagnetic radiations.

3.5.2 Energy Level

It has already been discussed that each orbit has fixed amount of energy associated with it. The electrons moving in a particular orbit possess the energy of that orbit. The larger the orbit, greater is its energy. It becomes clear that outer orbit electrons possess more energy than the inner orbit electrons.

Figure 3.13 shows the energy of different orbits. This is one way of the representing the energy in orbits and is known as energy band diagram. The first orbit represents first energy level; the second orbit indicates the second energy level and so on. The larger the orbit of the electron, the greater is its energy and higher is the energy level.

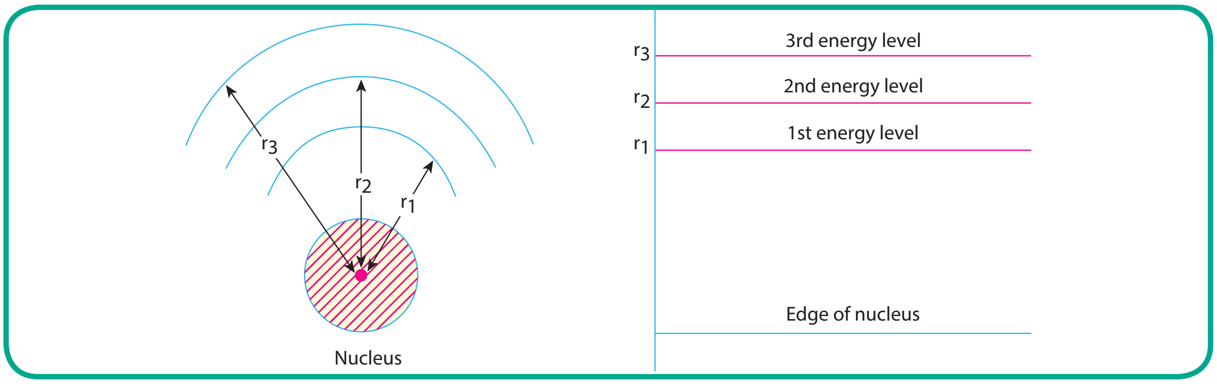


Figure 3.13 **Energy level diagram**

You might have heard about many types of energies used in our day-today life. For all those, electron energy is the base.

3.5.3 Important Energy Bands in Solids

Though there are number of energy bands in the solids, the following are of the important ones.

1. Valence Band

The range of energies (i.e., bands) possessed by valence electron is known as valence band.

The electron in the outermost orbit of an atom is known as valence electron. In a normal atom, valence band has the electron of highest energy. This band may be completely or partially filled. For instance, in case of inert gas, the valence band is full, whereas for other material, it is only partially filled. The partially filled band can accommodate more electrons.

2. Conduction Band

In certain material (e.g. metals) the electrons are loosely attached to the nucleus. Even at ordinary temperature, some of the valence electron may get detached to become free electrons. In fact, these free electrons are responsible for conduction of current in a conductor. For this reason, they are called conduction electrons.

The range of energy (i.e., band) possessed by the conduction electron is known as conduction band.

All electrons in the conduction band are free electrons. If a substance has empty conduction band, it means current conduction is not possible. Generally, insulators have empty conduction band. On the other hand, it is partially filled for conductors.

3. Forbidden Energy Gap

The energy gap between conduction band and the valence band on the energy level diagram is known as forbidden energy gap.

No electron of a solid can stay in a forbidden energy gap as there is no allowed energy state in this region. The width of the forbidden energy gap is a measure of bondage of valence electrons to the atom. The greater the energy gap, more tightly the valence electron are bound to the nucleus. In order to push an electron from the valence band to conduction band (i.e., to make the valence electron free), external energy must be supplied equal to the forbidden energy gap.

a) **Conductors:** Metals (e.g. Copper, Aluminium) or conductors allow the passage of electric current through them, because of large number of free electrons available in a conductor. In terms of energy band, the valence and conduction bands overlap each other as shown in Figure3.14.

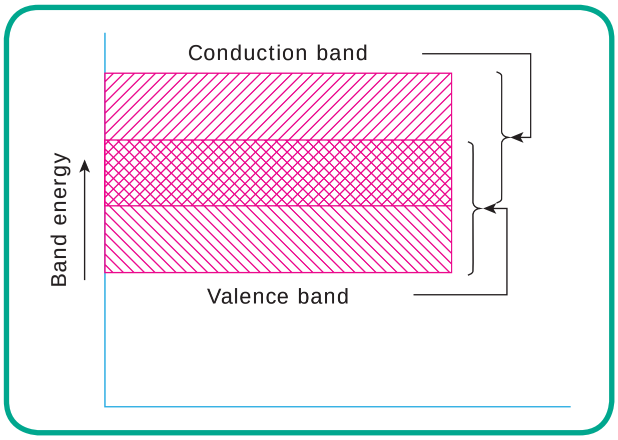


Figure3.14 Energy band of conductors

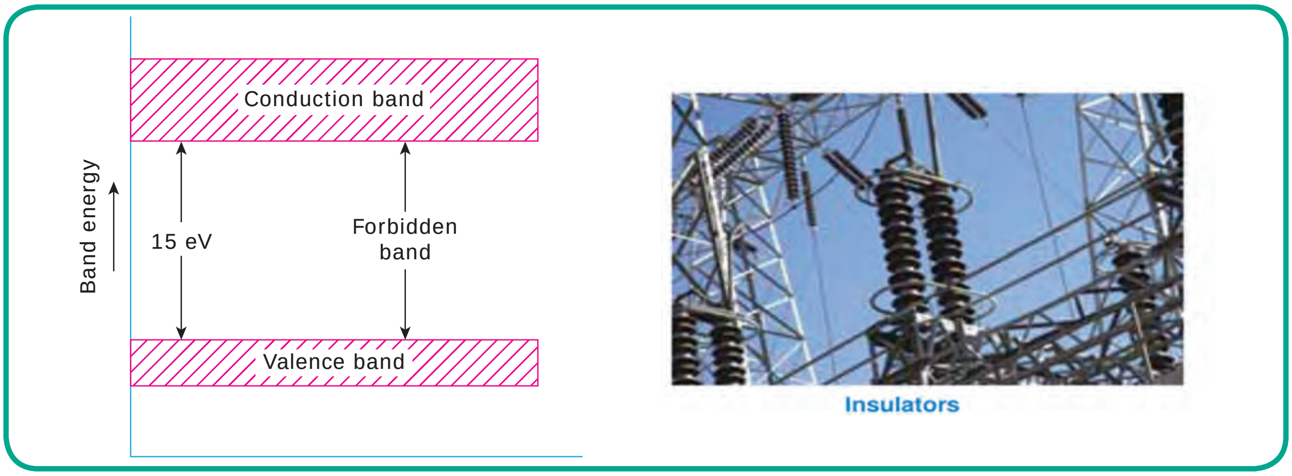


Figure3.15 Insulator and its energy band

(b) Insulators: Figure3.15 shows the forbidden energy gap of the insulators which is very large (15eV), e.g. wood, glass, etc.

c) Semiconductors: Semiconductors (e.g. Germanium, Silicon, Graphene, etc.)are those substance whose electrical property lies in between conductors and insulators. In terms of energy band, the valence band is almost full but the conduction band is empty. Further, the energy gap between valence band and conduction band is very small ($\simeq$, 1eV) as shown in Figure 3.16. Hence, smaller electric field is required to push the electron from the valence band to conduction band.

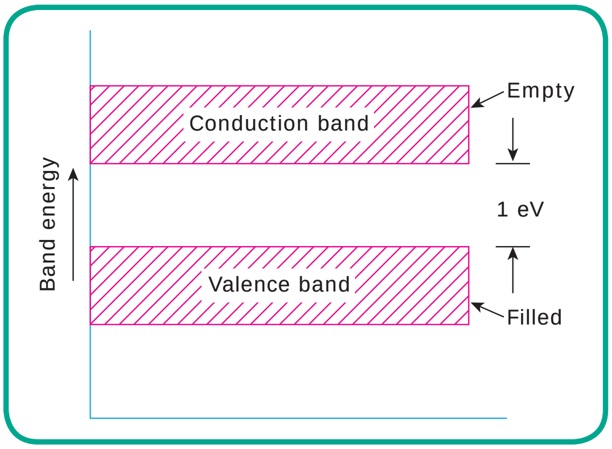


Figure3.16 Energy band of semiconductor

At low temperature, the valence band is completely full and conduction band is completely empty. Therefore at low temperature semiconductor behaves like an insulator. However, even at room temperature some of electrons cross-over to conduction band giving little conductivity to the semiconductor. As temperature increases, more number of electrons cross-over to the conduction band and the conductivity increases. Because of this, the entire characteristics of semiconductors get changed.

3.6 SEMI-CONDUCTOR

In lower standards you might have studied about the characteristics and principle of conductors, insulators. But you may not studied about semiconductors. Based on its character, it has been defined as semiconductor. But now, this semiconductor is the Back Bone of modern electronics. The character of semiconductor lies in between conductor and insulator.

The earlier period of (1950) electronics (communication equipments like Radio, Television and Amplifiers) which was dominated by vacuum tubes, gas filled tubes were replaced by this semiconductors.

Thus reducing the size of equipment considerably. Let we see in detail about this much important semiconductors.

It is not easy to define a semiconductor, if we want to take into account all its physical characteristics. However, generally a semiconductor is defined on the basis of electrical conductivity as under. A semiconductor is a substance which has resistivity (10-4 Ωto 0.5Ω) between conductors and insulators, e.g. Germanium, Silicon, Selenium, Carbon, Graphene, etc. Table 3.1 shows the resistivity of various semiconducting materials.

Table 3.1 Resistivity of Semiconductor Materials

SI. No.	Substance	Nature	Resistivity
1.	Copper	good conductor	1.7×10^{-8} Ωm
2.	Germanium	semicon-ductor	0.6 Ωm
3.	Glass	insulator	9×10^{11} Ωm
4.	Nichrome	resistance material	10^{-4} Ωm

3.6.1 Properties of Semiconductors

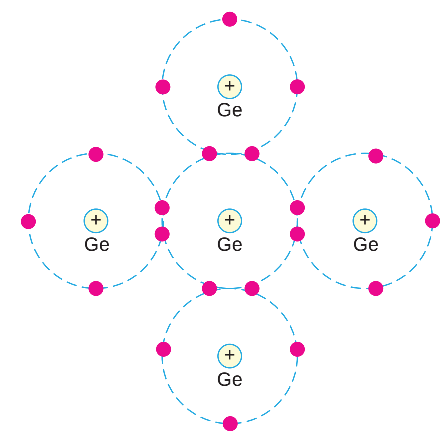
The resistivity of a semiconductor is less than an insulator but more than a conductor.

Semiconductors have negative temperature co-efficient of resistance, i.e., the resistance of the semiconductor decreases with the increase in temperature and vice-versa. For example, germanium is usually an insulator at low temperature but it becomes good conductor at high temperature.

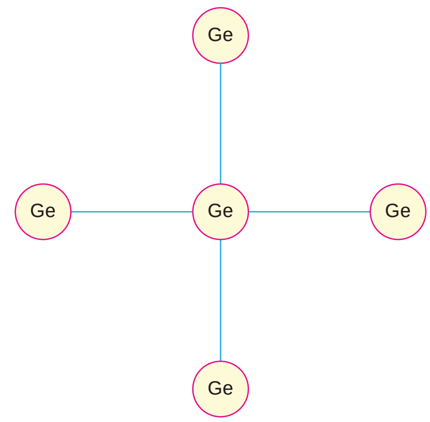
When metallic-impurity (e.g. Arsenic, Gallium, etc.) material is added to the semiconductor material then the current conduction property of the material changes, appreciably. This property is most important and is discussed later in detail.

3.6.2 Bonds in Semiconductors

In semiconductors, bonds are formed by sharing of valence electrons. Such bonds are called covalent bond. In the formation of a covalent bond, each atom contributes equal number of valence electrons and the contributed electrons are shared by the atoms engaged in the formation of the bond. The covalent bond of Germanium is shown in Figure 3.17.



(a). Covalent Bonds Among Ge Atoms



(b). Bonding Diagram

Figure 3.17 Formation of covalent bond

The following points may be noted regarding the covalent bonds:

1. Covalent bonds are formed by sharing of valence electrons.
2. In the formation of covalent bond, each valence electrons of an atom forms direct bond with the valence electrons of an adjacent atom. For this reason, valence electrons in a semiconductor are not free.

3.6.3 Crystals

A substance in which the atoms or molecules are arranged in orderly pattern is known as a crystal.

All semiconductors have crystalline structure. From the Figure 3.17, it is clear that each atom is surrounded by neighbouring atoms in a repetitive manner; therefore, a piece of Germanium is generally called crystalline structure.

3.6.4 Commonly Used Semiconductor

There are many semiconductors available, but very few of them have practical application in Electronics. The two most frequently used materials are Germanium (Ge) and Silicon (Si). These two are widely used because the energy required to break their covalent bond is very small (i.e., energy required to release an electron from their valence bonds) being about 0.7eV for Germanium and 1.1eV for Silicon. Let us see about these two.

1. **Germanium:** Germanium is the model substance among the semiconductors. The main reason being that it can be purified well and crystallized easily. It is discovered in 1886. It is recovered from the ash of certain coals. The atomic number of germanium is 32, i.e., it has 32 protons and 32 electrons. It is clear that germanium atom has 4 valence electrons i.e., tetravalent element.
2. **Silicon:** Silicon is an element available in most of the common rocks. Actually sand is silicon dioxide. The silicon compounds are chemically reduced to silicon which is 100% pure for use as semiconductors. The atomic number of silicon is 14 and hence it has 14 protons and 14 electrons. It is very clear that silicon atom has four valence electrons i.e. tetravalent element.

With references to the nature and characteristics of semiconductors, there are two types of current flow. As we know, at low temperature the conduction-band in semiconductors will be empty (no free electrons), but increase in temperature causes changes in conduction-band i.e. few valence electron would come to conduction-band thus constituting electric current. Here, we have to note one thing, each time a valence electron enters into the conduction band a hole is created in the valence band. These holes also contribute to current and this current is called as hole current. In fact, hole current is the most significant concept in semiconductors.

3.6.5 Energy Band Description of Semiconductors

It has been already discussed that a semiconductor is substance whose resistivity lies between conductors and insulators. The resistivity is of the order of 10 to 0.5 ohm metre. However, semiconductor can be defined much more comprehensively on the basis of energy bands as under:

A semiconductor is substance which has almost filled valence band and nearly empty conduction band with a very small energy gap (=1 eV) separating the two. Fig 3.18 shows the energy band diagrams of germanium and silicon respectively. It may be seen that forbidden energy gap is very small, being 1.1 eV for silicon and 0.7 eV for germanium. Therefore, relatively small energy is needed by their valence electrons to cross over to the conduction band and thus become free electrons. However, at this temperature, number of free electrons available is very small. Therefore, at room temperature, a piece of germanium or silicon is neither a good conductor nor an insulator. For this reason, such substances are called semiconductors.

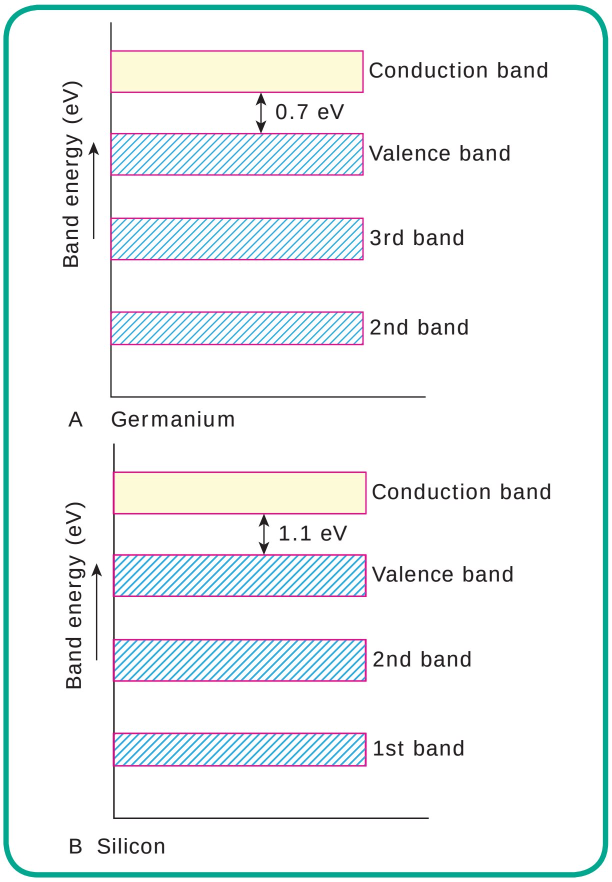


Figure3.18 Energy band description

The energy band description is extremely helpful in understanding the current flow through a semiconductor. Therefore, we shall frequently use this concept in our further discussion.

3.6.6 Hole Current

At room temperature some of the covalent bond in pure semiconductors breaks, setting up free electrons. Under the influence of electric field, these free electrons constitute electric current. At the same time, another current, the hole current also flows in the semiconductors. When the covalent bond is broken due to thermal energy, the removal of one electron leaves a vacancy, i.e., a missing element in covalent bond. This missing electron is called a hole, which acts as a positive charge. For one electron set free, one hole is created. Therefore, thermal energy creates hole-electron pairs. Hence, as many holes as free electrons are generated. The current conduction by holes can be explained as follows.

The hole shows a missing electron. Suppose the valence electron at L (Figure 3.19) has free electrons due to thermal energy.

This creates a hole in the covalent bond L. Now the hole becomes strong centre of attraction for the electron. So a valence electron (say at M) from nearby covalent bond comes to fill in the hole at L. This results in creation of hole at M. Another valence electron (say at N) in turn may leave its bond to fill the hole at M, thus creating a hole at N. Thus, the hole having positive charge has moved from L to N i.e., towards the negative terminal of supply. This constitutes the hole current.

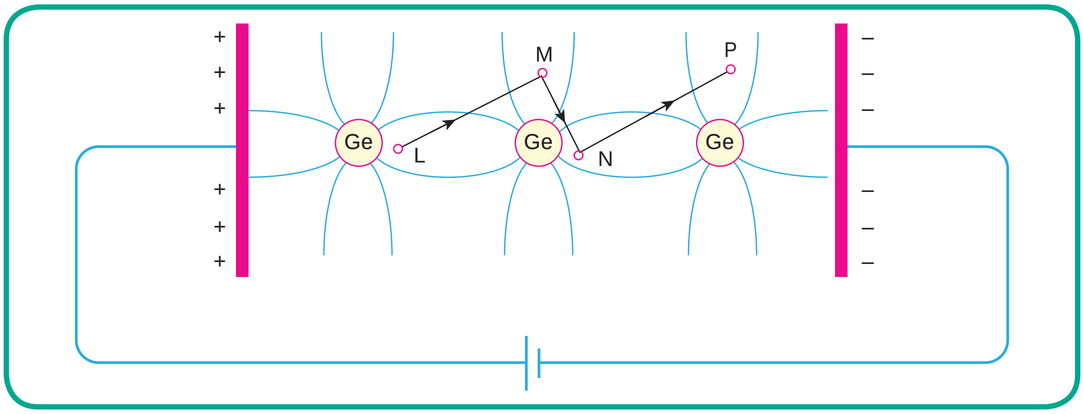


Figure 3.19 Electron and hole current formation in Ge

Though the hole current is happening due to the movement of electrons from one covalent bond to another bond, it is quite understandable why to call it as hole current. The basic reason for current flow is the presence of holes in the covalent bonds. Therefore, it is more appropriate to consider the current as the movement of holes.

3.6.7 Energy Band description of Hole Current

The hole current can be beautifully explained in terms of energy bands. Suppose due to thermal energy, an electron leaves the valence band and enter into the conduction band as shown in Figure 3.20.

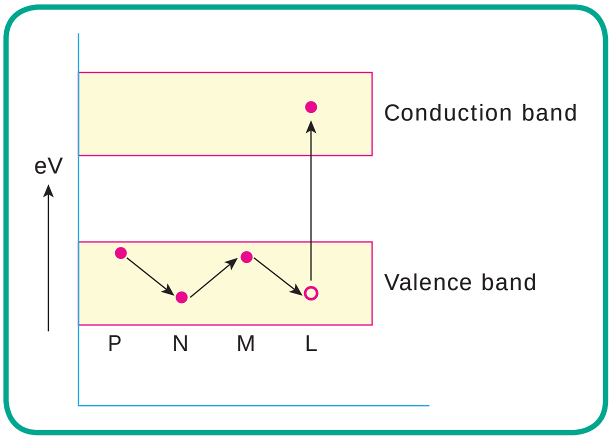


Figure 3.20 Hole movement across the band

This leaves a vacancy at L. Now, the valence electron at M comes to fill the hole at L. The result is that hole disappears at L and appears at M. Next, the valence electron at N moves to hole at M, consequently a hole is created at N. It is clear that valence electrons move along the path PNML whereas holes move in opposite direction i.e., along the path LMNP as shown in Figure 3.20.

3.7 INTRINSIC SEMICONDUCTOR

A semiconductor in an extremely pure form is known as an intrinsic semiconductor. In an intrinsic semiconductor, even at room temperature, hole-electron pairs are created. When electric field is applied across the semiconductor, the current conduction takes place by two processes such as (i) by free electrons and (ii) by holes as shown in the Figure 3.21. The free electrons are produced due to the breaking up of some covalent bonds by thermal energy.

At the same time, holes are created in the covalent bonds, under the influence of electric field. Thus, the conduction in semiconductors is by both electrons and

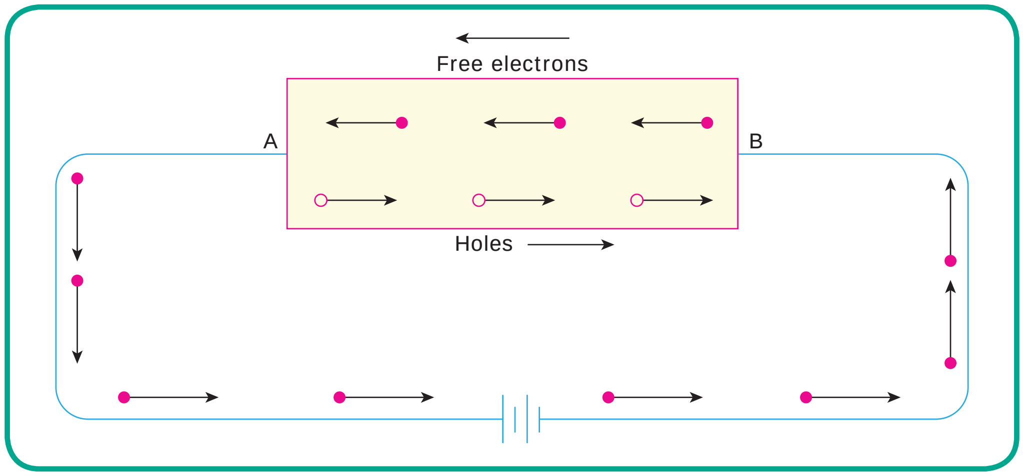


Figure 3.21 **Electron-hole current**

holes. Therefore, the total current inside the semiconductors is the sum of currents due to free electrons and holes.

It may be noted that current in the external wires is fully electronic i.e., by electrons. Then what about holes? Referring to the Figure 3.21, holes being positively charged and move towards the negative potential of supply. As the holes reach the negative terminal B, electrons enter the semiconductor crystal near the terminal and combine with holes, thus cancelling each other. At the same time, the loosely held electrons near by the positive terminal *A* are attracted away from their atoms into the positive terminal. This creates new holes near the positive terminal which again drift towards the negative terminal.

3.7.1 Extrinsic Semiconductors

The pure semiconductor must be altered so as to significantly increase its conductive properties. This is achieved by adding a small amount of suitable impurity to semiconductors. It is then called impurity or extrinsic semiconductors.

The process of adding impurities to a semiconductor is known as doping.

Generally, for 108 atoms of semiconductor, one impurity atom is added.

The purpose of adding impurity is to increase either the number of free electrons or holes in the semiconductor crystal. If the pentavalent impurity (having 5 valence electrons) is added to the semiconductor, a large number of electrons are produced in the semiconductor. On the other hand, addition of trivalent impurity (Having 3 valence electron) to semiconductor generates large number of holes.

Depending upon the type of impurity added extrinsic semiconductors are classified into:

1. N-type Semiconductor
2. P-type Semiconductor

3.8 N-TYPE SEMICONDUCTOR

When a small amount of pentavalent element is added to pure semiconductor, it is known as N-type semiconductors.

The addition of pentavalent impurity provides a large number of free electrons in the semiconductor crystal. Typical examples of pentavalent impurities are Arsenic (Atomic No. 33) and Antimony (Atomic No.51). Such impurities that produce n-type semiconductor are known as donor impurities, because they donate or provide free electrons to the semiconductor crystals.

To explain the formation of n-type semiconductor, consider a pure germanium crystal. We know that germanium atom has four valence electrons. When small amount of pentavalent impurity, like Arsenic is added to Germanium crystal, large number of free electrons available in the crystal. Arsenic is pentavalent i.e., its atom has five valence electrons. An Arsenic atom fits in the Germanium crystal in such a way that its four valence electron form covalent bonds with four Germanium atoms. The fifth valence electron of Arsenic atom finds no place in covalent bond and is thus become free electron as shown in Figure3.22. Therefore, for each Arsenic atom added, one free electron will be available in the Germanium crystal. Hence, an extremely small amount of Arsenic impurity provides enough atoms to supply millions of free electrons.

Figure 3.22 shows the energy band description of n-type semiconductor. The addition of pentavalent impurity has produced a number of conduction band electrons, i.e., free electrons. Therefore, valence electrons of pentavalent atom form covalent bonds with four neighbouring Germanium atoms. The fifth left-over valence electron of the pentavalent atom cannot be accommodated in the valence band; hence travels to the conduction band. The current flow in n-type semiconductor is shown in Figure 3.23. The following points may be noted carefully:

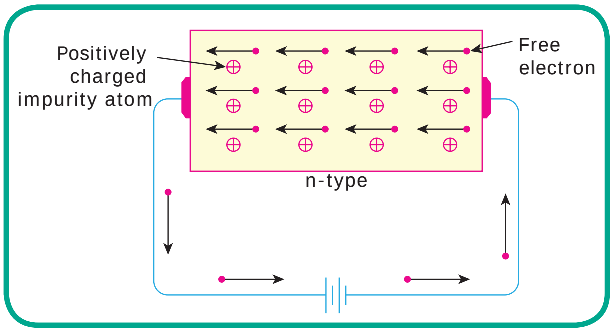


Figure 3.23 **Current flow in n-type semiconductor**

i. Many new free electrons are produced by the addition of pentavalent impurity.

ii. Thermal energy at room temperature still generates few hole-electron pairs.

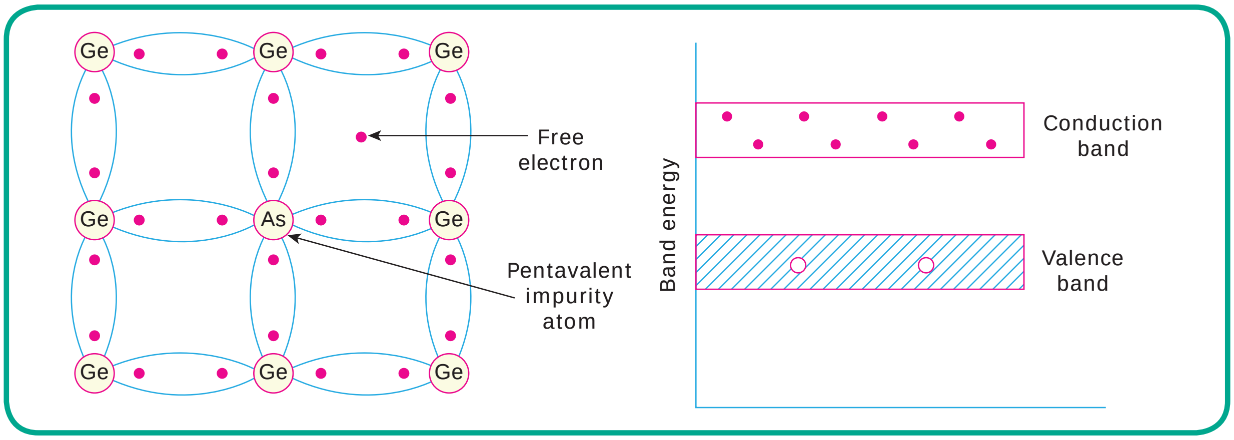


Figure 3.22 **Doping of Ge with pentavalent impurity Atom As**

However, the number of free electrons provided by the pentavalent impurity far exceeds the number of holes. It is due to this predominance of electrons over holes, hence it is called n-type semiconductors (n-stands for negative).

3.9 P-TYPE SEMICONDUCTORS

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

The addition of trivalent impurity provides a large number of holes in the semiconductor. Typical examples of trivalent impurities are Gallium (Atomic No: 31) and Indium (Atomic No: 49). Such impurities produce p-type semiconductors are known as acceptor impurities, because the holes created can accept the electron.

In Figure 3.24, Gallium is added with Germanium crystal to form p-type semiconductor. Each atom of gallium fits into the germanium crystal. But, only three covalent bonds can be formed. The fourth bond is incomplete, being short of one electron. The missing electron is called a hole. Therefore, for each Gallium atom added, one hole is created. A small amount of Gallium provides millions of holes.

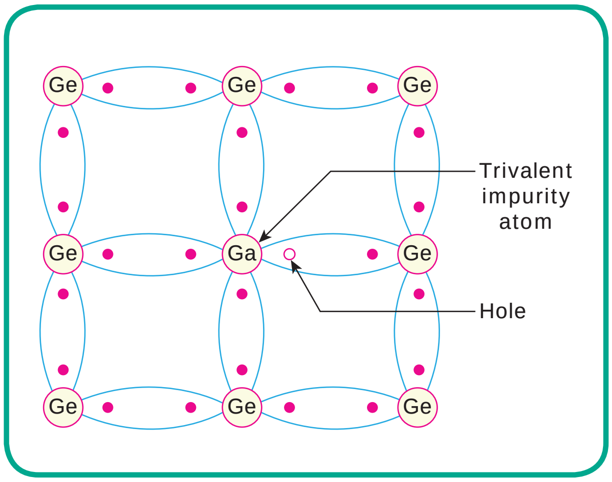


Figure 3.24 P-type semiconductor

Hence, in p-type semiconductor, holes are the majority carriers. When potential difference is applied to the p-type semiconductor the holes are shifted from one covalent bond to another. As the holes are positively charged, they are directed towards the negative terminal, constituting what is known as "hole current". The p-type semiconductor and its band structure are shown in Figure 3.25.

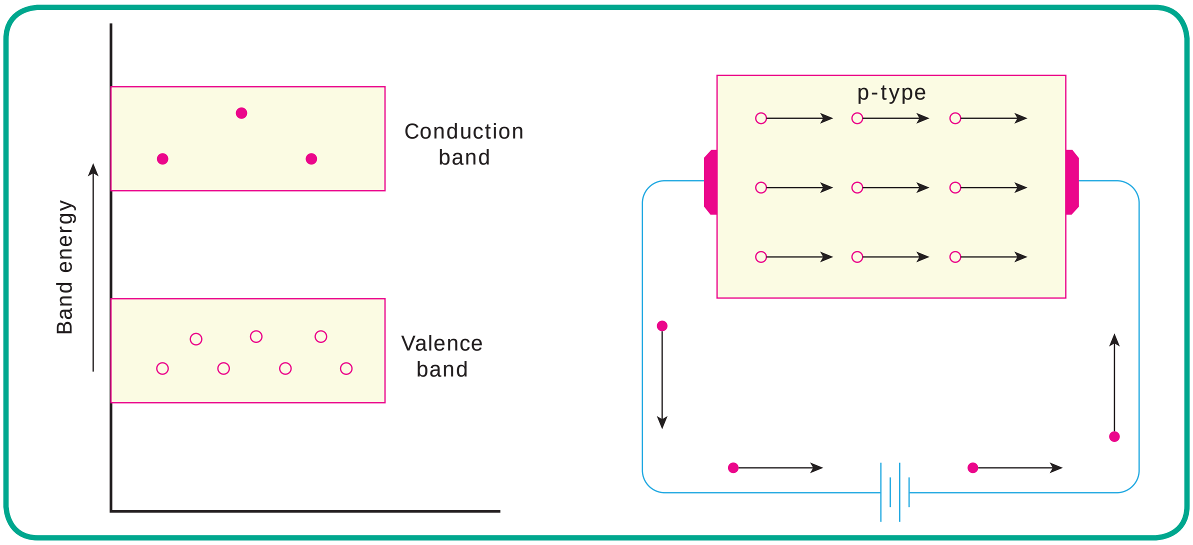


Figure 3.25 Energy band and current flow of P-type semiconductor

3.10 PN JUNCTION

"When a p-type semiconductor is suitably joined to n-type semiconductor, the contact surface is called pn junction"

Figure 3.26 shows the formation of pn junction. To explain the properties of a pn junction, p-type and n-type semiconductor are suitably joined. Keep in mind that n-type material has a high concentration of free electrons while p-type material has a high concentration of holes. Therefore, at the junction, there is a tendency for the free electrons to diffuse over to the p-side and holes to the n-side.

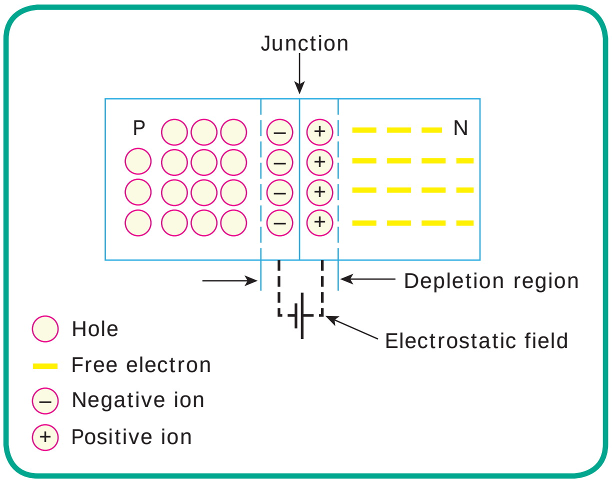


Figure 3.26 PN Junction

This process is called diffusion as shown in Figure 3.27. The combination of these holes and electrons create a new region between the two layers. This region is called "depletion layer". Only inside this, there is positive charge on 'n' side and negative charge on 'p' side. Because of this a potential is produced in this layer which is called "barrier potential". The barrier potential in directly related to depletion layer.

The barrier potential opposes the flow of majority carriers through the junction and it aids the flow of minority carriers. For both of these opposite effects, no charge carriers will flow through the junction at normal condition. The potential difference across a pn junction can be applied in two ways namely, forward biasing and reverse biasing.

3.10.1 Forward Biasing

To apply forward bias, connect positive terminal of the battery to p-type and negative terminal to n-type as shown in Figure 3.28. Due to this, barrier potential is very much reduced. Positive terminal of the battery repels holes in p-side and negative terminal of the battery repels electrons in n-side. Because of this, current flows in the circuit. This is called "forward current". The magnitude of current depends upon the applied forward voltage.

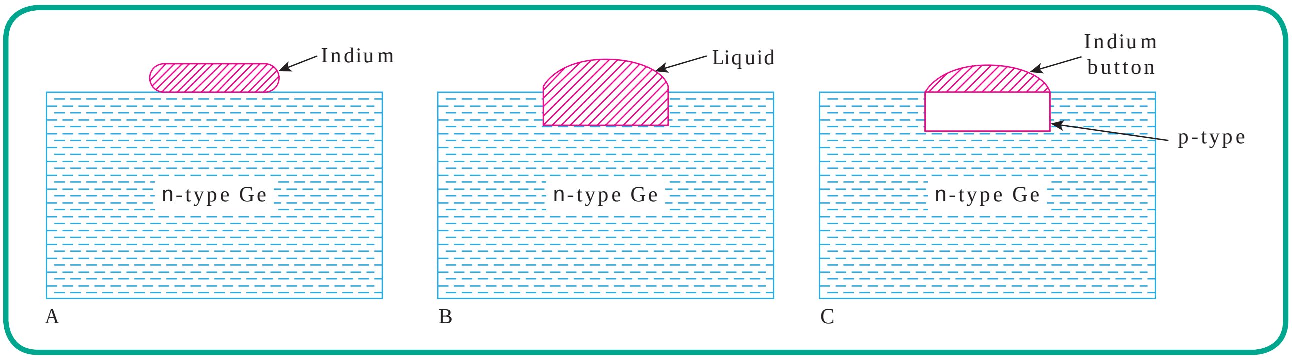


Figure 3.27 Diffusion process

"When external voltage applied to the junction is in such a direction that it cancels the potential barrier, thus permitting the current flow, is called as forward biasing"

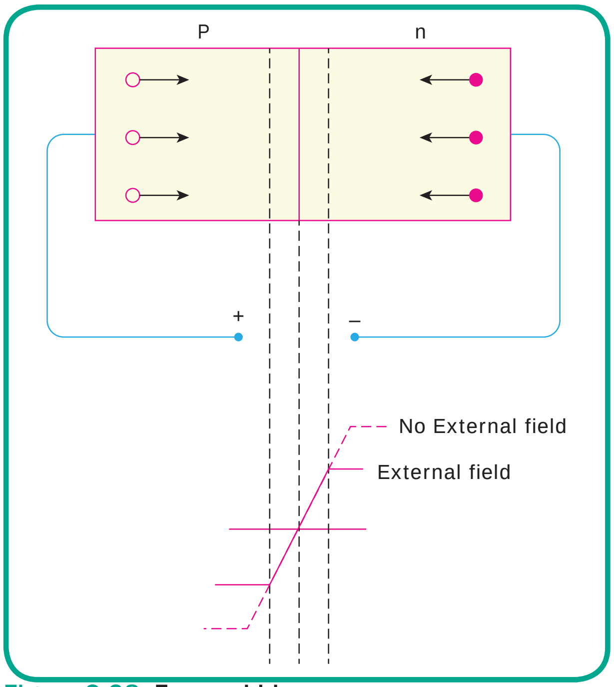


Figure 3.28 **Forward bias**

3.10.2 Reverse Biasing

"When the external voltage applied to the junction is in such a direction that potential barriers is increased, it is called reverse biasing"

To apply reverse bias, connect negative terminal of the battery to p-type and positive terminal to n-type as shown in Figure3.29. Because of increase in barrier potential the width of the depletion layer is also increased. As a result, the increased potential barrier prevents the flow of charge carriers (majority carriers) across the junction and hence the current does not flow.

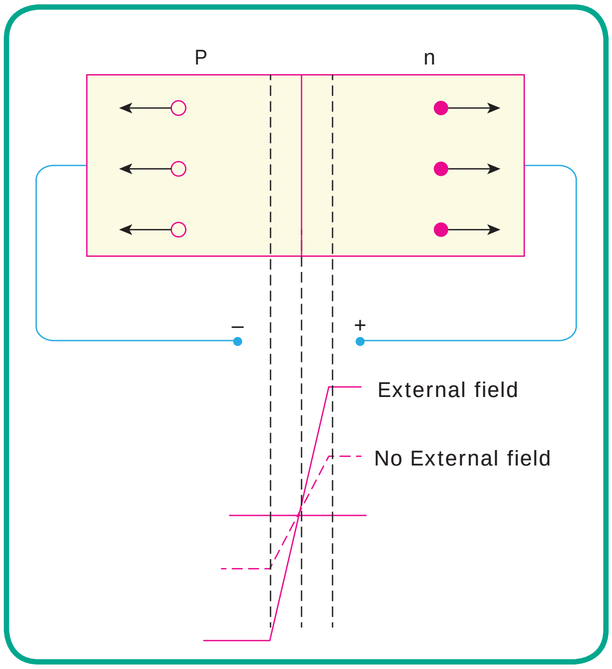


Figure 3.29 **Reverse bias**

From this, the students can understand the following:

1. *When pn junction is in forward biased condition, current flow occurs.*
2. *When pn junction is in reverse biased condition, no current flow occurs.*

The important terms often used with pn junction are breakdown voltage and knee voltage and are explained as follows:

T3DXNP

Breakdown voltage

"It is the minimum reverse voltage at which pn junction breakdown with sudden rise in reverse current"

Knee voltage

"It is the forward voltage at which the current through the junction starts to increase rapidly"

LEARNING OUTCOMES

At the end of this chapter the students came to know about the following:

1. **Knowledge about basic electronic principles**
2. **Atomic structure of elements.**
3. **Classification of Elements**
4. **Detailed knowledge of Semiconductors and its working**
5. **Working of PN-junction**

GLOSSARY

S. No	Terms	Explanation
1	Acceptor atoms	Trivalent atoms that accept free electrons from pentavalent atoms
2	Atomic number	The number of positive charges or protons in the nucleus of an atom
3	Covalent bond	The way some electrons complete their valence shells by sharing valence electrons with neighbouring atoms
4	Electron	Smallest sub atomic particle of negative charge that orbits the nucleus of an atom
5	Free electron	Electrons that are not in any orbit around the nucleus
6	Hole	A gap left in the covalent band when a valence electron gains sufficient energy to jump to the conduction band
7	Junction	The area where the P- type material and N-type material meet in the semiconductor
8	Semiconductor	An element which is neither a good conductor or a good insulator, but rather lies somewhere between the two
9	Proton	Sub atomic particle within the nucleus of an atom. Has a positive charge
10	Valence shell	The outermost electron shell for a given atom. The number of electrons in this shell determines the conductivity of the atom

QUESTIONS

I. Choose the right answer from the following questions (1 mark)

1. The atomic weight of an atom is determined by
   (a) No of protons (b) No of neutrons
   (c) No of Protons and No of neutrons (d) No of Protons or No of electrons

2. The number of protons present in an atom is called as
   (a) isotope number (b) atomic number (c) atomic weight (d) none of the above

3. Valence electrons are
   (a) Loosely packed electrons (b) mobile electrons
   (c) electrons present in the outermost orbit (d) electrons that do not carry any charge

4. The electrons in the third orbit of an atom have .... energy than the electrons in the second orbit.
   (a) more (b) less (c) the same (d) none of the above

5. When an electron jumps from higher orbit to a lower orbit, it .... energy.
   (a) absorbs (b) emits
   (c) sometimes emits, sometimes absorbs (d) none of the above

T3FJDI

6. Atomic number of Germanium
   (a) 6 (b) 14 (c) 29 (d) 32

7. The electrons in the conduction bands are known as.......
   (a) bound electrons (b) valence electrons (c) free electrons (d) none of the above

8. In an insulator the energy gap between valence and conduction band is ....
   (a) very large (b) very small
   (c) zero (d) none of the above

9. Which of the following element does not have three valence electrons?
   (a) Boron (b) Aluminium (c) Germanium (d) Phosphorous

10. Which of the following element does not have five valence electrons?
    (a) Phosphorous (b) Arsenic (c) Antimony (d) Indium

11. A semiconductor in its pure form is called
    (a) Intrinsic semiconductor (b) Extrinsic semiconductor
    (c) P-type semiconductor (d) N-type semiconductor

12. Which of the following is donor impurity element?
    (a) Aluminium (b) Boron (c) Phosphorous (d) Indium

Continued on next page

13. Which of the following is acceptor impurity element?

    (a) Antimony (b) Gallium (c) Arsenic (d) Phosphorous

14. In N-type semiconductor free electrons are the ……. Carriers

    (a) Minority (b) Majority (c) Magnetic (d) Neutral

15. A doped semiconductor is called

    (a) impure semiconductor (b) intrinsic semiconductor

    (c) Pure semiconductor (d) Extrinsic semiconductor

II. Answer in one or few Sentences

1. What is an atomic number?
2. What is atomic weight?
3. What is valence electron?
4. Draw the atomic structure of germanium atom.
5. What is called energy band?
6. What is meant by electron emission?
7. Write active components with examples.
8. What is meant by doping?

III Explain the following questions in one or two paragraph. (3 marks)

1. Write short notes on free electrons.
2. Explain energy bands.
3. Explain conductor, semiconductor and insulator.
4. Explain formation of n-type semiconductor with diagram.
5. Explain formation of p-type semiconductor with diagram.
6. Explain the mechanism of current flow in a forward biased pn junction.

IV Describe the following questions in a page. (10 marks)

1. Explain the Bohr's atomic model with neat diagram.
2. Explain the different types of electron emission with neat diagrams.
3. Explain the forward biasing of pn junction with necessary diagram.
4. Explain the reverse biasing of pn junction with necessary diagram.

Answers

1) **c**	2) **b**	3) **c**	4) **a**	5) **b**
6) **d**	7) **c**	8) **a**	9) **c**	10) **d**
11) **a**	12) **c**	13) **b**	14) **b**	15) **d**

CHAPTER 4

POWER SUPPLY

திறனறிந்து சொல்லுக சொல்லை அறனும்
பொருளும் அதனினூஉங்கு இல். குறள் –644

விளக்கம்:
சொல்லின் திறத்தை அறிந்து சொல்லை வழங்க வேண்டும்,
அத்தகைய சொல்வன்மையை விடச் சிறந்த அறமும் பொருளும் இல்லை.

English Couplet 644:

Speak words adapted well to various hearers' state;
No higher virtue lives, no gain more surely great.

Couplet Explanation:
Understand the qualities (of your hearers) and (then) make your speech; for superior to it, there is neither virtue nor wealth.

T3HTQC

CONTENT

LEARNING OBJECTIVES

After the completion of this Chapter, the students can

1. Identify the various sections of a power supply
2. State the purpose of each section of a power supply
3. Describe the purpose of various types of rectifier circuits used in power supply.
4. Describe the purpose of the various types of filter circuits used in power supply
5. Describe the function of voltage doubler.
6. Calculate the peak value of the output voltage of half-wave and full-wave rectifier given in the R.M.S input voltage.

4.1. INTRODUCTION

Generally every piece of electronics equipment in the world today is powered from a DC Source. This source may be either a battery or a power supply. Most electronics equipment requires not only a DC power source, but one that is well filtered and well regulated as well.

Three types of electronic power conversion devices are in common use today: the AC to DC Supply, the DC to DC Converter, and the DC to AC inverter.

DO YOU KNOW?

What is the other name for Power supply

Power supply is also called as "Power Source"

4.1.1 AC to DC Power Supply

Converter

It is a device that converts alternative current into direct current.

Applications

1. Radio and television receiver use this type of power supply.
2. It is also used in DVD player.
3. AC to DC power supply is used in all type of amplifiers.

4.1.2 DC to DC Converter

It is a device that converts a source of direct current (DC) from one voltage level to another.

Application

It is used in cellular phones and laptop computers.

4.1.3 DC to AC inverter

It is a device that converts a source of direct current into alternative current. It is also called inverter.

Application

An uninterruptible power supply uses an inverter to supply AC power when the main power is not available.

Each has its own specific areas of application. Of the three, AC to DC power supply is the most commonly used power supply. The objective of this lesson is how to rectify AC into DC power supply.

4.2. POWER SUPPLY BASICS

Now a days almost all electronics equipment consist a circuit that converts AC supply into DC supply is called DC Power Supply unit. A DC power supply unit (Commonly called as PSU) deriving power from the AC mains (Line). It performs a number of tasks.

The basic function of power supply is illustrated in Figure 4.1.

Transformer: Transformer is used to step down the AC supply voltage (220 V AC, 50 Hz) as per the requirement of the solid state electronic devices.

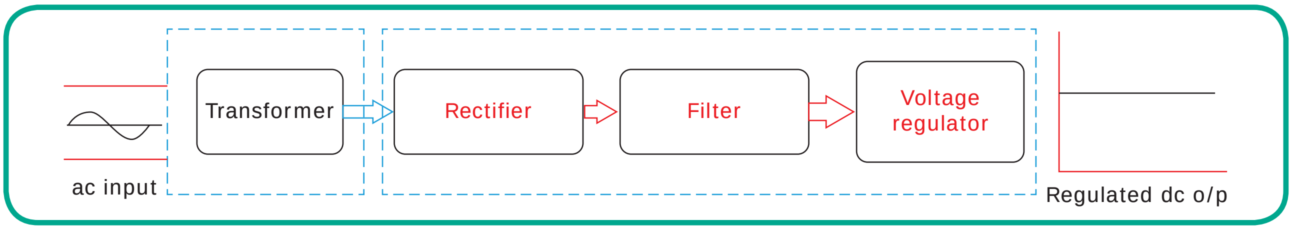


Figure 4.1 Basic power supply

Rectifier

Rectifier is a device which converts the sinusoidal AC voltage into either positive or negative pulsating DC.

Rectifier output contains unwanted AC components called as ripples. Diodes rectify the signal.

Filter

Filter is a device which passes DC components and blocks AC components of the rectifier output.

Resistor, capacitor and inductor (passive components) are used for this purpose.

Regulator

Regulator or stabilizer is a device that is used to maintain a constant DC output voltage.

Zener diode is used as regulator.

4.3. RECTIFIER

Figure 4.2 shows the schematic diagram of a Rectifier

Figure 4.2 **Rectifier**

Semiconductor diode (mostly silicon diode) is used as a rectifier element. It converts alternating current into direct current. Hence let we see the working of semiconductor diode.

4.3.1 Semiconductor Diode

A PN junction is known as a semi-conductor or crystal diode.

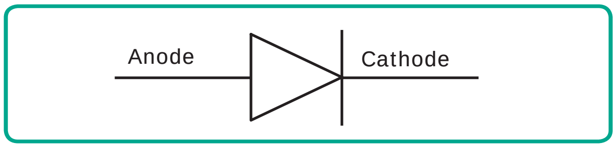


Figure 4.3 **Symbol of diode**

The character of a crystal diode is to conduct current in one direction only, permits it to be used as a rectifier. A crystal diode is usually represented by the schematic symbol shown in figure 4.3. The arrow in the symbol indicates the direction of conventional current flow.

The crystal diode has two terminals. When it is connected in a circuit, one thing to decide is whether the diode is forward or reverse biased. There is an easy rule to ascertain it. If the external circuit is trying to push the conventional current in the direction of arrow, the diode is forward biased. On the other hand, if the conventional current is trying to flow opposite to arrow head the diode is reverse biased. Putting in simple words:

1. If arrow head (i.e., Anode) of diode symbol is positive with respect to bar (i.e., Cathode) of the symbol the diode is forward biased.
2. If the arrow head (Anode) of diode symbol is negative with respect to bar(Cathode), the diode is reverse biased.

4.3.2 Identifying the Terminals of Diodes

The Anode or Cathode of the diode is clearly marked on the body or envelop. The cathode of the diode which is in the glass envelop is marked by a bar on the body. This is shown in figure 4.4.

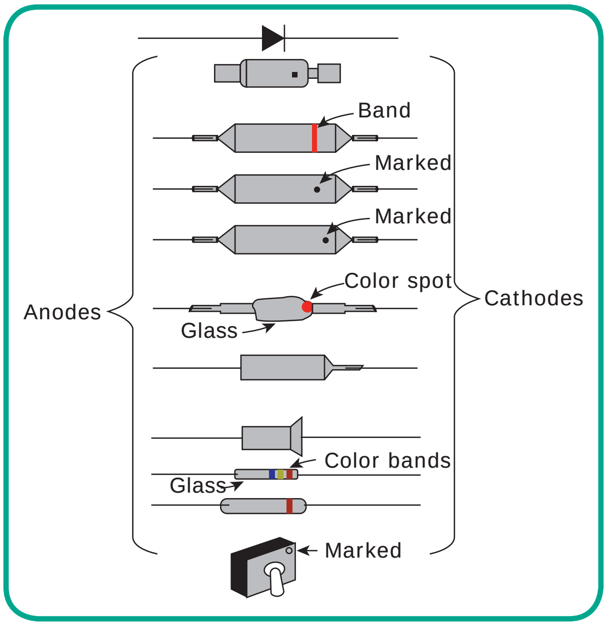


Figure 4.4 **Identification of diodes**

SMD Diode

An SMD diode is a type of diode that is directly soldered on the cooper soldered points in the surface of printed circuit board.

Uses of Diodes

Diodes are used as rectifiers and detectors.

4.3.3 Forward Biasing

To apply forward bias, connect positive terminal of the battery to p-type and negative terminal to n-type as shown in Figure 4.5. Due to this, barrier potential is very much reduced. Positive terminal of the battery repels holes in p-side and negative terminal of the battery repels electrons in n-side. Because of this, current flows in the circuit. This is called "forward current". The magnitude of current depends upon the applied forward voltage.

"When external voltage applied to the junction is in such a direction that it cancels the potential barrier, thus permitting the current flow is called as forward biasing"

The importent term often used with *pn* junction is knee voltage.

4.3.4 Knee Voltage

"It is the forward voltage at which the current through the junction starts to increase rapidly"

The figure 4.6 shows the characteristics of PN junction diode (forward bias).

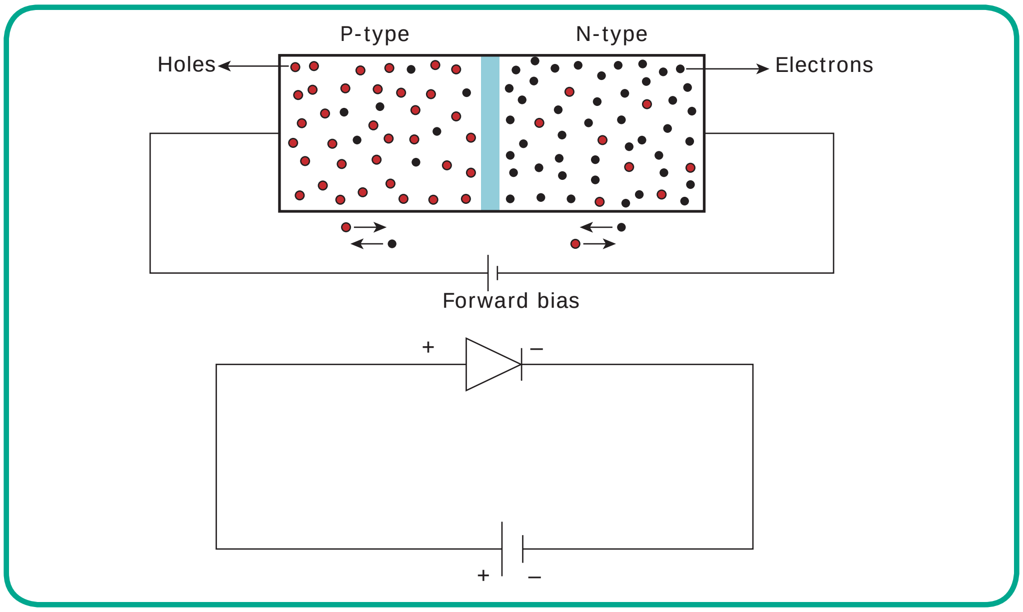


Figure 4.5 **Forward Bias**

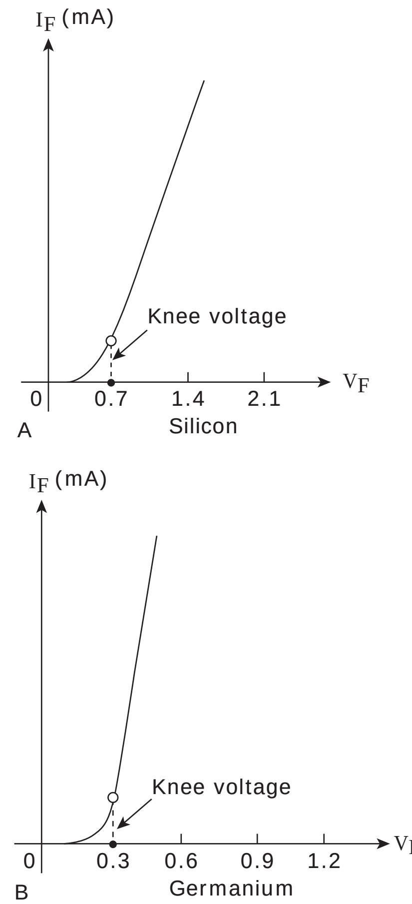


Figure 4.6 **Characteristics of PN junction diode (Forward bias)**

4.3.5 Reverse Biasing

"When the external voltage applied to the junction is in such a direction that potential barriers is increased, it is called reverse biasing"

To apply reverse bias, connect negative terminal of the battery to p-type and positive terminal to n-type as shown in Figure 4.7. Because of increase in barrier potential the width of the depletion layer is also increased. As a result, the increased potential barrier prevents the flow of charge carriers (majority carriers) across the junction and hence the current does not flow.

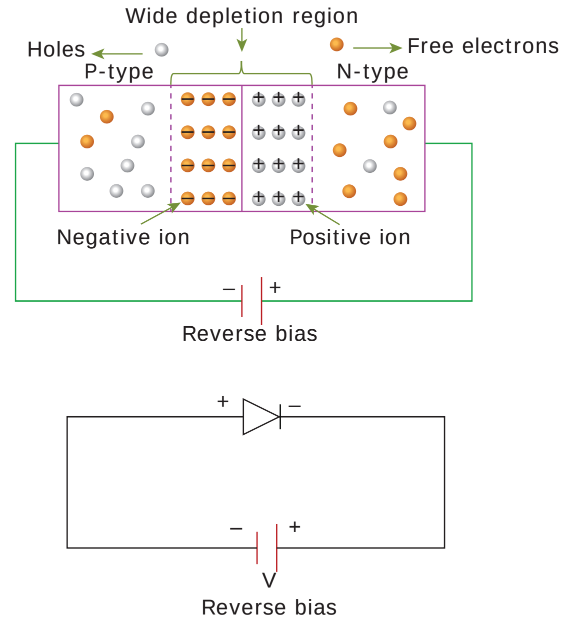


Figure 4.7 **Reverse bias**

From this, the students can understand the following:

1. *When pn junction is in forward biased condition, current flow occurs.*
2. *When pn junction is in reverse biased condition, no current flow occurs.*

The important term often used with *pn* junction is breakdown voltage which is explained as follows:

4.3.6 Breakdown voltage

"It is the minimum reverse voltage at which pn junction breakdown with sudden rise in reverse current".

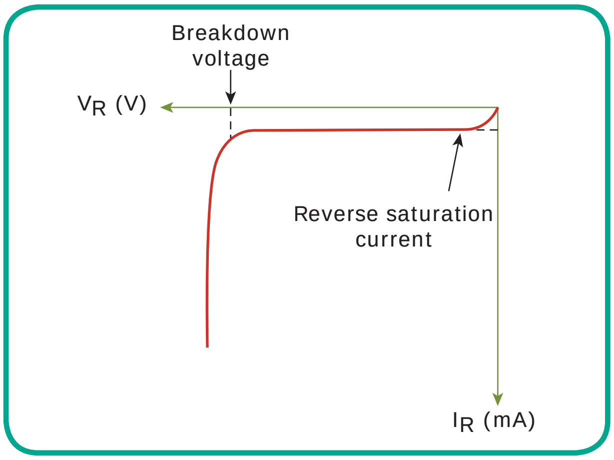


Figure 4.8 Characteristics of PN junction diode (Reverse bias)

The figure 4.8 shows the Characteristics of PN junction diode (Reverse bias)

4.4 TYPE OF RECTIFIERS

There are few type of rectifiers given in Figure 4.9.

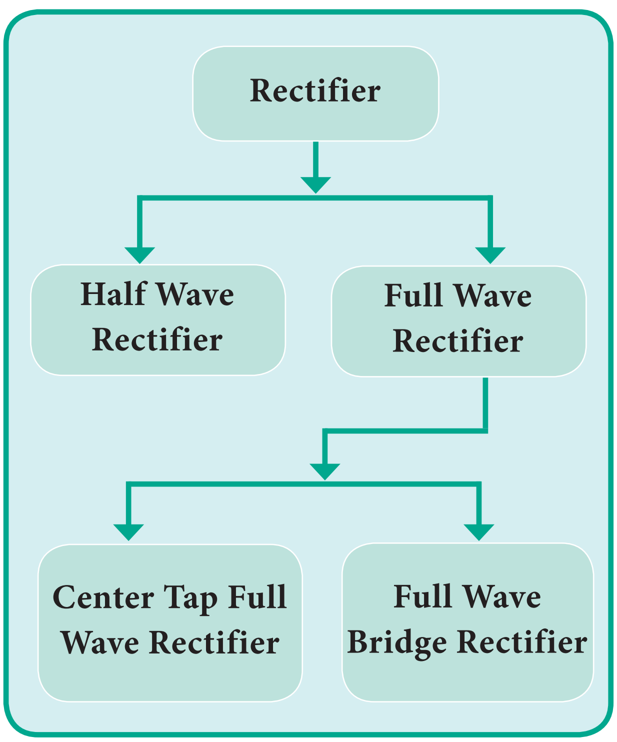


Figure 4.9 Type of Rectifiers

4.4.1 Half-wave Rectifier

This rectifier converts an AC input voltage into pulsating DC voltage for only one half cycle of the applied voltage. The circuit diagram of the half wave rectifier is shown in Figure 4.10(a).

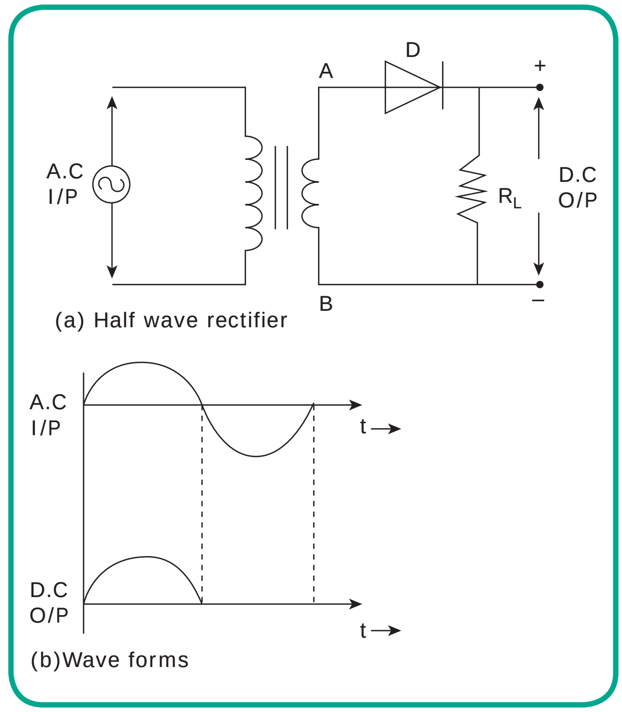


Figure 4.10 Half-wave Rectifier

During the positive half cycle, when the secondary winding of the upper end (A) is positive with respects to the lower end (B), the diode 'D' is under forward bias condition and conducts current.

During the positive half cycles, the input voltage is applied directly to the load resistance R_L, when the forward resistance of the diode is assumed to be zero. The waveforms of the output voltage and output current are same as that of the AC input voltage as shown in Figure 4.10(a).

During the negative half cycle when the lower-end (B) winding of the secondary is positive with respect of the upper-end (A), the diode D is under reverse-bias condition and it does not conduct current. Thus, the load and current across the load resistance is zero and so no power is delivered during the negative half-cycle. The input and output waveforms are shown in Figure 4.10(b).

The output voltage of a half-wave rectifier is calculated using the relationship $\frac{E_{max}}{\pi}$

Where E_{max} is the maximum voltage of the input and π is the phase angle (180°)

$$Ripple\ factor = f$$

Where f is the frequency.

$$Efficiency = 40.6\%$$

4.5 FULL-WAVE RECTIFIER

Full-wave rectifier rectifies the full cycle of the input AC waveform, i.e., it rectifies both the positive and negative cycles of the input waveform.

If a transformer with a centre-tapped secondary winding is used, the centre-tapped secondary produces two anti-phase outputs as shown in Figure 4.11.

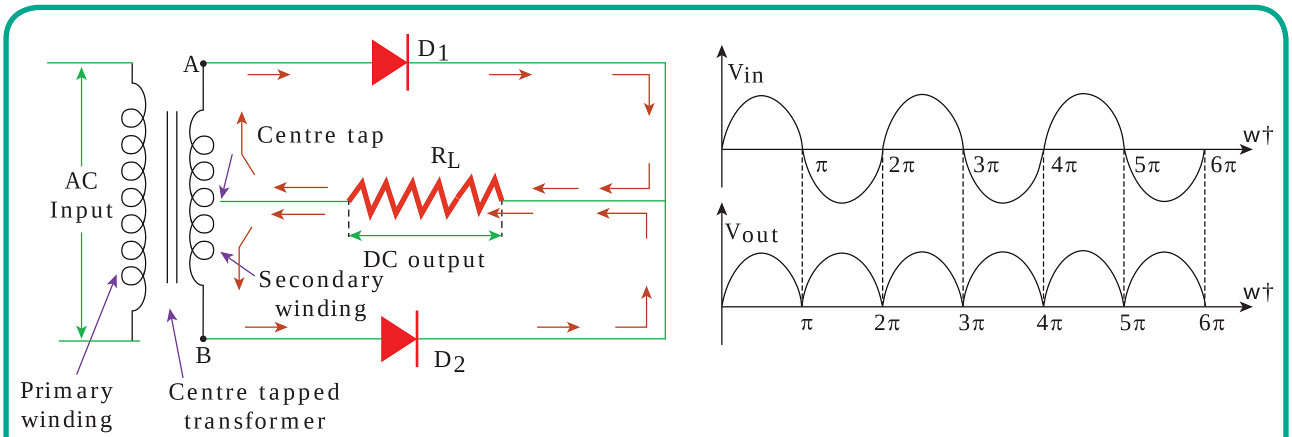
In the centre-tapped full wave rectifier, two diodes are used. These are connected to the centre-tapped secondary winding of the transformer. Centre-tapped winding divides the total secondary voltage into equal parts.

The circuit diagram of full-wave rectifier is shown in Figure 4.11(a). The primary winding of the centre-tapped transformer is applied with the A.C Voltage. The two diodes D_1 and D_2 are connected to the secondary winding of the transformer. These diodes D_1 and D_2 conduct both the positive and negative half cycle of the input waveform.

For the positive half cycle of the input, diode D_1 is connected with upper end (A) positive terminal and diode D_2 is connected with lower end (B) negative terminal. Thus, the diode D_1 is in forward bias and the diode D_2 is in reverse bias. As the diode D_2 is in reverse bias, it does not conduct. Only the diode D_1 starts conducting and thus current flows from diode D_1 and it appear across the load R_L. As a result, the positive half cycle of the input is appeared at the load R_L.

During the negative half cycle of the input, diode D_2 is connected with lower end (B) and diode D_1 is connected with upper end (A). The diode D_1 is in reverse bias and does not conduct, only diode D_2 starts conducting and thus current flows from diode D_2 and appears across the load R_L.

By comparing the current through the load R_L in the positive and negative half cycles, it can be concluded that the



(a) Full-wave rectifier

(b) Input and output waveforms

Figure 4.11 Full-wave Rectifier

direction of the current is same. Thus, the frequency of rectified output voltage is two times that of the input frequency.

The input and output waveforms are shown in Figure 4.11(b).

$$\textit{Output of the full wave rectifier} = \frac{2E_{max}}{\pi}$$

$$\therefore \textit{ The Average DC Voltage} = 0.637\,E_{max}$$

$$\textit{Ripple Factors} = 2 \times f$$

$$\textit{Efficiency} = 81.2\%$$

4.6 FULL-WAVE BRIDGE RECTIFIER

As the centre-tapped transformer is expensive and is difficult to implement, bridge rectifier was developed. In this, four diodes are arranged in the form of a bridge-configuration to produce the desired output. Figure 4.12 shows the full wave bridge rectifier circuit.

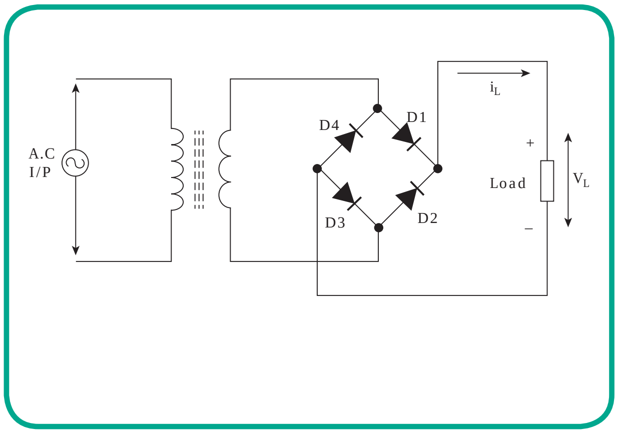


Figure 4.12 **Full-wave bridge rectifier circuit**

The four diodes labeled D1, D2, D3 and D4 are arranged in series pairs with only two diodes conducting current during each half-cycle. During the positive half cycle of the supply, diodes D1 and D3 conduct in series while D2 and D4 are reverse-biased. The current flows through the load is shown in Figure 4.13.

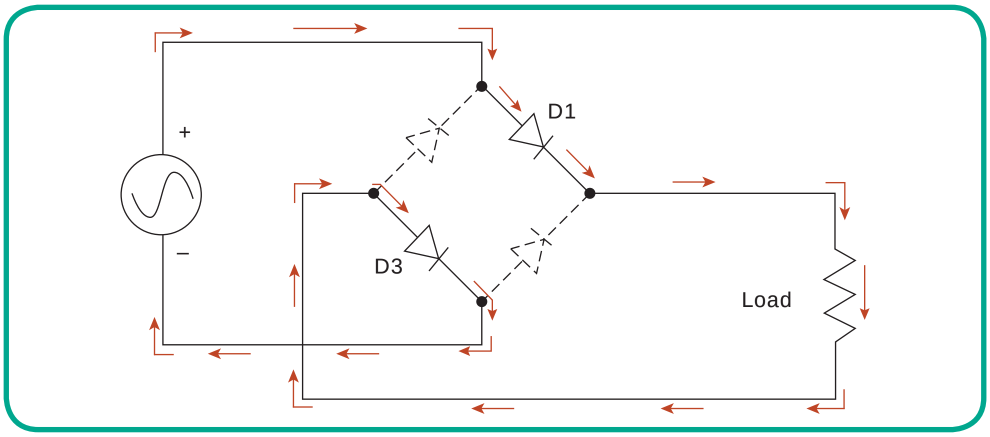


Figure 4.13 **Current flows through the load**

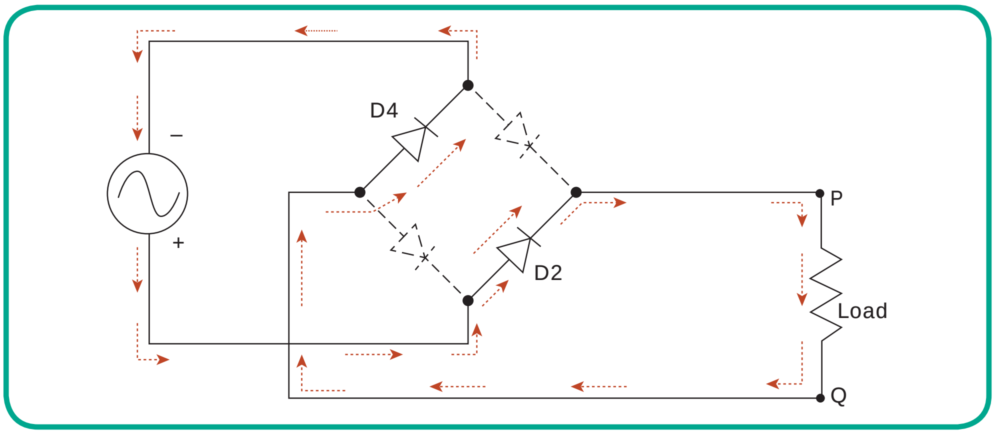


Figure 4.14 **Current flows through the load**

During the negative half cycle of the supply, diodes D2 and D4 conduct in series while D1 and D3 are reverse-biased. The current flows through the load as shown in Figure 4.14.

The bridge rectifier is also called the full wave rectifier as it produces an output pulse for each half-cycle of the input sine wave. The input and output waveforms are shown in figure 4.15.

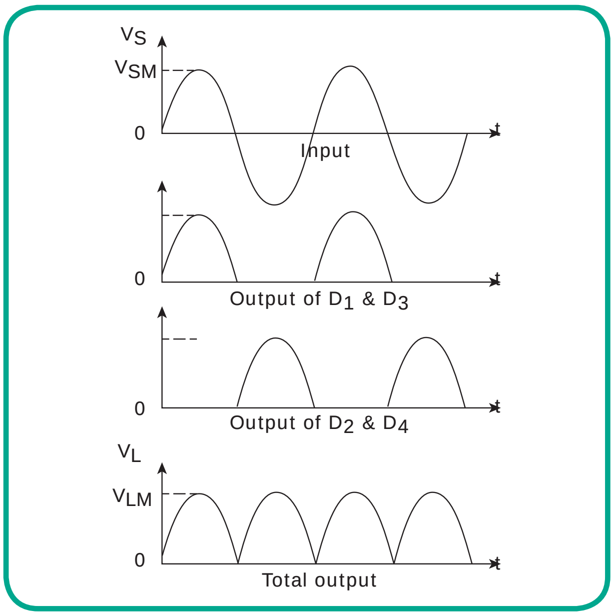


Figure 4.15 **Input and output waveforms of bridge rectifier**

$$Output\ of\ the\ full\ wave\ rectifier = \frac{2E_{max}}{\pi}$$

$$\therefore\ The\ Average\ DC\ Voltage = 0.637\,E_{max}$$

$$Ripple\ Factors = 2 \times f$$

$$Efficiency = 81.2\%$$

4.7 FILTER CIRCUITS

To remove the AC components or filter-out them in a rectifier circuit, a filter circuit is used. A filter circuit is a device to remove the AC components of the rectifier output (pulsating DC – it is also called ripples), but allows the DC components to reach the load.

A filter circuit consists of passive elements, i.e., inductors, capacitors, resistors and their combinations. Some of the important filters are given below.

1. Inductor or Choke filter
2. Capacitor filter
3. RC filter
4. Inductor-Capacitor filter (LC filter)
5. π or pie filter or CLC filter

4.7.1 Inductors Filter or Choke Filter

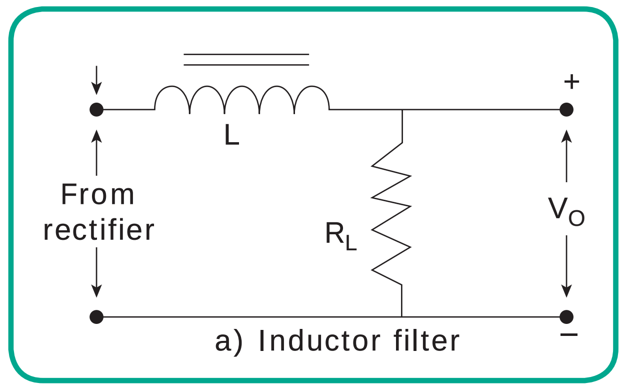


Figure 4.16 **Inductor filter circuit**

Figure 4.16 shows the inductor filter circuit. This type of filter consists of an inductor L inserted between the rectifier and the load resistance R_L. The rectifier output contains AC components as well as DC components. When the output passes through the inductor it offers a high resistance to the AC components and no resistance to the DC components. Therefore, an AC component of the rectifier is blocked and only DC component reaches at the load.

4.7.2 Capacitor Filter

Figure 4.17 shows the capacitor filter circuit. In this filter, an electrolytic capacitor is used as a reservoir capacitor, because it acts as a temporary storage for the power supply output current. During the rise of voltage cycle, it gets charged and this charge is supply to the load during the fall in the voltage cycle.

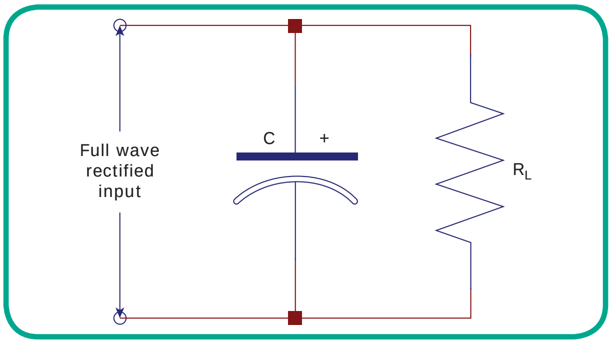


Figure 4.17 **Capacitor Filter**

This process is repeated for each cycle and thus the ripple is reduced across the load. It is popular, because of its low cost, small size, less weight and good characteristics.

4.7.3 RC Filter

RC low pass filters can be used to remove the ripple remaining after the reservoir capacitor. Figure 4.18 shows the RC filter circuit. In RC designs, the resistance of R must be a fairly low value, as the entire load current (may be several amperes) must pass through it generating huge amount of heat. The disadvantage of RC filter is the loss of DC voltage across each R. Hence, the RC filter is suitable only for very small loads.

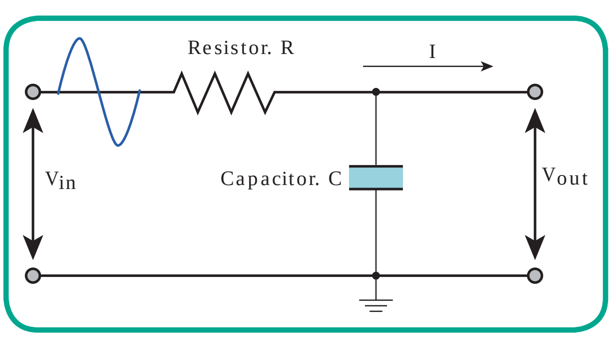


Figure 4.18 **RC Filter**

4.7.4 LC Filter

Figure 4.19 shows the LC filter circuit. In inductor filter, the ripple factor is directly proportional to the load resistance. On the other hand in a capacitor filter, it is varying inversely proportional to the load resistance. Hence, if we combine the inductor with the capacitor filter, the ripple factor will become almost independent of the load resistor.

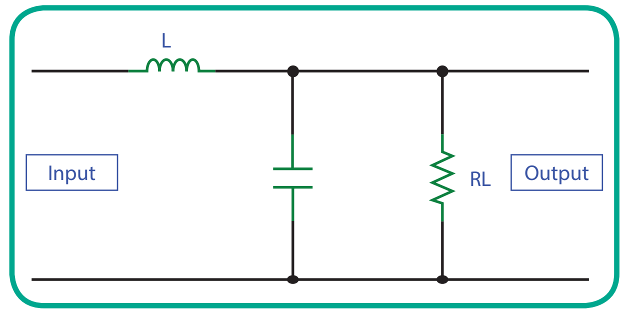


Figure 4.19 **LC Filter**

4.7.5 CLC Filter or Pie Filter (π filter)

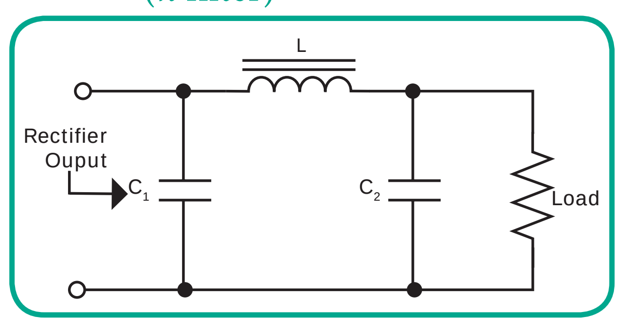


Figure 4.20 **CLC (or) Pi Filter**

Figure 4.20 shows the CLC filter circuit. It consists of one inductor and two capacitor connected across its each end. The three components are arranged in shape of Greek letter pie (π). The input capacitor C_1 is selected to offer very low reactance to the respective frequency, hence major parts of filtering is done by C_1. Most of the remaining ripples are removed by the combining action of L and C_2. This filter is used for the low current equipment.

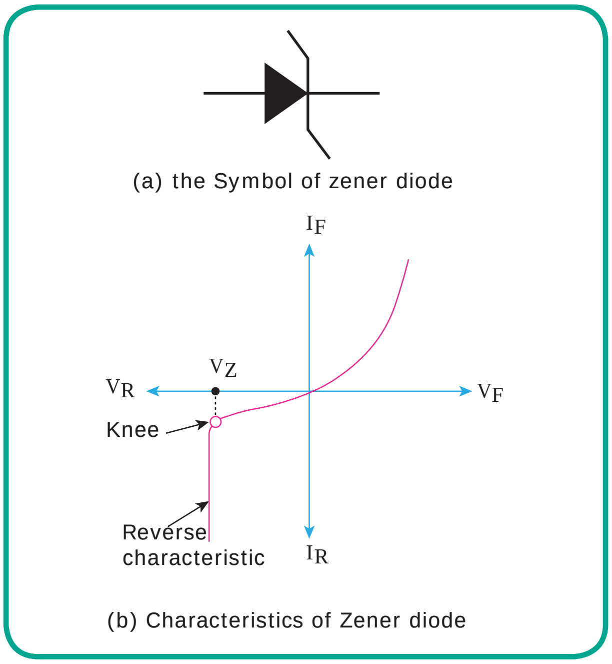
4.8 VOLTAGE REGULATOR

Voltage Regulator is used to maintain a constant DC output voltage

Zener diode is used as voltage regulator.

> *"A properly doped crystal diode which has a sharp breakdown voltage is known as a zener diode."*

It may be seen that it is just like an ordinary diode except that the bar is turned into z-shape.



(a) the Symbol of zener diode

(b) Characteristics of Zener diode

Figure 4.21 Symbol and characteristics of zener diode

The figure 4.21(a) shows the symbol of Zener diode. Figure 4.21(b) shows the characteristics of Zener diode. The breakdown or zener voltage depends upon the amount of doping. If the diode is heavily doped, depletion layer will be thin and consequently the breakdown of the junction will occur at a lower reverse voltage. On the other hand, a lightly doped diode has a higher breakdown voltage.

DO YOU KNOW?

Who discovered zener diode?
Clarence Melvin Zener.

Clarence Melvin Zener (December 1, 1905 – July 2, 1993) was the American physicist who first (1934) described the property concerning the breakdown of electrical insulators. These findings were later exploited by Bell Labs in the development of the Zener diode, which was duly named after him.

Clarence Melvin Zener.

The following points may be noted about the zener diode:

T3PFF6

1. A zener diode is like an ordinary diode except that it is properly doped so as to have a sharp breakdown voltage
2. A zener diode is always reverse connected i.e. it is always reverse biased.
3. A zener diode has sharp breakdown voltage, called zener voltage V_Z.
4. When forward biased, its characteristics are just those of ordinary diode.
5. The zener diode is not immediately burnt just because it has entered the breakdown region. As long as the external circuit connected to the diode current to less than burn out value, the diode will not burn out.

4.9. VOLTAGE DOUBLER

Voltage doubler is the circuit where we get twice the input voltage, like if we supply 10 V, we will get 20 V at the output. Generally, transformers are there to step-up or step-down the voltage but sometimes transformers are not feasible of their size and cost. The quick, easy and practical solution is to double the voltage using a voltage doubler. A full-wave voltage doubler is a voltage multiplier with a multiplication factor of two. A full-wave voltage doubler is shown in the Figure 4.22.

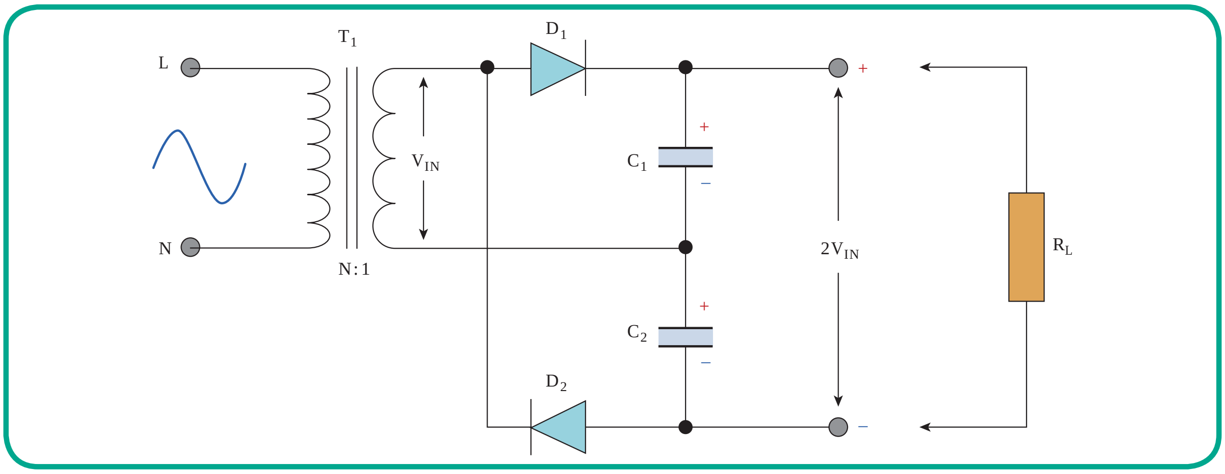


Figure 4.22 Voltage Doubler

When the secondary voltage is positive, the first diode D_1 is forward biased and the primary capacitor (C_1) charges to approximately Vp. During the negative half cycle, the second diode D_2 is forward biased and the secondary capacitor (C_2) charges to approximately Vp. Therefore, the output voltage 2Vp is taken across the two capacitors in series.

Thus the output voltage is double as that of the input AC voltage. It is important to note that the voltage rating of the capacitor should be higher than the AC voltage.

4.10. AC ADAPTER

Figure 4.23 shows an AC adapter. An AC adapter (AC/DC adapter) or (AC/DC converter) is a power supply built into an AC main power plug. AC adapters are also known by various other names such as plug-pack or plug-in-adapter or wall-wart.

DO YOU KNOW?

What type of charger is used in mobile phone?

The method of power supply employed in mobile phone charger is Switched Mode Power Supply (SMPS)

AC adapters typically have a single AC or DC output that is conveyed over a hard-wired cable to a connector, but some adapters have multiple outputs that may be conveyed over one more cables. "Universal" AC adapters have interchangeable input connectors to accommodate different AC mains voltages.

Figure 4.23 AC Adapter

Adapters with AC outputs may consist of a passive transformer (plus a few diodes in DC output adapters) or they may employ switched-mode circuitry. AC adapters consume power and produce electric and magnetic fields even when not connected to a load.

LEARNING OUTCOMES

Student will capable of

1. **Need of power supply**
2. **Types of AC to DC supply**
3. **Efficiency of power conversion**
4. **Power supply applications**
5. **Conversion of AC to DC, DC to DC AND DC to AC.**

GLOSSARY

S. No	Terms	Explanation
1	Step down transformer	Transformer in which the output AC voltage is less than the input AC voltage
2	Rectification	Process that converts alternating current to direct current
3	Regulator	Device or circuit that maintains a desired output under changing conditions
4	RPS	Abbreviation of Regulated Power Supply. It maintains a constant output voltage under changing load conditions
5	Ripple voltage	The small variation in DC voltage that remains after filtering in a Power supply
6	Filter	Network consisting of capacitors, resistors and inductors used to pass certain frequencies and block others
7	Center tapped transformer	Circuit that make use of a center tapped transformer and two diodes to provide fullwave rectification
8	Full wave Rectifier	Rectifier that makes use of the full AC wave in both the positive and negative half cycles
9	Cycle	When a repeating wave rises from zero to a positive maximum then back to zero and on to a negative maximum and back to zero it is said to have completed one cycle
10	Peak to peak	Difference between the maximum positive and maximum negative values of an AC waveform

QUESTIONS

PART A

I. Choose the Best Answer

1. The output of a rectifier is

   a) Pulsating DC b) Pure DC c) Pure AC d) None of the above

2. Which of the following rectifier needs four diodes

   a) Half-wave rectifier b) Full-wave rectifier c) Bridge rectifier d) None of the above

3. The maximum efficiency of a half-wave rectifier is

   a) 20.3% b) 80.6% c) 50% d) 40.6%

4. Center tapped transformer is used in a rectifier.

   a) Bridge type b) Half-wave c) Full-wave d) None of the above

5. In a full wave rectifier, if AC supply is 50 Hz then AC ripple in the output is

   a) 50 Hz b) 100 Hz c) 25 Hz d) 200 Hz

6. A bridge type rectifier uses ……………….. diodes.

   a) Four b) Two c) Three d) One

7. For high voltage applications, we use

   a) Center tap rectifier b) Bridge rectifier

   c) Half-wave rectifier d) None of the above

8. In filter circuits, we generally use ……………… capacitors.

   a) Mica b) Paper c) Air d) Electrolytic

9. In a half-wave rectifier, if AC supply is 50 Hz, then AC supply is 50 Hz, then AC ripple in the output is

   a) 100 Hz b) 25 Hz c) 50 Hz d) 12.5 Hz

10. The maximum rectification efficiency in full wave rectifier is

    a) 100% b) 81.2% c) 66.6% d) 40.6%

PART B

II. Answer in few sentences

1. What are the types of power conversion?
2. What is meant by PSU?
3. What is rectification?
4. Give the use of voltage regulator.
5. What is half-wave rectifier?
6. Give the uses of filter circuits.
7. Write short notes on an AC adapter.
8. Write important points of zener diode

PART C

III. Answer the following Questions.

1. Draw the block diagram of power supply unit and explain each block.
2. Explain half-wave rectifier with circuit diagram.
3. Explain the different types of power conversion.
4. Draw and explain CLC or pie filter.

PART D

IV. Answer the following Questions.

1. Draw the circuit diagram of full wave rectifier and explain its working function.
2. Draw the circuit diagram of bridge rectifier and explain its working function.
3. Explain the function of voltage doubler.

Answer Key

1. **(a)**	2. **(c)**	3. **(d)**	4. **(c)**	5. **(b)**
6. **(a)**	7. **(b)**	8. **(d)**	9. **(c)**	10. **(b)**

TRANSISTORS AND AMPLIFIERS

CHAPTER 5

T3YBGT

வாரி பெருக்கி வளம்படுத்து உற்றவை
ஆராய்வான் செய்க வினை. – குறள் 512

விளக்கம்:
பொருள் வரும் வழிகளைப் பெருக்கச் செய்து, அவற்றால் வளத்தை உண்டாக்கி, வரும் இடையூறுகளை ஆராய்ந்து நீக்க வல்லவனே செயல் செய்ய வேண்டும்.

English Couplet 512:

Who swells the revenues, spreads plenty o'er the land,
Seeks out what hinders progress, his the workman's hand.

Couplet Explanation:
Let him do (the king's) work who can enlarge the sources (of revenue), increase wealth and considerately prevent the accidents (which would destroy it).

CONTENT

LEARNING OBJECTIVES

After the completion of this Chapter, the student will

1. Understand the basic structure of the bipolar junction transistor (BJT)
2. Working principles of PNP and NPN transistor
3. Know the transistor configuration as an amplifier (or) a switch
4. Difference between voltage amplifier and power amplifier.
5. Construction and configurations of transistors (common base, common emitter, common collector)
6. Application of transistors

Try not to become a man of success, but rather try to become a man of value.

– Albert Einstein

5.1. INTRODUCTION

Transistors are the fundamental building block of modern electronic devices basically used for controlling, amplifying and generating electrical signals. When a third doped element is added to a crystal diode in such a way that two PN junctions are formed, the resulting device is known as transistor. The transistor is an entirely new type of electronic device, capable of achieving amplification of weak signals.

DO YOU KNOW?

Who invented the transistor?

The transistor was invented by William Schockley, John Bardeen, Walter Brattain.

History of Transistor

The transistor was first developed by John Bardeen, Walter Brattain and William Shockley at Bell Labs in December 1947. This new device has characteristics that could overcome many of the fundamental limitations of vacuum tubes. Transistors have very long life, small in size, light weight and mechanically rugged and required no filament.

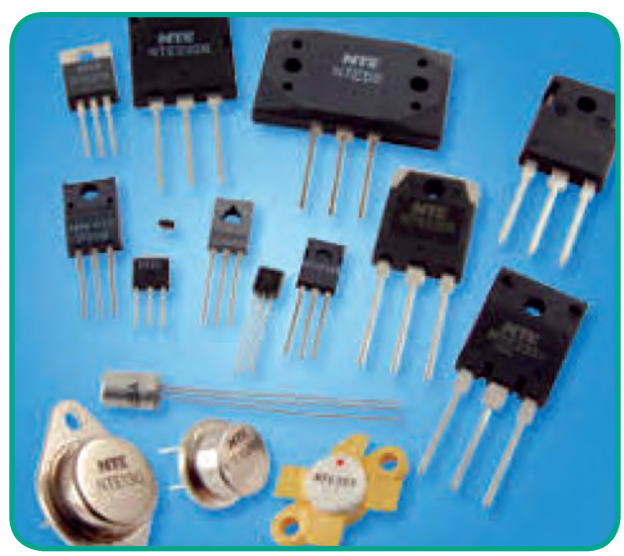
William Shockley

Initially, transistors were made from semiconductor material called Germanium. Further, silicon has been used as a semiconductor material, since silicon has superior performance at higher operating temperature. It is now widely used.

5.2. TRANSISTOR

It is made up of semiconductor material such as Si and Ge. Usually, it comprises of three terminals namely, base, emitter and collector for providing connection to the external circuit. Today, some transistors are packaged individually and many transistors are fabricated according to the design of an embedded integrated circuits.

A transistor is a semiconductor device used to amplify or switch electronic signals and electrical power.



Types of Transistors

Types of transistors

1. Bipolar Junction Transistor (BJT)
2. Field Effect Transistor (FET)
3. SMD Transistor
4. DIAC, TRIAC and IGBT.

5.3 BIPOLAR JUNCTION TRANSISTOR

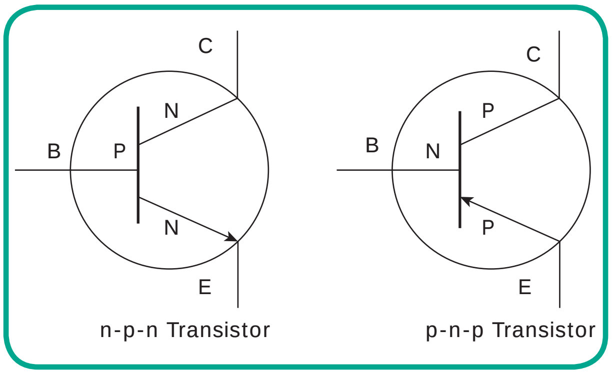


Figure 5.1 **NPN and PNP Transistors**

It is nothing but an ordinary transistor. These transistors are amongst the most widely used devices for amplification of all types of electrical signals and intermediate devices in discrete circuits, i.e., circuits made from individual components rather than integrated circuits. Transistors are also used in circuits together with integrated circuits, since it is often more practical to use discrete transistors where higher power output is needed, which is higher than the integrated circuit output.

There are two types of transistor

1. PNP Transistor
2. NPN Transistor

Remembering Tips:	
P-Points	N-Never
N-iN	P-Points
P-Permanently	N-iN

Figures 5.1 and 5.2 show the symbol and structure of PNP and NPN transistors, respectively. In PNP transistors, a thin layer of N type is sandwiched between two P type layers. In NPN transistors, a thin layer of P type is sandwiched between two N type layers.

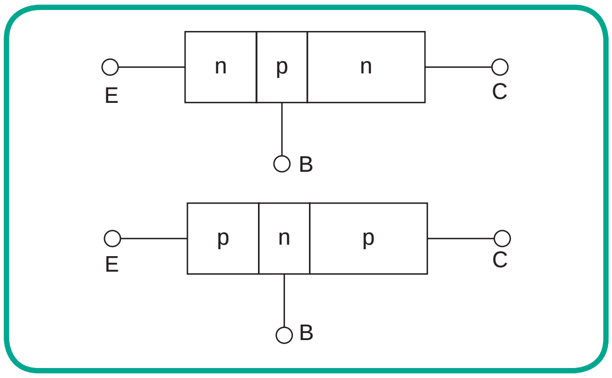


Figure 5.2 **PNP and NPN Transistor**

5.3.1 SMD Transistor

A SMD transistor is a type of transistor that is directly soldered on the copper points in the surface of printed circuit board.

Advantage of SMD Transistor

1. There is no need to make holes in printed circuit board.
2. Smaller in size.

5.4. SOME FACTS ABOUT THE TRANSISTOR

1. The transistor has three regions, namely emitter, base and collector.
2. The base is much thinner than the emitter while collector is wider than both.
3. The emitter is heavily doped, so that, it can inject large number of charge carriers (electrons or holes) into the base.
4. Usually the emitter is heavily doped, the base is lightly doped and very thin and the collector is moderately doped to collect majority carriers from the emitter.

5. The transistor has two PN junctions termed as the base-emitter junction and the base-collector junction.
6. In order to operate the transistor properly the two junctions must have the correct DC bias voltages.
7. Base-emitter junction is forward biased whereas base-collector junction is reverse biased.
8. The resistance of first junction is very small compared with the second junction. So, forward bias voltage applied to the first junction is very small compared to the second junction.

5.4.1 Transistor Lead Identification

There are three leads in a transistor viz. collector, emitter and base. When a transistor is to be connected in a circuit, it is necessary to know which terminal is which. The identification of the leads of transistor varies with manufacture. However, there are three systems in general use as shown in the figure 5.3.

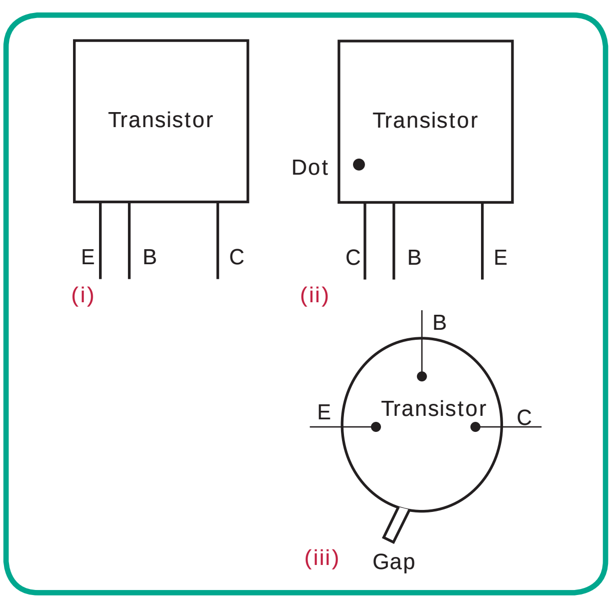


Figure 5.3 Transistor lead identification

i) When the leads of a transistor are in the same plane and unevenly spaced [see figure 5.3 (i)], they are identified by the position and spacing of leads. The centre lead is the base lead. The collector lead is identified by the large spacing existing between it and the base lead. The remaining lead is the emitter.

ii) When the leads of a transistor are in the same plane but evenly spaced [see figure 5.3 (ii)], the centre lead is the base, the lead identified by dot is the collector and the remaining lead is emitter.

iii) When the leads of a transistor are spaced around the circumference of a circle [see figure 5.3 (iii)], the three leads are generally in emitter, base, collector order clockwise from a gap.

5.5. TRANSISTOR TESTING

To test a transistor, we measure one diode junction with the multimeter leads positioned in one way and then we flip the leads of the multimeter to the reverse the polarities. One side of the diode junction should read a very high resistance of above 1MΩ of resistance (the anode to cathode side) and the other side should read a much lower resistance, may be of a few hundred thousand ohms (the cathode to anode side). This test has to be done for each junction. Figure 5.4 shows how to test a transistor.

For a single transistor there are six combination of testing the junctions as given below:

1. Emitter to Base
2. Base to Emitter
3. Emitter to Collector
4. Collector to Emitter

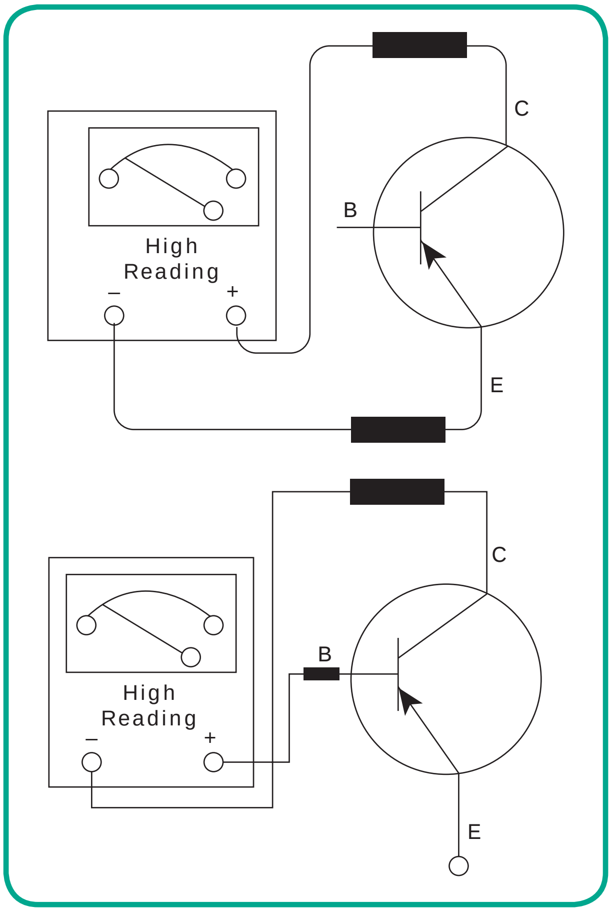


Figure 5.4 **PNP and NPN transistor testing**

5. Collector to Base
6. Base to Collector

Each pair should have one side with very high resistance (> 1 MΩ) and the other side with a much lower resistance of a few hundred thousand ohms. If this is the case for all the transistor leads, the transistor is good. If not, transistor is defective.

5.6. TRANSISTORS BIASING

Various Methods of Transistor Biasing

1. Base resister method or fixed bias method
2. Collector to base bias method or feedback bias method
3. Self-bias or emitter or voltage divider bias

Transistor biasing is the process of setting a transistor DC operating voltage or current condition to the required level. So that, any AC input signal can be amplified correctly by the transistor.

5.6.1 Fixed Bias

Fixed biasing circuit is very simple, biasing conditions can be easily set, calculations are very simple but there is no loading of source by the biasing circuit. Hence, this method is rarely used, due to poor stabilization. Figure 5.5 shows fixed biased method of a transistor.

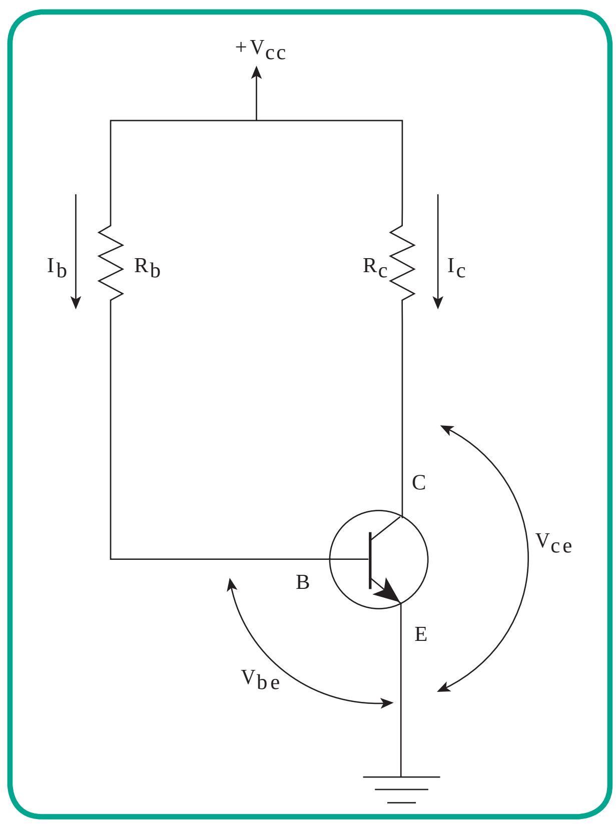


Figure 5.5 **Fixed bias**

5.6.2 Feedback Bias

This method is simple and provides better biasing stability but the circuit provides a negative feedback resulting in reduced amplifier gain and fairly high stability factor.

Figure 5.6 shows feedback bias of a transistor.

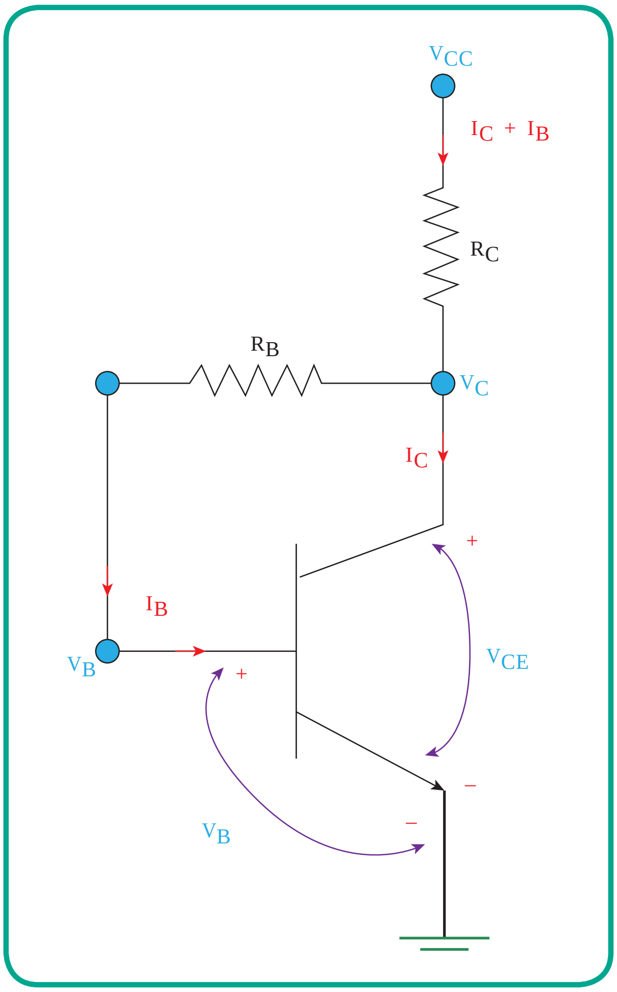


Figure 5.6 Feedback Bias

5.6.3 Voltage Divider Bias

This is the most commonly used biasing arrangement, as it provides good bias stability. The emitter resistance R_E provides stabilization. The resistance R_E causes a voltage drop in a direction so as to reverse bias the emitter junction. Since the emitter base junction has to be forward biased, the base voltage is obtained from the supply through R_1-R_2 network. The net forward bias across the emitter base junction is equal to V_B–DC voltage drop across R_E. The DC bias circuit is independent of transistors β to avoid the loss of AC signal. A capacitor having large capacitance is connected across R_E to bypass the unwanted AC fluctuations. Figure 5.7 shows voltage divider method of a transistor.

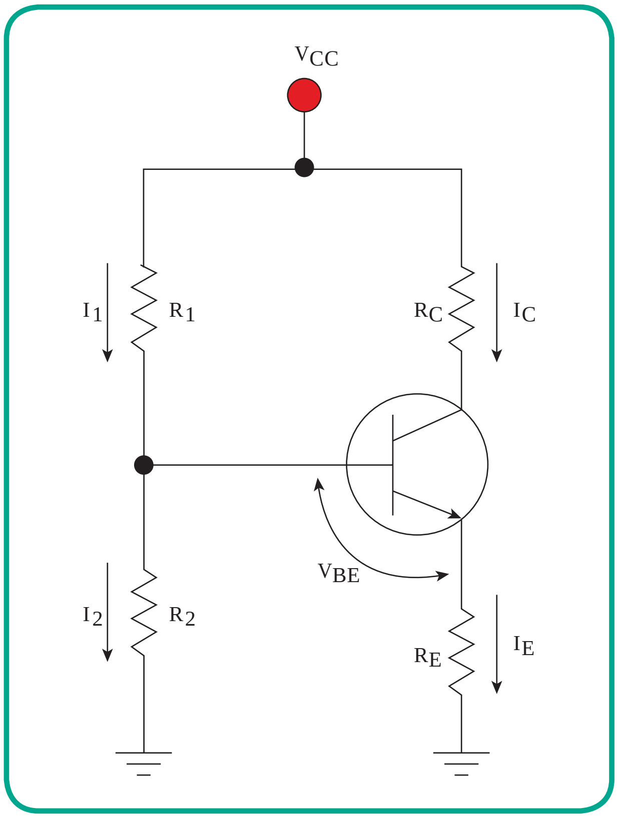


Figure 5.7 Voltage divider bias

5.7 WORKING OF NPN & PNP TRANSISTOR

5.7.1 Working of NPN transistor

Figure 5.8 shows the NPN transistor with forward bias to the emitter-base junction and reverse bias to collector-base junction. The forward bias causes the electrons in the n- type emitter to flow towards the base. This constitute the emitter current I_E. As these electrons flow through the p-type base, they tend to combine with holes. As the base is lightly doped and very thin, only a few electrons (less than 5%) combine with holes to constitute base current I_B. The reminder electrons (more than 95%) cross-over into the collector region to constitute collector current I_C. In this way, almost the entire emitter current flows to the collector circuit. It is clear that emitter current is the sum of collector and base current, i.e. $I_E = I_B + I_C$.

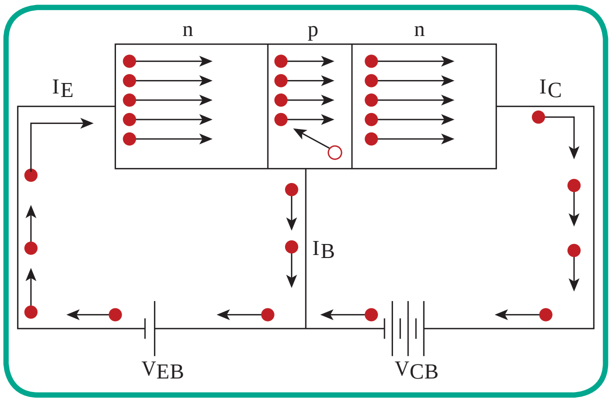


Figure 5.8 Working of NPN transistor

5.7.2 Working of PNP Transistor

Figure 5.9 shows the basic connection of a PNP transistor. The forward bias causes the holes in the p type emitter to flow towards the base. This constitutes the emitter current I_E. As these holes cross into n-type base, they tend to combine with electrons. As the base is lightly doped and very thin, only a few holes (less than 5%) combine with the electrons. The remainder holes (more than 95%) cross into the collector region to constitute the collector current I_C. In this way, almost the entire emitter current flows into the collector region. It may be noted that

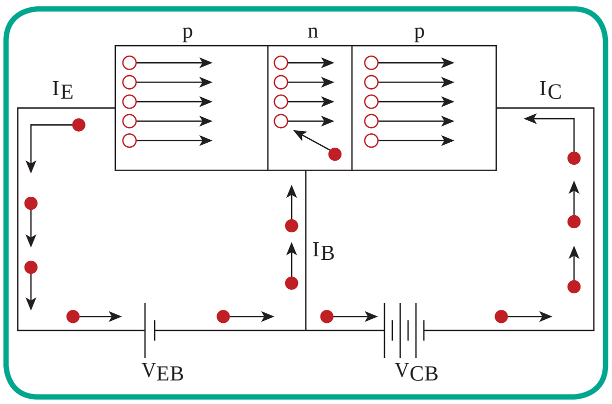


Figure 5.9 Working of PNP transistor

current conduction within PNP transistor is by holes. However, in the external connecting wires, the current is still denoted by electrons.

5.8 OPERATING MODES OF TRANSISTORS

Depending on the biasing conditions like forward or reverse, transistors have three major modes of operation namely, cut-off, active and saturation regions.

Active Mode: In this mode, transistor is generally used as a current amplifier. In active mode, two junctions are differently biased, that means, emitter-base junction is forward biased and collector-base junction is reverse biased. In this mode, current flows between emitter and collector and amount of current flow is proportional to base current.

Cut-Off Mode: In this mode, both collector-base junction and emitter-base junction are reverse biased. This in turn not allows the current to flow from collector to emitter, when the base-emitter voltage is low. In this mode, device is completely switched-off; as a result, the current flowing through the device is zero.

Saturation Mode: In this mode of operation, both the emitter-base and collector-base junctions are forward biased. Current flows freely from collector to emitter, when the base-emitter voltage is high. In this mode, device is fully in the switched ON condition.

DO YOU KNOW?

Transistor acts as a switch.

5.8.1 Transistor as a Switch

Transistor as a switch is a very important and useful application.

Transistor as a Switch – ON

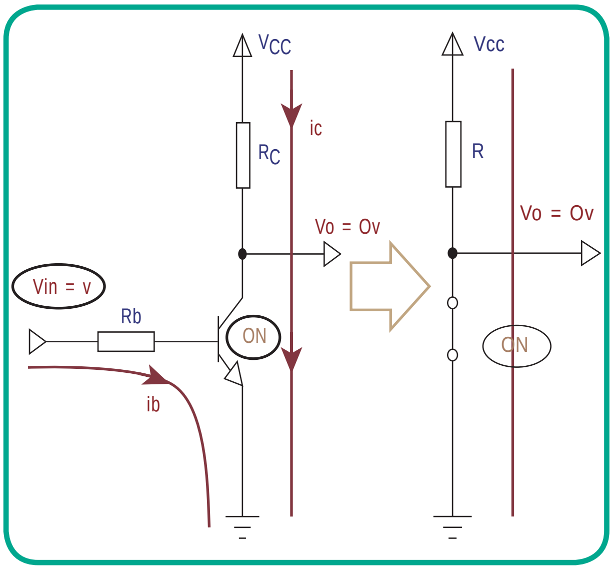


Figure 5.10 **Transistor as a switch – ON Position**

Figure 5.10 shows transistor as a switch (ON position). Transistor will become ON (saturation), when a sufficient voltage V is given to the input. During this condition, the collector-emitter voltage V_{CE} will be approximately equal to zero, i.e., the transistor acts as a short-circuit. For a silicon transistor, it is equal to 0.3 V.

Thus, the collector current $I_C = V_{CC}/R_E$ will flow through the circuit.

Transistors as a Switch – OFF

Figure 5.11 shows transistor as a switch OFF position. Transistors will be in OFF (cut off), when the input (V_{in}) is equal to zero. During this state, the transistor acts as an open- circuit and thus the entire voltage V_{CC} will be available at the collector.

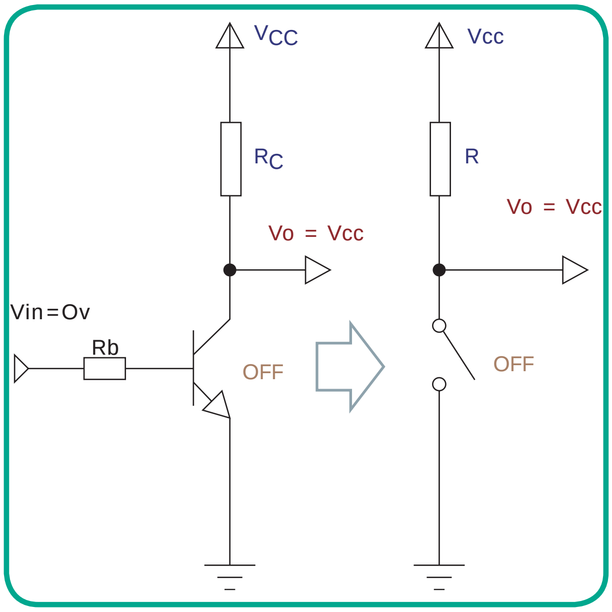


Figure 5.11 **Transistor as a switch – OFF Position**

5.8.2 Transistor as an Amplifier

We can use a transistor as an amplifier for increasing the strength of the weak signal. With the help of circuit diagram, we explain how a transistor acts as an amplifier.

Figure 5.12 shows the basic circuit of a transistor amplifier. The weak signal to be amplified is applied as the input signal between the emitter-base junction and the output is taken across the load R_L. For faithful amplification, the input circuit is forward biased and the output circuit is reverse biased. For this purpose, we apply dc voltage.

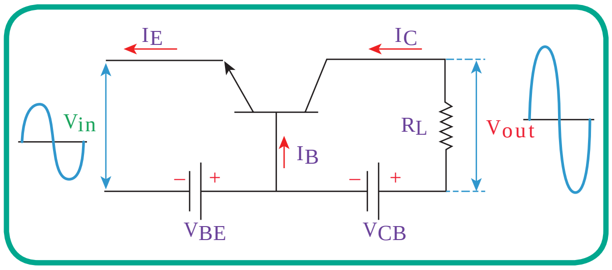


Figure 5.12 **Basic Circuit of a transistor amplifier**

As we know, the input circuit has low resistance; consequently, a small change in the signal voltage occurs at the input circuit lead to an appreciable change in the emitter current. Due to the transistor action, change in emitter current causes a similar change in the collector current. Now, the collector current flows through a high load resistance R_L, which produces a large voltage across R_L.

Thus, the weak signal applied in the input circuit appears in the amplified form in the collector circuit. In this way, transistor acts as an amplifier. For power amplification, heat sinks are used to fix the transistor in order to dissipate the heat generated from the power transistor.

5.8.3 Heat Sink

A metal plate specially designed to conduct and radiate heat from an electronic component. A layer of material place within the outer skin of high-speed aircraft to absorb heat.

5.9 TRANSISTOR CONFIGURATIONS

A transistor is a three terminal device, (i.e., base, emitter, collector). But it require four terminals for connecting it in circuits.

(i.e.) Two terminals for input, two terminals for output.

Hence one of the terminal is made common to the input and output circuits. Common terminal is grounded.

Types of Configuration

Three types of configuration is available

1. *Common Base configuration (CB)*
2. *Common Emitter configuration(CE)*
3. *Common Collector configuration(CC)*

5.9.1. Common Base Configuration

Common base configuration circuit is shown in figure 5.13. Here base is grounded and it is used as the common terminal for both input and output.

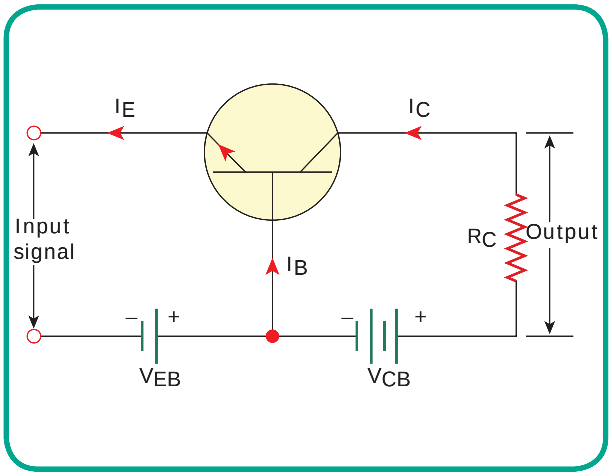


Figure 5.13 Common base configuration

It is also called as grounded base configuration. Emitter is used as an input terminal whereas collector is the output terminal.

Input characteristics:

It is defined as the characteristic curve drawn between input voltage to input current whereas output voltage is constant.

To determine input characteristics, the collector base voltage V_{CB} is kept constant at zero and emitter current I_E is increased from zero by increasing V_{EB}. This is repeated for higher fixed values of V_{CB}.

A curve is drawn between emitter current I_E and emitter base voltage (V_{EB}) at constant collector base voltage (V_{CB}) is shown in figure 5.14 .When V_{CB} is zero emitter base junction is forward biased. So it behaves as a diode so that emitter current increases rapidly.

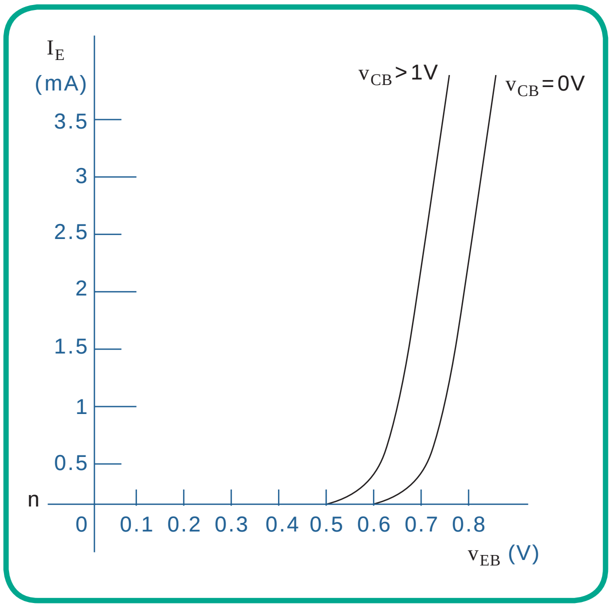


Figure 5.14 **Input characteristics**

Output Characteristics

It is defined as the characteristic curve drawn between output voltage to output current whereas input current is constant.

To determine output characteristics, the emitter current I_E is kept constant at zero and collector current I_c is increased from zero by increasing V_{CB}. This is repeated for higher fixed values of I_E.

A curve is drawn between the output voltage (V_{CB}) to output current (I_C) at constant input current (I_E) as shown in the figure 5.15.

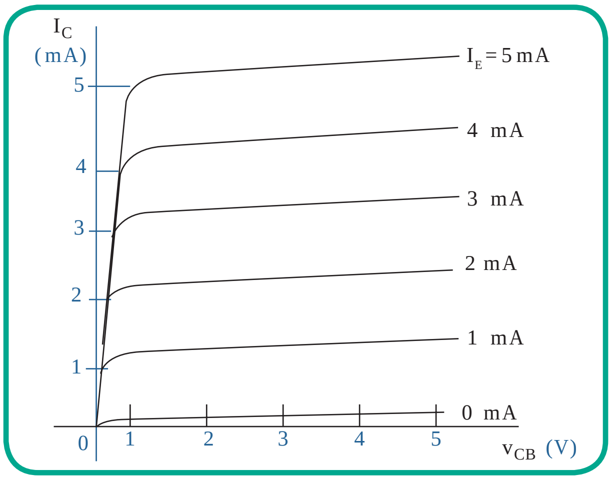


Figure 5.15 **Output characteristics**

Current Amplification Factor (α).

It is the ratio of output current to input current. In common base connection, the input current is the emitter current I_E and output current is the collector current $I_{C.}$

The ratio of change in collector current (ΔI_C) to the change in emitter current (ΔI_E)at constant collector base voltage V_{CB} is known as current amplification factor i.e.

$$\propto = \frac{\Delta I_C}{\Delta I_E} \text{ at constant } V_{CB}$$

5.9.2. Common Emitter Configuration

Common emitter configuration is shown in the figure 5.16. Here emitter is grounded and it is used as the common terminal for both input and output. It is also called as grounded emitter configuration. Base is used as an input terminal whereas collector is the output terminal.

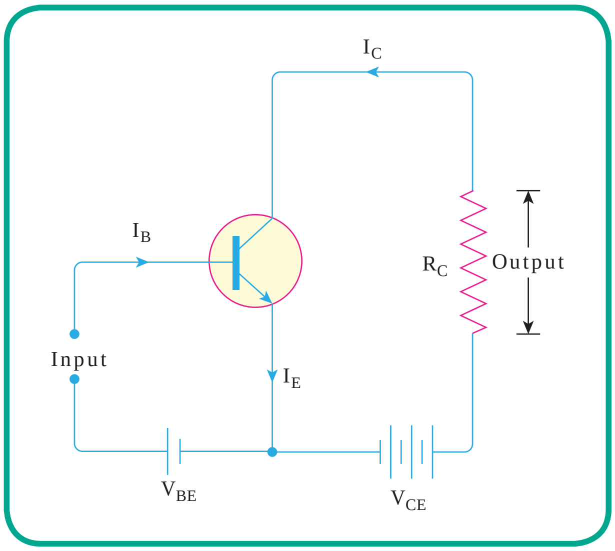


Figure 5.16 **Common Emitter configuration**

Input Characteristics

It is defined as the characteristic curve drawn between input voltage to input current whereas output voltage is constant.

To determine input characteristics, the collector base voltage V_{CE} is kept constant at zero and base current I_B is increased from zero by increasing V_{BE}. This is repeated for higher fixed values of V_{CE}.

A curve is drawn between base current and base emitter voltage at constant collector base voltage is shown in figure 5.17. Here the base width decreases. So curve moves right as V_{CE} increases.

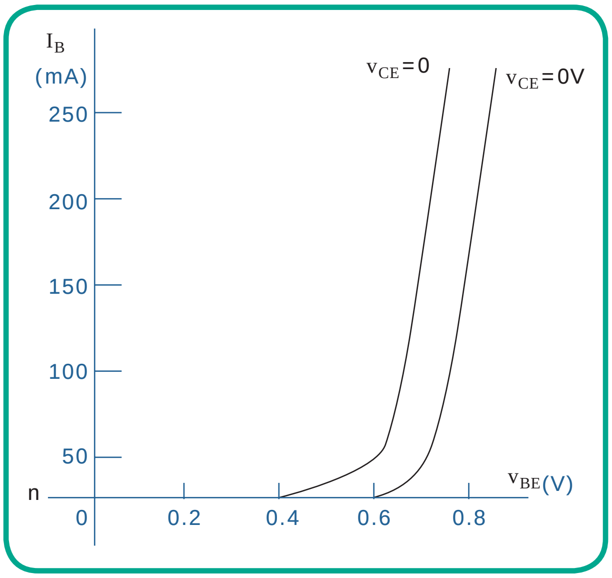


Figure 5.17 **Input characteristics**

Output Characteristics

It is defined as the characteristic curve drawn between output voltage to output current whereas input current is constant.

To determine output characteristics, the base current I_B is kept constant at zero and collector current Ic is increased from zero by increasing V_{CE}. This is repeated for higher fixed values of I_B.

From the characteristic it is seen that for a constant value of I_B, Ic is independent of V_{CB} and the curves are parallel to the axis of V_{CE} as shown in the figure 5.18.

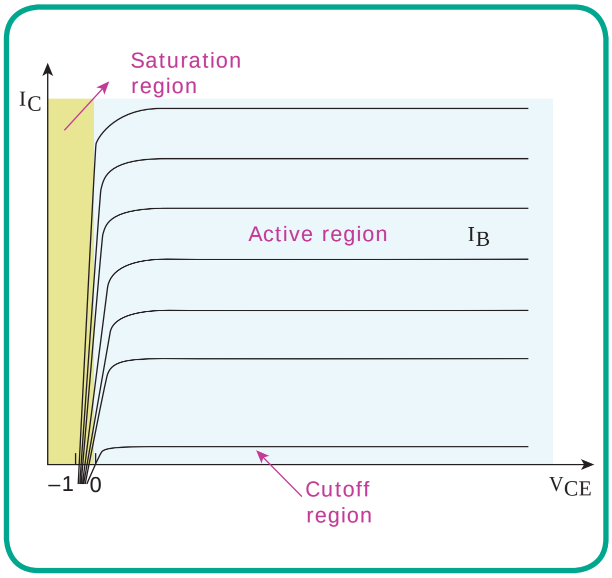


Figure 5.18 **Output characteristics**

Base current amplification factor (β).

It is the ratio of output current to input current. In common emitter connection, the input current is the base current I_B and output current is the collector current $I_{C.}$

The ratio of change in collector current to the change in base current at constant collector emitter voltage V_{CE} is known as current amplification factor i.e.

$$\beta = \frac{\Delta I_C}{\Delta I_B} \text{ at constant } V_{CE}$$

5.9.3 Common Collector Configuration

In common collector configuration circuit is shown in figure 5.19. Here collector is grounded and it is used as the common terminal for both input and output. It is also called as grounded collector configuration. Base is used as an input terminal whereas emitter is the output terminal.

Input Characteristics

It is defined as the characteristic curve drawn between input voltage to input current whereas output voltage is constant.

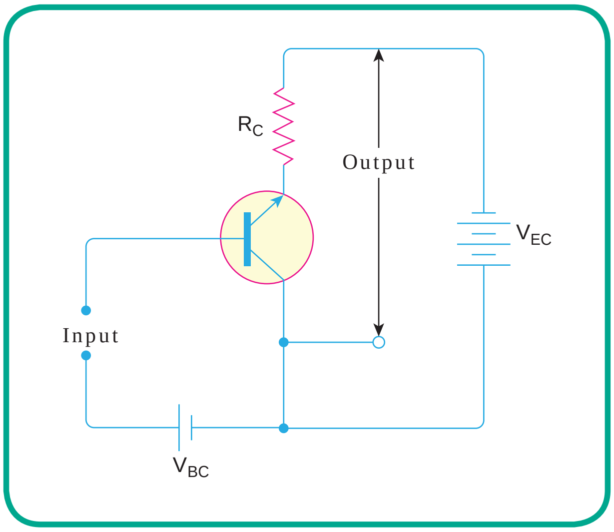


Figure 5.19 Common collector configuration

To determine the input characteristics, the emitter collector voltage V_{EC} is kept constant at zero and base current I_B is increased from zero by increasing V_{BC}. This is repeated for higher fixed values of V_{EC}. A curve is drawn between base current and base emitter voltage at constant collector base voltage is shown in figure 5.20.

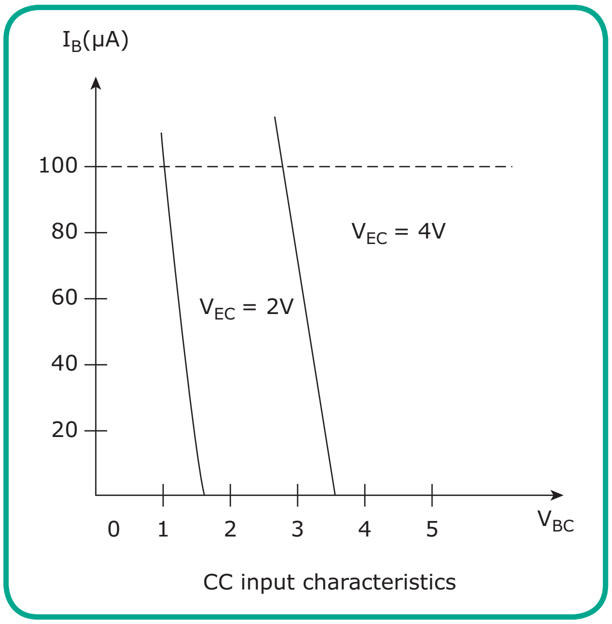


Figure 5.20 Input characteristics

Output Characteristics

It is defined as the characteristic curve drawn between output voltage to output current whereas input current is constant.

To determine output characteristics, the base current I_B is kept constant at zero and emitter current I_E is increased from zero by increasing V_{EC}. This is repeated for higher fixed values of I_B.

From the characteristic it is seen that for a constant value of I_B, I_E is independent of V_{EC} and the curves are parallel to the axis of V_{EC} as shown in the figure 5.21

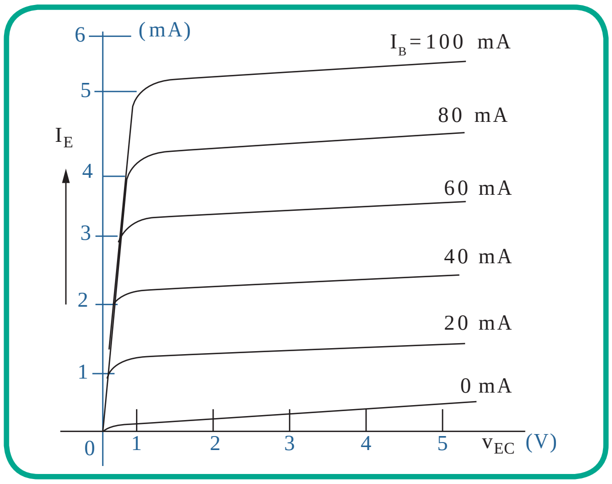


Figure 5.21 Output characteristics

Current Amplification Factor(γ).

It is the ratio of output current to input current. In common collector connection, the input current is the base current I_B and output current is the emitter current $I_{E.}$

The ratio of change in emitter current to the change in base current at constant emitter collector voltage V_{EC} is known as current amplification factor i.e.

$$\gamma = \frac{\Delta I_E}{\Delta I_B} \text{ at constant } V_{EC}$$

5.10 MULTISTAGE TRANSISTOR AMPLIFIER

A transistor circuit containing more than one stage of amplification is known as multistage transistor amplifier.

In a multistage amplifier, a number of single amplifiers are connected in cascade

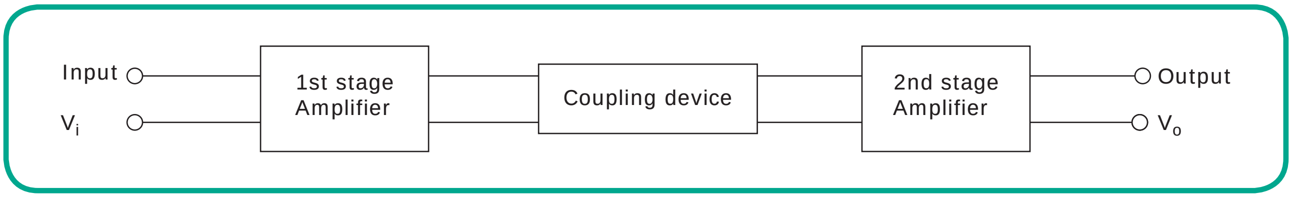


Figure 5.22 Multistage transistor amplifiers

arrangement, i.e., output of the first-stage is connected to the input of the second-stage through a suitable coupling device, and so on. Figure 5.22 shows the block diagram of the multistage transistor amplifier.

Coupling of Amplifiers

Name of Coupling	Name of Multistage Amplifier
RC coupling	RC coupled amplifier
Transformer coupling	Transformer coupled amplifier
Direct coupling	Direct coupled amplifier

5.10.1 RC Coupled Transistor Amplifier

This is the most popular type of coupling because it is cheap and provides excellent audio fidelity over a wide range of frequency. It is usually employed for voltage amplification.

Figure 5.23 shows two stages of an RC coupled amplifier. A coupling capacitor C_C is used to connect the output of first-stage to the base (i.e. input) of the second-stage and so on. As the coupling from one stage to next is achieved by a coupling capacitor followed by a connection to a shunt resistor, therefore, such amplifiers are called resistance-capacitance coupled amplifiers.

Operation: When AC signal is applied to the base of the first transistors, it appears in the amplified form across its collector load R_C. Then, the amplified signal is given to the base of next stage through coupling capacitor C_C. The second stage does further amplification of the signal. In this way, the cascaded (one after another) stages amplify the signal and the overall gain is considerably increased.

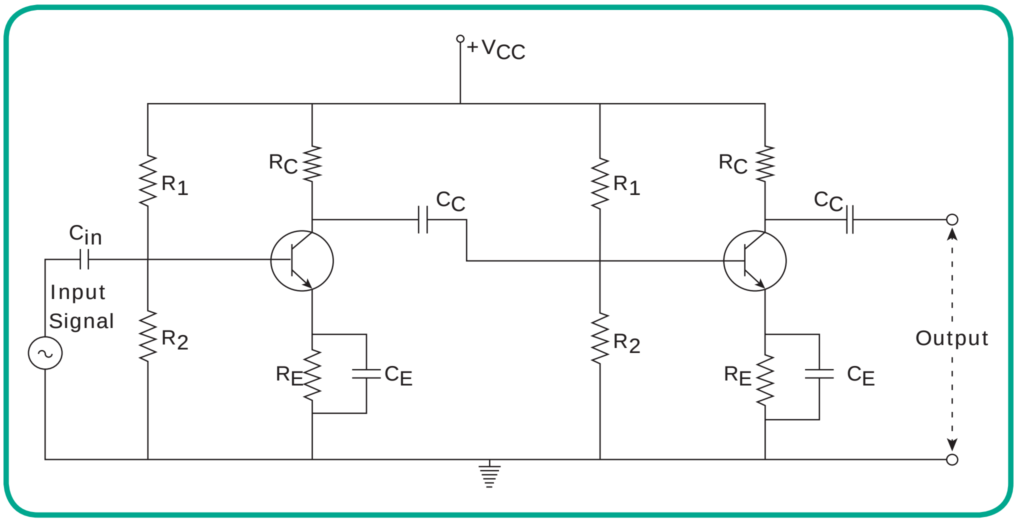


Figure 5.23 Stages of an RC coupled amplifier

Advantages

1. It has excellent frequency response. The gain is constant over the audio frequency range, which is the region of most importance for speech, music etc.,
2. Low Cost
3. The circuit is very compact

Disadvantages

1. The RC coupled amplifiers have low voltage and power gain
2. They have the tendency to become noisy with age, particularly in moist climates
3. Impedance matching is poor

Application

They are widely used as voltage amplifier, (e.g.) in the initial stages of public address system.

5.10.2 Direct-Coupled Amplifier

There are many applications in which extremely low frequency (less than 4 Hz) signals have to be amplified, (e.g.,) amplifying photoelectric current, thermo couple current, etc. The coupling devices such as capacitor and transformers cannot be used because the electrical sizes of these components become very large at extremely low frequencies. Under such situations, the output of one stage is directly connected to the next stage without any coupling device. This type of coupling is known as direct coupling.

Circuit details: Figure 5.24 shows the circuit of three stage direct coupled amplifier. It uses complementary transistors. Thus, the first stage uses npn transistor, the second stage uses pnp transistors and so on. This arrangement makes the design very simple. The output from the collector of first transistor T_1 is fed to the input of the second transistor T_2 and so on.

Operation: The weak signal is applied to the input of first transistor T_1. Due to transistor action, an amplified output is obtained across the collector load R_C of the transistor T_1.This voltage drives the base of the second transistor T_2 and amplified output is obtained across its collector load. In this way, direct coupled amplifier raises the strength of weak signal.

Advantages

1. The circuit arrangement is simple.
2. Low cost because of the absence of expensive coupling devices.

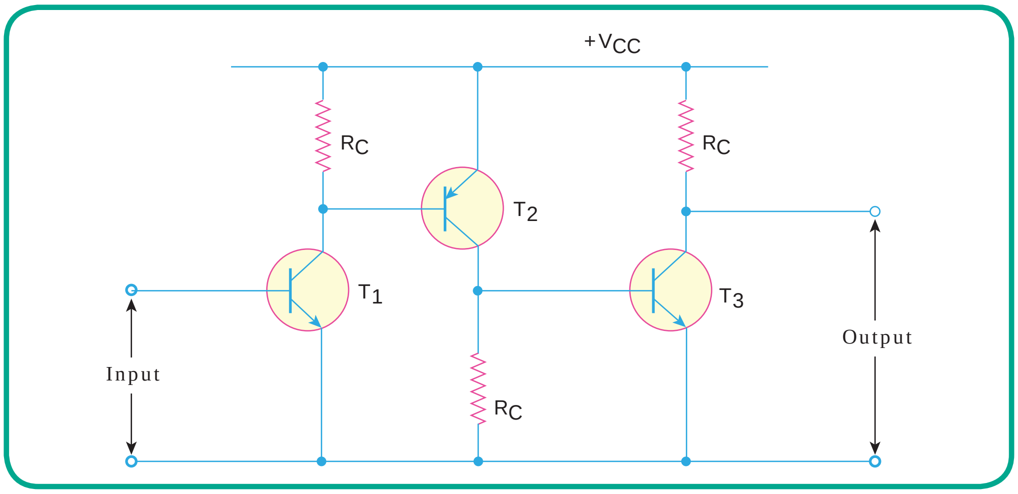


Figure 5.24 Stages of Direct Coupled Amplifier

Disadvantages

1. It cannot be used for amplifying high frequencies.
2. The operating point is shifted due to temperature variations.

Applications

Direct coupled amplifiers are used in television receivers, computers, regulator circuits and other electronics equipment.

5.11 VOLTAGE AMPLIFIER AND POWER AMPLIFIER

5.11.1 Voltage Amplifier.

A transistor amplifier which raises the voltage level (amplitude) of the signals is known as voltage amplifier

The first few stages in the multistage amplifier have the function of only voltage amplification. However, the last stage is designed to provide maximum power is known as power stage. Figure 5.25 shows the voltage amplifier and its use in audio circuits.

The first-stage voltage amplifier is called pre-amplifier. The next stage voltage amplifier is called driver amplifier.

5.11.2 Power Amplifier

A transistor amplifier which raises the power level of the signals is known as power amplifier.

A power amplifier is required to deliver a large amount of power and as such it has to handle large current. In order to achieve high power amplification, the following features are incorporated in such amplifiers.

1. The size of power transistor is made considerably larger
2. The base is made thicker to handle large currents
3. Transformer coupling is used for impedance matching

Voltage Gain: The voltage gain of an amplifier is given by

$$A_V = \frac{\text{Voltage of the output AC signal}}{\text{Voltage of the input AC signal}}$$

In common emitter circuits, voltage gain is calculated using

$$A_V = \beta \times \frac{R_L}{R_{in}}$$

Where β is current amplification factor, R_L is the collector load resistance and R_{in} is the resistance of base-emitter junction

Current Gain: Current gain of an amplifier is given by

$$A_I = \frac{\text{Output current}}{\text{Input current}},$$

Power Gain: Power gain of an amplifier is calculated by the formula

$$A_P = A_I \times A_V$$

Where Ap is the power gain, A_I is the current gain and A_V is the voltage gain.

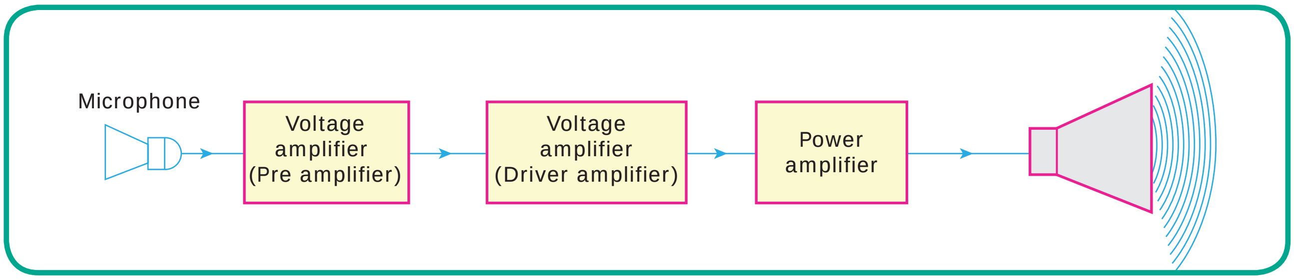


Figure 5.25 Voltage Amplifier

Comparison between voltage and power amplifier is given in the Table 5.1.

Table 5.1 Comparison of Voltage and Power Amplifier

SI. No.	Parameters	Voltage amplifier	Power amplifier
1.	β	High (> 100)	Low (5 to 20)
2.	R_C	High (4 – 10kΩ)	Low
3.	Coupling	Usually RC coupling	Invariably transformer coupling
4.	Input voltage	Low (a few mV)	High (2- 4V)
5.	Collector current	Low(1 mA)	High(>100mA)
6.	Power output	Low	High
7.	Output impedance	High (12kΩ)	Low(200Ω)

5.12 CLASSIFICATION OF POWER AMPLIFIERS

Transistor power amplifiers handle large signals. Many of them are driven so hard by the large input signal that the collector current is either cut-off or is in the saturation region, during the majority portion of the input cycle. Therefore, such amplifiers are generally classified according to the conduction angle produced.

1. Class A Power Amplifier
2. Class B Power Amplifier
3. *Class C Power Amplifier*

5.12.1 Class A power Amplifier

If the collector current flows at all times during the full cycle of the input signal, then the power amplifier is known as Class A power amplifier.

If the conduction angle is 360º, which means all of the input cycle is reproduced, the amplifier is called Class A power amplifier. Figure 5.26 shows the Class A power amplifier. The efficiency of Class A power amplifier is very low (less than 30%).

5.12.2. Class B Power Amplifier

If the collector current flows only during the positive half cycle of the input signal, it is called as Class B power amplifier.

If the conduction angle is 180º, which means that during the positive half cycle of the input signal the input circuit is forward biased and hence collector current flows. However, during the negative half cycle of the input signal the input circuit is reverse biased and no collector current flows. Such amplifiers are mostly used for power amplification in push-pull arrangement. In such an arrangement,

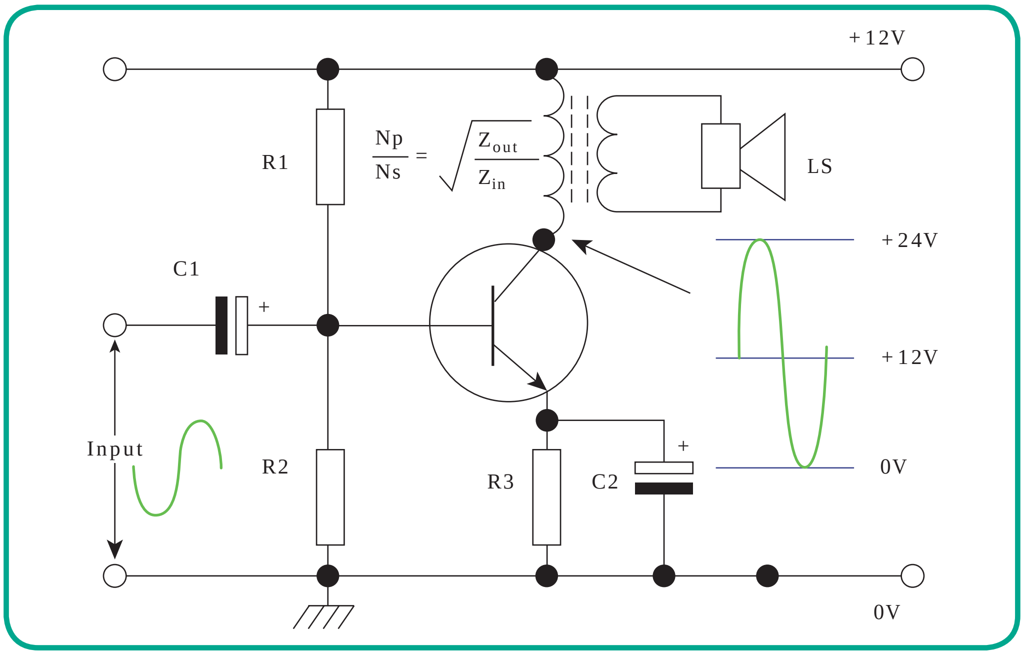


Figure 5.26 Class A Power Amplifier

two transistors are used in Class B operation as shown in Figure 5.27. One transistor amplifies the positive half cycle of the signal while the other amplifies the negative half cycle. The efficiency of Class B power amplifier is around 75%.

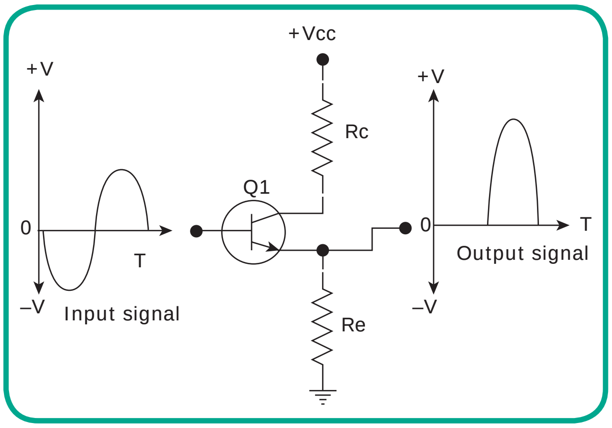


Figure 5.27 Class B Power Amplifier

5.12.3. Class C Power Amplifier

If the collector current flows for less than half cycle of the input signal, it is called as class C power amplifier. Class C power amplifiers are used as tuned amplifiers.

Class C amplifier has a conducting angle of class than 90º and is biased beyond cut- off. Figure 5.28 shows a Class C power amplifier with the associated input-output waveforms. The efficiency of Class C power amplifier is around 90%.

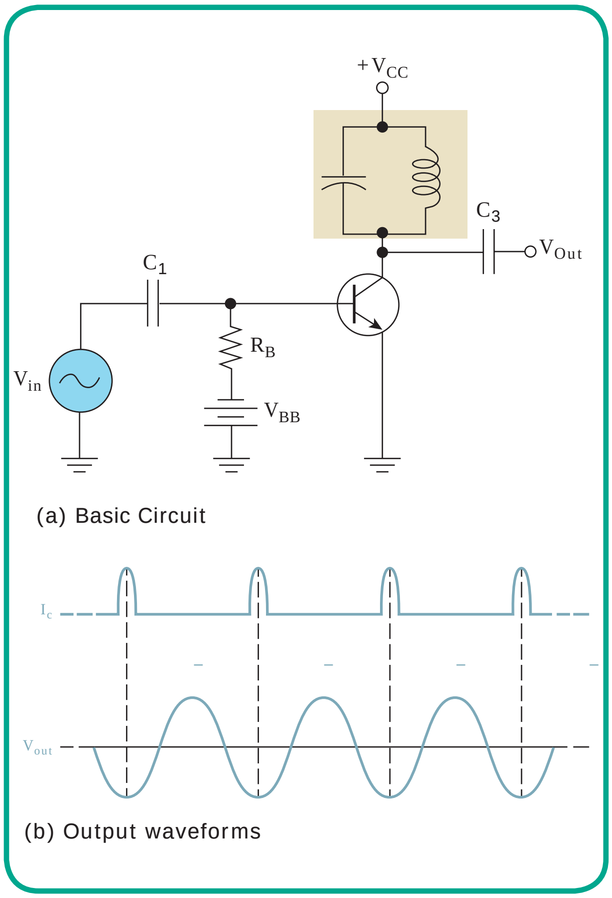


Figure: 5.28 Class C Power Amplifier

5.12.4 Complementary Symmetry Amplifier

Complementary Symmetry is based on the principle of assembling a push-pull class B amplifier without requiring centre-tapped transformers, at the input and output stages.

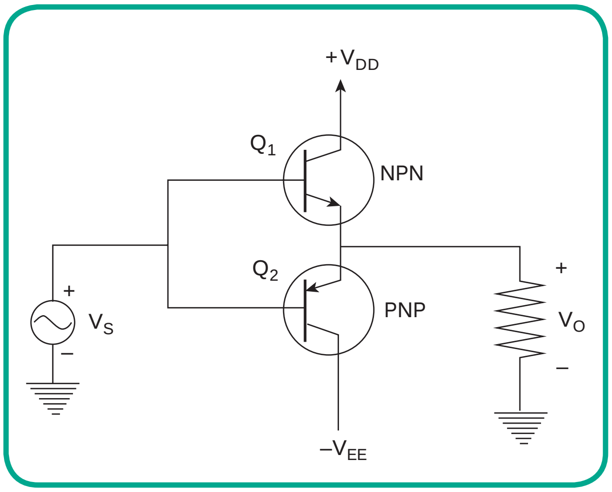


Figure 5.29 **Simplified complementary symmetry amplifier**

Figure 5.29 shows the transistor push-pull amplifier using complementary symmetry. It employs one NPN and one PNP transistor and requires no centre-tapped transformers. The circuit action is follows. During the positive half cycle of the input signal, transistor Q_1(the NPN transistor) conducts current while Q_2(the PNP transistor) is cut-off. During the negative half cycle of the input signal, transistor Q_2 (the PNP transistor) conducts current while Q_1 (the NPN transistor) is cut-off.

In this way, NPN transistor amplifies the positive half cycles of the signal while the PNP transistor amplifies the negative half cycles of the signal. Note that we generally use an output transformer (not centre tapped) for impedance matching.

Advantages

1. This circuit does not require transformer. It reduces both weight and cost.
2. Equal and opposite input signal voltages are not required.

Disadvantages

1. It is difficult to get a pair of transistors (NPN and PNP) having similar characteristics.
2. It requires both positive and negative supply voltages.

Application

This type of amplifier is used in stereo amplifiers.

5.12.5 Differential Amplifier

A differential amplifier amplifies the voltage difference between the two inputs. An example of a configuration of the amplifier is connecting the emitters of two transistors with equal characteristics as shown in Figure 5.30(a). The voltage difference applied to the base of these transistors is amplified. Figure 5.30(b) shows the waveforms at each node of the differential amplifier.

The output of differential amplifier circuitry shown in Figure 5.30(a) is further amplified and applied utilizing negative feedback. Presently, high performance and inexpensive differential amplifiers, so-called operational amplifiers (integrated circuit), are available in the market.

If two input signals of the differential amplifier are the same, the (differential) output will be nearly zero. That is, common mode noise of the input is greatly attenuated, and only the signal is amplified. A function of the amplifier to reduce the common-mode noise is CMRR (common- mode rejection ratio).

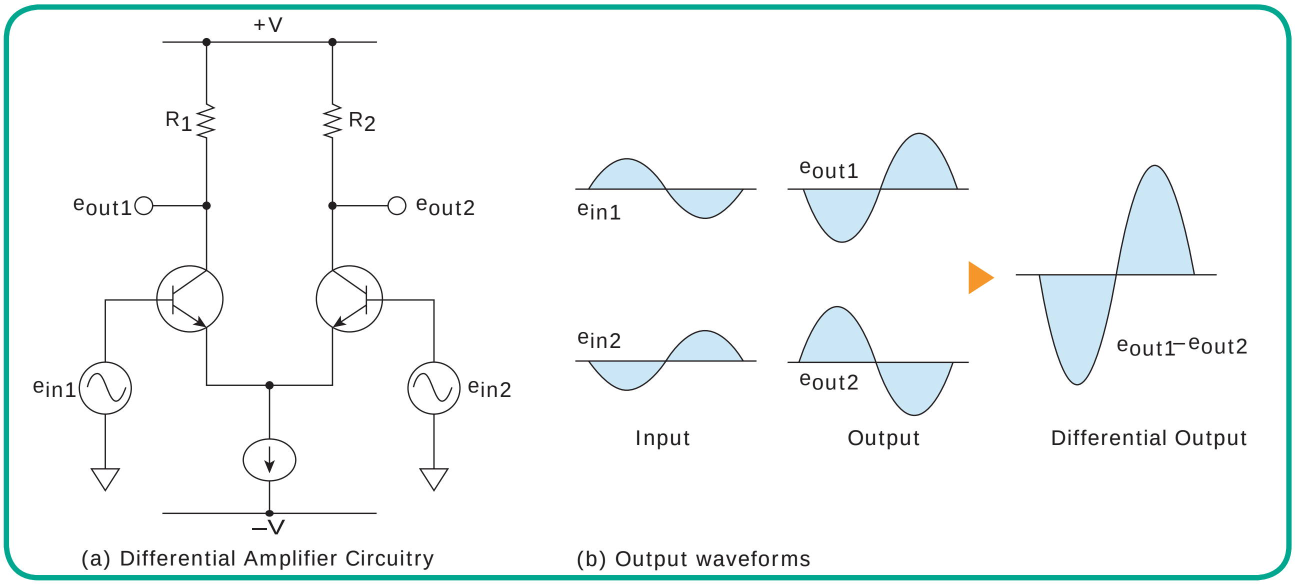


Figure: 5.30 **Differential Amplifier**

5.13 FEED BACK IN AMPLIFIERS

> *The process of injecting a fraction of output energy back to the input is known as feedback*

There are two basics types of feedback in amplifiers

1. Positive Feedback
2. Negative Feedback

5.13.1 Positive Feedback

When the feedback energy (voltage or current) is in phase with the input signal and thus enhances the input signal, the feedback is called positive feedback or regenerative feedback. This is illustrated in Figure 5.31.

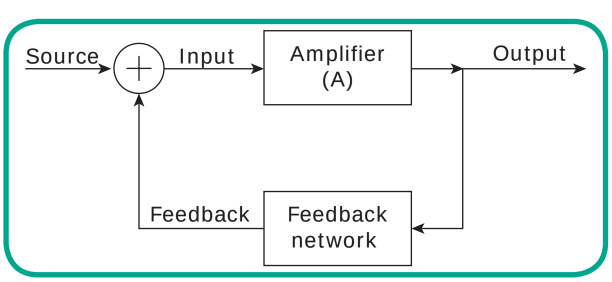


Figure 5.31 **Positive Feedback**

5.13.2 Negative Feedback

When the feedback energy (voltage or current) is out-off phase with the input signal and thus oppose the input signal, the feedback is called negative feedback or degenerative feedback. This is illustrated in Figure 5.32.

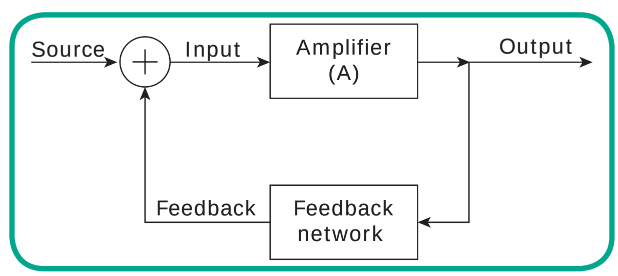


Figure 5.32 **Negative Feedback**

5.14 DISTORTION IN AMPLIFIERS

The change in output wave-shape from the input wave-shape of an amplifier is known as distortion.

The distortion can be classified as follows

1. Amplitude distortion
2. Phase distortion
3. Frequency distortion

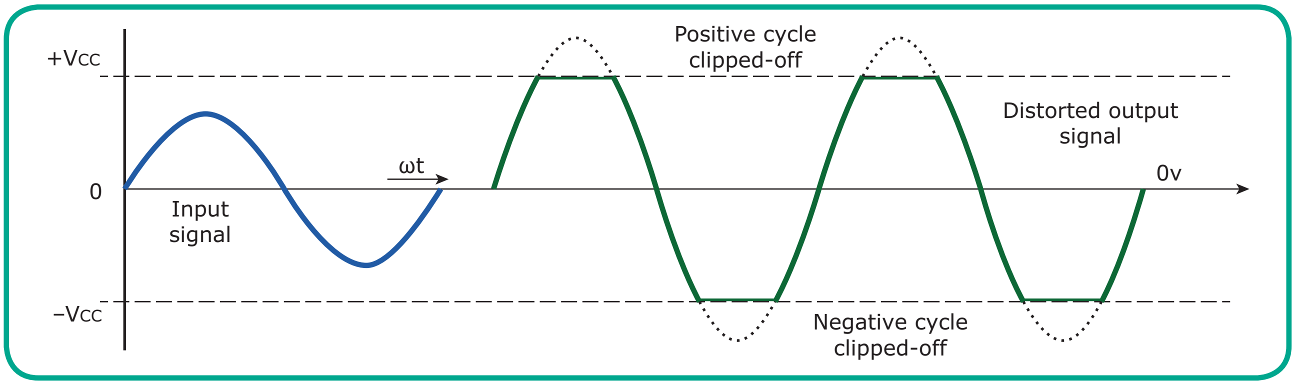


Figure 5.33 Amplitude Distortion

5.14.1 Amplitude Distortion

The amplitude distortion occurs, when the characteristic change of the amplifier is non-linear. This is shown in Figure 5.33

Figure 5.33 shows that the negative peak is flattened. This flattened portion is called as amplitude distortion. Low power supply and improper bias are the other reasons for this type of distortion. Since power amplifiers handles large signals and therefore, the problem of distortion immediately arises. For the comparison of two power amplifiers, the one which has the less distortion, is the better than the other.

5.14.2 Phase Distortion (or) Delay Distortion

Phase distortion is a type of amplifier distortion which occurs in a non-linear transistor amplifier when there is a time delay between the input signal and its appearance at the output.

5.14.3 Frequency Distortion

Frequency distortion is another type of amplifier distortion which occurs in a transistor amplifier when the level of amplification varies with frequency.

Noise: A noise is nothing but an unwanted voltage enters in the input of the amplifier. This may happen due to internal and external disturbances. Outside noises can be created through electrical devices such as motors, fluorescent bulbs. Internal noise can occur due to the inductor or coil used in the amplifier and this is termed as random noise.

The signal to noise ratio is one of the important factors to decide the quality of the amplifier. In order to eliminate the distortion and to increase the ratio between the signal and noise, negative feedback method is the best option.

5.15 APPLICATIONS OF A TRANSISTOR

1. When a transistor used for amplification purpose, it is called an Amplifier.
2. When a transistor acts as a switch, it is called a switch.
3. Transistor in active mode, (Analog Electronics).
4. Transistors in cut off saturation mode, (Digital Electronics).
5. Transistor can be used for an oscillation purpose, it is called as an Oscillator.
6. Transistors can be used from transistor radio to computer in all electronic circuits.

LEARNING OUTCOMES

Student will capable of

1. **Remembering the difference between NPN and PNP transistor**
2. **Identifying and testing BJT.**
3. **Understanding transistor configurations.**
4. **Designing simple electronics circuits using transistor.**
5. **Analysing the transistor applications.**

GLOSSARY

S. No	Terms	Explanation
1	**Active region**	The region of BJT operation between saturation and cutoff used for linear amplification
2	**Amplifier**	A circuit that increases the voltage, current or a power of a signal
3	**Cascaded amplifier**	An amplifier with two or more stages arranged in a series configuration
4	**Emitter follower**	A common collector amplifier. Has a high current gain, high input impedance and low output impedance
5	**Feedback amplifier**	An amplifier with an external signal path from its output back to its input
6	**Gain**	Increase in voltage, current and/or power. Gain is expressed as a ratio of amplifier output value to the corresponding amplifier input value
7	**High fidelity**	Sound reproduction equipment that reproduces sound as near to the original sound as possible
8	**Noise**	Unwanted electromagnetic radiation within an electrical or mechanical system
9	**PNP transistor**	A bipolar junction transistor with an N-type base and P-type emitter and collector
10	**Power Amplifier**	An amplifier designed to deliver maximum power output to a load. Example : in an audio system, it is the power amplifier that drives the loudspeaker

ELEC_EQUIP_Chapter05.indd 118 11/10/2020 11:41:49 AM

QUESTIONS

T487IG

PART A

I Choose the best answer. **1 Mark**

1. A transistor has ……..
   a) One pn junction b) Two pn junction c) Three pn junction d) Four pn junction

2. The number of depletion layers in a transistor is ……………
   a) Four b) Three c) One d) Two

3. The base of a transistor is ……… doped.
   a) Heavily b) Moderately c) Lightly d) None of the above

4. In a PNP transistor, the current carriers are ………
   a) Acceptor ions b) Donor ions c) Free electrons d) Holes

5. A transistor is a ……….. operated device.
   a) Current b) Voltage c) Both voltage and current d) None of the above

6. In an NPN transistor, the current carriers are ……………
   a) Acceptor ions b) Donor ions c) Free electrons d) Holes

7. The emitter of a transistor is ……….. doped.
   a) Lightly b) Heavily c) Moderately d) None of the above

8. In a transistor, the base current is about …….. of emitter current.
   a) 25% b) 20% c) 35% d) 5%

9. Most of the majority carriers from the emitter ………………
   a) Recombine in the base b) Recombine in the emitter
   c) Pass through the base region to the collector d) None of the above.

10. In a transistor, ……………
    a) $I_C = I_E + I_B$ b) $I_B = I_C + I_E$ c) $I_E = I_C - I_B$ d) $I_E = I_C + I_B$

11. A heat sink is generally used with a transistor to …………
    a) Increase the forward current b) Decrease the forward current
    c) Compensate for excessive doping d) Prevent excess temperature

12. Which of the following amplifier have lowest efficiency
    a) Class A b) Class B c) Class C d) Class AB

13. A complementary symmetry amplifier has
    a) 1 PNP & 1 NPN transistor
    b) 2 PNP transistor
    c) 2 NPN transistor
    d) 2 P channel FETS
14. The most commonly used transistor arrangement is …………..
    a) Common emitter
    b) Common base
    c) Common collector
    d) None of the above
15. Transistor operates in ……. biasing.
    a) AC
    b) DC
    c) both AC and DC
    d) none of the above.

PART B

II. Answer in few sentences — 3 Marks

1. What is meant by a transistor?
2. Give the symbol of PNP and NPN transistor.
3. Write short notes on SMD transistor.
4. What are the various methods of transistor biasing?
5. Write about the different modes of transistor.
6. Define an amplifier
7. What is meant by voltage amplifier?
8. What is meant by power amplifier?
9. What is meant by feedback?
10. What are the types of feedback?
11. What is distortion?
12. Write down the types of distortion occurs in amplifier.

PART C

III Explain the following questions — 5 Marks

1. How will you identify the leads of transistor?
2. Explain the working principles of NPN transistor
3. Compare voltage amplifiers and power amplifiers.
4. What are the applications of transistor?

PART D

IV Explain briefly the following questions. — 10 Marks

1. Explain how transistor works as an amplifier.
2. Write some factors about transistor
3. Briefly explain about operating modes of transistor.
4. Explain the working principle of RC coupled amplifier.

ANSWERS

1. **(b)**	2. **(b)**	3. **(c)**	4. **(d)**	5. **(c)**
6. **(c)**	7. **(b)**	8. **(d)**	9. **(c)**	10. **(a)**
11. **(d)**	12. **(a)**	13. **(a)**	14. **(a)**	15. **(b)**

CHAPTER 6

SPECIAL TYPE SEMICONDUCTOR DEVICES

Thiruvalluvar reitrated the importance of light in the following couplets

ஒளிஒருவற்கு உள்ள வெறுக்கை இளிஒருவற்கு
அஃதிறந்து வாழ்தும் எனல். # குறள் 971

விளக்கம்
ஒருவனுக்கு ஒளி ஊக்கமிகுதியே ஆகும், ஒருவனுக்கு இழிவு அந்த ஊக்கம் இல்லாமலேயே உயிர்வாழலாம் என்று எண்ணுதலாம்.

English Couplet 971:

The light of life is mental energy; disgrace is his
Who says, 'I 'ill lead a happy life devoid of this.'

Couplet Explanation:
One's light is the abundance of one's courage; one's darkness is the desire to live destitute of such (a state of mind).

T4FGVA

CONTENT

LEARNING OBJECTIVES

While learning this Chapter, the student can

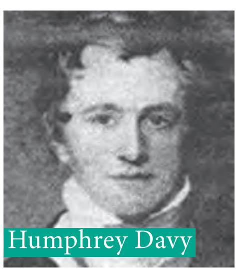
1. Understand the basic concepts of special type of semiconductor devices.
2. Describe the working principles of special semiconductor devices.
3. Understand the switching action of Thyristor devices.
4. Know about various applications of the semiconductor devices.

INTRODUCTION

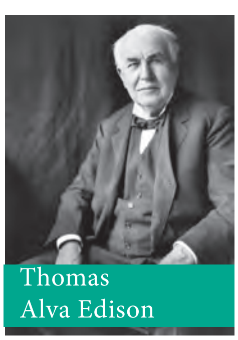
We are experiencing many hoardings, advertising displays, high definition television in our daily routine life. Of course, these devices have very good features with long life and attractive characteristics. Do you have any idea about these devices and their origin? Most of these devices are built around a special type of semiconductor devices called LED, LDR, LCD, photodiode and photo transistor. They are opto-electronic devices.

With these devices we study about the working of FET, MOSFET, SCR, DIAC, TRIAC, IGBT and their application.

History of Electric bulb


Humphrey Davy

The first electric bulb was made in 1800 by Humphrey Davy. When he connected wires to the battery and a piece of carbon, the carbon gets glowed and producing light. It was known as electric arc lamp, but failed to glow for a long time.


Thomas Alva Edison

The inventor Thomas Alva Edison (USA) discovered a carbon filament in an oxygen free bulb glowed for over 1500 hours. Before this, he met hundreds of failures in his experiments. He discovered incandescent light bulb on 1879.

Edison and Tesla experimented with florescent lamps in 1890s, but Peter Cooper Hewitt successfully made fluorescent lamp in the early 1900s.


Nick Holonyak

Edward E. Hammer from General Electric Company invented the spiral compact fluorescent lamp invented in the year 1976. The first practical LED was created by Nick Holonyak in 1962. It emitted light in the visible part of the frequency range. It was red LED. In 1972, M-George Craford invented the first yellow LED and a brighter red LED.

6.1 LIGHT EMITTING DIODE (LED)

LED is a PN junction device, which emits light when forward biased, by a phenomenon called electroluminescence. In all semiconductor PN junctions, some energy will be radiated as heat and some in the form of photons.

LEDs are widely used in indicators, smart phones, digital watches, solid state video displays, calculators, digital computers, electronic panels and optical communication system.

Construction

Figure 6.1 shows the construction of LED and its symbol. Here, an *N* type layer is grown on a substrate over which a *P* type layer is deposited by the process called diffusion. The metal anode connection is made at the outer edges of the 'P' layer. It provides more central surface area for the light to escape.

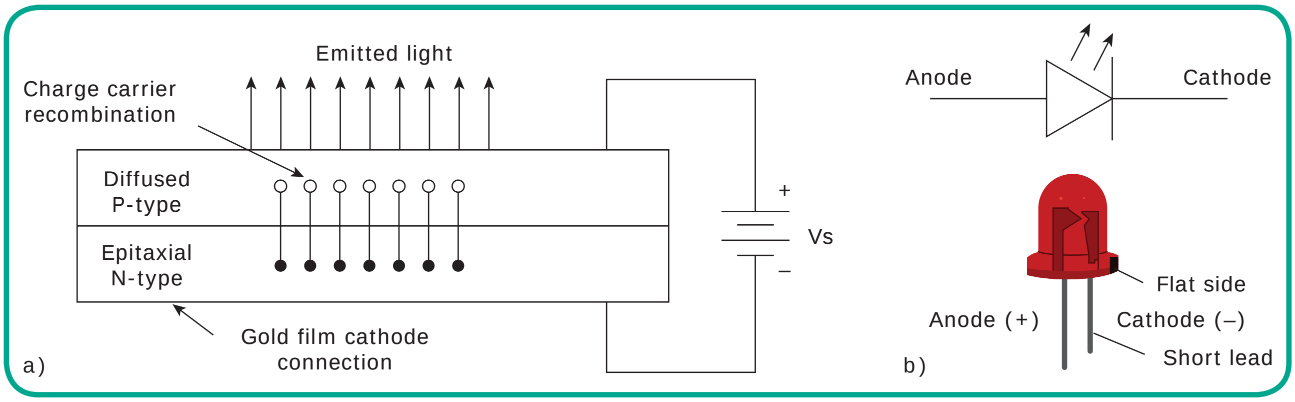


Figure 6.1 Construction and Symbol of LED

LEDs radiate different colours like red, green, yellow, orange, blue and white depend on material used. Some LEDs emit infrared (invisible) light also. The colour of the emitted light depends on the type of material used as given below.

- Gallium arsenide (*GaAs*) –Infrared Radiation (Invisible)
- Gallium phosphide (*GaP*) –Red or Green
- Gallium arsenide phosphide (*GaAsP*)- Red or Yellow

Working Principle

When an LED is forward biased, the electrons and holes move towards the junction and recombination takes place. This makes the electrons lying in the conduction band of *N* region fall into the holes lying in the valence band of *P* region.

The difference of energy between the conduction band and the valance band is radiated in the form of the light energy. The brightness of the emitted light is directly proportional to the forward bias current.

Advantages

- LED can be switched ON and OFF at very fast speed (1 ns).
- Its operating voltage is from 1.5 V to 3.3 V with low current (some mA).
- It has a life time of 1,00,000 hours.
- LEDs are small in size and light in weight.
- They require no heating and warm up time.

6.2 SEVEN SEGMENT LED

LEDs are often grouped to form seven segment displays. They are generally used as numerical indicators and consist of a number of LEDs arranged as seven segments as shown in the Figure 6.2.

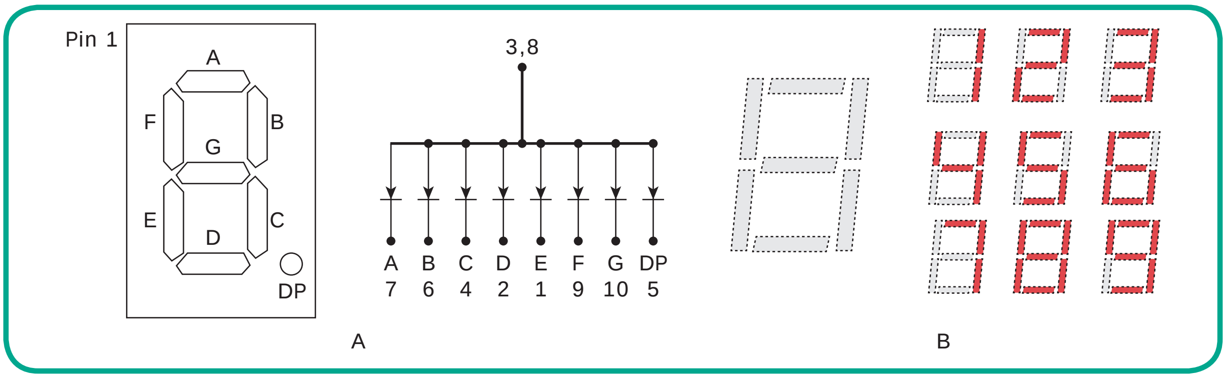


Figure 6.2 Seven Segment LED

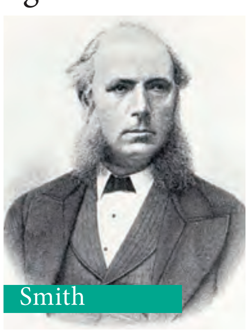
The seven LEDs are labelled *A* through *G*. By forward biasing different LEDs, we can display the digits 0 to 9. For example, if LEDs *A,B,C, D and G* are lit (by forward biasing them), then the display will show the number 3.

There are two types of seven segment LED arrangement, they are

- Common Anode Type
- Common Cathode Type

6.3. LIGHT DEPENDENT RESISTOR (LDR)

A light dependent resistor is a semi-conductor device, whose resistance value changes when illuminated (exposed) with light. It is also called as photo-resistor or photo-conductive cell.


Smith

History: LDR is a photoconductive device made from Selenium. It was discovered by Smith in 1873. In 1952, Rollin and Simmons developed their photoconductors using Silicon and Germanium.

Construction: The Figure 6.3(a, b) shows the basic structure and symbol of LDR. It consists of a thin layer of cadmium sulphide (*CdS*), which is used as photo cell. It also contains Antimony or Indium which could be deposited on an insulating substrate. Ohmic contacts are made at the opposite ends of the *CdS* layer. The value of resistance is about 2 MΩ, at absolute darkness. But, strong incident light focussing on it reduces the resistance value fall below the 100 Ω.

Working Principle

When radiation is incident on a semiconductor, amount of light is absorbed by the material and its conductivity increases. This effect is called photo-conductive effect.

The radiation falls on the semiconductor produces charge carriers. This charge carrier produces electron-hole pairs. If the intensity of the light falling on the surface increases, it will generates large number of electron hole pairs. This will lower the value of resistance of the photo-conductor.

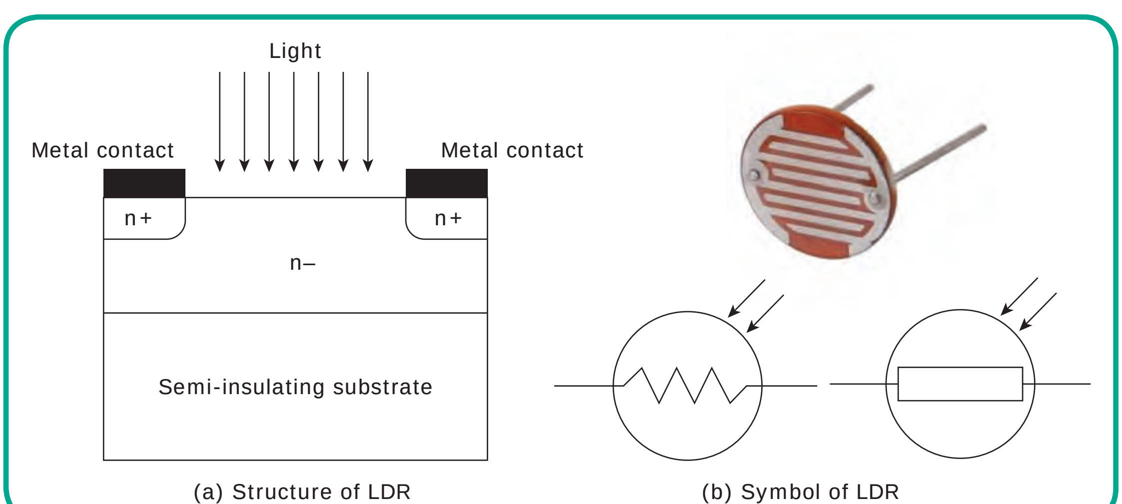
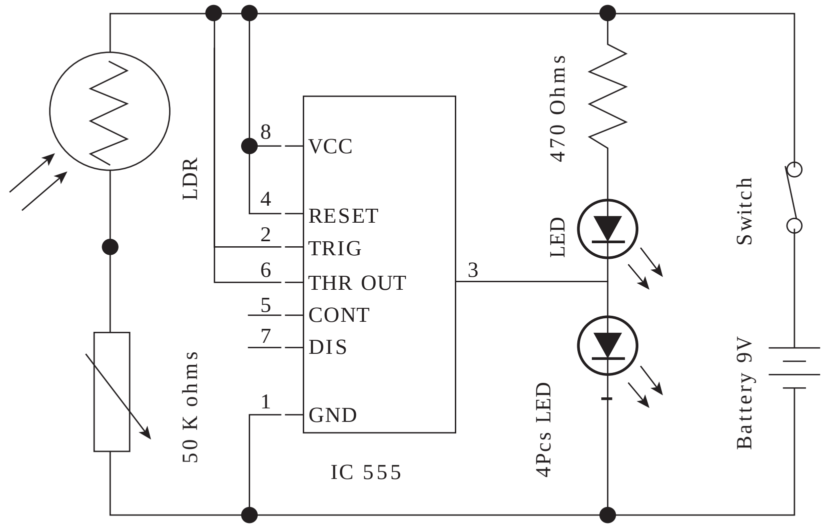


Figure 6.3 Light Dependent Resistor

Activities

Construct Automatic Street light using LED and LDR



When an external voltage source (V) is connected to the photo-conductor, current I flows in the external circuit. If strong radiation incident on the LDR, the photo current may be as high as 10 mA, otherwise the LDR photo current may be negligibly small.

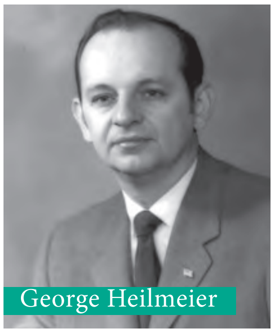
Applications

1. Used to measure intensity of light.
2. Used in counting system.
3. Used in burglar alarm.
4. Widely used in cameras to control shutter opening for flash light.
5. Used in automatic street light.

6.4. LIQUID CRYSTAL DISPLAY (LCD)

Liquid Crystal Display (LCD) are used for displaying of numeric and alphanumeric character in dot matrix and segmental displays. There are two types of liquid crystal materials used, they are nematic and cholesteric. In the Nematic Liquid Crystal (NLC), all the molecules align themselves approximately parallel to a unique axis, while retaining the complete translational freedom.

The liquid is normally transparent, but if subjected to a strong electric field, disruption of the well-ordered crystal structure takes place causing the liquid to polarise and turn opaque. The removal of the disruption of the crystal structure regains its original form and the materials become transparent.


George Heilmeier

History: Liquid crystal was first observed by an Austrian Botanist, Friedrich Reintzer in the year 1888. The material discovered by him was Cholesteryl Benzoate. In 1968, George Heilmeier and his team of scientists revealed the LCD to the public. Based on the construction, LCDs are classified into two types. They are,

1. Dynamic scattering type
2. Field effect type

6.4.1. Dynamic Scattering LCD

Construction: Figure 6.4(a) shows the construction of dynamic scattering LCD. The display consists of two glass plates, each coated with tin oxide (SnO_2) on the

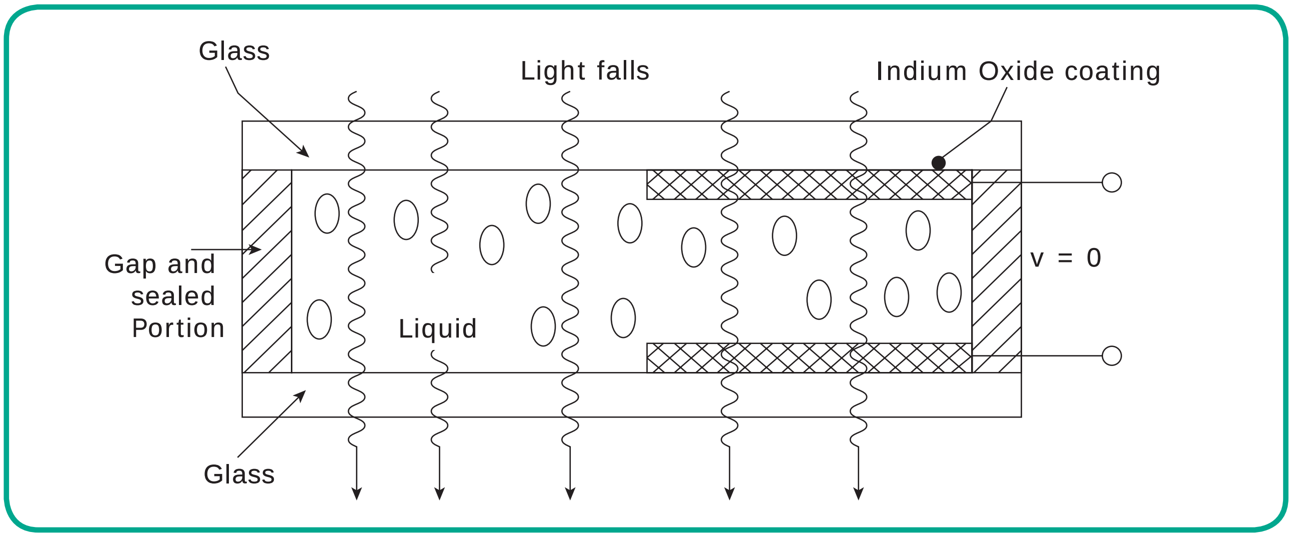


Figure 6.4(a) **LCD Construction**

inside with transparent electrodes separated by a liquid crystal layer of 5 to 50 μm thick. The oxide coating on the front sheet is etched to produce a single or multi-segment pattern of characters with each segment properly insulated from each other.

Working Principle: Figure 6.4(b) shows the LCD working principle. When AC voltage is not applied to the plates of the molecules of liquid crystal, which align themselves in perpendicular (or parallel) direction and appear transparent. When a voltage is applied across the conductive coatings, the arrangement of molecular pattern gets disturbed. As a result, refractive index of the medium of the crystal changes. Therefore, the incident light is reflected in different directions. Now, the liquid appears dark in the white background. The area not enclosed by conducting surfaces remains translucent.

Advantages of LCD

1. The operating voltage required is small (3 to 20 V/AC).
2. They are economical.
3. They have low power consumption.

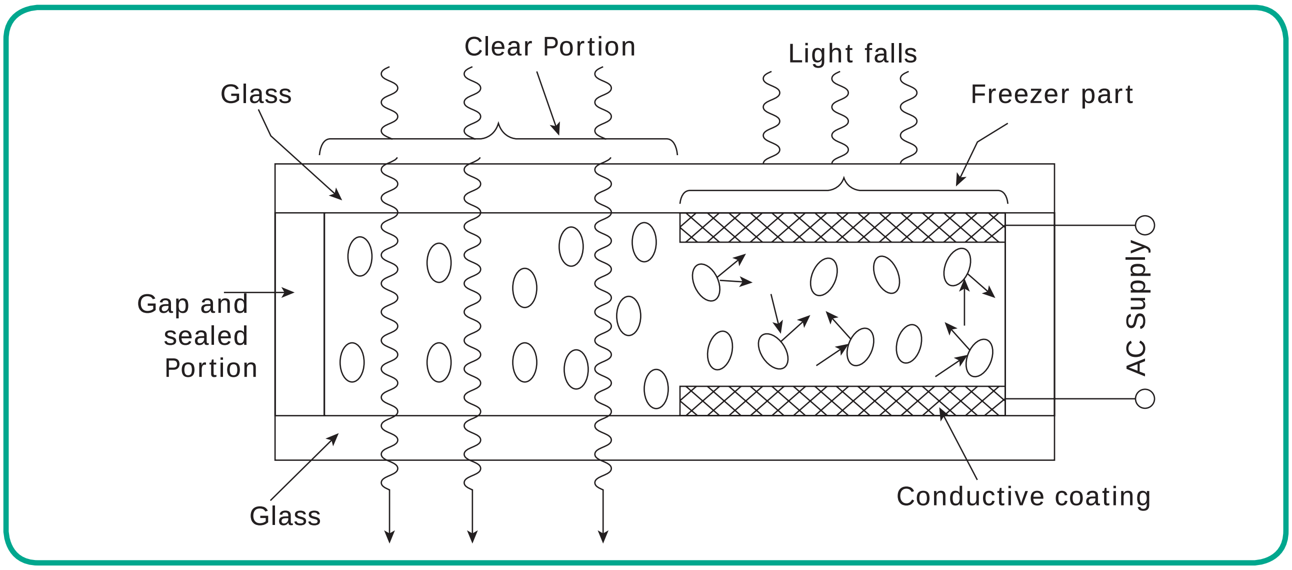


Figure 6.4(b) **LCD Working**

TABLE 6.1

LED	LCD
Consumes more power (10-250 mW per digit)	Consumes less power (10-200 mW per digit)
Good brightness level	Moderate brightness level
Lifetime is around 1,00,000 hours	Lifetime is limited to 50,000 hours due to chemical degradation
Operating voltage range is from 1.5 V to 3.3 V DC	Operating voltage range is from 3 to 20 V AC
Emits light in red, green, orange, yellow, blue and white	Invisible in darkness and requires external illumination

Disadvantages of LCD

1. LCD requires an external or internal light source. (poor visibility in darkness)
2. Its life time is limited due to chemical degeneration.
3. It operates slowly. Turn-On time is few ms.

When used on DC, the life-span is quite small and therefore, they are used with AC supplies having a frequency less than 50 Hz.

Application of LCD

1. It is used in solid state video displays.
2. It is used in laptop computers.
3. It is used in pocket calculators.
4. It is used in instrument displays and digital watches.
5. It can be used as numerical counter for counting items.

Comparison of LED and LCD

Table 6.1 is the comparison between LED and LCD.

6.5. PHOTO DIODE

Silicon photo diode is a light sensitive device, also called photo detector, which converts light signal into electrical signal.

Construction: Figure 6.5 shows the construction and symbol of photo diode. The diode is made of a semiconductor PN

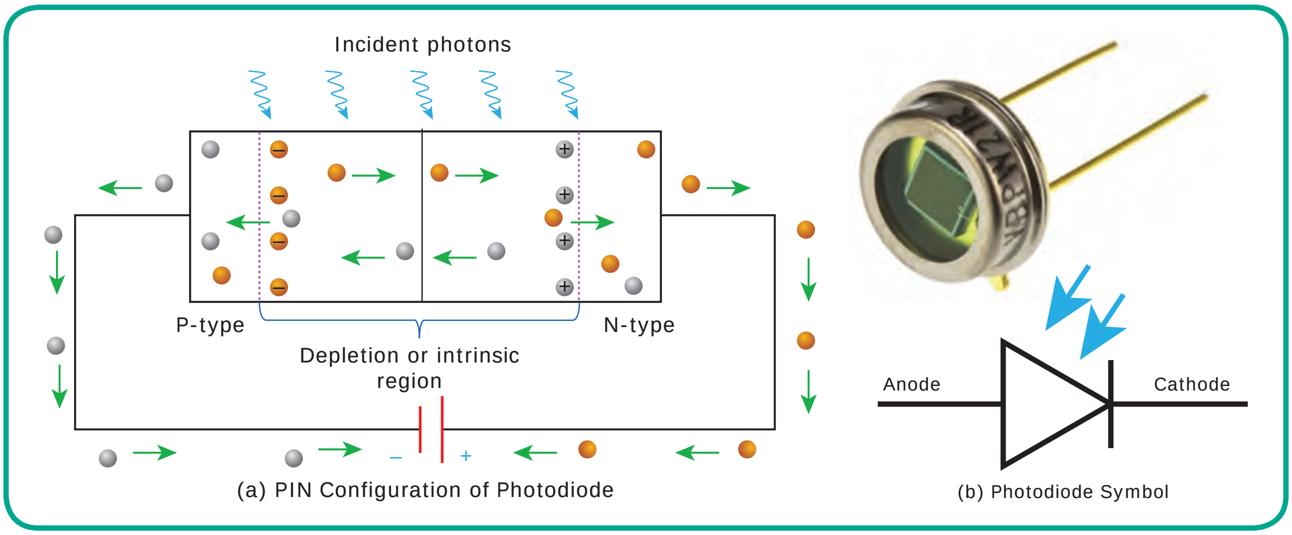


Figure 6.5 Construction and Symbol of Photo Diode

junction kept in a sealed plastic or glass casing. The cover is so designed that the light rays are allowed to fall on one surface across the junction. The remaining sides of the casing are painted to restrict the penetration of the light rays. A lens permits light to fall on the junction.

Working Principle: When light falls on the reverse-biased PN photo diode junction, electron-hole pairs are created. The movement of these electron-hole pairs in a properly connected circuit results in current flow. On illumination on the diode, the magnitude of the photo current depends on the number of charge carries generated. This current is also affected by the frequency of the light falling on the junction of the photo diode.

Applications

1. Photo diodes are used as light-detectors, demodulators and encoders.
2. They are also used in optical communication system.
3. They are used in high speed counting and switching circuits.

6.6. PHOTO TRANSISTOR

Photo transistor is a much more sensitive semiconductor photo device than the PN photodiode. The current produced by a photodiode is very low which cannot be directly used in control applications. Therefore, this current should be amplified before applying to the control circuits. The photo transistor is a light detector which combines a photodiode and a transistor amplifier. When the photo transistor is illuminated, it permits the flow of current.

History: Phototransistor was made by John N. Shive and his team members from Bell Laboratory during the years 1948-1950.

Figure 6.6 shows the NPN phototransistor. It is usually connected in common emitter (CE) configuration with base open. A lens focuses the light on the base-collector junction. The modern photo transistor uses efficient light effective materials instead of making a hole and fixing a lens on it. Photo transistor has three terminals, but only two terminals are generally used. Here the base current is supplied by the current created by the light falling on the base-collector junction.

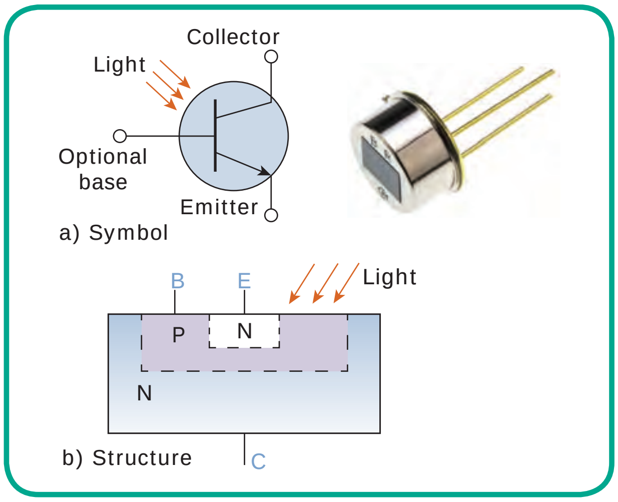


Figure 6.6 NPN Photo Transistor

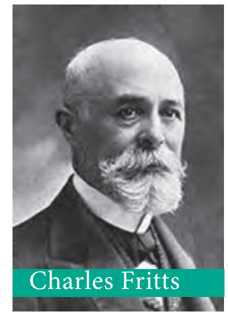
The voltage (V_{CE}) applied to the transistor makes emitter-base junction forward biased and collector-base junction reverse biased. When the transistor is kept in darkness, there will be a very few minority charge carrier flow. This makes negligible collector current. When the light is turned '*ON*', and focused at the collector-base junction, the transistor starts conducting and the amplified current starts flowing through the reverse-biased junction. The amount of current flow depends upon the intensity of focused light.

Application

1. They are used in light detection system.
2. They are widely used in high speed reading of computer punching cards.
3. They also used in light operating switches.

6.7. SOLAR CELL

It is widely used in satellites to provide electrical power, when sunlight is incident on a photovoltaic cell. It is converted into electric energy and the energy converter is called solar cell or solar battery. Basically, solar cell is large PN junction diode. It is made up of Silicon and Selenium.



History: In the year 1839, photovoltaic effect was discovered by Edmond Becquerel. This process occurs and creates electric voltage, when light is absorbed by the material. In 1883, Charles Fritts created the first solar cell by coating selenium with a thin layer of gold. Silicon solar cells were produced by Bell laboratory during 1953-1956. In 1958, solar cells were used in space.

Construction: Figure 6.7 shows the basic construction of PN junction solar cell. It consists of single semiconductor crystals, which has been doped with both *P* and *N* type impurities, thereby forming a *PN* junction. A glass window is provided at the top of the *P* type layer. The thickness of the *P* layer is small, so that the incident light can easily reach the junction of the diode. A nickel plated ring is provided around the *P* layer, which acts as a positive terminal. A metal contact provided at the bottom of the *N-layer*, acts as negative terminal.

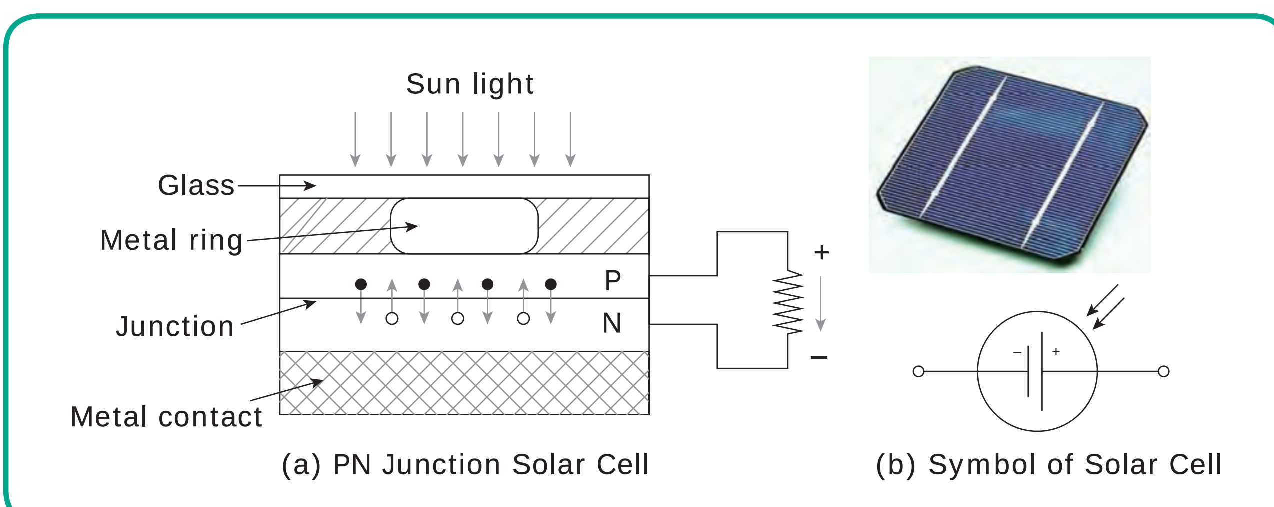


Figure 6.7 Basic Construction of PN Junction Solar Cell

Working Principle: The sunlight incident on the glass plate passes through and reaches the junction. An incident light photon at the junction may collide with a valence electron and impart sufficient energy to make a transition to the conduction band. As a result, an electron-hole pair is formed. The newly formed electrons are minority carriers in the *P* region. They move freely across the junction. Similarly, holes formed in the *N-region* cross the junction in the opposite direction. The flow of these electrons and holes across the junction is in a direction opposite to the conventional forward current in a *PN* junction. Further, it leads to the accumulation of majority carriers on both sides of the junction.

In bright sunlight, 0.6 V is developed by a single solar cell. The amount of power the cell can deliver depends on the extent of its active surface. An average cell will produce about 30 mW per square inch of surface, operating in a load of 4 Ω. To increase the power output, large banks of cells are used in series and parallel combinations.

Application

1. It is used to provide electrical power to satellites and space vehicles
2. It is used to energize these storage cells
3. It is also used in home for electrical requirements.

6.8. UNIPOLAR JUNCTION TRANSISTOR (UJT)

UJT is a three terminal semiconductor switching device. As the name indicates, it has only one *PN* junction (i.e. unijunction). UJT can be used to control a large AC power with small gain, and not to be used as amplifier. It exhibits negative resistance characteristics and can be used as an oscillator.

History: The UJT was invented as a by-product of research on germanium tetrode transistors at General Electrical Company. It was patented in 1953.

Construction: Figure 6.8 shows the basic structure of UJT and its symbol. It consists of lightly doped N-type silicon bar with ohmic contacts at the two ends, called base1 (B_1) and base2 (B_2). A P-type emitter is diffused nearer to the base2 of the bar, and this forms a *PN* junction diode with the base as shown in Figure 6.8(a). The *P-type* region is called emitter (*E*), since the device contains two base terminals with one *PN* junction and hence it is also called as double base diode. The resistance (R_{BB}) between the

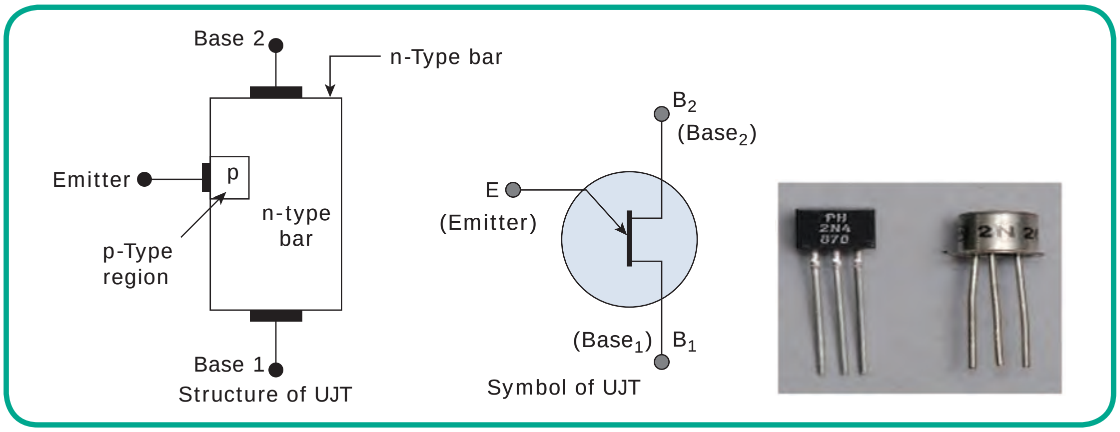


Figure 6.8(a) **Basic Structure of Unijunction Transistor and its Symbol**

bases (B_1 *and* B_2) is called inter-base resistance and is very high (5 to 10 kΩ), when emitter is in open condition.

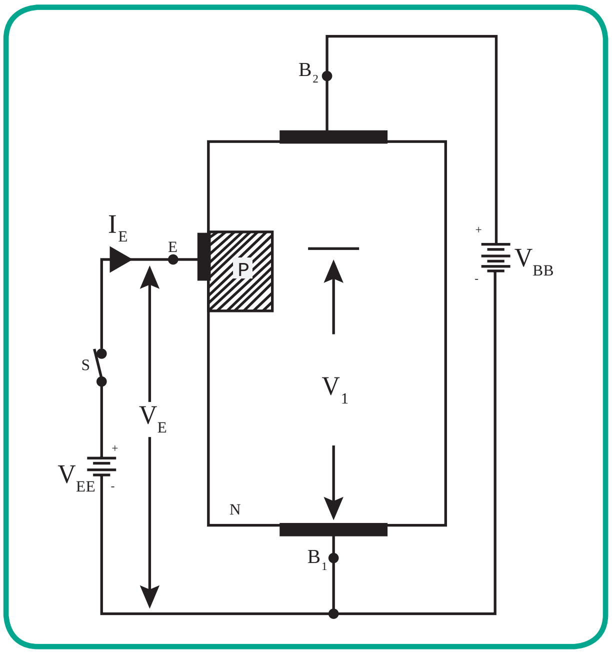


Figure 6.8(b) UJT Biasing

Working Principle: Figure 6.8(b) shows the biasing arrangement of UJT. The base B_2 is kept at positive potential with respect to B_1 using the battery terminal V_{BB}. The *PN* junction is always forward biased by making emitter (*E*) positive with respect to base B_1 using the battery terminal V_{EE}.

When No Voltage is Applied at the Emitter: The emitter is open (switch *S* is open). When a voltage V_{BB} is applied between the two bases, a voltage gradient is established along the N-type silicon bar. The voltage drop (V_1) between emitter and base B_1, reverse bias the *PN* junction and hence no emitter current flows (i.e. UJT is in *OFF* state). However, a small leakage current flows from base B_2 to emitter *E*.

When a Positive Voltage is Applied at the Emitter: When a positive voltage is applied to the emitter. (Switch *S* is closed). The *PN* junction is also reverse biased. If the emitter voltage is linearly increased, which reduces the amount of reverse bias of the *PN* junction. When the applied voltage is increased and greater than V_1, the *PN* junction will be forward biased. Now, the holes are injected from P-region into N-region. The holes are repelled by the terminal B_2 and are attracted by the terminal B_1. Now, the accumulation of holes in *E* to B_1region reduces the resistance in this section. Hence, if the emitter current I_E and the voltage V_E increases, the UJT becomes in the *ON* state.

When a Negative Voltage is Applied at the Emitter: If a negative voltage is applied to the emitter (*E*), the *PN* junction is reverse biased, and the emitter current is very low. The device is now in the *OFF* state.

Application

1. UJT is used as relaxation oscillator.
2. It is widely used as triggering device for SCR and TRIAC.
3. It is used in phase control circuits.
4. UJTs can also be used to measure magnetic flux.
5. It is used in switching circuits
6. It is used as sawtooth generator.
7. It is used in tuning circuits (TV).

6.9. FIELD EFFECT TRANSISTOR (FET)

In the previous Chapters, we have discussed about the Bipolar Junction Transistor (BJT). They are controlled by both electrons and holes and called current operated devices. BJT has two main disadvantages; first, it has low input impedance because of forward biased emitter junction. Secondly, it has considerable noise level.

To overcome the above problems, FET can be developed and become important electronic device in the integrated circuit (IC) technology. The FET is a device in which the flow of current through the conducting region is controlled by an electric field (voltage).

There are two types of field effect transistor,

1. Junction Field Effect Transistor (JFET)
2. Metal Oxide Semiconductor Field Effect Transistor(MOSFET)

6.9.1 Junction Field Effect Transistor (JFET)

JFET is a three terminal semiconductor device in which current conduction is by one type of carrier (i.e.) electrons or holes. It is a unipolar device. It has high input impedance and low noise level.


Jun-ichi Nishizava

History: The FET was first patented by Julius Edgar Lilienfeld in 1926 and by Oscar Heil in 1934. The first type of JFET was the static induction transistor (SIT), invented by Japanese engineer Jun-ichi Nishizava and Y. Watanabe in the year 1950.

There are two types of JFET. They are

1. N-Channel JFET
2. P-Channel JFET

6.9.1.1 N-Channel JFET

Construction: Figure 6.9 shows the construction of n-channel JFET and its symbol. It consists of a uniformly doped N-type semiconductor bar made of silicon. On both sides of this N-type semiconductor bar, two heavily doped P-type regions are formed by diffusion. The two P-regions are internally connected and a single lead is taken out, which is called Gate (*G*). Ohmic contacts are made at the two N-type semi-conductor bar. One lead is called as Source(*S*) and the other as Drain (*D*). These two terminals may be interchanged. The source(*S*) is a terminal through which the majority carriers (electrons in the *N* type bar) enter the bar. The drain (*D*) is a terminal through which the majority carriers leave the bar.

Since the two P-regions are heavily doped and N-type bar is lightly doped, two depletion layers are formed in the N-type bar as shown in Figure 6.9. The region between the two layers is called channel. The majority carriers move from

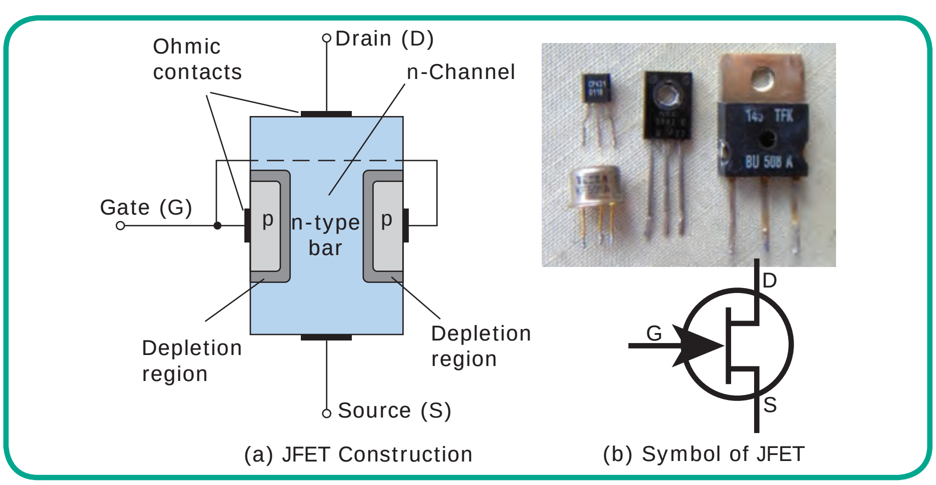


Figure 6.9 **Construction of N-Channel JFET and its Symbol**

source to drain through this channel. The gate terminal controls the flow of majority carriers from source to drain.

Working Principle of N-Channel JFET

Figure 6.10 shows the circuit of n-channel JFET with normal polarities. Here, the gate is kept negative potential with respect to the source called V_{GS}. The drain is kept positive potential with respect to the source known as V_{DS}. Let a voltage V_{DS} is applied across the drain and source terminals and no voltage is applied between gate to source ($V_{GS}=0$), now the two *PN* junctions establish a very thin and uniform depletion layer as shown in Figure 6.10(a). Thus, a large amount of electrons will flow from source to drain through a normally wide channel formed between the two depletion layers. This constitutes drain current I_D.

Let a reverse voltage V_{GS} is applied across the gate and source terminals (by closing the switch *S*) as shown in Figure 6.10(b). Now, the width of the depletion layer is increased due to the reverse biasing of the two *PN* junctions. This reduces the width of the conducting channel thereby decreasing the flow of electrons through it (I_D decreases). So the depletion layer will be thicker near the drain and the channel becomes wedge shaped as shown in Figure 6.10(b). Thus, the current flowing through the channel is controlled by width of the channel as well as reverse-potential applied to the gate. That is why the device is field effect transistor.

Advantages

1. The JFET has higher input impedance.
2. It is a low power consumption device.
3. It can be fabricated in small size area.
4. It has negative temperature coefficient of resistance, so they possess higher temperature stability.
5. It has less noise.

Disadvantages

1. The JFET is relatively low gain bandwidth product.
2. Its voltage gain is low.
3. It requires special handling during installation.

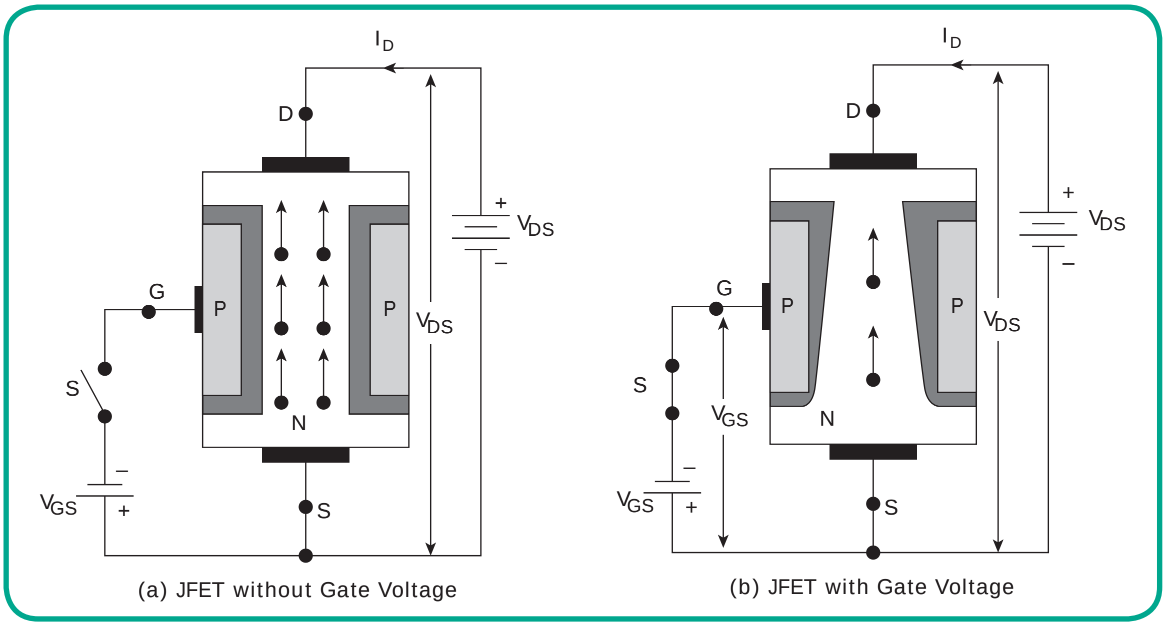


Figure 6.10 Working of N-Channel JFET with Normal Polarities

Table 6.2 Comparison of BJT and JFET

S.No	BJT	JFET
1.	Bipolar device (current conduction by both type of carriers i.e. majority and minority -electrons and holes)	Unipolar device (current conduction is only due to one type of majority carrier either electron or hole)
2.	Current driven device	Voltage driven device
3.	Low Input impedance	High Input impedance
4.	High noise level	Low noise level
5.	Low Power gain	High Power gain
6.	Low switching speed	High switching speed
7.	Less thermal stability	Better thermal stability
8.	Emitter and collector terminals are not interchangeable	Source and drain terminals are interchangeable

Application

1. The JFET is used as a constant current source.
2. It is used as buffer amplifier.
3. It is used as electronic switch.
4. It is used as phase shift oscillator.
5. JFET is used as a voltage variable resistor (VVR).
6. It is used as high impedance wide band amplifier.

6.10. MOSFET

The MOSFET is an abbreviation of Metal Oxide Semiconductor Field Effect Transistor. In MOSFET, the gate is insulated from the channel by using SiO_2 layer. The input impedance of MOSFET is high, because the gate current is extremely small. It is also called as Insulated Gate FET (IGFET).

History: MOSFET, largely superseded the JFET and has profound effect on digital electronic development, which was invented by Dawankahng and Martin Atalla in 1959. There are two types of MOSFET. They are

1. Enhancement MOSFET (E-MOSFET).
2. Depletion MOSFET (DE-MOSFET).

6.10.1 Enhancement MOSFET (E-MOSFET)

The enhancement MOSFET works only in enhancement mode. It does not conduct when gate to source voltage (V_{GS}) is equal to zero, therefore it is called as 'normally OFF MOSFET'. It is widely used in digital circuits. There are two types of enhancement MOSFET. They are

1. N-channel E-MOSFET
2. P-channel E-MOSFET

6.10.1.1 N-Channel E-MOSFET

Figure 6.11 shows the construction and symbol of n-channel E-MOSFET. It consists of lightly doped *P* type substrate into which two highly doped N-type regions are

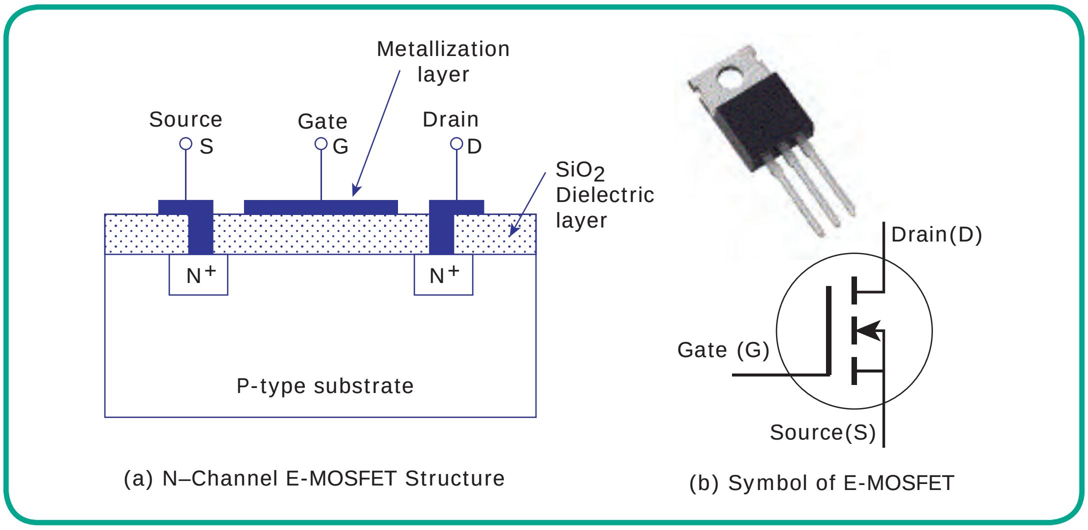


Figure 6.11 **Construction of N-Channel E-MOSFET and Its Symbol**

diffused. These two *N* regions act as Source (*S*) and Drain (*D*). A thin layer of SiO_2 is grown over its surface then a metal contact is provided at the top of the SiO_2 layer, which acts as a Gate (*G*). The oxide layer provides high input impedance ($10^{10}\ \Omega$ to $10^{15}\ \Omega$) to the MOSFET.

Working Principle: Figure 6.12 shows the normal biasing of n-channel E-MOSFET. It is always operated with positive gate to source voltage (V_{GS}). The drain is kept at positive potential (V_{DS}) with respect to the source. When V_{GS} is equal to zero, the *PN* junction between the drain and the substrate is reverse biased. Hence, only very small leakage current (I_D) flows through the device.

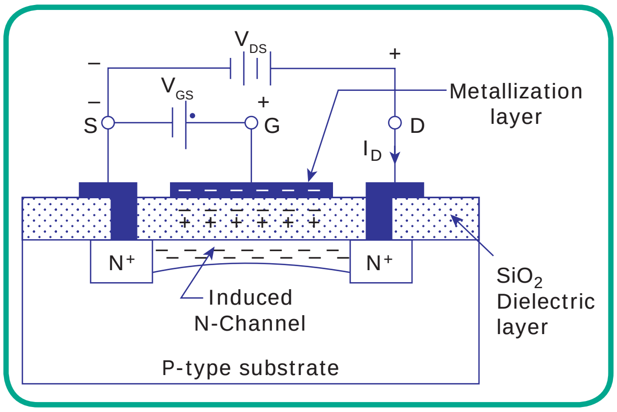


Figure 6.12 **Operation of N-Channel E-MOSFET**

When gate is given a positive voltage (due to capacitor action), induced negative charges will be setup in the P-type substrate just adjacent to the SiO_2 layer. These negative charges, which are minority carriers in the P-type substrate form an inversion layer (N-type layer) between source and drain. This layer formed only if V_{GS} exceeds a certain value called threshold voltage ($V_{GS(th)}$). When the gate to source voltage is greater than $V_{GS(th)}$, drain current (I_D) will flow from drain to source through the induced N-channel (Inversion layer). Thus, the drain current is 'enhanced' by the positive gate voltage and hence this device is called enhancement type MOSFET.

6.10.2 Depletion MOSFET (DE-MOSFET)

The depletion MOSFET can be operated in either depletion mode or enhancement mode. Therefore, it is called as DE-MOSFET. There are two types of depletion MOSFET. They are

1. N channel depletion MOSFET
2. P-channel depletion MOSFET

6.10.2.1 N-Channel Depletion MOSFET

Figure 6.13 shows the construction and symbol of N-channel depletion MOSFET. It consists of a lightly doped p-type semiconductor substrate. In the substrate, two highly doped N+ regions are diffused. One region is source (*S*) and other is drain (*D*). A lightly doped N-channel is formed between source and drain by diffusion. A thin layer of SiO_2 is grown over its surface. Then, an aluminium layer is formed over SiO_2, which acts as gate (*G*). SiO_2 acts as insulator. These setup acts as a parallel plate capacitor.

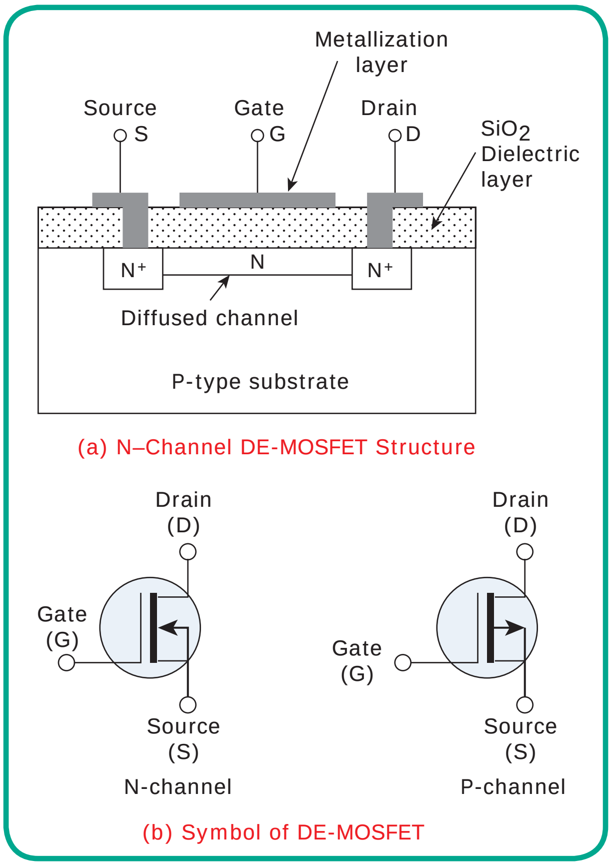


Figure 6.13 Construction and symbol of N-Channel and p-Channel Depletion MOSFET

Working Principle: The depletion MOSFET can be operated in two different modes as given below

Depletion Mode: Figure 6.14 shows the n-channel depletion mode operation. In this mode, the gate is maintained at negative potential and drain is at positive potential with respect to source. The negative voltage on the gate attracts the holes in the P-type substrate. Thus, the holes are moved towards the gate terminal. Because of the SiO_2 (insulator) layer, the holes are induced in the N-channel, which reduces the charge carriers (electrons) in the N-channel. So, the conductivity decreases, the value of drain current also decreases.

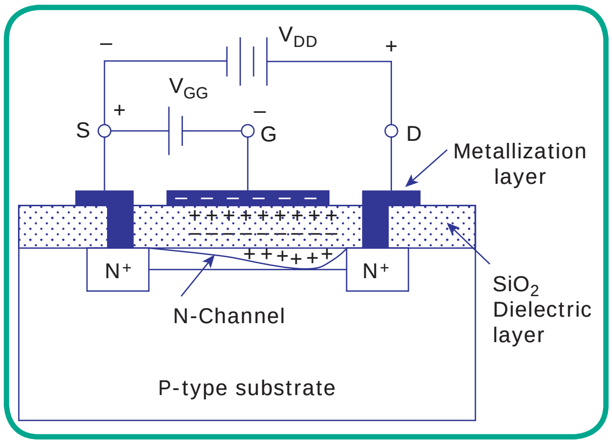


Figure 6.14 Operation of N-Channel DE-MOSFET

Enhancement Mode: In this mode, both the gate and drain are maintained at positive potential with respect to source. The positive gate voltage induces the charges in the N-channel. These induced negative charges make N-channel between source and drain more conductive. As the positive gate to source voltage increases, the drain current also increases. Hence, the mode of operation is called 'enhancement mode'.

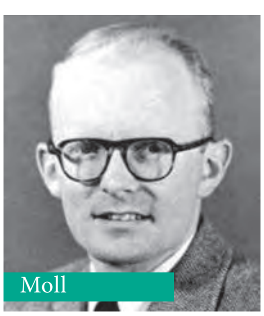
Application

1. MOSFET is widely used for switching and amplifying the signals.
2. It is used in FM radio and TV receivers (for mixer operation).
3. It is used in computer memories.
4. It is used as auto intensity control of street lights.

Table 6.3 Comparison of JFET and MOSFET		
S.No	**JFET**	**MOSFET**
1.	JFET stands for Junction Field Effect Transistor	MOSFET stands for Metal Oxide Semiconductor Field Effect Transistor
2.	It can be operated only in the depletion mode	It can be operated either depletion or in enhancement mode
3.	It has high input impedance ($10^8\ \Omega$)	It has very high input impedance (from $10^{10}\ \Omega$ to $10^{15}\ \Omega$)
4.	It is difficult to fabricate	It is easier to fabricate
5.	Gate current (Ig) is high	Gate current (Ig) is low
6.	It is mainly used in low noise application	It is widely used in VLSI circuits

6.11. SILICON CONTROLLED RECTIFIER (SCR)

SCR is a three terminal and three junction semiconductor device acts as true electronic switch. It is a unidirectional device. It converts AC to DC and controls the amount of power fed to the load. It contains the features of a rectifier and transistor. SCR is widely used device in the Thyristor family, so it is commonly called as Thyristor.


Moll

History: The SCR was proposed by William Shockley in 1950 and championed by Moll and others at Bell Lab. It was developed by Gordon Hall and his team engineers at General Electric Company in the year 1956.

Construction: SCR consists of four semiconductor layers forming a PNPN-structure as shown in the Figure 6.15. There are three junctions namely J_1, J_2, J_3. SCR have three leads, they are anode (A), cathode (K) and gate (G). The end P-layer acts as anode, the end N-layer acts as cathode and the P-layer nearer to cathode acts as gate.

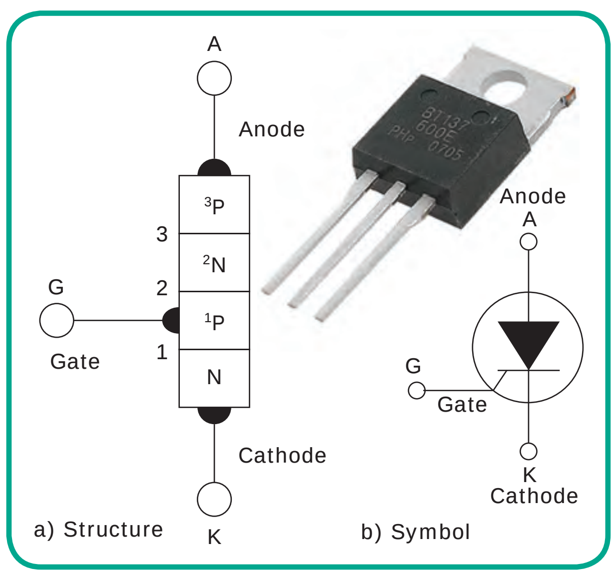


Figure 6.15: **SCR Structure and Symbol**

Working Principle: In the normal operating conditions of SCR, the anode (A) is always kept at high positive potential with respect to cathode (K), and gate (G) is at small positive potential with respect to cathode. A load resistor (R_L) is connected in series with Anode (A). The working of SCR can be studied under the following two conditions.

1. ***When Gate is Open***

   Figure 6.16 shows, the forward biasing of SCR (Anode kept positive with respect to cathode). Here no gate voltage ($V_G = 0$) is applied. The supply voltage V forward biases the junction J_1 and J_3 and reverse biases the junction J_2.So no current flows through SCR. Therefore the SCR is in 'OFF' state. It offers very high resistance.

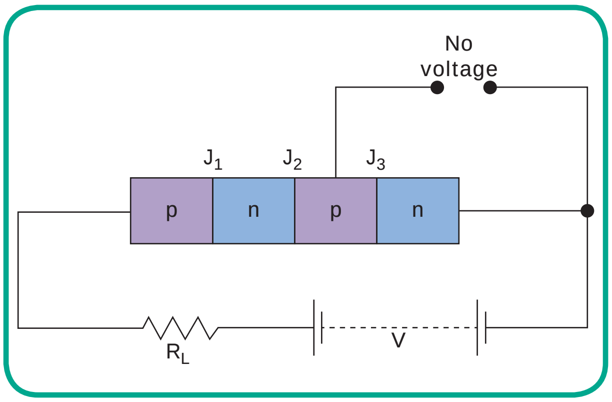


Figure 6.16 Forward Biasing of SCR

When supply voltage is gradually increased to a particular voltage called forward break over voltage, the reverse biased junction J_2 breaks down. The SCR now conducts heavily and is said to be in 'ON' state.

2. ***When Gate is applied positive voltage with respect to cathode***

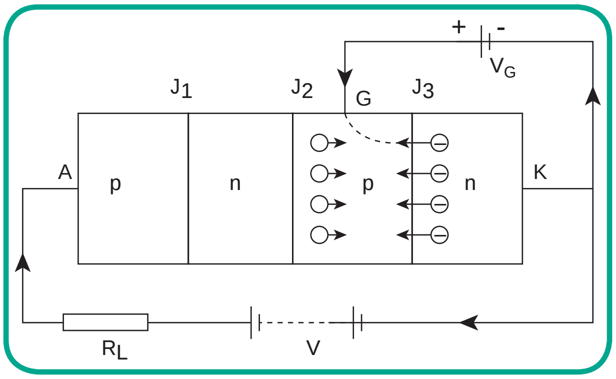


Figure 6.17 SCR with Gate Voltage

Figure 6.17 shows the small positive voltage applied to the gate. Now the junction J_3 is forward biased and junction J_2 is reverse biased. The electrons from N-layer (cathode) start moving across junction J_3 towards left, whereas holes from P-layer (Gate) move towards, right, consequently, the electrons from junction J_3 are attracted across junction J_2 and gate current starts flowing. This makes the anode current to increase. This increased anode current in turn makes more electrons available at junction J_2. This process continues and in short time the junction J_2 breaks down and SCR starts conducting heavily. Once the SCR starts conducting the gate loses its control. Even if gate voltage is removed, the anode current does not decrease at all. The only way to stop conducting is to reduce the supply voltage (V) to zero.

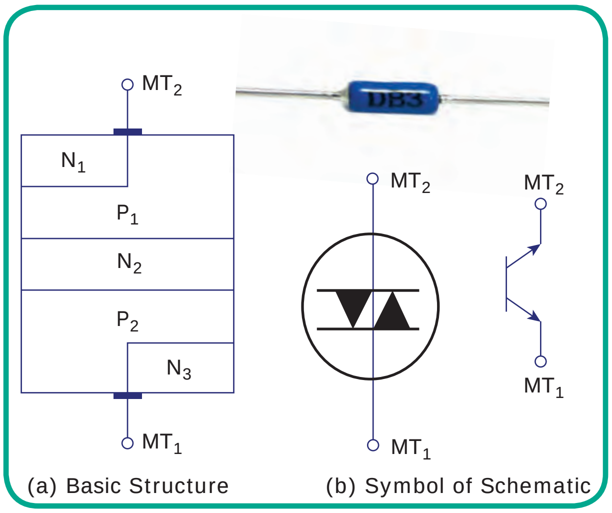
Application of SCR

1. The SCR is used in the circuit of AC voltage stabilizer.
2. It can be used as switch.
3. It is used in inverters.
4. It is used with AC power control with solid relay.
5. It is used to control motor speed.
6. It is used in light dimmer control circuits.

6.12. DIAC

The DIAC is a bidirectional semiconductor switching device. It can be switched 'ON' using both polarities. DIAC is a short version of DIODE Alternating Current. It is widely used as a triggering device of a Triac, especially, for AC switches, dimmer application and starter circuits in fluorescent lamps.

Construction: Figure 6.18 shows the structure and symbol of DIAC. The DIAC is a two terminal device, namely MT_1, MT_2. It is a combination of parallel semiconductor layers ($P_1N_1P_2N_2$, $P_2N_1P_1N_3$) connected in anti-parallel. The DIAC can be configured to conduct in both the directions. The structure of DIAC is similar to transistor, but no terminal attached to the base layer.

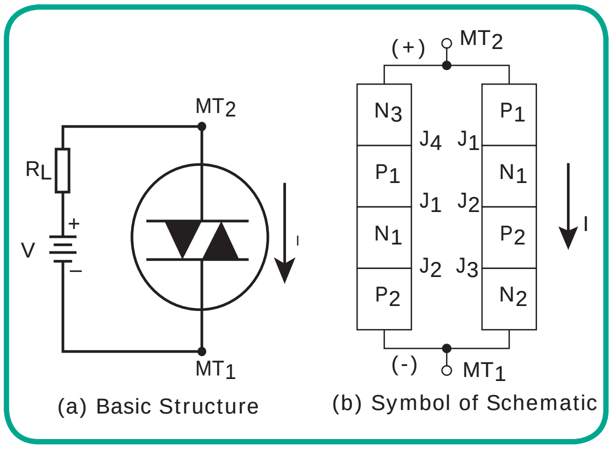


(a) Basic Structure (b) Symbol of Schematic

Figure 6.18 Basic Structure and Symbol of DIAC

Working Principle: The DIAC can conduct in either direction depending upon the polarity of the voltage applied across MT_2 and MT_1. It can be switched ON only, when the applied voltage reaches the break-over voltage (V_{BO}).

When MT_2 is positive with respect to MT_1, the junction J_1 and J_3 are forward biased, whereas junction J_2 and J_4 are reverse biased. Therefore, no current flows through the diode $P_2N_1P_1N_3$. Since the junction J_2 is under reverse biased condition, initially a small leakage current flows through the diode $P_1N_1P_2N_2$. When the applied voltage exceeds the break over voltage, the reverse biased junction J_2 breaks due to avalanche effect. Therefore, the current flows from MT_2 to MT_1 through $P_1N_1P_2N_2$ as shown in Figure 6.19.

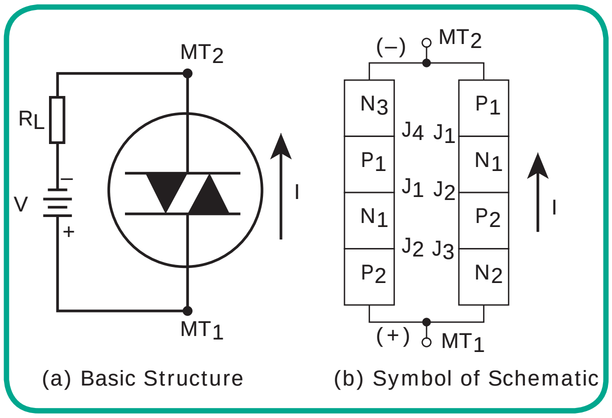


(a) Basic Structure (b) Symbol of Schematic

Figure 6.19 Structure and Symbol Schematic when MT_2 is positive w.r.t. MT_1

When MT_2 is negative with respect to MT_1 the junction J_2 and J_4 are forward biased, whereas junctions J_1 and J_3 are reverse biased. Therefore, no current flows through the diode $P_1N_1P_2N_2$. Since the junction J_1 is under reverse biased condition, initially a small leakage current flows through the diode $P_2N_1P_1N_3$. When the applied voltage exceeds the break over voltage, the reverse biased junction J_1 breaks due to avalanche effect.

Therefore, the diode passes current (I) through the diode $P_2N_1P_1N_3$ from MT_1 to MT_2 as shown in Figure 6.20.



(a) Basic Structure (b) Symbol of Schematic

Figure 6.20 Structure and Symbol Schematic when MT_2 is negative w.r.t. MT_1

Application of DIAC

1. Used as Triggering device in TRIAC Power Control System.

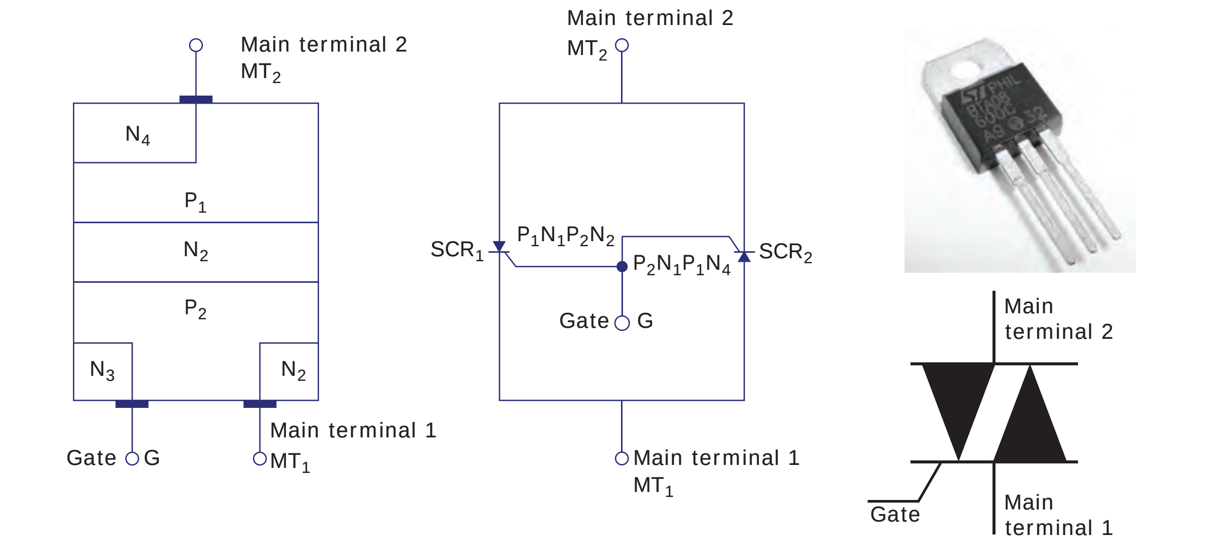
2. Used in Lamp Dimmer Circuit.
3. Used in Heater Control Circuit.
4. Used in Motor Speed Control.

6.13. TRIAC

TRIAC is a three terminal semiconductor switching device. They are MT_1, MT_2 and gate. Here, the gate terminal is used to control the *AC* in a load. TRIAC is a short version of TRIODE AC switch. The flow of current in TRIAC is bi-directional that means current can flow in both directions.

Construction: The structure and symbol of TRIAC is shown in the Figure 6.21. It comprises of two SCRs connected in the anti-parallel direction. It acts as a switch for both the directions. From the diagram we can understand that the MT_1 and gate terminals are close to each other. The gate provides control over conduction in either direction.

Working Principle: Figure 6.22 shows the TRIAC circuit; here the A.C supply is connected across the main terminals (MT_1&MT_2) of TRIAC through a load resistor R_L. The gate circuit consists of battery, a variable resistor and switch. The TRIAC operation depends upon the polarity of voltage across its main terminals and gate terminal.



(a) Basic Structure Electrical equivalent circuit (b) Symbol

Figure 6.21 TRIAC

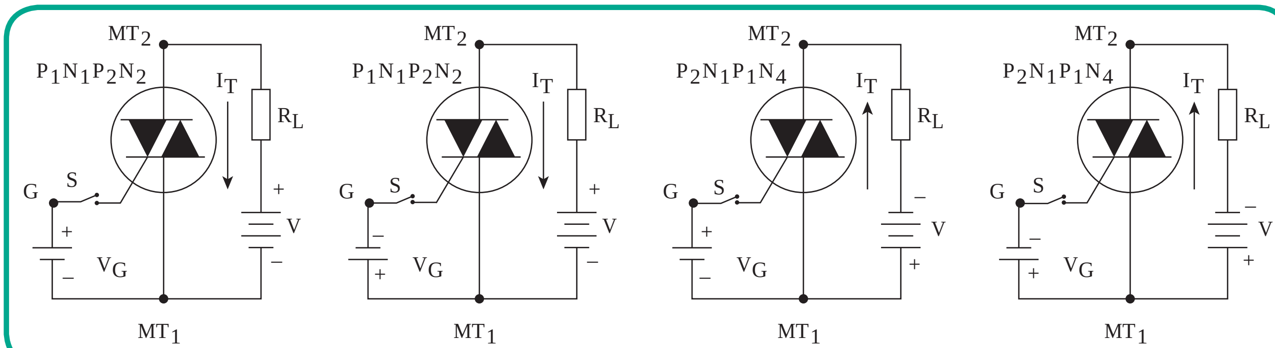


Figure 6.22 TRIAC Biasing Circuit

When switch 'S' is open, there will be no gate current and the TRIAC is cut-off. Even with no gate current, the TRIAC can be turned 'ON' by providing the supply voltage equal to break over voltage (V_{BO}). However, the normal way to turn 'ON' TRIAC is by applying proper gate current.

When switch 'S' is closed, the gate current starts flowing in the circuit. The break over voltage of TRIAC can be varied by making proper gate current to flow by applying few mA at the gate. Now, the TRIAC will start conducting whether terminal MT_2 is positive or negative with respect to MT_1.

If the MT_2 is positive with respect to MT_1, the TRIAC turns *ON* and the conventional current will flow from MT_2 to MT_1. If the MT_2 is negative with respect to MT_1, the TRIAC is again turned *ON* but this time the conventional current flows from MT_1 to MT_2.

Application of TRIAC

1. It can be used as a static switch to turn AC power ON and OFF.
2. It is used for motor speed control.
3. It is used for illumination control.
4. It is used for heater control.
5. It is used for phase control.

6.14. INSULATED GATE BIPOLAR TRANSISTOR (IGBT)

IGBT is a three terminal semiconductor device with huge bipolar current carrying capability. So, this device is designed to make use of the benefits of both BJT and MOSFET devices in the form of monolithic.

IGBT has several applications in power electronics, particularly, PWM, UPS, SMPS and other power circuits. It increases the efficiency, dynamic performance and reduces the level of the audible noise. IGBT are also named as bipolar MOS transistor and conductivity modulated field effect transistor (COMFET).

History: The IGBT was proposed by Yamagami in 1968, but experimentally reported by B.W.Scharf and J.D.Plummer in 1978.

Construction: Figure 6.23 shows the structure, equivalent circuit and symbol of an IGBT. It is similar to the structure of MOSFET and the main difference

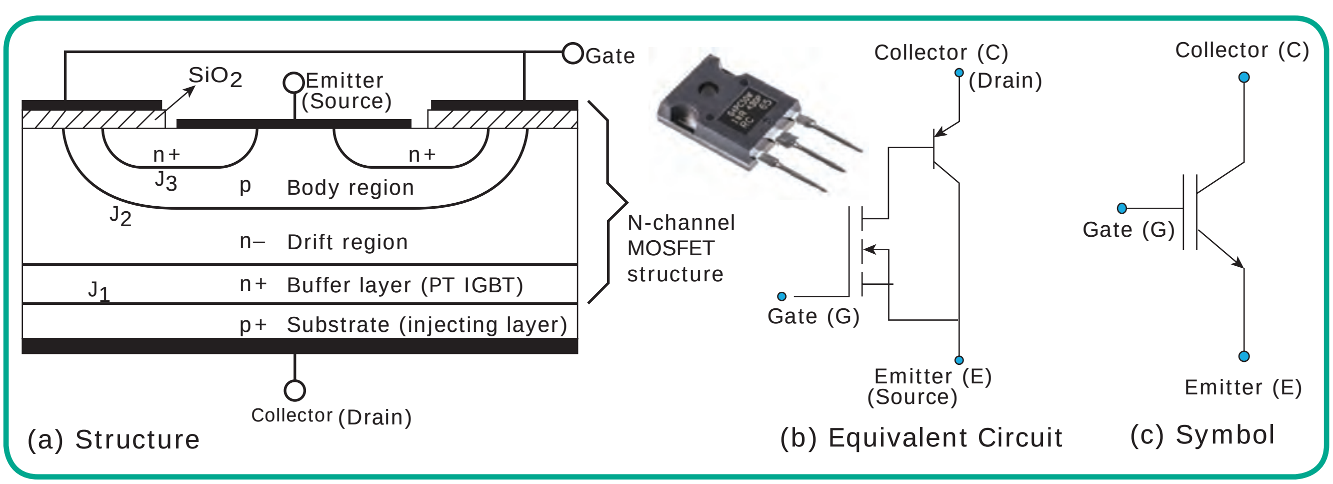


Figure 6.23 Insulated Gate Bipolar Transistor

is the presence of p+ layer that is added to the drain side. This p+ layer is also called injecting layer. The next layer is n+ layer also called as buffer layer. There is a p-n junction J_1 between the injecting layer and the buffer layer. There are two more p-n junctions J_2 and J_3 as shown in Figure 6.23. The junction J_1 blocks reverse voltage. The junction J_2 blocks forward voltage when IGBT is off.

Working Principle: When a positive voltage is applied between the gate and source, the power MOSFET turns 'ON' and acts as a low resistance between the base and collector of the PNP transistor, thereby the IGBT is turned 'ON'. When there is no gate to source voltage the MOSFET is turned off and hence the PNP transistor is also off because no longer base current is supplied. Thus, the IGBT acts as a switch.

Application of IGBT

1. The IGBT is used in medium to high power application like SMPS, traction motor control etc.
2. Large IGBT modules consist of many devices in parallel have the capability to control current in hundreds of amperes with blocking voltage of 6500 V.

6.15 INTEGRATED CIRCUIT (IC)

An integrated circuit consists of number of circuit components (e.g., transistors, diodes, resistors, capacitors etc.,) and their inter connections in a single small package to perform a complete electron function. Those components are formed and connected within a small chip of semiconductor material. The following points are worth noting about Integrated Circuits.

i. In an IC, the various components are automatically part of a small semiconductor chip and the individual components cannot be removed or replaced. This is in contrast to discrete assembly in which individual components can be removed or replaced if necessary.

ii. The size of an IC is extremely small. In fact, ICs are so small that it normally need a microscope to see the connections between the components. Figure 6.24 shows a typical semiconductor chip.

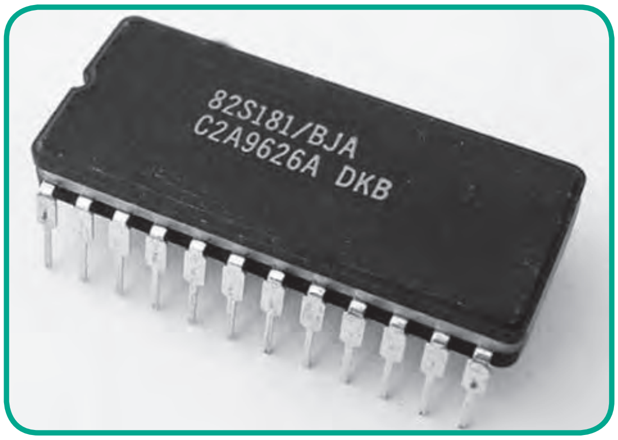


Figure 6.24 Integrated Circuit (IC)

iii. No components of an IC are seen to project above the surface of the chip. This is because all the components are formed within the chip.

LEARNING OUTCOMES

After learning this Chapter, the student will

1. **Apply the concept of special type semiconductor devices to design various circuits.**
2. **Acquire the basic knowledge in opto-electronic devices and Thyristor devices.**
3. **Understand how to control the power using Thyristor type devices.**
4. **Design, fabricate and test small electronic circuit.**

GLOSSARY

S. No	Terms	Explanation
1	Diffusion	The intermingling of substances by the natural movement of their particles
2	Electroluminescence	Luminescence produced electrically by the application of a voltage
3	Gate	The controlling terminal of a FET. A voltage on the gate control the current flow between the source and drain
4	Indicators	A thing that indicates the state or level of something
5	Intensity	The measurable amount of a property such as force, brightness or a magnetic field
6	Monolithic	Solid state circuit composed of active and passive components formed in a single chip
7	Nematic	Relating to or denoting a state of liquid crystal in which the molecules are oriented in parallel but not arranged in well-defined planes
8	Optoelectronics	Technology concerned with the combined use of electronics and light
9	Q Factor	A measure of the quality of a resonant circuit
10	Radiation	The emission of energy as electromagnetic waves or as moving subatomic particles especially high energy particles which causes ionization
11	Selenium	It is a grey crystalline non-metal with semiconductor properties
12	Substrate	An underlying substance or layer
13	Terminal	A point of connection for closing an electric circuit
14	Threshold	The magnitude or intensity that must be exceeded for a certain reaction to occur
15	Thyristor	A four layered semiconductor rectifier in which the flow of current between two electrodes is triggered by a signal at a third electrode

QUESTIONS

PART A

I Choose the best answer

1) Which of the following material finds application in yellow LED?
   a) Gallium arsenide b) Gallium phosphide
   c) Gallium arsenide phosphide d) Phosphorous

2) A strong incident light focusing on LDR, the resistance will be
   a) 2 MΩ b) 1 MΩ c) 100 Ω d) 500 KΩ

3) A liquid crystal display can
   a) Emit light b) Generate light
   c) Alter the externally available illumination d) None of the above

4) The power consumption of LCD is
   a) Very low b) Low c) High d) Very high

5) A UJT is not used as a
   a) Phase control circuit b) Timing device
   c) Switching device d) Transistor amplifier

6) Which material widely used in solar cell production?
   a) Carbon b) Lead c) Copper d) Selenium

7) For satellites the source of energy is
   a) Fuel cells b) Edison cells c) Cryogenic storage d) Solar cell

8) A JFET is also called .... transistor
   a) Unipolar b) Bipolar c) Unijunction d) None of the above

9) The enhancement type basically termed as normally-off MOSFET works only with large ....
   a) Positive gate voltage b) Negative gate voltage
   c) Positive drain voltage d) Negative drain voltage

10) Gate of MOSFET is insulated with layer of ....
   a) SiO_2 b) Si c) O_2 d) H_2O

11) The control element of an SCR is ....
   a) Cathode b) Anode c) Anode supply d) Gate

12) SCR is turned off by ....
   a) Reducing anode voltage to zero b) Reducing gate voltage to zero
   c) Reverse biasing the gate d) None of the above.

13) The device that does not have gate terminal is …………

a) TRIAC b) FET c) SCR d) DIAC

14) The normal way to turn 'ON' a diac is by ....

a) Gate current b) Gate voltage

c) Break over voltage d) None of the above

15) An IGBT is also known as

a) MOIGT b) COMFET c) GOMFET d) All the above.

PART B

II Answer in few sentences 3 Marks

1. What are the advantages of LED?
2. How will you display number 9 in seven segment display?
3. Draw the symbol of LDR. Also mention its other names.
4. Differentiate photodiode and phototransistor.
5. What are the disadvantages of LCD?
6. State any three applications of MOSFET.
7. What is DIAC?
8. Draw the symbol of TRIAC. Mention its terminals.
9. Write any three application of TRIAC.
10. What is the function of IGBT?

PART C

III Explain the following questions 5 Marks

1. Write short notes on seven segment display.
2. Compare LED and LCD.
3. Explain the working principle of solar cell.
4. Compare JFET and MOSFET.
5. Write short notes on IGBT.

PART D

IV Answer the following questions in detail. 10 Marks

1. Explain the construction and working principle of LCD with neat diagram.

2. Explain the working principle of UJT with neat diagram.

4. Write in detail the working of SCR with biasing diagram.

ANSWERS

1. (c)	2. (c)	3. (c)	4. (a)	5.(d)
6. (d)	7.(d)	8. (a)	9. (a)	10.(a)
11.(d)	12. (a)	13. (d)	14. (c)	15. (b)

CHAPTER 7

OSCILLATORS

T4QYLR

ஆக்கம் அதர்வினாய்ச் செல்லும் அசைவிலா
ஊக்க முடையா னுழை. – குறள் 594

விளக்கம்
சோர்வு இல்லாத ஊக்கம் உடையவனிடத்தில் ஆக்கமானது தானே அவன் உள்ள இடத்திற்கு வழிக் கேட்டுக்கொண்டு போய்ச் சேரும்.

English Couplet 594

The man of energy of soul inflexible,
Good fortune seeks him out and comes a friend to dwell.

Couplet Explanation:
Wealth will find its own way to the man of unfailing energy.

CONTENT

LEARNING OBJECTIVES

While learning this Chapter, the student will

1. **Understand fundamental principles of oscillator circuits using positive feedback.**
2. **Working principles of LC, RC and crystal oscillators.**
3. **Understand the multivibrator functions and their types.**
4. **Study the applications of oscillator in various fields.**

INTRODUCTION

Have you heard the sound from FM radio receiver or a beeper or a horn? How the sound is generated? What is the source of the sound? All these questions have only one answer, i. e. the sound is generated by an oscillator.

Any circuit, which is used to generate an ac voltage without an ac input is called an oscillator. The oscillator circuit needs energy from a DC source. It is widely used in electronic equipment. For example, in Radio and Television receivers, oscillators are used to generate high frequency wave called carrier wave. Oscillator generates both sinusoidal (sine) and non-sinusoidal (square, rectangle, triangular, sawtooth, etc.) waveforms.

History of Oscillator

E. H. Armstrong

In 1912, E. H. Armstrong and Lee Deforests developed a new device audion (triode vacuum tube), by coupling one terminal of the device to another. Armstrong achieved the first electronic amplifier with large gain. He called the process “regeneration” (positive feedback). Further, he had made the first electronic oscillator. These two made a revolution in radio broadcasting.

Armstrong had created components necessary to make continuous wave (CW) radio practicable. Primarily, at that time radio was similar to wireless telegraphy (i.e., dots and dashes) and hence CW radio was used to transmit audio information. With Armstrong oscillator, CW signals at high frequencies in the range of kHz to MHz could be easily generated.

7.1. CLASSIFICATION OF OSCILLATORS

Oscillators are classified based on different methods and are summarized in the following sub-sections.

7.1.1. According to the Waveforms Generated

Sinusoidal oscillator: If the output voltage is a sine wave function of time the oscillator is called as “sinusoidal” or Harmonic oscillator. Positive feedback and negative resistance oscillators belong to this category. The waveform generated by the sinusoidal oscillator is shown in Figure 7.1(a)

Non sinusoidal (or) Relaxation Oscillator: This type of oscillators has non-sinusoidal output such as a square, triangular and sawtooth waveforms. The waveform generated by Non sinusoidal oscillator shown in Figure 7.1(b)

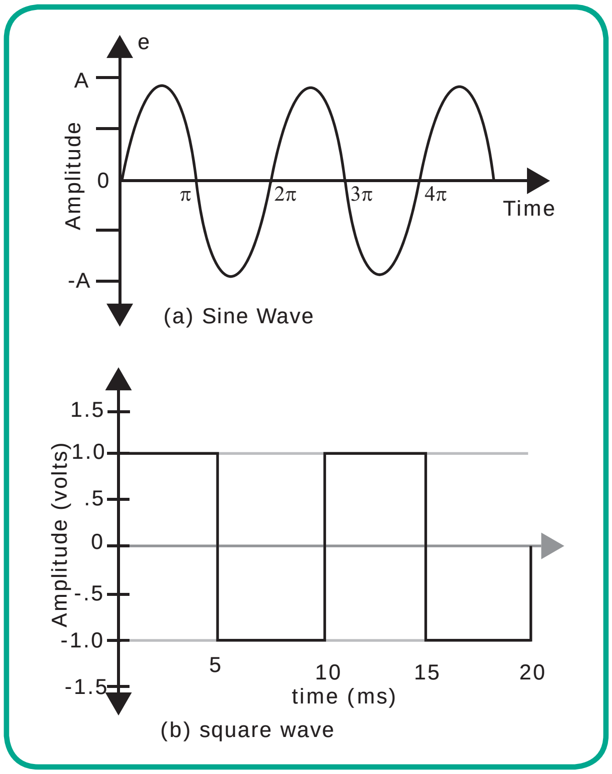


Figure 7.1 (a) Sine Wave, (b) square wave

7.1.2. According to the Fundamental Mechanism Used

1. Negative Resistance Oscillators
2. Feedback Oscillators

Negative resistance oscillator has the negative resistance amplifying device to neutralize the positive resistance of the oscillator. Feedback oscillator uses positive feedback in the feedback amplifiers to satisfy the Barkhausen criterion

7.1.3. According to the Frequency Generated

1. Audio frequency (AF) oscillator:
   20Hz to 20 kHz
2. Radio frequency (RF) oscillator
   20 kHz-30 MHz
3. Very high frequency (VHF) oscillator:
   30 MHz-300 MHz
4. Ultra high frequency (UHF) oscillator:
   300 MHz-3 GHz
5. Microwave frequency oscillator:
   above 3GHz

7.2. TYPES OF SINUSOIDAL OSCILLATION

Sinusoidal electrical oscillation can be of two types

1. Damped oscillation
2. Undamped oscillation

7.2.1. Damped Oscillation

Figure 7.2(a) shows the damped oscillation. In this type of oscillators, during each oscillation, some energy is lost due to electrical losses (I^2R).The amplitude of the oscillation reduced to zero, when no compensating arrangement for the electrical losses is provided.

7.2.2. Undamped Oscillation

Figure 7.2(b) shows the undamped oscillations. In these types, the amplitude of each oscillation remains constant with time. Although the electrical system in which these oscillations are being generated has losses, but now right amount of energy is being supplied to overcome these losses. Therefore, the generated wave remains constant. It is also called as sustained oscillations. These continuous waves are produced by electronic oscillator circuits for utilizing in various electronic equipment.

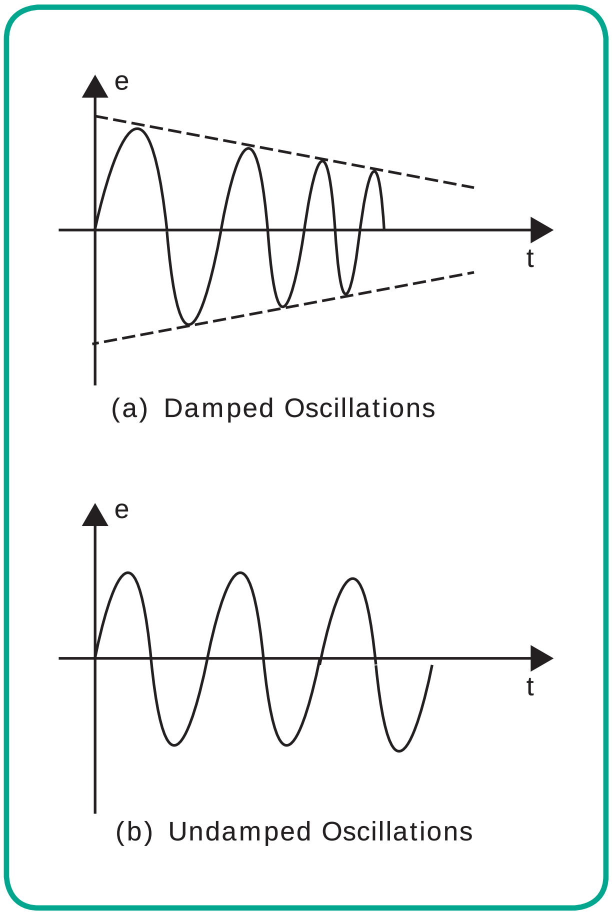


Figure 7.2 Damped and Undamped Oscillations

7.3. ESSENTIAL PARTS OF AN OSCILLATOR

Figure 7.3 shows the block diagram of an oscillator. Its essential components are:

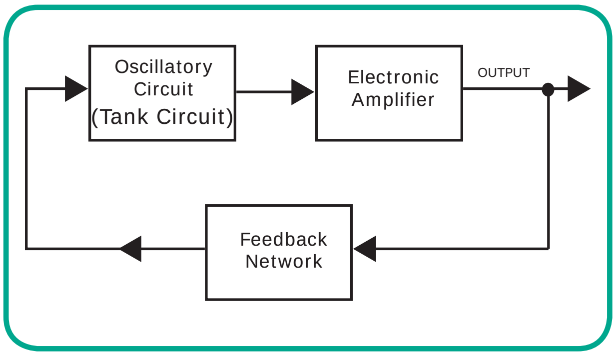


Figure 7.3 **Block Diagram of an Oscillator**

Tank Circuit: It consists of inductor or coil (L) and capacitor (C). The frequency of oscillation depends upon the values of inductance of the coil and capacitance of the capacitor.

Transistor Amplifier: The transistor amplifier receives DC power from the battery and changes it into AC power for supplying to the tank circuit. The main function of the amplifier is to amplify the generated oscillation from the tank circuit.

Feedback Circuit: This circuit provides positive feedback to the oscillator. It gives a part of amplifier output to the tank circuit in correct phase to make oscillation as undamped (constant amplitude).

7.4. FEEDBACK IN OSCILLATOR

In feedback, a part of the output signal is fedback to the amplifier input in such a way that the feedback signal re-generates, re-amplifies and sustain the feedback to maintain a constant output Signal.

Commonly an oscillator is constructed from an amplifier that has part of its output signal feedback to the input. This is done in such a way to keep the amplifier producing signal without the need for any external signal input as shown in the Figure 7.4. Here, the DC supply is converted into AC signal.

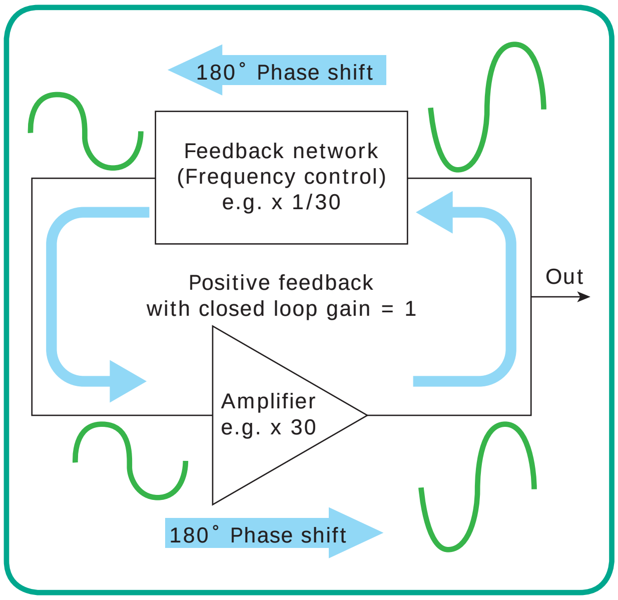


Figure 7.4 **Positive Feedback**

7.4.1. Positive Feedback

The feedback in the amplifier section of an oscillator must be positive feedback. Here a fraction of the amplifier output signal is feedback as input. Note that the feedback signal is in phase with the input signal. As a result, the amplitude of the signal is increased.

For example, common emitter amplifier creates a phase shift of 180° between its input and output. Similarly, the positive feedback loop also produce a 180° phase shift in the signal feedback from output to input in order to provide positive feedback.

The result of small amount of positive feedback in amplifiers results in higher gain, at the cost of increased noise and distortion. If the amount of positive feedback is large enough, the result is oscillation where the amplifier circuit produces its own signal.

7.4.2. Using Positive Feedback

When an amplifier is operating without feedback is called as "open-loop" mode and with feedback *(either +ve or -ve)*, is known as "closed-loop" mode. In ordinary amplifiers, negative feedback is used to provide advantages in bandwidth, distortion and noise generation, and in these circuits the closed-loop gain of the amplifier is much less than the open-loop gain. However, when positive feedback is used in an amplifier system, the closed-loop gain (with feedback) will be greater than the open-loop gain; the amplifier gain is now increased by the feedback. Additional effect of positive feedback are reduced bandwidth, (but this does not a matter in an oscillator producing a sine wave having a single frequency), and increased distortion. However, even severe distortion in the amplifier is allowed in some sine wave oscillator designs, where it does not affect the shape of the output waveform.

In oscillators using positive feedback, it is important that amplitude of the oscillator output remains stable. Therefore, the closed loop gain must be 1 (unity). In other words, the gain within the loop (provided by the amplifier) should exactly match the losses (caused by the feedback circuit) within the loop. In this way, there will be no increase or decrease in the amplitude of the output signal as shown in the waveform 7.5.

This is achieved by Barkhausen criteria given by $|A\beta| = 1$.

where A is the amplifier gain and β is the transfer function of feedback.

7.4.3. The Condition for Oscillation

Positive feedback must occur at a frequency where the voltage gain of the amplifier is equal to the losses (attenuation) occurring in the feedback path. For example, 1/30 of the output signal feedback to be in phase with the input at a particular frequency, and the gain of the amplifier (with feedback) is 30 times or more, thus oscillation should take place. The conditions for oscillation are, (i) the oscillations should take place at one particular frequency and (ii) the amplified output of the oscillation should be constant.

There are many different oscillator designs in use, each design achieving the above criteria in different ways; some designers are particularly suited to producing certain wave shapes or work best within certain band of frequencies. Whatever design is used, the way of achieving a signal of constant frequency and constant amplitude, by using one or more of the following three basic methods.

Method 1: Make sure that positive feedback occurs only at one frequency of oscillation. This may be achieved by ensuring that only signal of the required frequency are feedback or by ensuring feedback signal is the correct in-phase at only one frequency.

Method 2: Make sure that sufficient amplification for oscillation can take place only the required frequency by using an amplifier that has an extremely narrow bandwidth extending to the frequency of oscillation only.

Method 3: Use amplifiers in "Switch mode" to switch the output between two set voltage levels together with some form of time delay to control the time at which the amplifiers switch-on or off, thus controlling the period of the signal produced.

Methods 1 and 2 are used extensively in sine wave oscillators.

Method 3 is used in square wave generators (multivibrator).

7.4.4. Constant Amplitude

As shown in Figure 7.4, oscillators must have an amplifier, a positive feedback loop and some method of controlling the frequency of oscillation. In RF sine wave oscillator, the frequency may be controlled by an LC tuned circuit, but as well as controlling the frequency of oscillation, there must be some means, such as negative feedback for stabilizing the amplitude of signal produced.

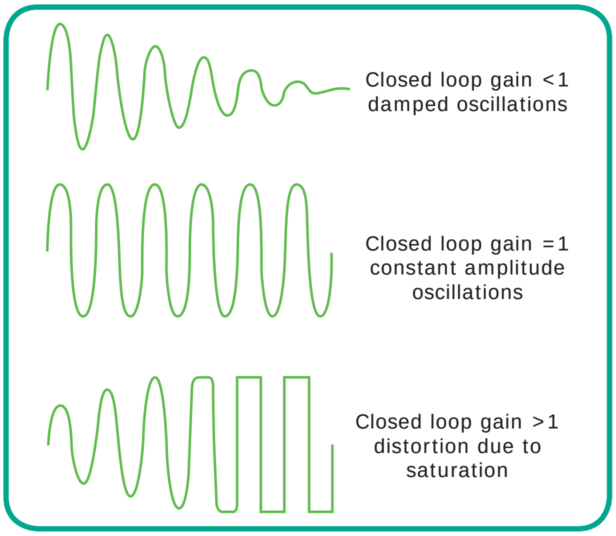


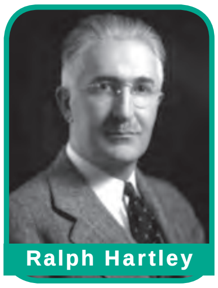
Figure 7.5 Constant Amplitude

Without this stabilization, the oscillations would either die away and stop (damped oscillation) or rapidly increased in amplitude until the amplifier produces severe distortions due to the transistors within the amplifier becoming "saturated" as shown in Figure 7.5. To produce constant amplitude output the gain of the amplifier is automatically controlled during oscillation.

7.5. TYPES OF OSCILLATOR

There are several types of transistor oscillators commonly used in electronic circuits. Let us study the few important types. 1. Hartley Oscillator, 2. RC Phase Shift Oscillator, 3. Crystal Oscillator

7.5.1. Hartley Oscillator



This type of LC oscillator is used to produce RF waves in the range of 30 kHz - 30 MHz The frequency of oscillation is decided by its tank circuit, which has a capacitor (C) connected in parallel with inductors (L_1 and L_2).

History: The Hartley oscillator circuit was invented in 1915, by Ralph Hartley. The distinguishing feature of the circuit is that the tuned circuit consists of a single capacitor in parallel with two inductors in series, and the feedback signal needed for oscillation is taken from the center connection of two inductors.

Construction: Figure 7.6 shows the Hartley oscillator. The circuit consists of CE configuration, in which Resistor R_1 and R_2 form the voltage divider bias network. Next, the capacitor C_{C2} and C_{C1} are input and output decoupling capacitor, while the emitter capacitor C_E is the bypass capacitor used to bypass the amplified AC signals.

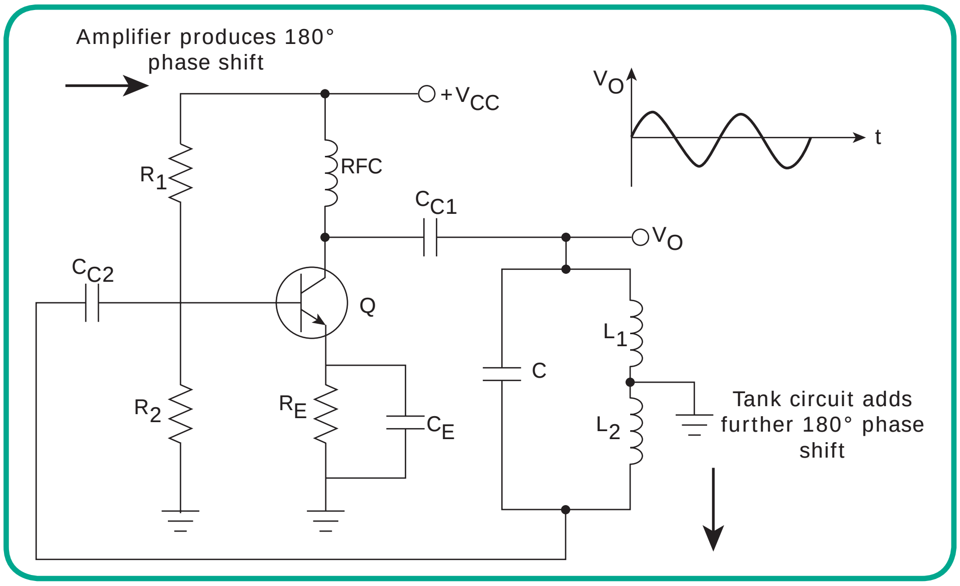


Figure 7.6 **Hartley Oscillator**

Working Principle: When the circuit is turned 'ON', the capacitor 'C' is charged. It is fully charged, starts discharging through the coils L_1 and L_2, which starts the oscillations. The output voltage of the amplifier appears across L_1 and the feedback voltage appears across L_2. The voltage across L_2 is 180^0 out-off phase with the output voltage. It is a feedback signal and thus the total phase shift is $180^0 + 180^0 = 360^0$, since the output waveform provides 180^0 phase shift and the feedback provides another 180^0 phase shift. In this way, feedback is properly phased to produce continuous Undamped oscillation.

The oscillator frequency is calculated by the values of L_1, L_2 and C and is given by,

$$F = \left(\frac{1}{2\pi\sqrt{LC}}\right), \text{ where } L=L_1+L_2$$

Advantages

1. The frequency adjusted by single variable capacitor.
2. The output amplitude remains constant over the frequency range.

7.5.2. RC Phase Shift Oscillator

An oscillator which have resistive and capacitive element with a phase shift circuit is called RC phase shift oscillator. Previously, we have studied about LC circuits. They have two general drawbacks. Firstly, they suffer from frequency instability and poor waveform. Secondly, they cannot be used for low frequencies because they become too bulky and expensive.

History: Transistor phase shift oscillator was first patented by Robert W. Blanchard in the year 1958.

Construction: Figure 7.7 shows the circuit of phase shift oscillator. It consists of transistor amplifier and 'RC' phase shift network. The phase shift network has three sections R_1C_1, R_2C_2 and R_3C_3. At some particular frequency f_0, the phase shift in each 'RC' section is 60^0 so that the total phase-shift produced by the three RC network is 180^0.

The oscillator frequency

$$f_o = \frac{1}{2\pi RC\sqrt{6}},$$

where $R_1=R_2=R_3=R$ and $C_1=C_2=C_3=C$.

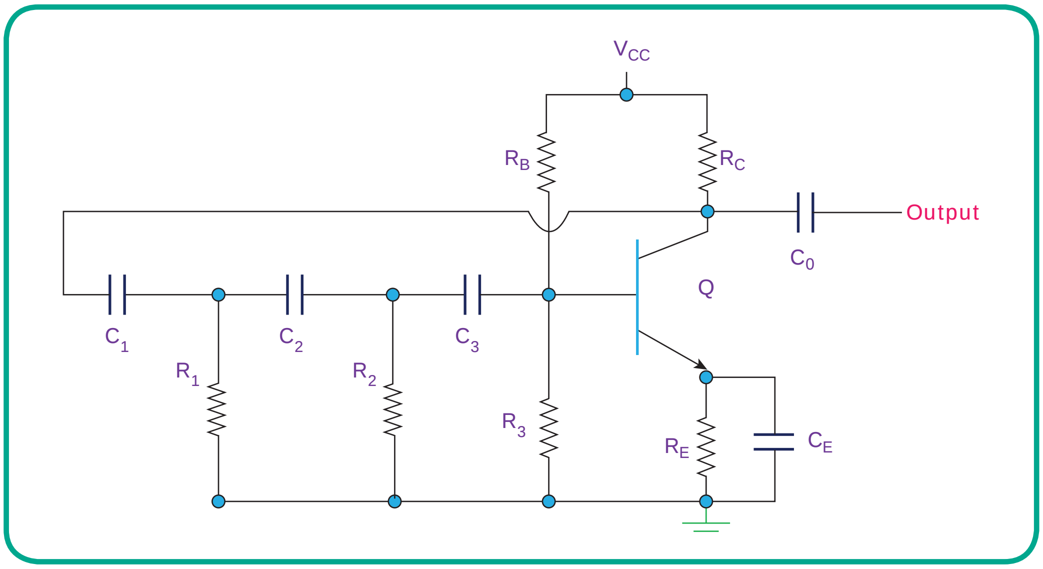


Figure 7.7 RC Phase Shift Oscillator Using BJT

Working Principle: When the circuit is switched 'ON', random variation in the DC power supply or noise variation in the transistor oscillator occurs. This can be amplified by the transistor. The output 'E_O' of the amplifier is feedback through the RC network. This network produces a phase shift of 180° and a voltage E_i appears at its output is applied to the transistor amplifier. Obviously, the feedback fraction $m=E_i/E_0$, if the feedback phase is correct, a phase shift of 180° is produced by the RC network. As a result, the phase shift around the entire loop is 360°.

Advantages

1. Does not require transformer or inductor
2. It can produce very low frequency signal
3. The circuit provides good frequency stability

Disadvantages

1. It gives low power output
2. It is difficult to start oscillation as the feedback signal is small

7.5.3. Crystal Oscillator

The transistor crystal oscillator resembles Colpitts oscillator modified to act as crystal oscillator. The only change is the addition of the crystal (Y) in the feedback network. It replaces the LC resonant circuit.

W. G. Cady

History: Piezoelectricity was discovered by Jacques and Pierre Curie in 1880. Paul Langevin first investigated quartz resonators for use in sonar during World War I. The first crystal controlled oscillator using a crystal of Rochelle salt was built in 1917 and patented in 1918 by Alexander M. Nicholson at Bell Lab, although his priority was disputed by Walter Guyton Cady. Cady built first quartz crystal oscillator in 1921.

The crystal is a thin slice of piezoelectric material, such as quartz, tourmaline and Rochelle salt, which exhibits a property called piezoelectric effect. It means the crystal reacts to any mechanical stress by producing electric charge, in

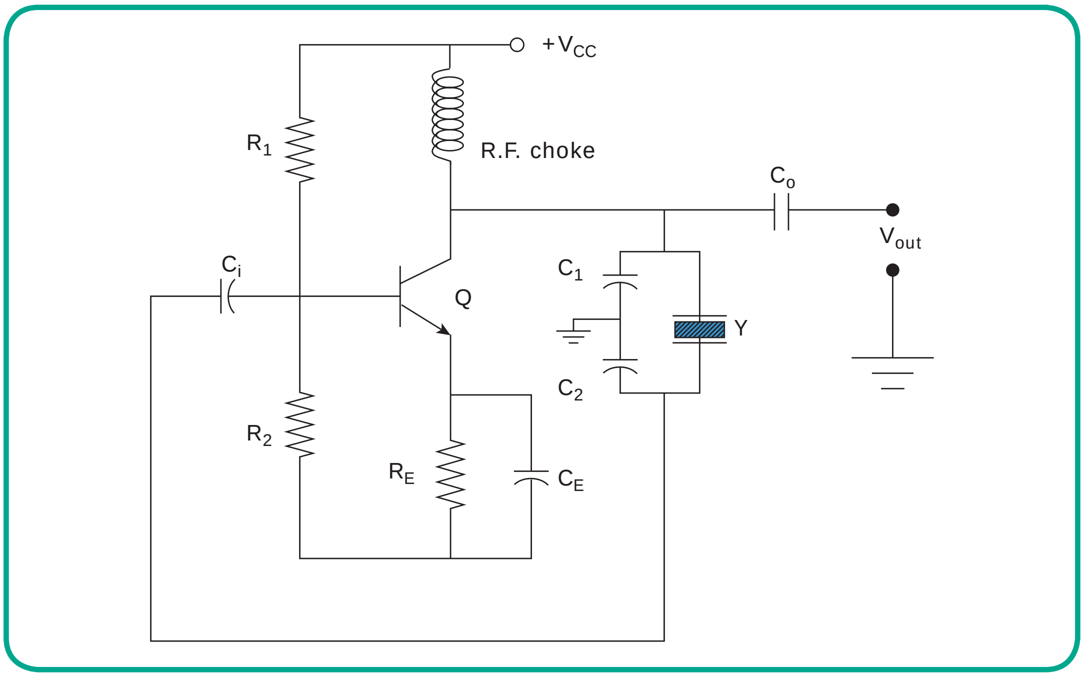


Figure 7.8 **Crystal Oscillator**

the converse effect, an electric field results in mechanical strain. The advantage of the crystal is its very high Q as a resonant circuit, which results in good frequency stability for the oscillator.

Circuit Description: In the circuit shown in Figure 7.8, the resistors R_1 and R_2 form the voltage divider network, while the emitter resistor R_E stabilizes the circuit. Further, C_E acts as an AC by pass capacitor, while the coupling capacitor C_i is used to block DC signal propagation between collector and base terminals. The RF coil in the circuit which offers dual advantages, as it provides even the DC bias and frees the circuit output from being affected by the AC signal on the power lines.

Working Principle: When the supply is switched 'ON', the capacitor C_1 is charged. It fully charged, then starts discharging through the crystal and produces oscillation. The frequency of the oscillation depends upon the values of C_1, C_2 and the RLC values of the crystal. If the frequency of the oscillation is equal to its crystal resonant frequency, the circuit produces more stable oscillations. The crystal frequency is dependent on temperature.

Advantages

1. High 'Q' factor
2. Excellent frequency stability
3. Simple circuit

Disadvantages

1. Not to be used as tuned oscillators
2. Crystal is fragile type, hence it is used only in low power circuits

7.5.4. Application of crystal oscillator

Crystal oscillators are used in the microprocessor and microcontroller for providing the clock signals. It generates clock pulses required for the synchronization of all the internal operations. The use of crystal oscillator in military and aerospace is to establish an efficient communication system for navigation purpose in the guidance systems.

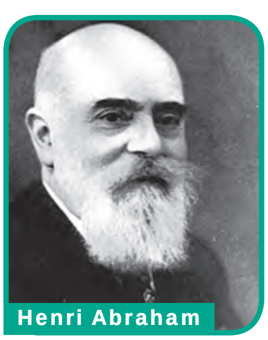
The oscillator is used in research and measurement of celestrial navigation, space tracking purpose, and the timing signal in the measuring instruments and medical devices. There is variety of industrial applications of crystal oscillator such as computers, digital systems, marine, modems, sensors, telecommunications and disk drives. It is used in automotive field by engine controlling, stereo and in GPS system. It is also used in consumer applications like TV systems, PCs, video games, toys, radio systems and cellular phones.

DO YOU KNOW? **Which oscillator circuit used for medical treatment?**

Multi wave oscillator is applied for the treatment of cancer.

7.6. MULTIVIBRATORS

Multivibrators are two stage switching circuits in which the output of the first stage is fed to the input of the second stage and vice versa. The outputs of the two stages are complementary (high or low). A specific characteristic of multivibrator is that it uses passive elements like resistor and capacitor to determine the output state.


Henri Abraham

History: The first multivibrator circuit, the astable multivibrator oscillator was invented by Henri Abraham and Eugene Bloch in 1920. They called their circuit 'a' multivibrator because its output waveform was rich in harmonics.

Multivibrators are of three types namely

1. Astable multivibrator
2. Monostable multivibrator
3. Bistable multivibrator

7.6.1. Astable Multivibrator

The astable or free running multivibrator generates square wave without any external triggering pulse. It has no stable states, i.e. it has two quasi-stable states. It switches back and forth from one state to the other, remaining in each state for a time depending upon the discharging of a capacitive circuit.

7.6.2. Monostable Multivibrator

Monostable multivibrator has one stable and one quasi-stable. It is also known as one- shot multivibrator. In this, the output pulse duration is determined by the RC time constant and is given as $1.11 * R * C$. This multivibrator cannot generate square waves of its own like an astable multivibrator. One external triggering pulse will cause it to generate the rectangular waves.

7.6.3. Bistable Multivibrator

The bistable multivibrator has two stable states. A triggering pulse is applied to the circuit causes it to switch from one state to other. Another trigger pulse is then required to switch the circuit back to its original state.

T4Y8YK

Construction: Figure 7.9 shows the circuit of a bistable multivibrator using two NPN transistors. In this circuit, the output of a transistor Q_2 is coupled to the base of

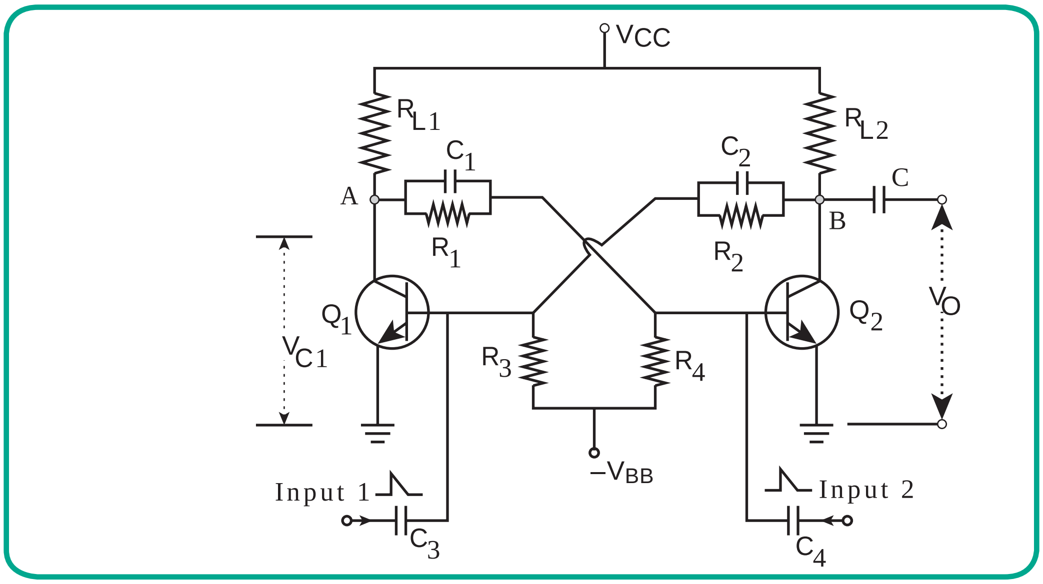


Figure 7.9 **Bistable Multivibrator**

transistor Q_1 through a resistor R_2. Similarly, the output of Q_1 is coupled to the base of Q_2 through resistor R_1. The main purpose of capacitors C_1 and C_2 is to improve the switching characteristic of the circuit by passing the high frequency components of the square wave pulses. This allows fast rise and fall times, so that these square waves will not be distorted. C_1 and C_2 are called commutating capacitors or speed up capacitors.

Working Principle: When the circuit is switched-ON, one of the transistors will start conduct slightly higher than the other. This transistor is thus driven into saturation (i.e. ON). Then, because of the regenerative feedback action, the other transistor is taken into cut-off (i.e. OFF) state. Let us consider transistor Q_1 is ON and Q_2 is OFF. It is a stable state of the circuit and will remain in this state till a trigger pulse is applied from outside. A positive triggering pulse applied to the reset input (base of Q_2) increases its forward bias, thereby turning transistor Q_2 ON, and there is an increase in collector current and decrease in collector voltage occur. The fall in the collector voltage is coupled to the base of Q_1, which in turn turned OFF. The circuit is then in its second stable state until a positive trigger pulse is applied to the base of Q_1.

A similar action can be achieved by applying a negative pulse at the set input for transition from the first stable state to the second stable state and by applying a negative pulse at the reset input, reverse transition can be obtained.

Applications

1. It is used in computer memory circuits.
2. It is used as memory element in shift registers, counters and so on.
3. It can also be used as a frequency divider.

DO YOU KNOW? **Uses of multivibrator**

- They are used as a frequency divider
- Used as sawtooth generators
- They are used as wave and pulse generator.
- They are used as standard frequency source.
- They are used in Radar and TV circuits
- They are also used as memory elements in computer.

LEARNING OUTCOMES

Through this Chapter, the student will

1. **Acquire basic knowledge in sinusoidal and non sinusoidal waves.**
2. **Understand how the oscillator circuit is essential for communication equipment.**
3. **Understand the use of positive feedback in an oscillator.**
4. **Understand bistable multivibrator as the foundation of digital electronics.**

GLOSSARY

S. No	Terms	Explanation
1	Amplitude	Magnitude or size of a signal or voltage
2	Bandwidth	It is a range of frequencies or information, that a circuit can handle
3	Crystal	A crystalline piece of semiconductor used as an oscillator
4	Damped	To cause a decrease in amplitude of successive oscillations or waves
5	Feedback	A part of output signal from an amplifier is given to the input of the same device
6	Frequency	The number of cycles occur at a particular period of time
7	Multivibrator	A device consisting of two amplifying transistors, each with its output connected to the input of the other, which produces an oscillator signal
8	Non sinusoidal	Other than sine wave (square, triangular, rectangular and sawtooth wave)
9	Oscillation	Regular variation in magnitude or position about a central point, especially of an electric current or voltage
10	Phase shift	A change in phase of a waveform
11	Regeneration	Positive feedback
12	Resonant circuit	A resonant, or tuned circuit combines an inductor and capacitor to make a circuit that is responsive to a frequency
13	Sinusoidal	Having a form of sine curve, a sinusoidal waveform
14	Synchronization	The operation or activity of two or more things at the same time or rate
15	Undamped	Oscillations having constant amplitude

QUESTIONS

PART A

I Choose the correct answer — 1Mark

1. An oscillator converts ………………..
   a) AC power into DC power
   b) DC power into AC power
   c) Mechanical power into AC power
   d) None of the above

2. In an LC transistor oscillator, the active device is …………
   a) LC tank circuit
   b) Biasing circuit
   c) Transistor
   d) RC circuit

3. An oscillator produces ………… oscillations
   a) Damped b) Undamped c) Modulated d) None of the above

4. Hartley oscillator is commonly used in ……………..
   a) Radio receivers
   b) Radio transmitters
   c) TV receivers
   d) TV transmitters

5. In a phase shift oscillator, we use …….. RC sections.
   a) Two b) Three c) Four d) One

6. In a phase shift oscillator, the frequency determining elements are …………..
   a) L and C b) R,L and C c) R and C d) R and L

7. In a crystal, the piezoelectric effect causes …………..
   a) A voltage is developed because of mechanical stress
   b) A change in resistance occurs because of temperature
   c) change in frequency occurs because of temperature
   d) None of the above

8. The crystal oscillator frequency is very stable due to ………. of the crystal.
   a) Rigidity b) Vibrations c) Low Q d) High Q

9. Astable multivibrator is ………. in any state.
   a) Stable b) Unstable c) Saturated d) Both (a) and (c)

10. Bistable multivibrator is ………… in any state.
    a) Stable b) Unstable c) Saturated d) Independent

11. A monostable multivibrator has ……….
    a) No stable state
    b) One stable state
    c) Two stable state
    d) None of the above

12. Circuit which consists of a quasi-stable state is called ………………
    a) Bistable circuit b) Monostable circuit c) Tristable circuit d) Tristate circuit

PART B

II Answer in few sentences — 3 Marks

1. What is an oscillator? How is it classified?
2. What is meant by piezoelectric effect?
3. How will you produce square wave?
4. What are the types of transistor oscillator?
5. What is positive feedback in an oscillator?
6. What is multivibrator? Give its types.
7. Give merits and demerits of crystal oscillator.

PART C

III Explain the following questions — 5 Marks

1. Explain damped and undamped oscillation with waveform diagram.
2. Draw and explain the essentials parts of an oscillator.
3. Write short notes on Astable and Monostable multivibrators.
4. Why positive feedback is much needed in an oscillator function? Justify it.

PART D

IV Answer the following questions in detail — 10 marks

1. Describe the construction and working principle of Hartley oscillator circuit.
2. Explain the working principle of RC phase shift oscillator with circuit diagram.
3. Draw and explain the working functions of crystal oscillator.
4. Explain the construction and working principle of bistable multivibrator with circuit diagram.

ANSWERS

1. (b)	2. (c)	3. (b)	4.(a)
5. (b)	6. (c)	7. (a)	8. (d)
9. (b)	10. (a)	11. (b)	12. (b)

ELEC_EQUIP_Chapter07.indd 161 11/10/2020 11:46:13 AM

DIGITAL ELECTRONICS

CHAPTER 8

T54HCB

Thiruvalluvar pointed out the concept of digital electronic in kural 392.

"The twain that lore of numbers and of letters give are eyes, the wise declare, to all on earth that live". # kural 392

Meaning - Letters and numbers are the two eyes of man.

எண்ணென்ப ஏனை யெழுத்தென்ப இவ்விரண்டும்
கண்ணென்ப வாழும் உயிர்க்கு.. குறள்#392

எண் என்று சொல்லப்படுவன, எழுத்து என்று சொல்லப்படுவன ஆகிய இரண்டையும் வாழும் மக்களுக்குக் கண்கள் என்று கூறுவர்.

CONTENT

LEARNING OBJECTIVES

After the completion of this Chapter, the student will

1. Understand the basic concepts of analog and digital signals
2. Understand the functions of digital circuit
3. Know about the number system
4. Understand the conversion of number system and basic of arithmetic operations
5. Develop the skill of converting one code format into other code formats
6. Realize the function of basic logic gates

INTRODUCTION

The branch of electronics, which deals with digital circuits, is called digital electronics. Over the past several decades, digital electronics have been utilized in the design and manufacturing of various industrial, commercial and household electronic gadgets. Due to the proliferation of digital electronics, it is very important to inculcate the basic knowledge of digital electronics to develop conceptual knowledge and practical experience among the stakeholders.

Electronic systems can be classified into two types of systems in which the mode of electron transfer from one end to another end differs. They are,

1. Analog system
2. Digital system

This Chapter covers the basic concepts in digital electronics.

DO YOU KNOW?

Who is the inventor of logic gates?

Walther Bothe, inventor of the coincidence circuit, got part of the 1954 Nobel Prize in Physics, for the first modern electronic AND gate in 1924. Konrad Zuse designed and built electromechanical logic gates for his computer Z1 (1935-38)

8.1. ANALOG AND DIGITAL SIGNALS

i) Analog Signals

A continuously varying signal(voltage or current) is called as an analog signal.

Example: Sinusoidal waves.

A sample of analog signal that varies with time is shown in Figure 8.1.

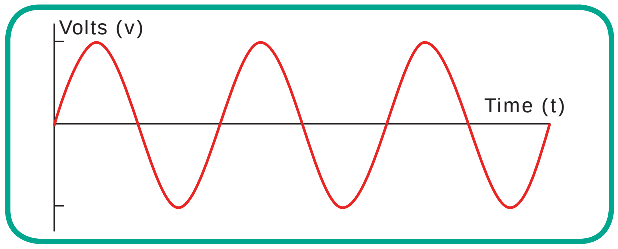


Figure8.1 Representation of an Analog signal

ii) Digital Signal

A signal (voltage or current) that can have only two discrete values is called a digital signal. Example: Square wave. The digital waveform is shown in Figure 8.2.

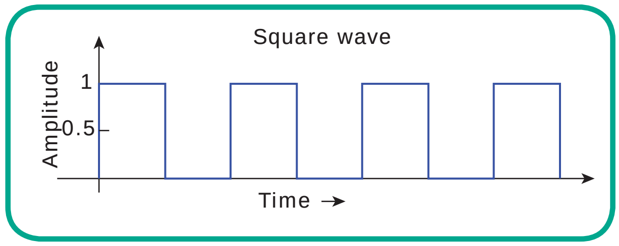


Figure 8.2 Representation of Digital Signal

Digital operations have two states (i.e. ON or OFF) and hence it is more simple and reliable than many valued analog operations.

8.2 DIGITAL CIRCUITS

An electronic circuit that handles only a digital signal is called a digital circuit.

Example: Digital calculator, Digital computer

The digital operation is a two state operation (i.e. ON or OFF, 1 or 0) and therefore a digital circuit uses only two digits 1 and 0 in the binary number system. In order to understand the concepts in digital circuits, first we discuss about the number system in the following Chapter.

8.3 NUMBER SYSTEM

Number system is commonly used to count any activity or articles. In practical life, we are using decimal number system. In decimal number system, 10 digits(0,1,2,3,4,5,6,7,8,9) are used. But in digital electronics, we use '1' and '0'.

Computers, microprocessor and digital electronic devices do not process decimal numbers. Instead, they work with binary number, which use only the two digits'0' and'1'.

People do not like working with binary numbers, owing to their very lengthy combinations of digits, while representing larger decimal values.

As a result, octal and hexadecimal numbers are widely used to compress long strings of binary numbers. Some number systems are given below.

8.3.1 Binary Number

Binary number contains only two numbers of '0' and '1'. It has radix or base of '2'.

Example: 1010_2

Almost all digital systems are based on binary number. A switch is one example of a natural binary device, because it exists only two states, namely ON or OFF, 1 or 0.

8.3.2 Octal Number

Octal number contains only eight numbers of 0,1,2,3,4,5,6 and 7. It has a radix or base of 8.

Example: 7612_8

8.3.3 Hexadecimal Number

Hexadecimal number contains only sixteen numbers of 0,1,2,3,4,5,6,7,8,9,A,B,C,D,E, and F. It has a radix or base of 16.

Example: $508D_{16}$

8.3.4 BCD (Binary Coded Decimal) Number

A nibble is a string of 4 bits. BCD numbers express each decimal digit as nibble. It is a decimal number represented in binary form with 0 and 1. The lowest number is 0000 (0) and the highest number is 1001(9)

Example: $1000\ 0111_{BCD}$

8.3.4.1 Place Value

The binary, octal, decimal, and hexadecimal numbers are weighted numbers. Hence, every number system can be converted into any other number system through a process called conversion. After conversion, the weight of the number should not be varied. The weight of each number is represented as follows.

8.3.4.2 Decimal Number System

Number	2	8	5	7	.4	5
Weight of each digit	10^3	10^2	10^1	10^0	$.10^{-1}$	10^{-2}

8.3.4.3 Binary Number System

Number	1	0	1	1	.0	1
Weight of each digit	2^3	2^2	2^1	2^0	$.2^{-1}$	2^{-2}

8.3.4.4 Octal Number System

Number	7	3	5	6.	3	2
Weight of each digit	8^3	8^2	8^1	8^0	$.8^{-1}$	8^{-2}

8.3.4.5 Hexadecimal Number System

Number	8 A B 5 . C 9
Weight of each digit	16^3 16^2 16^1 16^0 . 16^{-1} 16^{-2}

DO YOU KNOW?

Which electronic component can work as a binary switch?

The transistor can work as a binary switch.

8.4 CONVERSIONS

Conversion of binary number from one number format to another number format can be performed by adapting some rules and regulations. Some of the important conversion processes are explained below. For the conversion of integer and fractional number, separate conversion methods are used.

8.4.1 Decimal to Binary Conversion

In this case, the decimal number is divided by 2, and writing down the remainder after each division. The remainders are taken in reverse order to form the binary number.

Example: Conversion of 26_{10} to its equivalent binary number

2|26
2|13 – 0
2|6 – 1
2|3 – 0
1 – 1

Hence, $11010_2 = 26_{10}$

8.4.2 Binary to Decimal Conversion

To convert binary number to its equivalent decimal number, multiply each binary digit by its weight and then add the resulting products.

Example: Conversion of 1101_2 to its equivalent decimal number.

1	0	1	1
2^3	2^2	2^1	2^0

Equivalent decimal number

$= (1 \times 2^3) + (0 \times 2^2) + (1 \times 2^1) + (1 \times 2^0)$

$= (1 \times 8) + (0 \times 4) + (1 \times 2) + (1 \times 1)$

$= 8 + 0 + 2 + 1 = 11$

Hence, $1011_2 = 11_{10}$

8.4.3 Decimal to Octal Conversion

In the case of decimal to octal conversion, the decimal number is divided by 8, and writes down the remainder after each division. The remainders are taken in reverse order to form the octal number.

Example: Conversion of the decimal number 408 to its equivalent octal number.

8|408
8|51 – 0
6 – 3

Hence, $408_{10} = 630_8$

8.4.4 Octal to Decimal Conversion

To convert an octal number to its equivalent decimal number, multiply each octal digit by its weight and then add the resulting products.

Example: Conversion of an octal number 375 into its equivalent decimal number.

The weight of 5 is 8^0, 7 is 8^1 and 3 is 8^2.

Hence, the equivalent decimal number is

$= (3x8^2)+(7x8^1)+(5x8^0)$

$= (3x64)+(7x8)+(5x1)$

$= 192+56+5= 253$

Hence, $375_8 = 253_{10}$

8.4.5 Decimal to Hexadecimal Conversion

In decimal to hexadecimal conversion, divide the decimal number by 16 and write down the remainder after each division. The remainders are taken in reverse order to form the hexadecimal number.

Example: Conversion of a decimal number 4538 to its equivalent hexadecimal number.

$$
\begin{array}{r|l}
16 & 4538 \\
16 & 283 - 10 \\
16 & 17 \; - 11 \\
 & 1 \;\; - 1
\end{array}
$$

Hence, $4538_{10} = 11BA_{16}$

8.4.6 Hexadecimal to Decimal Conversion

To convert the hexadecimal to its equivalent decimal number, multiply each hexadecimal digit by its weight and then add the resulting products.

Example: Conversion of a hexadecimal number of B35 to its equivalent decimal number.

The weight of B is 16^2, 3 is 16^1 and 5 is 16^0

Hence its equivalent Decimal number is

$= (Bx16^2)+(3x16^1)+(5x16^0)$

$= (11x256)+(3x16)+(5x1)$

$= 2816+48+5$

$=2869$

Hence, $B35_{16} = 2869_{10}$

8.4.7 Octal to Binary Conversion

In this, each octal digit is converted into its equivalent three digit binary form. The octal number and its equivalent three digit binary numbers are shown in the Table 8.1.

Table 8.1: Conversion of Octal into Equivalent Binary Number

Octal number	Equivalent Binary number
0	000
1	001
2	010
3	011
4	100
5	101
6	110
7	111

Example: Conversion of an octal number 43 to its equivalent binary number.

4 3

100 011

$43_8 = 100011_2$

8.4.8 Binary to Octal Conversion

The binary numbers are grouped as 3-bit from left to right. If there is any binary digit left with one or two bits then sufficient numbers of zero are added to the left most side of the binary number. Then, grouped 3-bit number is converted into an equivalent octal number.

Example: Conversion of a binary number of 010111011 to its equivalent octal number.

$\underline{010}\ \underline{111}\ \underline{011}$

2 7 3

Hence, $010111011_2 = 273_8$

8.4.9 Hexadecimal to Binary Conversion

In this, each hexadecimal digit is converted into its equivalent four digit binary form.

The hexadecimal number and its equivalent 4 digit binary numbers are shown in the Table 8.2.

Table 8.2: Conversion of Hexadecimal into Equivalent Binary Number

Hexadecimal Number	Equivalent Binary Number
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001
A	1010
B	1011
C	1100
D	1101
E	1110
F	1111

Example: Conversion of a hexadecimal number 7B3 into its equivalent binary number.

7 *B* 3
0111 1011 0011

Hence, $7B3_{16} = 011110110011_2$

Note: Delete the left most zeros.

8.4.10 Binary to Hexadecimal Conversion

In this conversion, the binary number is arranged in group of 4 bits. Suppose the binary number grouping is not completed with the 4 digits, sufficient numbers of zero are added to the left most side of the binary number.

Example: Conversion of a binary number 110110101011100 into its equivalent hexadecimal number.

0110 1101 0101 1100
6 *D* 5 *C*

Hence, $110110101011100_2 = 6D5C_{16}$

8.4.11 Decimal to BCD Conversion

In this method, each decimal digit is converted into its equivalent 4 digits binary form (BCD).

Example: Conversion of a decimal number 892 to its equivalent BCD number.

8 9 2
1000 1001 0010

Hence, $892_{10} = 100010010010_{BCD}$

8.4.12 BCD to Decimal Conversion

In this method, each BCD number grouped in the form of 4 digit binary pattern is converted into its equivalent decimal number.

Example: Convert a BCD number100100111000 to its equivalent decimal number.

$\underline{1001}$ $\underline{0011}$ $\underline{1000}$
9 3 8

Hence, $100100111000_{BCD} = 938_{10}$

8.5 BINARY ADDITION AND SUBTRACTION

A logic circuit can be used to perform arithmetic functions like addition, subtraction, multiplication, division etc. For performing these operations, compliment method of number patterns are used. First, we will see the complement methods in order to understand the basic arithmetic operations.

8.5.1 One's Complement Method

In one's complement method, each binary bit of the number is changed from 0 to 1 or 1 to 0 depending on the existing bit value.

For instance, the binary number is $A_3\,A_2\,A_1\,A_0 = 0010$, its corresponding one's complement number is $\overline{A_3}\,\overline{A_2}\,\overline{A_1}\,\overline{A_0} = 1101$

The same principle will apply for number having any bit length and its corresponding one's complement number can be obtained by complement each bit.

8.5.2 Two's Complement Method

The two's complement of a binary number is the number that results when we add '1' to the one's complement number. The formula for two's complement of a binary number is given below.

Two's complement number = one's complement +1

For instance, to find the two's complement number of 0101, the following procedure is employed.

$$0101 \Rightarrow 1010 \ (1\text{'s } complement)$$
$$1010+1 \Rightarrow 1011 \ (2\text{'s } complement)$$

8.5.3 Binary Addition

For binary addition, the arithmetic rules used are given below.

1. 0+0=0
2 0+1=1, No carry is formed
3. 1+0=1, i.e. carry=0
4. 1+1=0,with a carry of 1, and sum = 0 i.e. 1+1 =10_2.

This is a binary number10 and not the decimal number ten. Here, the first digit 0 is called sum and next digit 1 is called carry.

Examples:

1. Add the binary numbers 1011 and 1100

$$\begin{array}{r} 1011+ \\ \underline{1100} \\ \underline{10111} \end{array}$$

Sum=0111, and Carry=1

2. Add the binary number 11101 with 11011001.

The first number = 00011101+

The second number = $\underline{11011001}$

Result = $\underline{11110110}$

8.5.4 Binary Subtraction

The general rules for carrying out the binary subtraction are given below.

1. 0-0=0
2. 1-0=1
3. 1-1=0
4. 0-1=1,with a borrow of 1 from the next higher bit.
5. 10-1=1

Example: Subtract 0111 from 1011

$1011 \Rightarrow 11_{10}$

$\underline{0111 \Rightarrow 7_{10}}$

$\underline{0100 \Rightarrow 4_{10}}$

First column => 1-1 =0

Second column =>1-1 = 0

Third column =>0-1 = 10-1 = 1

Forth column => After borrowing, the fourth column becomes 0

Hence, 0-0=0

$1011_2 - 0111_2 = 0100_2$

8.6 BINARY CODES

All digital circuits operate with only two states namely, High and Low or ON and OFF or 1 and 0. In binary number system, the number of bits required goes on increasing as the numbers become larger and larger. So, some special binary codes are required to represent alphabets and special characters. Based on these points, different types of binary code have been developed.

They are,

1. BCD codes
2. Gray codes
3. Excess 3 code
4. ASCII code

8.6.1 BCD - 8421 Code Conversion

A group of bits (usually four) which are used to represent decimal numbers 0 to 9 are called BCD(Binary Coded Decimal) codes. The most popular BCD code is 8421 code. The 8421 indicates the binary weights of the four bits (2^3, 2^2, 2^1, 2^0). Using the four bits with weights 8,4,2,1, we can easily represent the decimal numbers 0 to 9 as given in the Table 8.3.

Table 8.3: Conversion of Decimal Number into BCD Code

Decimal Numbers	BCD Code
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001
10	0001 0000
56	0101 0110
963	1001 0110 0011

8.6.2 Gray Code

The gray code is not a weighted code. Therefore it is not suitable for arithmetic operations, but finds applications in input/output devices and in some types of analog to digital converters.

Table 8.4: Gray code conversion

Decimal numbers	Binary code	Gray code
0	0000	0000
1	0001	0001
2	0010	0011
3	0011	0010
4	0100	0110
5	0101	0111
6	0110	0101
7	0111	0100
8	1000	1100
9	1001	1101
10	1010	1111
11	1011	1110
12	1100	1010
13	1101	1011
14	1110	1001
15	1111	1000

The gray code is a minimum change code in which only one bit in the code group changes when moving from one step to the next. The gray code is also called as reflected binary code, which has a special property of containing two adjacent code numbers that differ by only one bit. The gray code representation for the decimal numbers 0 to 15, together with the binary code is given in the Table 8.4.

8.6.3 Excess-3 Code

The excess-3 code is another BCD code used in earlier computers. The excess-3 code is not a weighted code. It is a self-complementing code and helps in performing subtraction operations in digital computers. The excess–3 code is also a reflection code.

An excess–3 code is obtained by adding 3 to each digit of a decimal number. For example, to encode the decimal number 6 into an excess–3 code, we must first add 3, in order to obtain 9. The 9 is then encoded into its equivalent 4 bit binary code 1001.

Example: Conversion of the decimal number 548 to its equivalent excess-3 code.

Decimal number	5	4	8
Add 3 to each bit	+3	+3	+3
Sum =	8	7	11

Hence, the equivalent excess-3code 1000 0111 1011

The representation of Excess-3 code for the decimal numbers is given in the Table 8.5.

Table 8.5: Excess-3 Code of Decimal Number

Decimal Number	Excess-3 Code
0	0011
1	0100
2	0101
3	0110
4	0111
5	1000
6	1001
7	1010
8	1011
9	1100

8.6.4 Binary to Gray Conversion

To convert a given binary number to its equivalent gray code, the following rules are applied.

1. The MSB of the gray code is same as the MSB of the binary.
2. Coding starts from left to right, add each adjacent pair of bits to get the next bit of the gray code. Omit the carry, if occurs.

Example: Conversion of the binary number 1011 to gray code.

Step1: The MSB in gray code is same as the MSB of the binary

1 0 1 1 Binary
↓
1 1 Gray

Step2: Add the left most bit to the adjacent one.

1 + 0 1 1 Binary
↓
1 1 Gray

Step3: Add the next adjacent pair.

1 0+ 1 1 Binary
↓
1 1 1 1 Gray

Step4: Add the next adjacent pair and omit the carry.

1 0 1+ 1 Binary
↓
1 1 1 0 Gray

Hence, $(1011)_2 = (1110)_G$

Suffix 'G' is used to represent the Gray code.

8.6.5 Gray to Binary Conversion

To convert a given Gray code number into equivalent binary, the following rules are applied.

1. The MSB of the binary is same as the MSB of the Gray.
2. Coding from left to right, add the binary digit generated to the adjacent gray bit to get the next bit of the binary. Omit the carry if occurs.

Example: convert the gray code 1110 to its equivalent binary.

Step1: The MSB in binary is same as the MSB of the gray

1 1 1 0 Gray
↓
1 Binary

Step2: Add the binary digit generated to the adjacent bit of the Gray code.

1 1 1 0 Gray

+

1 0 Binary

Step 3: Add the binary digit generated to the adjacent bit of Gray codes.

1 1 1 0 Gray

+

1 0 1 Binary

Step 4: Add the binary digit generated to the adjacent bit of gray code.

1 1 1 0

+

1 0 1 1

Hence, $(1110)_G = (1011)_2$

8.7. LOGIC GATES

Logic gates are digital circuits. Digital circuits operate in binary modes, each input and output signal is either '1' or '0'. The '1' and '0' designation represents predefined voltage ranges. These electronic switching circuits are called as logic gates. Each logic gate can have one or more inputs and only one output.

All logic gates can be analysed by constructing a truth table. A truth table represents all possible input and the corresponding output combinations.

The term "logic" is usually used to refer to a decision making process. A logic gate makes logical decisions regarding the existence of output depending upon the nature of the input. Hence, such circuits are called logic circuits.

8.7.1 Basic Logic Gates

The three basic logic gates that makeup all digital circuits are

i) OR gate
ii) AND gate
iii) NOT gate.

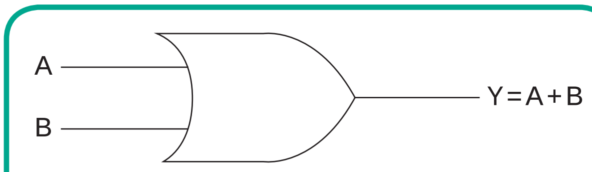
The following points may be noted about logic gates.

1. A binary '0' represents 0V and binary '1' represents +5V. It is common to refer to binary '0' as LOW input or output and binary '1' as HIGH input or output.
2. A logic gate has only one output and the output will depend upon the input signals and the type of gates.
3. The operation of a logic gate may be described either by truth table or Boolean algebra.

8.7.2 OR Gate

An OR gate has two or more input signals and only one output signal. An OR gate performs logical addition.

In OR gate, the inputs A,B, C, etc., produce the output as A+B+C+ etc. The symbol and the truth table of two input OR gate are shown in the Figure 8.12.



A	B	Y=A+B
0	0	0
0	1	1
1	0	1
1	1	1

Figure 8.12 **Symbol and Truth Table of OR Gate**

A two input OR gate contains two input signals and only one output signal.

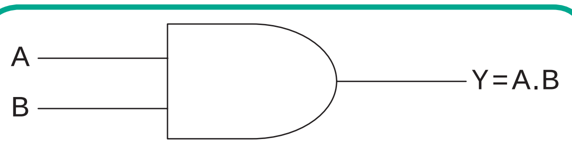
The two input signal makes 2^2 combination of outputs.

In OR gates, the output is high when any one of the input is in high level. Conversely, the output is low when all the inputs are in low level.

8.7.3 AND Gate

An AND gate has two or more inputs and one output. An AND gate performs logical multiplication. In an AND gates, the inputs A, B, C, etc., produce the output as A.B.C.etc. The symbol and the truth table of two input AND gate are shown in Figure 8.13.

It contains two input signals and only one output signal. In AND gates, the output is only high when all inputs are in high level. Conversely, the output is low only when any one of the input is in low level.



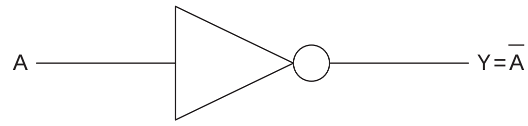
A	B	Y=A.B
0	0	0
0	1	0
1	0	0
1	1	1

Figure 8.13 Symbol and Truth Table of AND Gate

8.7.4 NOT Gate

A NOT gate has only one input and one output. For the NOT gate, when the input is '0' (LOW), the output is '1' (HIGH)and when the input is '1' (HIGH), the output is '0' (LOW). That is, the output is complement or inverse of the input.

Figure 8.14 shows the symbol and truth table for the NOT gate. The input is marked as A and the output is marked as $Y = \overline{A}$. The output can be read as complement of A or inverse of A or simply A bar. It is also known as inverter.



A	$Y = \overline{A}$
0	1
1	0

Figure 8.14 Symbol and Truth Table of NOT Gate

8.8 BOOLEAN ALGEBRA

Digital circuits perform the binary arithmetic operations with binary digits 1 and 0. These operations are called logic functions or logic operations. *The algebra used to symbolically describe logic function is called* **Boolean algebra.**

Boolean algebra is a set of rules and theorems by which logical operations can be expressed symbolically in equation form and be manipulated mathematically. As with the ordinary algebra, the letters of alphabet (e.g. A, B, C, etc.) can be used to represent the variables. Boolean algebra differs from ordinary algebra, since the Boolean constant and variables can have only two values 0 and 1. There are four connecting symbols used in Boolean algebra viz.

i) equals sign(=) ii) plus sign(+)

iii) Multiply sign (.) iv) bar (-)

1. **Equals Sign (=):** The equals sign in Boolean algebra refers to the standard mathematical equality. In other words, the logical value on one side of the sign is identical to the logical value on the other side

of the sign. Suppose, we are given two logical variables such that A=B, if A=1, then B=1 and if A=0, then B=0.

2. Plus Sign (+): The plus sign in Boolean algebra refers to the logical OR operation. Thus, when the statement A+B=1 appears in Boolean algebra, it means A ORed with B equals1.Consequently, either A=1 or B=1 or both equals1.
3. Multiply Sign (.): The multiply sign in Boolean algebra refers to AND operation .Thus, when the statement A.B=1 appears in Boolean algebra, it means A ANDed with B equals 1. Consequently, A=1 and B=1. The function A.B is often written as AB, omitting the dot for convenience.
4. Bar sign (-): The bar sign in Boolean algebra refers to NOT operation. The NOT has the effect of inverting (complementing) the logical value. Thus, if A=1, then $\overline{A}$=0.

8.8.1 Boolean Theorems

We now discuss the basic Boolean theorems that are useful in manipulating and simplifying Boolean expression. For convenience, we divide the theorems into two groups:

1. Single variable theorem
2. Multi variable theorem

Single Variable Theorems: These theorems refer to the condition when only one input of the logic gate is variable. Table 8.6 gives single variable Boolean theorems.

Table 8.6: Single Variable Boolean Theorems

Name of the Theorem	Mathematical Function
Theorem 1	$A + 0 = A$
Theorem 2	$A \bullet 1 = A$
Theorem 3	$A + \overline{A} = 1$
Theorem 4	$A \bullet \overline{A} = 0$
Theorem 5	$A + A = A$
Theorem 6	$A \bullet A = A$
Theorem 7	$A + 1 = 1$
Theorem 8	$A \bullet 0 = 0$
Theorem 9	$\overline{\overline{A}} = A$

Theorem 1 (A+0=A): This theorem can be verified by ORing a variable A with a 0 and is illustrated in Figure 8.3. Here, one input to OR gate is always 0 and the other input A can be a value 1 or 0. When A is at 1, the output is 1 which is equal to A. When A is at 0, the output is 0 which is also equal to A(=0). Therefore, a variable ORed with 0 is equal to the value of the variable. This is easy to remember, since 0 added to anything does not affect the value of the variable, either in regular addition or OR addition.

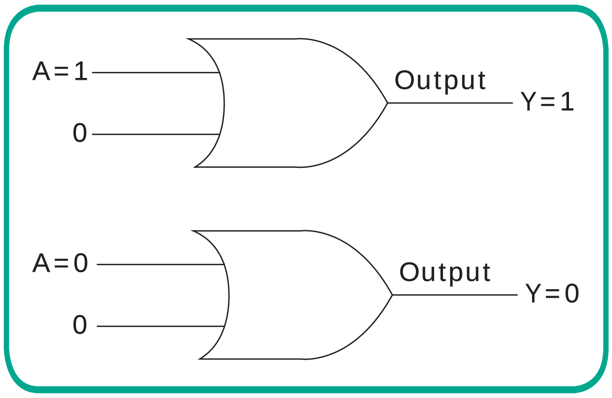


Figure 8.3 Logic gate representation of Theorem 1

Theorem 2(A.1=A): This theorem can be verified by ANDing a variable A with a 1 and is illustrated in Figure 8.4. Here, one input to AND gate is always 1 and other can be value 1 or 0. If A is 1, the output of the AND gate is 1 because both the inputs are now 1. If A is 0, the output of the AND gate is 0.Therefore, a variable ANDed with a 1 is equal to the value of the variable (A.1=A).This is easy to remember because AND operation is just like ordinary multiplication.

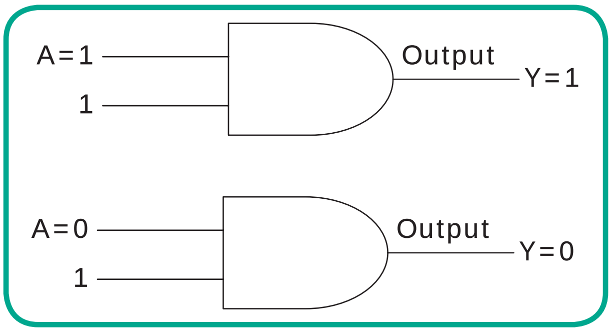


Figure 8.4 **Logic gate representation of Theorem 2**

Theorem 3($A+\overline{A}=0$): This theorem can be easily explained. If a variable A and its complement ($\overline{A}$) are ORed, the result is always 1. If A is 0,then $0+\overline{0} = 0+1 = 1$. If A is 1, then $1+\overline{1} = 1+0 = 1$.

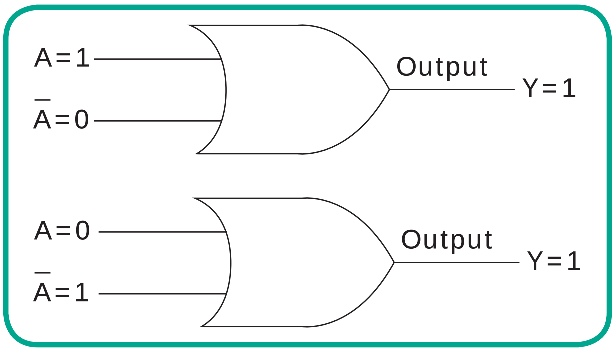


Figure 8.5 **Logic gate representation of Theorem 3**

Theorem 4 ($A \cdot \overline{A}=0$): This theorem states that if a variable A is ANDed with its complement, the result is zero. This is readily apparent because either A or $\overline{A}$ will always be 0. Therefore, when one of the inputs to an AND gate is 0, the output is always 0.

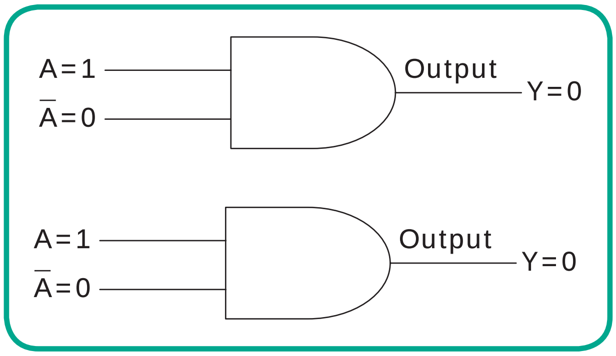


Figure 8.6 **Logic gate representation of Theorem 4**

Theorem 5(A+A=A): This theorem states that when a variable A is ORed with itself, the output is equal to the variable. Thus, if A is 0, then 0+0=0, and if A is 1, then 1+1=1.

T58518

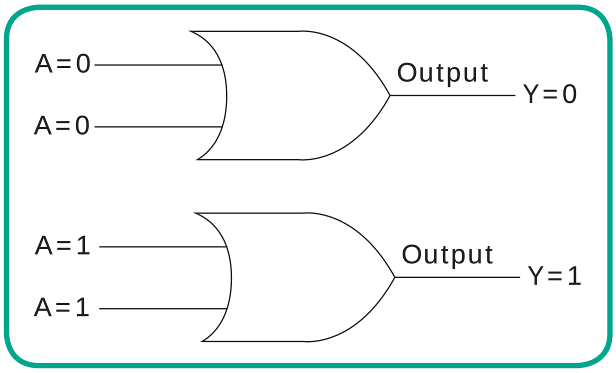


Figure 8.7 **Logic gate representation of Theorem 5**

Theorem 6(A.A=A): This theorem states that when a variable A is ANDed with itself, the result is equal to the variable. For example, if A=0, then 0.0=0 and if A=1,then 1.1=1. For either case, the output of an AND gate is equal to the value of the input variable A.

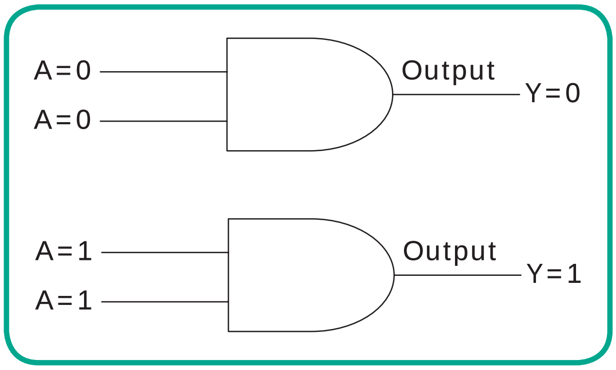


Figure 8.8 **Logic gate representation of Theorem 6**

Theorem 7(A+1=1): This theorem states that when a variable A is ORed with 1, the output is always equal to1. One input to an OR gate is always 1 and the other input A can be either 1 or 0. Now, 1 on one of the inputs to the OR gate produces 1 on the output regardless of the value of the variable on the other input.

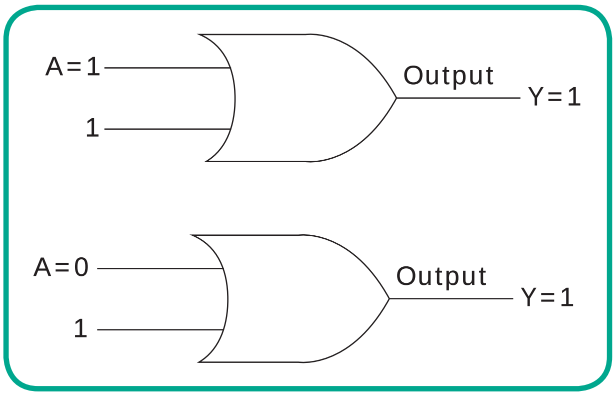


Figure 8.9 Logic gate representation of Theorem 7

Theorem 8(A.0=0): This theorem states that variable A ANDed with 0 always produces 0. Recall that any time one input to an AND gate is 0, the output is 0 regardless of the variable A on the other input.

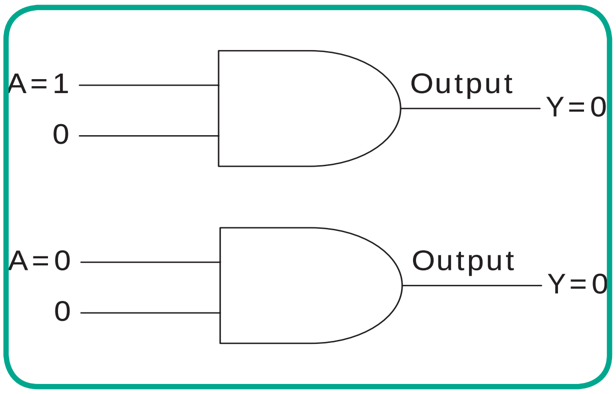


Figure 8.10 Logic gate representation of Theorem 8

Theorem 9($\overline{\overline{A}}$=A): This theorem states that if a variable A is complemented twice, the result is the variable itself. Starting with A and inverting (complementing) it once gives $\overline{A}$. Inverting it once more, gives $\overline{\overline{A}}$ the original value.

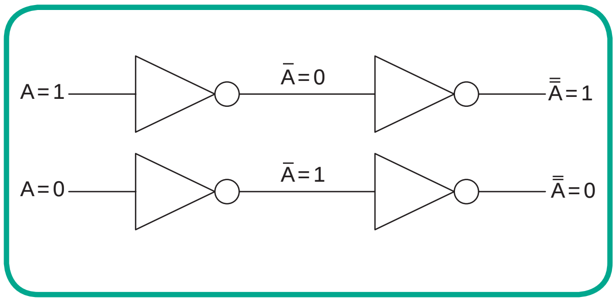


Figure 8.11 Logic gate representation of Theorem 9

8.9 ADVANTAGES AND DISADVANTAGES OF DIGITAL ELECTRONICS

8.9.1 Advantage

1. Very simple logic the lead to identify the faults very easily
2. Immune to noise
3. Flexibility of programming
4. Design and testing is very simple compared to analog electronics
5. Achieve very high speed switching

Disadvantage

1. High energy consumption than analog electronic circuits
2. Higher cost of design
3. Portability is difficult
4. Real world signals need conversion
5. Less accurate than the analog electronics

> **"One of the very important characteristics of a student is to question. Let the students ask questions."**
>
> **-A.P.J. Abdul Kalam**

LEARNING OUTCOMES

Student will capable of

1. **Remembering of the difference between analog and digital signals.**
2. **Identification of basic gates using the symbols and truth table.**
3. **Conversion of one number system into another number system.**
4. **Understanding of basic digital circuits.**
5. **Constructing and testing of simple digital circuits.**
6. **Designing and testing of small digital application circuits.**

GLOSSARY

S. No	Terms	Explanation
1	**BCD**	Binary Coded Decimal. Four bit code used to portray each digit of a display numbers by its 4 binary equivalent
2	**Binary**	A number system having only two symbols, 0 and 1. A base of 2 number system
3	**DAC**	Abbreviation for digital to analog converter
4	**Digital**	Relating to devices or circuits that have outputs of only two discrete levels. Example: 0 or 1, high or low, on or off, true or false etc
5	**LSB**	Least Significant Bit. Right most bit (smallest weight) of a binary expressed quantity
6	**Logic**	In digital electronics, the decision making capacity of gate circuits, in that HIGH represents a true condition and a LOW represents a false condition
7	**Low**	Logic level 0 or false state
8	**High**	Logic level 1 or true state
9	**MSB**	Most Significant Bit. Left most binary bit (largest weight) of a binary expressed quantity
10	**Truth table**	Method describing how a logic circuit output is dependent upon the logic levels present at the circuit input

QUESTIONS

PART A

I. Choose the best answer

1. The number of levels in a digital signals

   a) One b) Two c) Eight d) Ten

2. A sinewave is a

   a) digital signal a) analog signal

   c) both digital and analog signal d) neither digital nor analog.

3. Decimal number 16 in binary system can be written as

   a) 11111 b) 10000 c) 11100 d) 11000

4. Binary 10101 in decimal system is equivalent to

   a) 13 b) 19 c) 21 d) 23

5. Decimal 19 in octal system is represented by

   a) 21 b) 23 c) 25 d) 22

6. Octal 16 is equal to decimal

   a) 15 b) 16 c) 13 d) 14

7. Which logic gate is called inverter

   a) AND b) OR c) NOT d) All of the above

8. How many digits in octal system

   a) 10 b) 2 c) 8 d) 16

9. Which of the following relation is valid according to Boolean algebra

   a) 0+A=1 b) A+A=A c) A+A=0 d) 1+A=0

10. The input to NOT gate is ‘1’, then the output will be

    a) 0 b) 1 c) 0 or 1 d) None of the above

PART B

II. Answer in few sentence

1. What is a digital signal?
2. What are the three basic logic gates?
3. What is a binary number system?
4. What is a digital circuit?
5. What is a logic gate?
6. Describe NOT function
7. What is the single variable theorem?
8. Convert the decimal number 18 into binary number?

9. Why digital system is reliable?
10. List the binary code.

PART C

III Answer the following questions with suitable examples.

1. Write a short note on analog and digital signals?
2. Explain Binary number system.
3. Write the tabular column of single variable Boolean theorem.
4. What are the advantages and disadvantages of digital electronics?

PART D

IV Answer the following questions with neat sketches.

1. Explain the three logic gates.
2. With neat diagram explain any five of the single variable theorem.
3. Explain the connecting symbols used in Boolean algebra.

ANSWERS

1. **(b)**	2. **(b)**	3. **(b)**	4. **(c)**	5. **(b)**
6. **(d)**	7. **(c)**	8. **(c)**	9. **(b)**	10. **(a)**

CHAPTER 9

FUNDAMENTALS OF DIGITAL COMPUTERS

T5DDDY

CONTENT

LEARNING OBJECTIVES

While learning this Chapter, the student would come...

1. To know about the evolution of a Computer.
2. To understand the development of digital computer.
3. To understand the purpose of computer languages.
4. To know about the computer jargon words Hardware & Software
5. To understand the basic principle and working of CPU (ALU, Memory & Control Unit)
6. To learn about Translators
7. To Understand about Operating System (OS)

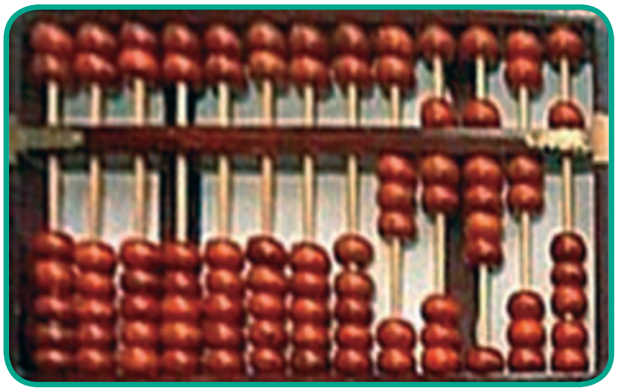
INTRODUCTION

In this modern world, none other word is more popular than the word ‘computer’. Through the computer we can bring the entire world in our hand, we feel. Because with the help of computer we able to watch all incidents happening in any part of the world like enjoying the music, movies etc. Above all there is a slave to do my routines.

9.1 HISTORY OF COMPUTER

Many centuries ago humans try to develop machine to perform some calculations. The speed of this development increased after the arrival of numerals.

‘ABACUS’ was the first calculating tool developed by human. The credit belongs to Chinese, some says it is Babylonians and Egyptians, but it is not



Abacus

actually known. Many calculating tools were derived or developed after the arrival of ABACUS, like Slide rule, Pascal calculating machine, Nappier Bones, etc.

Among these the most important one is 'Analytical Engine' a mechanical device which was developed by the British mathematician Mr. Charles Babbage (1791-1871).The above was developed by using gear wheels. Moving of each teeth rotate the numeral form 0-9. This way the counter was set.

The simple example to understand this concept is 'speedometer' used in vehicles. By keeping this as the base the first electronic calculating machine i.e. 'calculator' was developed. From this computer was developed. So to say a 'computer' is nothing but a developed-stage of calculator.

Nappier Bones

In simple terms we can say calculator is a small calculating machine and computer is a big calculating machine.

Why?

- *Because of calculator is small in size.*
- *Computer is big in size?*

Before entering into the computer field we have to keep two important basic things in our mind.

1. ***Basically computer is a fool. It is an idiot. It cannot do anything on its own.***
2. *Computer never do mistakes. (Unless or otherwise we do mistake....)*

Clearly to say computer cannot think on its own.

For example: If you want to add 2, 3, etc., by switching on the computer if you give 2 + 3 = ? . You can't get the answer as '5'. Because the computer unable to understand what is '2' or '3'. So, we have to instruct the computer as like a first or second standard child to perform the above addition, in the following format.

Pascal Calculating Machine

Keep the value of '2' in your memory. Leave three fingers and start to count three, four, five, etc.

Just like the same we have to instruct the computer. For your easy understanding there is an example.

A = 2
B = 3
C = A + B
PRINT C
END

Memory Location

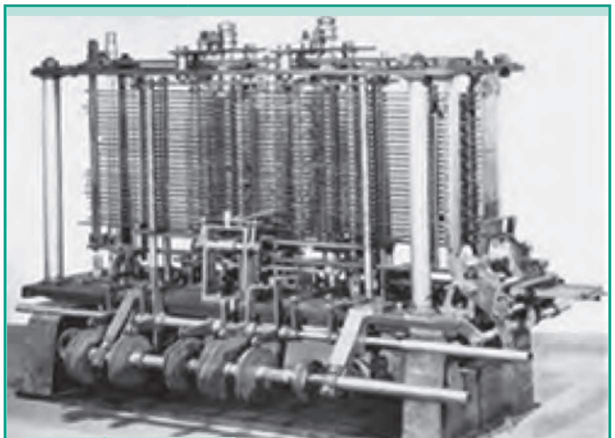
1. The first line A = 2 means we are asking the computer to keep the value of '2' in the memory location called 'A'.
2. Then B = 3 means we are asking the computer to keep the value of '3' in the memory location called 'B'.
3. C = A + B means asking the computer to keep the sum of A, B in the third memory location called 'C'.
   (Performing this addition process is done by exclusive part in computer. That we see later.)
4. Since the result is in 'C', we are asking the computer to show the result of 'C' i.e., PRINT C the result will be displayed on the screen.
5. Then the last one is END.

Here, the last two words 'PRINT & END' are new to us. All other are just like mathematical terms.

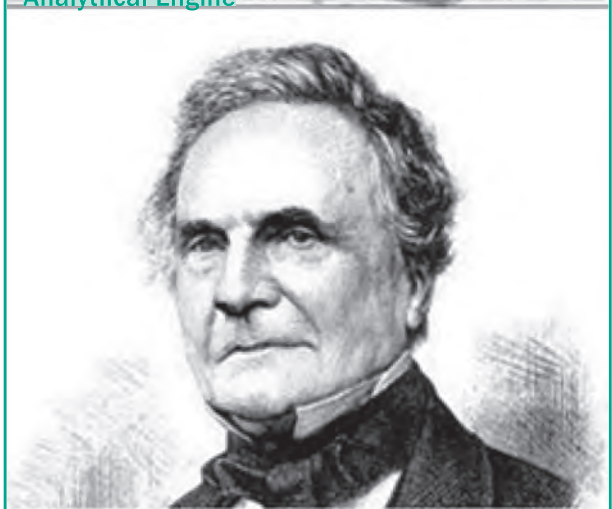
In mathematical A = 2 means, the value of 'A' is 2, whereas in computer terminology A = 2 means, we are asking the computer to keep the value of '2' in the memory location called 'A'. B = 3 means, keep the value of 3 in the memory location called 'B'.

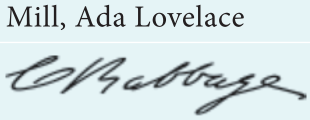
John Napier (1550–1617)	
Born	February 1, 1550, Merchiston Tower, Edinburgh, Scotland
Died	4 April 1617 (Aged 66–67) Edinburgh, Scotland
Nationality	Scottish
Alma mater	University of St Andrews
Known for	Logarithms Napier's bones, Decimal notation
Scientific Career	
Fields	Mathematician
Influenced	Henry Briggs

Blaise Pascal (1623-1662), the French philosopher and scientist, was one of the greatest and most influential mathematicians of all time. He was also an expert in hydrostatics, an inventor, and a well-versed religious philosopher.

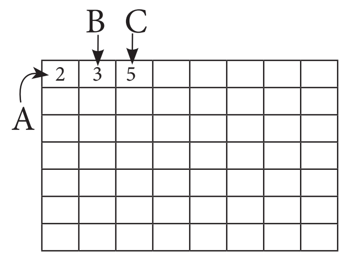


Analytfical Engine



Charles Babbage	
Born	26 December 1791 London (likely Southwark)
Died	18 October 1871 (aged 79) Marylebone, London, UK
Alma mater	Peterhouse, Cambridge
Known for	Mathematics, engineering, early computing
Scientific Career	
Fields	Mathematics, engineering, political economy, computer science
Institutions	Trinity College, Cambridge
Influenced	Robert Woodhouse, GaspadMonge, John Herschel
Influenced	Karl Marx, John Stuart Mill, Ada Lovelace
Signature	

Likewise, we have to define each and everything to its memory. The memory location can be defined as follows,



A thought may arise in your mind.

Just to add two numbers, we have to write five lines. If so, to add the numbers from 1 to 1000, how many lines we have to write?

Because till now our understanding of computer is, it is a machine which will do all my work easily.

Yes, your expectation is quite reasonable. You may be disappointed of writing 1000 more lines to perform the addition of 1-1000 in the computer. Don't worry students. We can make computer to perform this addition process just by writing five lines as like the above.

To understand this., for eg.,

Teacher: Priyan., keep 1 – 1000 in your memory.

I will ask you to give the number one by one. You have to give on sequence.

If I ask you first number what you will give..?

Priyan : 1 Sir.

Tr : Good.

Now I am adding this number with my memory.

Tr : What was in my memory before adding this 1..?

Stud : 0 sir.,

Tr : Yes, exactly..

On receiving 1 from Priyan, I am adding that with my memory. Now my memory is incremented to '1' from '0'.

$\boxed{0+1 = 1}$

Now I am checking, whether I received all the numbers from Priyan. Since it is not., I am asking the next number.

Tr : What the number Priyan will give?

Stud : 2

Tr : Yes, correct.,

Now I am going to add with my memory.. What will happen in my memory.

Now $\boxed{1+2 = 3}$

Again the above said steps will be continued, till Priyan gives the last number i.e., 1000..

Tr: After receiving the last number what will be in my memory?

Stud: The sum of 1 to 1000 sir.,

Tr: Very Good., exactly..

We are going to make the computer to perform this task.

Table 9.1 summarizes the way of thinking of computers and humans.

Table 9.1: Comparison of Human and Computer way of performing Addition

Human way	Computer way
Keep 1-1000 in your memory	FOR I =1 TO 1000
Give the first number	
Sum it with your memory, i.e. (S=S+I)	S =S + I
Check whether you received all the numbers.. If not ask for the next value.	NEXT I
Repeat the above process till you receive the last value, i.e. 1000	PRINT S
Now the sum of 1-1000 is in 'S', PRINT S will display the total	END

Now you may have a thought that how much time the computer takes to perform this task. It can do this within a fraction of a second (Micro Second).

Since the computer be able to perform such a big task, without committing any error, that too with high speed, is termed as big calculating machine.

This is the first major difference between Calculator and Computer.

Yet another big difference is there. Let we see it later.

Now let us see the evolution of computer (i.e., generation of computer).

Figure 9.1 First Generation Computer

9.2. GENERATION OF COMPUTER

First Generation computer (1940-56)

Actually the construction of computer was started well before 19th century. In 1940s the development got momentum in University of Philadelphia, Pennsylvania state, U.S.A, where the world first computer called ENIAC (Electronic Numerical Integral and Computer) was developed and is shown in Figure 9.1.

This computer was developed using the same device which were used to develop a Radio receiver i.e., Valves (vacuum tubes) as shown in Figure 9.2. 18000 valves were used to construct this first computer. Obviously, the size became very big. Its length was 30' and width was 20' (30' x 20'). It dissipated much heat while on working. In order to reduce the heat, many ACs were used. Therefore, the cost of the computer became very high.

In 1950's the semiconductor elements such as silicon and germanium brought into use which replaced the valves. By using these semiconductor devices, the second generation computer was developed.

Second Generation Computer (1956 – 1963)

This was developed by using transistor (semiconductor device). These transistors performed the functions of valves. Hence,

Figure 9.2 Vacuum tube

Figure 9.3 Analytical Engine

18000 values have been replaced by 18000 transistors. Now the size of the computer was reduced to 5’ (feet). The first transistor based computer is shown in Figure 9.3.

Third Generation Computer (1964 – 1971)

This third generation computer was developed using Integrated Circuits(ICs). An IC is nothing but group of transistors. For example, instead of 100 transistors, if we are using 1 IC, then for 18000 transistors it is enough to use 180 ICs. We know IC is a small device, occupying minimum space. Hence, the size of the computer becomes considerably small. On arrival of third generation, the computer was able to place it on a table. A third generation computer made up of ICs is shown in Figure 9.4.

Figure 9.4 Third Generation Computer

Fourth Generation Computer (1971 of above)

This was developed by using a big IC called Very Large Scale Integrated Circuit (VLSI).The VLSI is nothing but group of ICs. For example, 100 numbers of ICs have been put together and made a single big IC, i.e., VLSI. And this big IC is termed as Microprocessor (µp).The computer what we are using now are belongs to this fourth generation, which is shown in Figure 9.5

Figure 9.5 Fourth Generation Computer

Fifth Generation Computer

Further, the development was going-on but yet to complete. In this, computer scientists want to prove that the computer having some Artificial Intelligence (AI), which is under development stage. The fifth generation computer and its processors as shown in Figure 9.6

Figure 9.6 Fifth Generation Computer

9.3 LANGUAGES

DO YOU KNOW?

Apart from human, the term *language* is used or needed is only in computer field.

Why the computer need a language?

If a human want to converse with other, certainly he/she is in need of a language. Likewise, if we want to interact with the computer, we are in need of a language.

Generation of Language

Hence, during the development of first generation computer, there was a language and along with generations of computer the language were also developed, concurrently.

First Generation Language

The name of the first generation language is called as **'Machine language'**.

What is meant by machine language? Here, the word machine denotes the computer. Basically, this machine is an electrical machine. So, the 'Machine Language' can also be called as 'Electrical language'. How about this Electrical language?

To understand this, let we take a SWITCH as shown in Figure 9.7. In how many modes we can operate a switch?

Normally a switch can be operated in two states.

1. ON – state
2. OFF - state

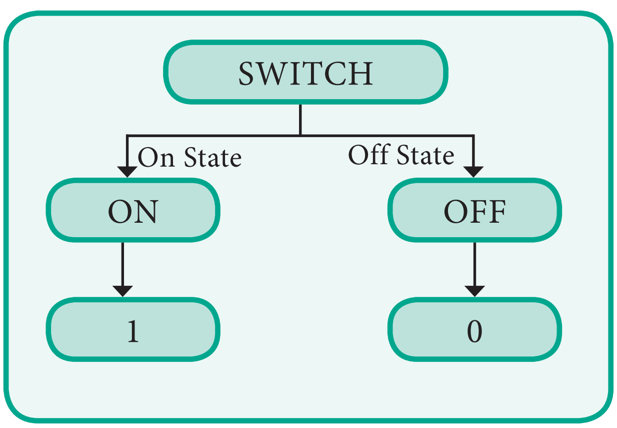


Figure 9.7 **Switch**

NOTE: Switch cannot be operated in any other modes.

When there is supply (ON-state), it is denoted by the letter (numeral) '1' and if there is no supply (OFF-state), it is denoted by the letter '0'.

So, in electrical language, there are only two (1, 0) digits, which are the direct electrical notations and thus machine language is nothing but 1s and 0s. Hence, during the period of first generation computer, they were able to interact with the computer only by using 1s and 0s. During the first generation computer, this machine language was used as shown in Figure 9.8.

Decimal No	Machine Lang
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101

Figure 9.8 **Machine Language**

Since the computer doesn't know anything other than this 1s and 0s, any other alphabets or letters should be converted into this 1s and 0s. This becomes much laborious and tough for the people to understand and follow. Hence, along with second generation computer the second generation language was also developed.

Second Generation Language

The name of the second generation language is **'Assembly Language'** as shown in Figure 9.9. In this, we can use both alphabets and also numbers but only in the form of abbreviations.

Instead of

ADDITION → ADD

SUBTRACTION → SUB

MULTIPLICATION → MUL

DIVISION→DIV.........etc.,

Figure 9.9 **Assembly Language**

Likewise, we can give only three or four letter words. Because, those days computer was just like three year old child.

Eg: As we use to teach a small child with CAT, RAT, BAT & BALL.

The words which are more than 3 or 4 letters should be abbreviated and used. Keeping so many abbreviations in memory is very tough and more to say abbreviations don't have any meaning also. Hence, this was also very tough for the people to understand and lead to the next generation language.

Third Generation Language

The name of the third generation language is called as **High Level Language** (HLL). In this, we are having:

BASIC, FORTRAN, PASCAL, 'C', PROLOG, ALGOL, PL-I, C++....

Likewise, thousand and odd languages are there.

We have seen, the previous two generation languages were so tough to understand and follow.

What is the development and advantage in third generation?

In this, we can write any type of instruction to the computer just in the form of English like sentence.

Example:
IF AGE >18 ALLOW THE PERSON TO VOTE

If we ask the meaning for the above sentence, any one can say.

No one can believe, if the above sentence is written in computer language. But, this is a typical COBOL language statement. Like this, in all the High Level Languages, we can write any instruction in simple English like sentences.

Now tell me, which generation language is easy?

Certainly the third generation is quite easier than previous two. After the arrival of third generation language many start to learn, interact and extract work from the computer. Further, the development was going on and fourth generation was developed.

Fourth Generation Language

The name of the fourth generation language is Application language or packages. In this, there are so many numbers of languages as given below.

FoxBASE, FoxPro, EXCEL, ACCESS, POWER POINT, MS –WORD …etc.

We have seen that the III generation language itself becomes more easy to use.

Then, what is the added development in fourth generation language?

A question may arise in your mind, why the computer cannot be operated as like a calculator? like addition, subtraction, multiplication and division directly.

As we have seen earlier in third generation language even a small procedure can be executed only by writing four or five lines (instruction).But in fourth generation language we can execute few things directly (even without writing few lines).

For Example, in FoxPro language after giving a question mark ?10 + 20 and press enter. You will get the answer as 30. Whereas in COBOL(III- generation language), if you give as like above, it won't give you the answer. Because here in III-generation if we give10 + 20, the computer cannot understand what is meant by this 10 and 20 (since the computer doesn't know anything on its own).

Then, how it becomes possible in fourth generation language like FoxPro? Even, there the computer doesn't know anything, then how the answer 30 comes.

> ***Please remember whatever we are giving to the computer it should be referred to its memory.***

So in FoxPro, if we give any value after giving a question mark(?), it will be referred to a memory as shown in Figure 9.10.

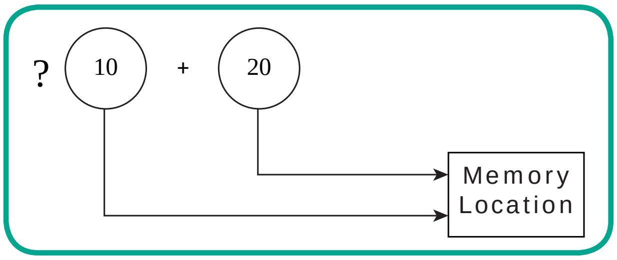


Figure 9.10 Addition in FoxPro

These referring instructions were given inside the FoxPro language itself. Hence, it is enough to give remaining instructions. But in third generation language, no such referring instructions were written inside the language. So we have to instruct the computer from minimum level.

If we want to understand the advantage of fourth generation language, it is better to understand the difference between the both.

Difference between III & IV Generation Language

In third generation language anything (even a small task) can be done only by writing a program. But, in fourth generation language, we can do few things (small task) even without writing a program. Since, we can directly use the fourth generation language, it is termed as Application Language or Packages.

9.4. MAJOR PARTS OF COMPUTER

Figure 9.11 Parts of the Computer

But to be precise only one particular part is said to be computer. To understand this let us see the working of each part illustrated in Figure 9.11.

> Teacher: From the above, which is the computer?
>
> Student: All the parts, Sir.
>
> Teacher: Hmm... ofcourse...

1. ***KEYBOARD:*** It is a device which is used to give any data or instruction to the computer.

2. ***MOUSE:*** Mouse is used to select the instruction to the computer by clicking the icons.
3. ***MONITOR (OR) VDU:*** This will show what we are giving and what the computer is doing.
4. ***CPU*** (Central Processing Unit):This is the part which is going to execute all the instructions given by us. So to say, this is the heart and brain of the computer. (The other parts keyboard, mouse, VDU are peripherals as like human hands and legs)

Teacher: Now tell me, from the above which part is the computer?
Student: CPU, Sir.
Teacher: Good

DO YOU KNOW? Do you know two frequently used computer jargon words?

(i) Hardware
(ii) Software

9.5. HARDWARE PARTS OF COMPUTER

With reference to the computer, the parts which we able to see through our eyes are called as Hardware parts of computer as shown in Figure 9.12.

Example: Keyboard, Mouse, VDU, CPU and even the parts inside these, right from IC to small screw.

9.5.1 Software Parts of Computer

With reference to the computer the parts which we unable to see through our eyes are termed as software parts of computer.

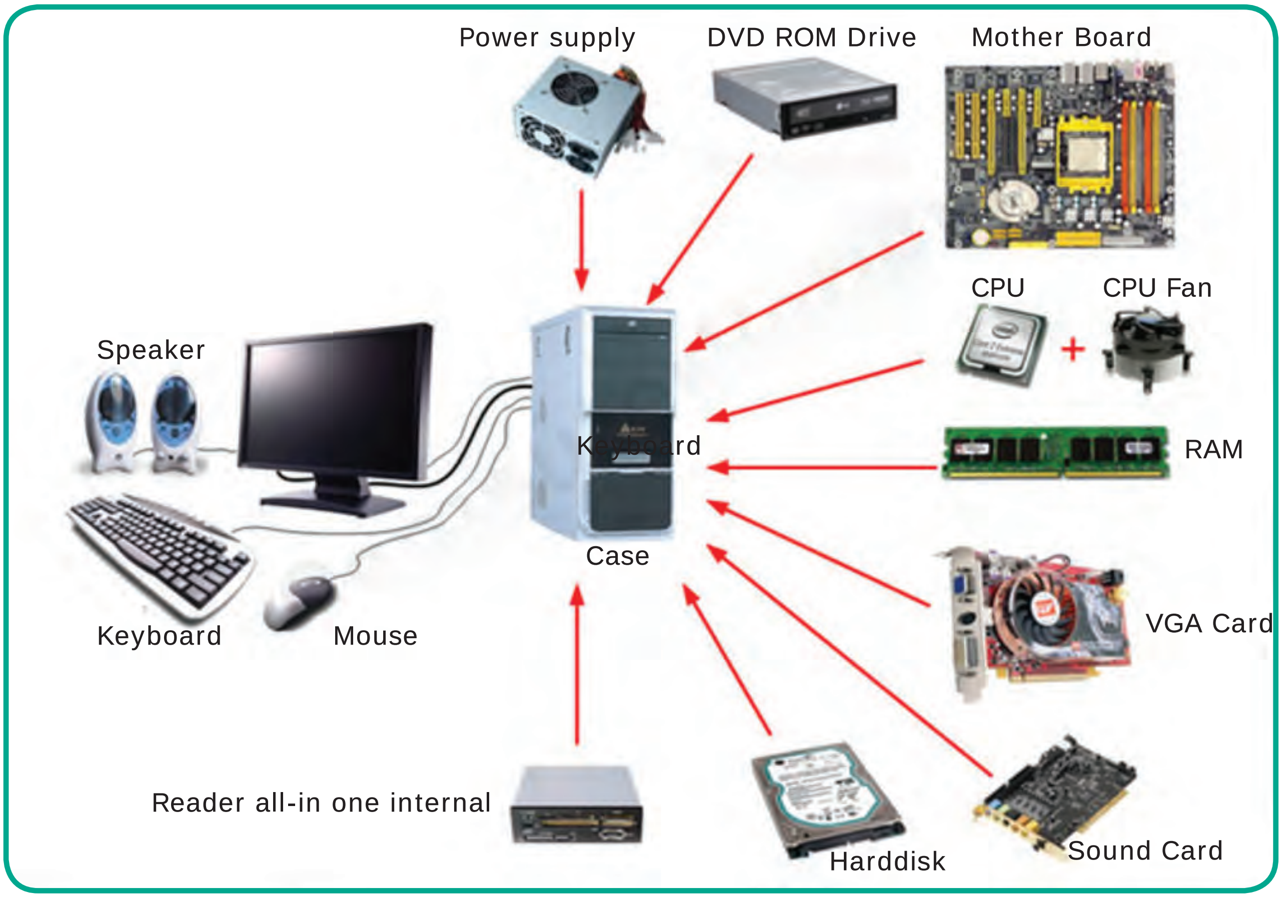
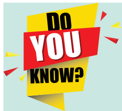


Figure 9.12 Parts of the Hardware

Example: All languages, program, even a single instruction that we are giving to the computer.



- CD, Memory card, Pen drive - these are hardware.
- What are the things (song, cinema, video game or anything) stored inside the hardware are termed as software.

9.5.2 Classification of Computer Parts

The computer parts are classified into three categories based on its functions

1. Input Devices (I/P)
2. Output Devices (O/P)
3. Both (I/P) and (O/P)

9.5.2.1 Input Device

1. Key Board
2. Mouse
3. Light Pen

9.5.2.2 Output Device

1. VDU (or) Monitor
2. Printer
3. Plotter

9.5.2.3 Both (I/P) & (O/P) Device

1. Touch Screen
2. Compact Disk
3. Hard Disc
4. Memory Card
5. Pen Drive

Till this, we have seen the peripherals of computer. Now let us see the working of computer i.e., CPU.

9.6. MAJOR DIVISION OF CPU

The CPU consists of three major divisions as shown in Figure 9.13. They are,

1. ALU
2. MEMORY UNIT
3. CONTROL UNIT

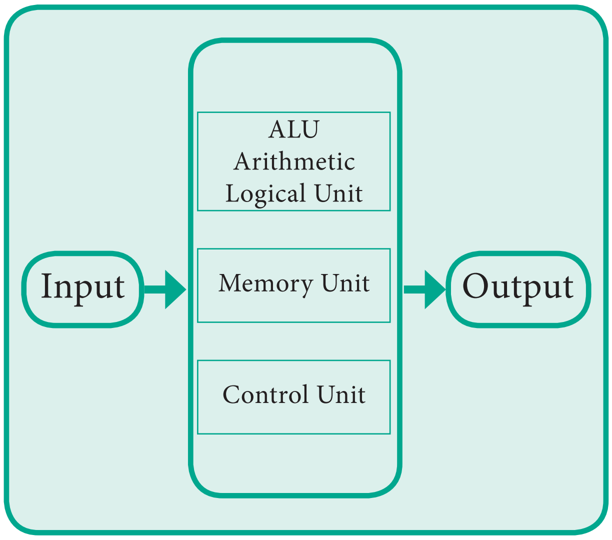


Figure 9.13 Major Division of Central Processing Unit

9.6.1 ALU → Arithmetic Logical Unit

What is meant by Arithmetic?

In general, Arithmetic means operations using numbers like Addition, Subtraction, Multiplication, division, etc. In computer, any type of calculation is known as Arithmetic operations.

LOGIC →What is meant by this?

To say, the speciality of computer lies in this word. Let us see regarding this in a different way.

What do you means by this word logic?

For example: Assume that there is a long-standing issue in your area where you are residing. You and your friends decided to find a solution for it. What will be your first step? You start to discuss among with your friends regarding that issue. By the time, everyone will say their idea to find a solution.Among these you can select only one, which is going to be the decision.The following illustration shown in Figure 9.14 simply explains the concept "logic".

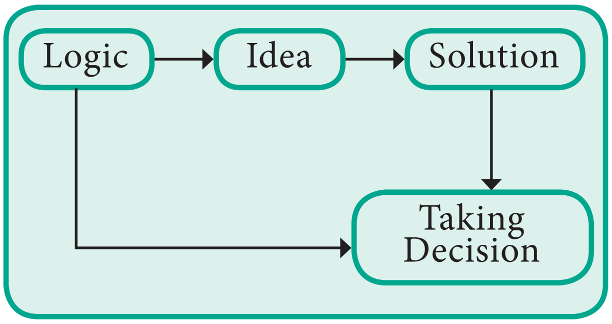


Figure 9.14 **Illustration of Logic**

With reference to the above example and illustration, Logic is nothing but an idea, idea is nothing but a solution and solution is nothing but taking decision.

Hence, logic is nothing but taking decision.

If so! Whether the computer has decision taking capacity?

If not, there is no use of thinking about all these things.

Logical Capability → Decision taking capacity

How foolish computer be able to take decision? How it possible?

Let us think. In general, while we are taking decision, in how many ways we can able to take decision?

For example:

Assume that your friend is inviting you to come for a movie.

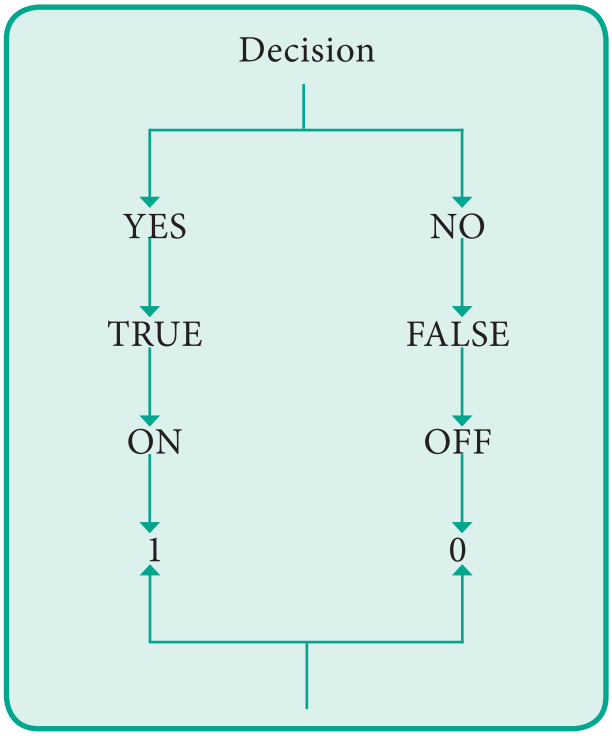
What you will say?

If you intent, you say yes, otherwise, Sorry no.

Is there any other option?

Usually we say, let us see,which is not at all an answer. Because any answer should give finite result.

Hence, for any action there are only two possible answers. i.e., Yes or No



At last where we came? We come to the 1,0, i.e., the machine language.

Till date the computer directly knows only one thing, i.e., the Machine Language

ELEC_EQUIP_Chapter09.indd 191 11/10/2020 11:53:06 AM

That is,

1. When the given condition is true, the computer will get the electrical notation '1' pulse.

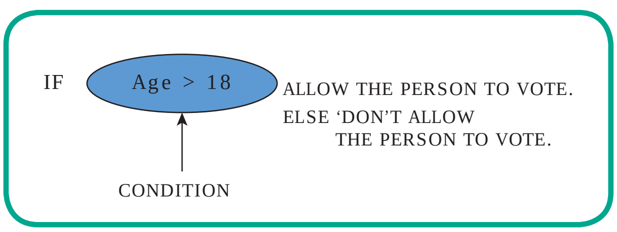
   When it gets '1' pulse, the computer will read the next part after the condition.

2. When the given condition is false, the computer will get '0' pulse.

   On getting '0' pulse, the computer will terminate that line and start to read the next line.

Go through the following statement

Example:



NOTE: whenever we are coming across a condition, we have to take a decision

While the computer is reading the above particular statement, it has to take decision.

1. When the given condition is true, (i.e., the person age is more than 18) it receives '1' pulse. When it receives '1' pulse, the computer continuously reads the remaining part of the statement after the conditions and do accordingly.

2. When the given condition is false (i.e., the person age is below 18), it receives a '0' pulse. On receiving the '0' pulse the computer terminates that particular time (it won't continue that line) and starts to read the next line.

Because of this, while you are writing program you will be instructed to write, 'what to be done if the condition is true', immediately following the condition, and 'what to be done if the condition is false ', in the next line.

Though the decision taking capacity is in the form of machine language, i.e., 1, 0 the computer can take the decision directly. Otherwise it can't.

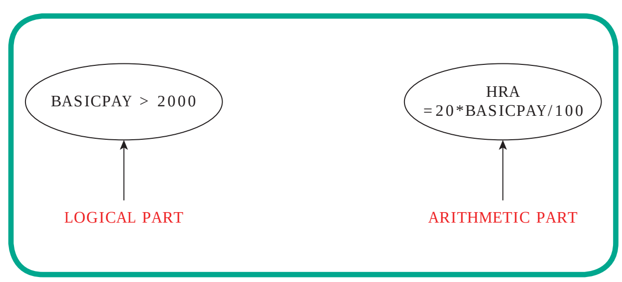
Because of this logical capability the computer is said to be superior than the calculator.

This is the second major difference between calculator and computer.

The action of ALU can also be explained through yet another example.

Example: IF BASICPAY > 2000 CALCULATE HRA = 20 * BASICPAY/100.

From the above example,



So, whenever the computer reads this line, this will be carried out by the arithmetic logical unit.

9.6.2 Memory Unit

This is yet another important division of CPU. Normally this is classified into two broad categories.

1. Internal Memory
2. External Memory

9.6.2.1 Internal Memory

The memories which are kept inside the CPU (or) on mother board are known as Internal Memory. There are five types, such as ROM, RAM, PROM, EPROM and EEPROM. All are nothing but IC's. Let us see the purpose and usage of each memory device in following sections.

ROM →Read Only Memory

From the above expansion itself, we could understand that the content of this IC can be read only. The function and working of this IC can be easily explained through the following example.

Let we take a calculator:

Switch on the calculator.

What you will get on the screen?

'0'

But you didn't press zero. Then, how the zero comes?

Whether it came automatically?

No, someone is making it to display.

Just like the same, whenever we are switching on the computer, the computer has to do something on its own to get ready.

We know basically the computer cannot do anything on its own.

Then, it is doing something means, the necessary command is delivered from a particular memory. That particular memory is called as ROM.

This is an IC (Integrated Circuit), whenever we are switching ON the computer, the pointer will enter into this memory, read the content and do accordingly.Initially, it will do a self-test, which is called as POST(Power On Self-Test). After performing POST, it will hand over the charge to us. Then only, we can give anything to the computer.

DO YOU KNOW?

POST - Who written and stored these necessary testing commands inside the ROM?

- It is written and stored by the manufacturer.

After storing the necessary instruction, the IC will be sealed. Then, the content cannot be altered, deleted and changed. But, can only be read. Because of this it is called as Read Only Memory or permanent memory. Without this ROM, no calculator or computer can get ready.

RAM →Random Access Memory

Random means without any proper order. Let we see the purpose of this memory. Let we again take calculator for example.

Assume that you want to perform the addition of 5, 10 in the calculator. What we will do?

Step1 : Switch ON the calculator.
:You can get '0' on the screen.

Step2 :Now press'5'.
:5 will be displayed on the screen.

Step3 : Next press '+'.

Step4 : For '10' you have to press'1'.

Now what will happen to that '5' it is not on the screen, then where it would be. Certainly, these numbers have gone to a memory and that particular memory is RAM. Since we cannot find the location where it is going is called as Random Access Memory.

As like the calculator, the computer is also having RAM. After the computer got ready whatever be the thing that we are giving, it should go to a memory and that particular memory is RAM. But, it will lose or the content of this memory will get erased when the computer is switched OFF or due to power failure. Hence, it is called as temporary memory or volatile memory. But it is live memory.

> **DO YOU KNOW?** Without the concern of the RAM nothing can be done in the computer

If we are seeing something on the monitor, it is understand that, it is present from the RAM. Hence, the capacity of RAM is much important. Even the configuration of the computer is decided by the capacity of the RAM. So, without this ROM and RAM, no calculator or computer can work.

PROM→Programmable Read Only Memory

This is like a ROM. The purpose of this IC is also the same as ROM. The difference between ROM and PROM is, in PROM we can (a software engineer) store the necessary booting(POST) instruction. But it can be done only once. After that the content cannot be altered, deleted or changed.

EPROM→Erasable Programmable Read Only Memory

The purpose and use of this memory is similar to ROM and PROM. The difference is, the content of this memory can be erased by passing ultra violet rays through a small hole provided on the top surface of the IC. Again it can be re-programmed.

EEPROM→Electrically Erasable Programmable Read Only Memory

This is also same like EPROM. Here the content of this IC can be erased by passing external electrical pulse through a particular pin of the IC. And again it can be re-programmed. From the above, ROM, PROM, EPROM and EEPROM are doing the same work and hence any one can be used in the computer. In majority of recent computers, EPROM is used as Booting IC and RAM is the live memory.

So far, we have seen the purpose and working of internal memory. For your notice, we cannot store anything permanent in this.

9.6.2.2 External Memory

If we want to store anything permanent it can be stored only under external memory. There are few types of external memory.

1. Floppy Disc
2. Hard Disc
3. Magnetic Tape
4. Compact Disc
5. Pen Drive
6. Memory Card

From the above, floppy disc is totally outdated. CD, Hard disc, pen-drive and memory-card are widely used. Let us see about the capacity of these. When we talk about any capacity, it should have its own unit. Normally the unit of memory is 'Byte'. It is better to know about hierarchical structure of it.The memory capacity is mentioned by the following units summarized in Table 9.2.

> **As like 10 mm = 1 cm.**
>
> **Approximately 10 Bits = 1 Byte**

Table 9.2: Memory Capacity	
0	Bit
1	Bit
8Bits	1 Byte
1024 Bytes	1 kilo Byte
1024 KB	1 Mega Byte
1024 MB	1 Giga Byte
1024 GB	1 Terra Byte

9.6.3 CONTROL UNIT

In general the computer is doing various activities besides handling many peripherals. In order to monitor and control all these, a system is used, which is called as control unit.

9.6.3.1 Controls Input Device

Assume that you are typing a matter consist of many pages. While you are typing speedy, we press one or more keys at a time. That moment, the respective letters altogether try to enter into the RAM, which is not possible. By that time the control unit will take charge and block it and give a beep sound. On hearing beep sound, we can able to identify that we are doing something wrongly. Thus, the control unit is controlling the input device, i.e., keyboard.

9.6.3.2 Controls Output Device

Assume that you typed around 50 pages of a matter. Now the matter is in RAM and you want to take a print-out. On giving print command, all the 50 page content will try to go to the printer, which is not possible. Here too, the printer and CPU are interfaced through a set of wires. It is possible to travel or send data with reference to the capacity of the wire, but all the pages tend to go at a time. This is explained by the following example.

Example:

- Assume a class room
- Evening closing bell rang.
- There is only one door in the class room.
- What the students will do?
- Everyone will tend to go-out of the class through the single door.
  By that time if a master is there, he will control them and regulate to go one by one.

Just like students, here all the pages will tend to go to the printer, which is not possible. There the control unit is taking charge, regulate and send little by little to the printer. Thus, the control unit controls the output device.

9.6.3.3 Controls both I/P and O/P Devices

E.g.: Assume that there is a movie in a pen-drive and you want to view it.

After inserting the pen-drive into the respective slot, you will click the particular icon. Now the entire movie will try to go to the RAM (Live Memory). Once again the pen-drive(External Memory) and the RAM(Internal Memory) is connected through set of wires, which cannot transfer entire data at a time. Now the control unit will take charge, regulate and send little by little to RAM. Now, the control unit controls both input and output devices.

Thus, the control unit controls the entire system. Without the concern of the control unit nothing can be done in the system.

Control unit – Is as like a father in a family.

9.7 COMPILERS AND INTERPRETERS

We studied, till date the computer knows only one language,i.e., machine language. But we know only High Level Languages and Application Languages, which the computer does not know. But, we both want to interact. How this become possible?

Example:

- *Assume that our prime minister is going to RUSSIA to meet the Russians president.*
- *Our PM knows Hindi and English. And the Russian president knows only RUSSIAN language.*
- *But, both want to converse.*
- *How?*
- *You can see a man (translator) who knows both Russian and English will sit near to them. He will translate English to Russian and vice versa.*

Just as like the above, we need a translator to translate our High Level Languages and Application Languages into corresponding machine language.The compilers and interpreters are here used as translator.

Oh....fine...

- Whether it is software or hardware?

Absolutely, it is a software written in one particular high level language.

Then, why we should need both, compiler and interpreters?

To understand this let we see the working method of complier and interpreter.

Compiler: Compiler means taking together. This will take entire program (whatever be the number of lines) and convert it into machine language. Wherever the mistake, just it will mark it and go to next line. After completing the entire program, it will list out the errors at the last.

Interpreter: The interpreter will read line by line. If there is a mistake in the first line, it will stop there and the error will be displayed. It can go to the next line, only after the particular line gets corrected.

This is the difference between Compiler and Interpreter.

NOTE: Along with each High Level Language and Application language either Compiler or Interpreter will be attached. Widely compilers are used.

9.8 OPERATING SYSTEM

The word system denotes computer. Hence Operating System means operating computer. In this, we are going to see actually how the computer gets operated.

Before going further, recollect the following.

- Basically computer never do anything on its own.
- ROM, RAM (Internal Memory).
- Hard disc (External Memory)... etc.

Operating System helps us to do some important and vital operations (like copy, delete, etc.) before entering into any particular language and after coming-out. It forms a bridge in between the user and the computer.

DO YOU KNOW?

- Whether the computer can work without the Operating System(O.S)
- No.(modern computer)

Let us see why?

Whenever we are switching on the computer what it will do?

It will read the content of ROM and do accordingly. After finishing the POST it will hand over the charge to the RAM. Now we can start to give instruction to the computer.

DO YOU KNOW?

If we want to interact with the computer, we are in need of a language. Without a language we cannot give even single instruction or interact with the computer.

i.e., the speciality of computer.

If so, I need a language. Where are they?

- They all in external memory. To select a particular language, we have to give a command to the computer. But, even that particular command should also be in one particular language. Now, I don't have any language on my hand.
- Everything is get locked in the external memory, then, what can we do?

A family of rats are living in a house and there is a CAT also. The cat catches a rat per day, as its food. Due to this the rats are so worried and decided to find a solution. They conversed a meeting. While on discussion a rat says, let we tie a bell on the cat neck. So that on getting the bell sound we could run away. Yes good idea, all the other rats appreciate that particular rat. It brought a rope and a bell and asks other rats., come-on go and tie the bell. Each rat is asking other rat to perform the task. Now the rats realised that they cannot able to execute the task on their own.

A Rat can tie the bell to the CAT, when only a third person helps them.

- In order to understand this, let me try to explain you through an old story.

Now our situation is also the same. In order to bring any one of the language from the external memory, someone has to help us. Here, that particular helping hand is this Operating System.

If it so ...whether it is a hardware or a software?

- **Absolutely it is software.**

If it is software, it should be stored in a particular memory permanently. Permanent in the sense, it should be stored only in external memory. So, whenever we are switching on the computer, this operating system which is normally in the hard disk should be loaded to the RAM, to serve the user instruction.

Whether it can be loaded automatically to the RAM? Certainly, Not. If so where would be the command? It should be in ROM. After performing the POST the next command is to seek the hard disk (or any external memory) in the computer and to search for operating system program.

On finding that, bring it and load it in the RAM. These sequences of commands will be in ROM. Now, the Operating System will be loaded to the RAM. (You can see it on the monitor as,"Loading Windows", because Windows is the operating system).

Earlier there was an operating system named as DOS (Disk Operating System). It was developed as PC-DOS (Personnel computer DOS) and then, Microsoft Company entered into the Operating System development and released MS-DOS (Version 1 to 6). These were up to the years 1993-94. Then, Windows operating system evolved. But, truly speaking till now the windows is working on the platform of MS-DOS. The difference is, in DOS, we have to type commands to execute few things like COPY to Copy files, DEL to delete files, MD to create directory (say folders), CD to change folders, etc., whereas in Windows these operations are performed by selecting the respective menus or icons.

Loading Operating System either from hard-disk or from any other external memory to the RAM is known as Booting process.

Now the computer is ready to take our commands or instructions.

LEARNING OUTCOMES

At the end of this Chapter student could understand the following about the Computer.

1. **Know about the evolution of a Computer.**
2. **Understand the development of digital computer.**
3. **Understand the purpose of computer languages.**
4. **Know about the computer jargon words Hardware & Software**
5. **Understand the basic principle and working of CPU (ALU, Memory & Control Unit)**
6. **Learn about Translators**
7. **Understand about the purpose of Operating System (OS) and its working.**

GLOSSARY

S. No	Terms	Explanation
1	**Bit**	Digit in the binary system
2	**Byte**	Group of eight binary digits
3	**Hardware**	The physical parts of a computer system, such as the electronic circuitry, chips, monitor, disks drives, keyboard, modem

4	**Operating system**	A program or collection of program that coordinates and controls the various devices making up a computer system
5	**Output**	The act or result of printing and displaying information generated by a computer
6	**Peripherals**	The add on hardware devices used in conjunction with a computer, printer, display screen, disk drives etc
7	**Cursor**	A moving position indicator displayed on a computer monitor that shows a computer operator where the next action or operation will take place
8	**File**	A set of data that is stored in the computer
9	**Input**	Data that goes into a computer device
10	**Microprocessor**	A complete central processing unit (CPU) contained on a single silicon chip

QUESTIONS

T5H12V

PART A

I. Choose the Best Answer

1. The first calculating tool developed by human..........

   a) Slide Rule (b) Nappier Bones (c) Abacus (d) Analytical Engine

2. Who developed Analytical Engine?

   a) Blaise Pascal (b) Newton (c) Neil Bohr (d) Charles Babbage

3. Who is father of Computer?

   a) Blaise Pascal (b) Charles Babbage (c) Bill Gates (d) John Nappier

4. What is the name of the first computer?

   a) IBM (b) Microsoft (c) ENIAC (d) DELL

5. With reference to the computer Machine language is ....

   (a) High level language (b) Low Level Language
   (c) Very High level language (d) None of the above

6. With reference to the computer the parts which we cannot see through our eyes are termed as ....

   (a) Hardware (b) Software
   (c) Both Hardware & Software (d) None of the above

7. Write the Odd one from the following.

   a) Monitor (b) Printer (c) Mouse (d) Plotter

8. Which is the Live memory among the below?

a) ROM (b) RAM (c) PROM (d) EPROM

9. Choose the odd one

a) Bit (b) Byte (c) Kilowatt (d) Megabyte

10. Compilers & Interpreters are ....

a) Hardware parts (b) Language (c) Translators (d) Operating System

PART B

II. Write answers in One or Two sentences. (3 marks)

1. Define computer.
2. Write down the names of the generation of computer.
3. Write down the major divisions of CPU.
4. What is the difference between Compiler and Interpreter?
5. Define arithmetic operations in computer.

PART C

III. Explain in One or Two Paragraphs. (5 marks)

1. Write about generations of computer.
2. Define the working of ROM & RAM.
3. Define Operating System.

PART D

IV. Write answers in detail. (10 marks)

1. Explain in detail the generations of languages.
2. Explain the working of CPU with neat diagram.

ANSWERS

1. **(c)** 2. **(d)** 3. **(b)** 4. **(c)** 5. **(b)**

6. **(b)** 7. **(c)** 8. **(b)** 9. **(c)** 10. **(c)**

ELEC_EQUIP_Chapter09.indd 200 11/10/2020 11:53:06 AM

CHAPTER 10

ELECTRONIC MEASURING INSTRUMENTS

T5ILRP

The measurement has been practiced from very long back, which is evident from the Tamil literature.

ஆற்றில் போட்டாலும் அளந்து போடு – பழமொழி
If you put something on river, measure it and then drop it.

ஆற்றின், அளவு அறிந்து கற்க–அவை அஞ்சா
மாற்றம் கொடுத்தற்பொருட்டு. # குறள் 725

By rule, to dialectic art your mind apply,
That in the council fearless you may make an apt reply.

விளக்கம்: அவையில் (ஒன்றைக் கேட்டவர்க்கு) அஞ்சாது விடை கூறும் பொருட்டாக நூல்களைக் கற்கும் நெறியில் அளவை நூல் அறிந்து கற்க வேண்டும்.

அற்றால், அளவு அறிந்து உண்க! அஃது உடம்பு
பெற்றான் நெடிது உய்க்கும் ஆறு.# குறள் 943

Who has a body gained may long the gift retain,
If, food digested well, in measure due he eat again.

விளக்கம்: முன் உண்ட உணவு செரித்துவிட்டால், பின் வேண்டிய அளவு அறிந்து உண்ணவேண்டும்; அதுவே உடம்பு பெற்றவன் அதை நெடுங்காலம் செலுத்தும் வழியாகும்.

LEARNING OBJECTIVES

In this Chapter, a student can learn and understand the working principles of the following instruments:

1. Multimeter (Analog & Digital)
2. Cathode Ray Oscilloscope (C.R.O.)
3. Signal Generator
4. Function Generator
5. Spectrum analyser
6. Logic probe
7. IC tester
8. Digital Energy meter

INTRODUCTION

In daily life, we use several measuring instruments such as manual balance, litre cans and scale to measure quantities like weight (rice, wheat, etc.), volume of liquid (oil, petrol, diesel, etc.), length (cloth, wood, etc.), respectively. Presently, digital instruments are used, owing to their accurate measurement of quantities with minimum error. Likewise to measure and test electronic components and parameters, we are using several analog and digital instruments.

10.1. TESTING AND MEASURING INSTRUMENTS

Testing and measuring instruments are used to check the electronic components, whether they are in good condition or not and to measure electrical parameters such as current, voltage, resistance, frequency and phase etc. Though, there are numerous measuring instruments in practice, we will see some of the basic and important measuring instruments and their functions in this Chapter.

Some of the basic instruments to be discussed are,

- ❍ Multimeter (Analog & Digital)
- ❍ Cathode Ray Oscilloscope (C.R.O.)
- ❍ Signal Generator
- ❍ Function Generator
- ❍ Spectrum analyser
- ❍ Logic probe
- ❍ IC tester
- ❍ Digital Energy meter

10.2. MULTIMETER

A multimeter is an electronic instrument which can measure multiple parameters such as current, voltage and resistance.

(i) 0–300 V A.C Voltmeter (ii) 0–10 V A.C Voltmeter

Figure 10.1 Separate range A.C voltmeters

10.2.1. History

Multimeter was invented by a British telecom engineer Donald Macadie. He had the difficulty of carrying many separate instruments while troubleshooting the telecommunication circuits. To avoid these difficulties, he invented an instrument which could measure Ampere, Volt and Ohm, which was named as AVO meter. Earlier, we used separate meters to measure multi-ranges of AC and DC voltages, AC and DC currents and resistance values. Figure 10.1 shows the separate range AC voltmeters.

Figure 10.2 **Analog Multimeter Front Panel with Dial and Selector Switch**

For example, to measure 230 volts AC, we used a voltmeter of 0-300 V range, whereas for measuring 6 V AC a 0-10 V AC voltmeter was recommended to measure the voltage accurately.

Using a single meter, we can measure AC and DC voltages (various ranges such as 0-10 V, 0-250 V), AC and DC currents (various ranges such as 0-0.25 A, 0-10 A) and resistance values (various ranges x 1, x 10, x 1 kΩ etc.). So it is called as multimeter or multi-tester or AVO meter. Using a multimeter, the measurements carried out using 20 separate meters can be measured in a single multimeter as shown in Figure 10.2.

To understand the various functions available in the multimeter, you should keenly watch the front panel of a multimeter. In a Multimeter, you can see 20 switching positions indicating various ranges of AC and DC voltage, AC and DC current and resistance values as shown in Figure 10.3. Thus, we can conclude that a single multimeter can be used in place of 20 separate meters.

Figure 10.3 **Analog Multimeter Front Panel Selector Switch (Enlarged View)**

10.2.2. Types of Multimeter

There are two types of multimeters

1. Analog multimeter
2. Digital multimeter

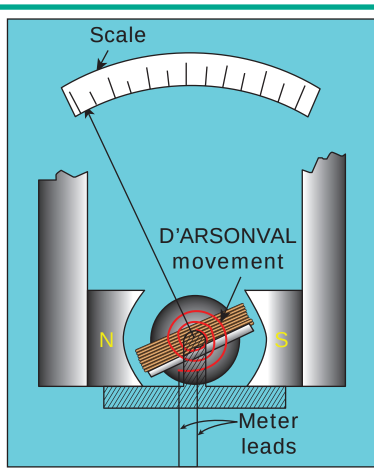
10.2.2.1. Analog Multimeter

An analog multimeter consists of an ordinary pivoted type of moving coil galvanometer.

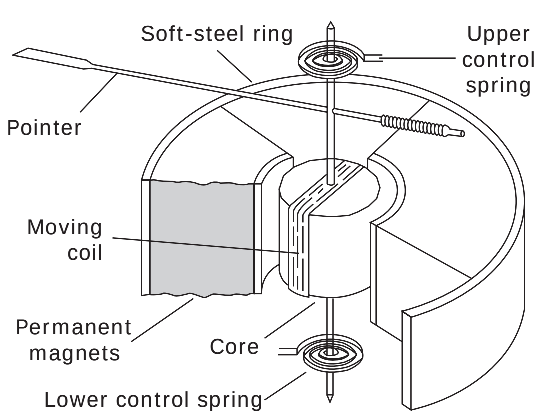
> **DO YOU KNOW?** Galvanometer is also called as D'ARSONVAL meter, named after the inventor of galvanometer.

A galvanometer consists of a coil pivoted on a jewel bearing between the poles of a permanent magnet. An indicating needle is fastened to the coil. When electric current passes through the coil, magnetic flux is generated. This magnetic flux is converted into a mechanical force to move the pointer over the scale. The movement of pointer is called as meter reading. After the measurement is finished, the control spring is used to bring back the needle to the resting position (0 or ∞). The analog multimeter components are shown in Figure 10.4.

To measure voltages, currents and resistances, proper circuits are connected with the galvanometer. The galvanometer used in a multimeter is always of left zero type i.e., the needle normally rests in extreme left position, whereas in ordinary galvanometers the needle rests in centre zero position as shown in Figure 10.5.



(a) Analog Multimeter Showing Coil



(b) Permanent Magnet and Control Spring

Figure 10.4 Internal construction of Analog Multimeter

(a) Multimeter (Left - Zero)

(b) Galvanometer (Centre-Zero)

Figure 10.5 Needle at Zero Position in Multimeter and Galvanometer

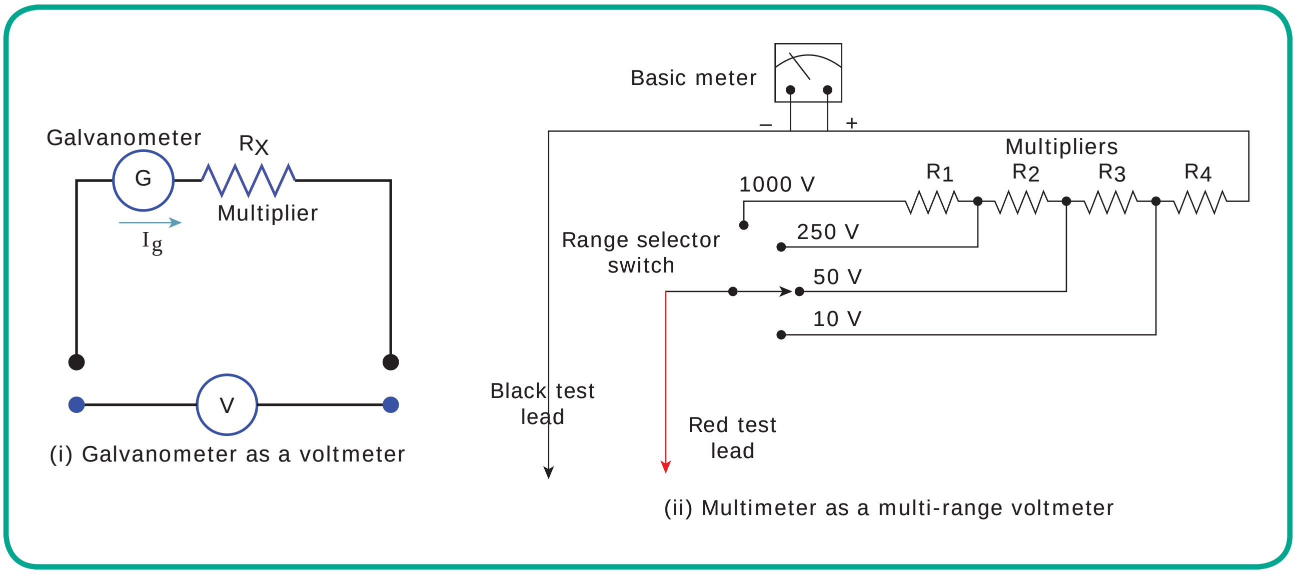


Figure 10.6 **Multimeter as a Voltmeter - circuit**

10.2.2.2. Multimeter as a Voltmeter

A meter used for measuring voltage is called as voltmeter.

To measure accurate voltage values, various voltage ranges are incorporated in the meter. To measure multiple ranges of voltage, resistors (R_1, R_2, R_3, & R_4) are connected in series (called as multipliers) with the basic meter as shown in the Figure 10.6. With the help of selector switch, we can select a particular range of interest. After selecting the range, the voltage in a circuit can be measured. To measure various ranges of AC and DC voltage measurements, separate multipliers are used in series with the meter.

Note: In general, a galvanometer (basic meter) does not work while measuring AC voltage or current. It works in DC source only.

If AC source is applied to a galvano meter, the needle of the meter tends to oscillate either in the clockwise or anti-clockwise direction with respect to zero position. As a result, there is no movement of the needle takes place and the needle rests near zero position. So, a rectifier is connected in series with the meter to measure AC voltage and current, separately.

10.2.2.3. Multimeter as an Ammeter

An instrument used for measuring current is called Ampere meter shortly Ammeter.

When low resistance is connected in parallel with a galvanometer, it becomes an Ammeter.

Figure 10.7 shows a low value resistance R_S (generally called shunt resistance) connected in parallel with the galvanometer coil. Since the resistance of the coil is higher than the shunt resistance, the majority current is passing through the coil of the meter. The shunt resistance R_S protects the coil from over-current.

In practice, shunt resistances (such as R_1, R_2, R_3, & R_4) are connected in parallel with the meter through selector switch

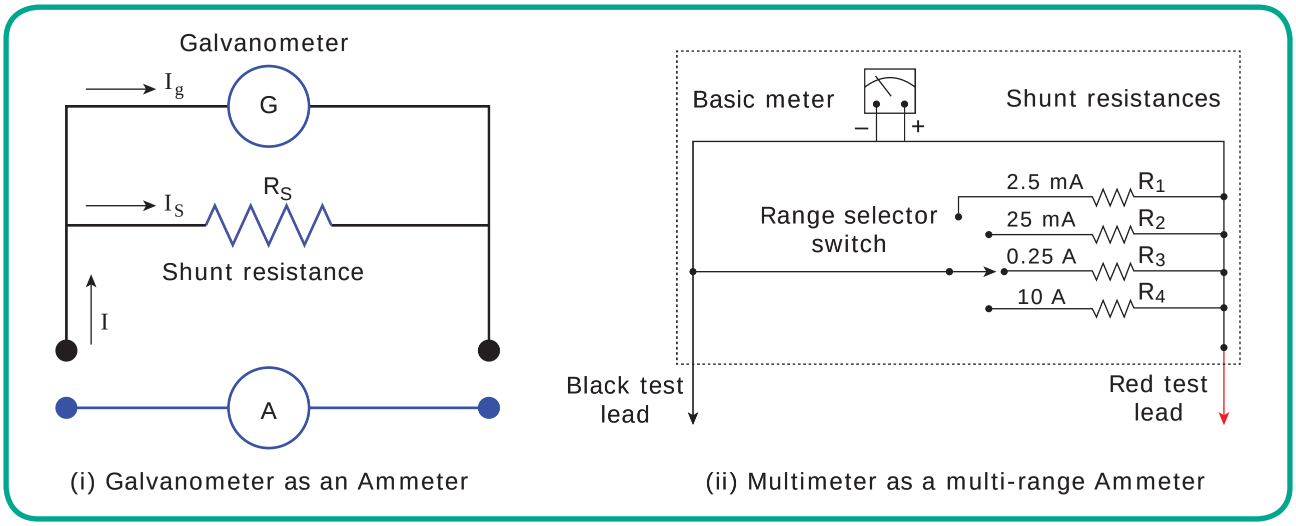


Figure 10.7 Multimeter as an Ammeter - circuit

to provide a required number of current ranges as shown in Figure 10.7. To measure AC current, a diode should be connected in series with the meter.

10.2.2.4. Multimeter as an Ohmmeter

An instrument which is used for measuring ohms is called as Ohm meter.

Figure 10.8 shows the circuit of an Ohmmeter. A fixed resistance *R* and a variable resistance R_V are connected in series with the meter and a battery (fixed inside the meter). The fixed resistance *R* limits the current within the desired range and the variable resistance R_V is used for setting zero ohm of the needle before taking any range of resistance measurements. This setting is called as zero ohm adjustment. As a result, accurate ohmic readings can be measured.

Two probes (A and B terminals) of the multimeter are connected across the resistance to be measured. If the resistance is high, lower current flows through the circuit and the meter will indicate higher ohms and vice versa.

To measure multi range Ohmic readings, various resistance values such as R_1, R_2 & R_3 should be connected in series with battery through selector switch as shown in the Figure 10.8 (ii)

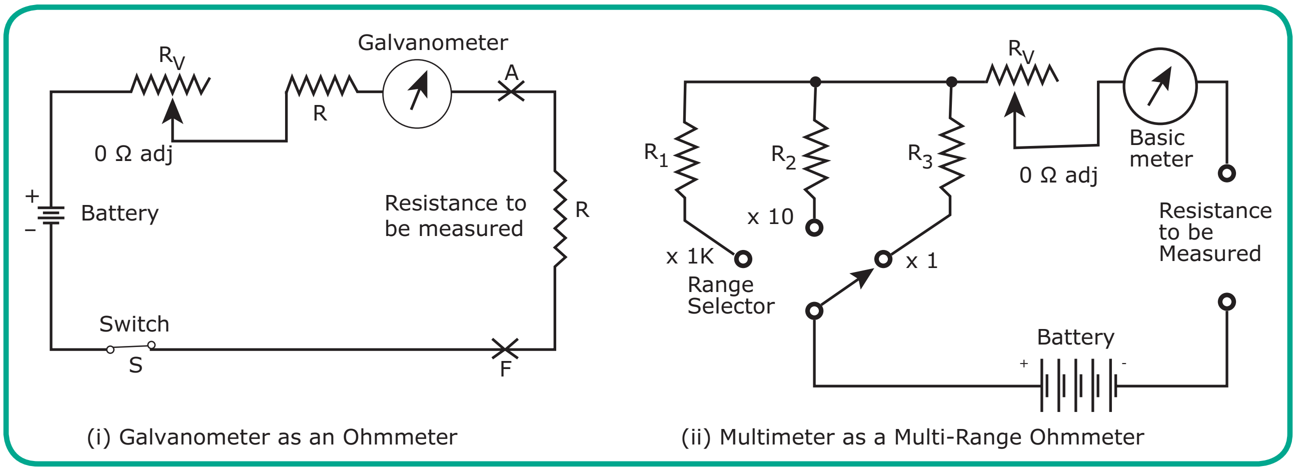


Figure 10.8 Multimeter as an Ohmmeter - circuit

10.2.2.5. Functions of a Multimeter

It can measure the following electrical and electronic quantities.

1. DC Voltage
2. DC Current
3. AC Voltage
4. AC Current (available in few meters only)
5. Resistance
6. Continuity Test
7. Checking the Transistor (NPN or PNP) (available in few meters only)
8. Collector Emitter Leakage Current (I_{CEO}) of a transistor (when base kept open)
9. Capacitance up to 20 µF (available in few meters only)
10. Frequency up to 20 kHz (available in few meters only)

Figure 10.9 Sensitivity of an analog multimeter

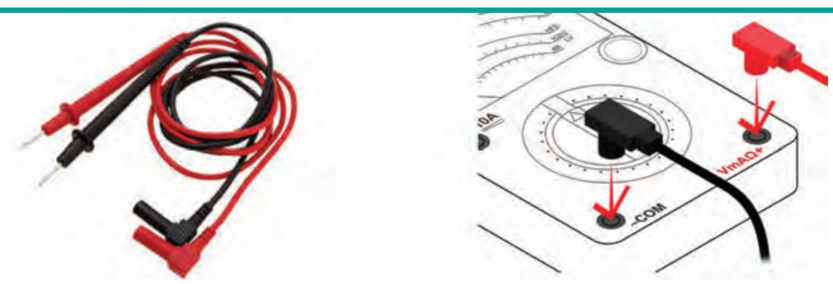
10.2.2.6. Sensitivity of an Analog Multimeter

A good quality analog multimeter offers an input impedance of 20 kΩ/V DC and 9 kΩ/V AC. This is known as sensitivity of an analog multimeter. It is printed on the bottom of the dial as shown in Figure 10.9. It means, to measure one volt DC, the meter offers 20 kΩ of impedance and to measure one volt AC, the meter offers 9 kΩ of impedance. Hence, the meter draws minimum current. Because of this, sensitive components such as transistors, IC etc., are not affected while testing with multimeter.

But low sensitivity meters (having an impedance below 5 kΩ/V AC and DC) draw high current from the circuit to be measured, which results in damage of transistors or ICs in circuit to be tested.

10.2.2.7. Precautions to be taken while handling an Analog Multimeter

A multimeter has one **positive probe** (Red colour) and a negative probe (black colour) to measure parameters as shown in Figure 10.10.



(i) Probes

(ii) connecting probes with correct polarities

Figure 10.10 Connecting colour probes to correct polarities

Precautions

1. When measuring DC voltage, care must be taken while connecting the two probes of the meter with the DC source. It should be connected with correct polarities in parallel connection with DC supply. That is, positive probe of the meter should be connected to positive terminal of the DC supply and negative probe to negative terminal of the DC supply as shown in Figure 10.11(a).

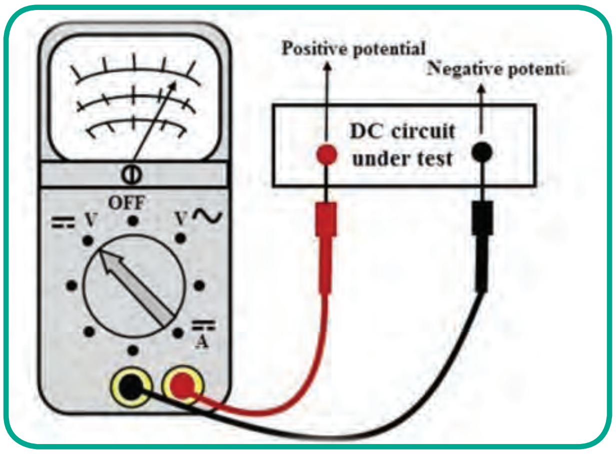


Figure 10.11 (a) Connecting a Multimeter while Measuring DC Voltage

2. When measuring DC current, multimeter should be connected in series with the DC supply and the load with correct polarities. That is, positive probe should be connected with positive terminal of the supply and negative probe to the load as shown in Figure 10.11(b).

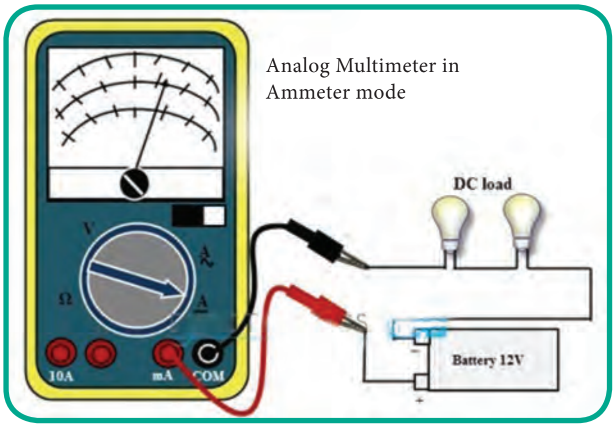


Figure 10.11 (b) Connecting a Multimeter while Measuring DC Current

3. In the above two measurements, if we wrongly connect the probes, the meter needle will get reversed and subsequently the meter will get damaged.

4. While measuring AC voltages, it should be connected in parallel but polarity need not be considered as shown in Figure 10.12. Because AC supply has no fixed polarities (+ and -).

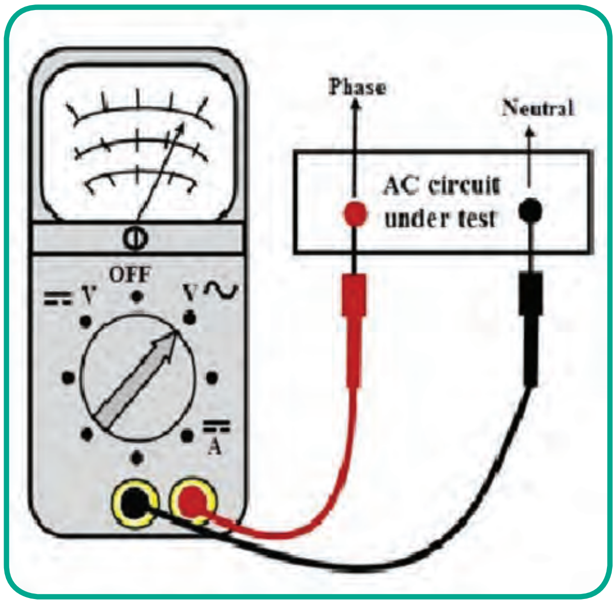


Figure 10.12 Connecting a multimeter while measuring AC voltage

5. While measuring AC current, as like the measurement of DC current, the meter should be connected in series with the supply and the load as shown in Figure 10.13. Polarity need not be considered as like in measuring AC voltage.

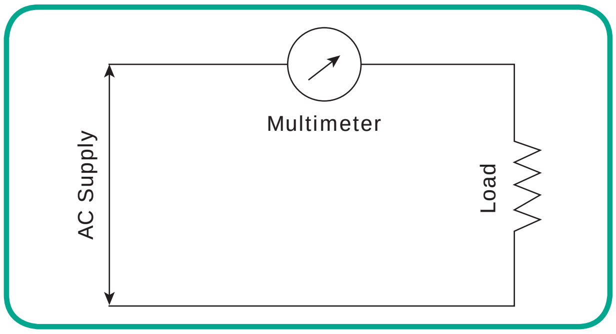


Figure 10.13 AC current Measurement

6. We should not measure voltage or current in ohm's range. Otherwise, the meter will become faulty.

7. While measuring, the angle of vision towards the meter should be straight. Otherwise, parallax error will result in the measuring quantities.

DO YOU KNOW?

While taking measurements in a scale, the angle of vision towards the scale should also be straight. If we see the scale from sidewards, measurements will be wrong.

Like this, in an analog multimeter, if the angle of vision towards the meter be straight, the measurement will be accurate.

8. We should not measure high voltage or current by keeping one probe at the supply and the other probe's metal point in contact with our hand, which will result in fatal electric shock.

9. We should presume the voltage and current to be measured at a point of circuit. If any doubt arises, we should first select high range and then measure it. If it is a low voltage, then we select the lower ranges for measuring.

DO YOU KNOW?

We can also measure Extra High tension voltage up to 30 kilo Volts using ordinary multimeter. How? Using EHT probes, we can measure the above said range. EHT probes have a multiplier resistance value above 100 MΩ. The multiplier reduces the EHT voltage and the reduced voltage is applied to the meter. Now, we can measure the voltage reading.

Warning !

Don't try to measure EHT voltage using ordinary probes. It is shock *hazardous.*

10. High voltage must not be measured using low voltage range. Otherwise the meter will become faulty.

DO YOU KNOW?

Selecting the Colour of the Probe

While using multimeters, we frequently ask a question within our mind. What happens if we connect **black probe** to **positive socket** of the meter and **red probe** to **negative socket** during measurement?

Nothing will happen

Apart from the colours, they are just wires. But, meter should be connected in correct polarities with the circuit. The concept **Black probe** should be connected with **negative socket** and **red probe** to **positive socket** of the meter is accepted all over the world. So, we use this concept.

Uses of Analog Multimeter

1. It is used in trouble shooting Radio, TV and all other electronics equipment.
2. It is also used to check electrical appliances.
3. It is used in assembling of electronics equipment.
4. It is used in installation of electronics equipment.
5. It is used to measure A.C and DC voltages and currents and resistance.

Calibration

Calibration is a process of correcting a faulty meter using a properly functioning multimeter. In this process, burnt resistors and defective components are replaced and the movement of the coil is also smoothened. In companies, this process is often done to maintain accuracy and quality of their products.

10.2.3. Digital Multimeter

It is a type of meter which shows measurement in digits, is called as digital multimeter. Figure 10.14 shows a typical digital multimeter.

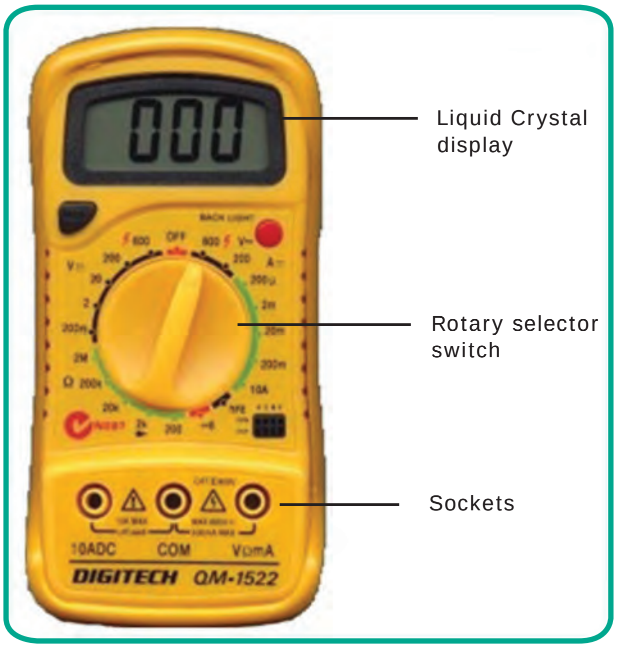


Figure 10.14 Digital Multimeter Front Panel

10.2.3.1. Components of a digital Multimeter

Figure 10.14 shows a typical digital multimeter. A digital multimeter comprises of three parts viz

1. Liquid Crystal Display
2. Rotary Selector switch and
3. Test probes.

The display usually has four digits and has the ability to display a negative sign. A few meters have illuminated displays for better viewing in low-light situations. The selector switch allows the user to set the multimeter to read different parameters such as current, voltage and resistance.

Two probes with banana plugs are plugged into two ports on the front of the instrument. COM stands for common and is always connected to ground or '-' of a circuit. VΩmA is the port in which the red probe (+ terminal) is conventionally plugged-in. This means, using this port, we can measure current up to 200 mA, voltage and resistance values.

10.2.3.2. Probe types

There are different types of probes available for multimeters. Here are some of the important probes in regular use.

1. Banana plugs to crocodile clips

   These cables are used for connecting large wires or pins on a bread board as shown in Figure 10.15. It is good for performing longer term tests where the user doesn't have to hold the probes in hands while testing the circuit.

Figure 10.15 Banana Plugs to Crocodile Clips

2. Banana Plugs to IC Hook

   These probes are used to connect the legs of ICs with the meter and can be measured easily. It is shown in Fig 10.16

Figure 10.16 Banana Plugs to IC Hook

Figure 10.17 **Banana plugs to Tweezer**

Figure 10.18 **Banana plugs to test leads**

3. Banana plugs to Tweezer :
   These are handy to test SMD components as shown in Figure 10.17.
4. Banana plugs to test leads :
   These are ordinary probes to measure Ampere, Voltage and Ohm as shown in Figure 10.18.

DO YOU KNOW? The clips that looks like a opened crocodile's jaw, are called as crocodile clips.

10.2.3.3. How does a digital multimeter work?

All digital multimeters are voltmeters.

It is configured in such a way to measure current, voltage and resistance by measuring the corresponding voltage values produced across the internal resistor. Figure 10.19 shows the block diagram of a digital multimeter. The working of each

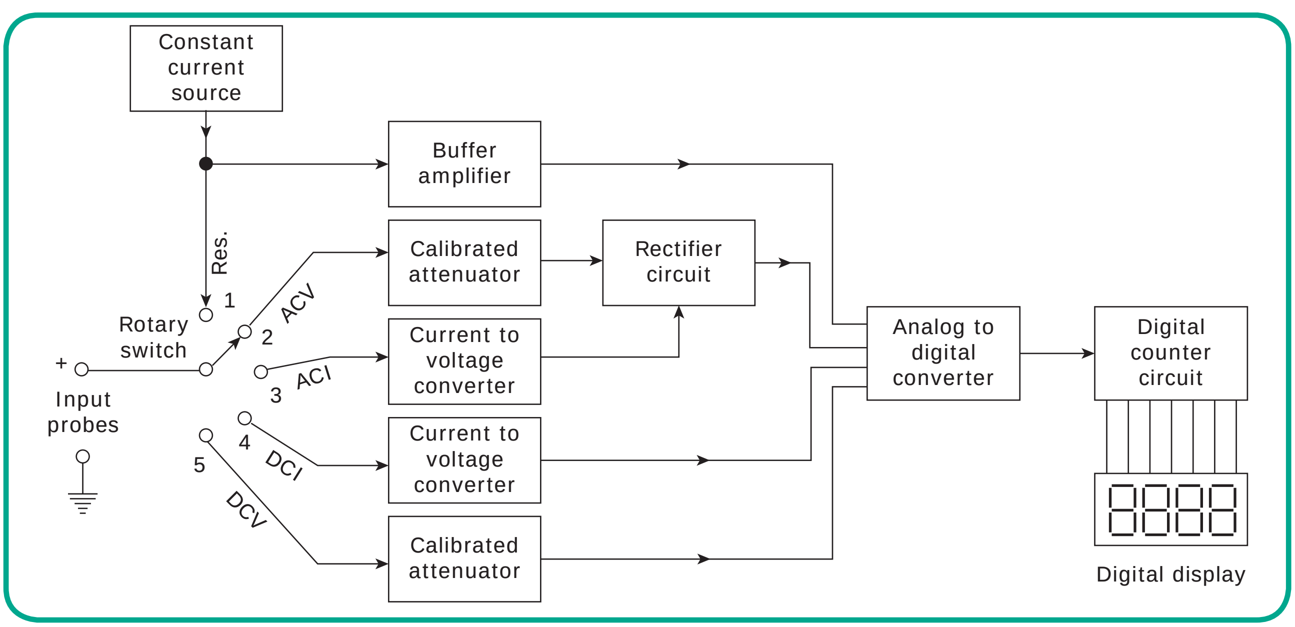


Figure 10.19 **Block Diagram of Digital Multimeter**

block to measure different types of electrical quantities is as follows.

How to measure resistance?

Keep rotary switch in the position 1. Connect an unknown resistor across its input probes. The proportional current flows through the resistor, from constant current source (Battery). According to Ohm's law, a potential difference is obtained across it. This voltage is directly proportional to its resistance. That is, higher the resistance value, higher the potential difference and vice versa. This voltage is buffered and fed to A-D converter, to show in the digital display in Ohms.

How to measure AC voltage?

Keep rotary switch in position-2. Connect an unknown AC voltage across the input probes. If the voltage is above the selected range, the voltage should be attenuated and then rectified to convert it into proportional DC voltage. It is then fed to A-D converter to show in the digital display in Volts.

How to measure AC current?

Keep the switch in position-3. Current is indirectly measured by converting it into proportional voltage. Connect an unknown AC current across input probes. The current is converted into voltage proportionally with the help of I-V converter and then rectified. Now the voltage in terms of AC current is fed to A-D converter to show in the digital display in Amperes.

How to measure DC current?

Keep the switch in position-4. The DC current is also measured indirectly. Connect an unknown DC current across input probes. The current is converted into voltage proportionally with the help of I-V converter. Now the voltage in terms of DC current is fed to A-D converter to show in the digital display in Amperes.

How to measure DC voltage?

Keep the switch in position-5. Connect an unknown DC voltage across input probes. If the voltage is above the selected range, the voltage should be attenuated and then directly fed to A-D converter to show in the digital display in Volts.

The comparison between the digital and analog multimeter is given in Table 10.1.

Table 10.1 Comparison between digital and analog multimeter

S. No.	Digital Multimeter (DMM)	Analog Multimeter (AMM)
1.	Reading in digits.	Needle shows reading but the users have to find values.
2.	More accurate	Less accurate
3.	If polarity is reversed in measuring the DC actual reading with '-' sign is shown in the display.	If polarity is reversed, the needle gets reversed and subsequently the meter will become faulty.
4.	Cost is high.	Cost is lesser than DMM.
5.	If fault occurs in DMM, rectification is complicated.	If fault occurs, it may be rectified.

10.3. CATHODE RAY OSCILLOSCOPE (CRO)

Cathode Ray Oscilloscope is an electronic device in which various types of waveforms can be seen on the screen. In abbreviated form, it is called as CRO.

> DO YOU KNOW? CRO was invented by German Scientist Karl Ferdinand Braun in 1897.

Figure 10.20 shows Front panel of a Cathode Ray Oscilloscope.

Functions of important front panel controls of a CRO

Display controls

Intensity control

An intensity control is used to adjust the brightness of the screen.

Focus control

A focus control is used to adjust the sharpness of the waveform.

500 V AC MAX

It is the input socket, in which the waveform to be seen, should be connected through a CRO cable.

Vertical controls

- *Volts/div* : For selecting desired voltage sensitivity of the vertical amplifier to obtain the proper wave form on the screen i.e., to bring the waveform within the viewing area of the screen.
- *Vertical Position knob:* To move the waveform up or down on the screen.

Horizontal controls

Sec / division : To get distinct and stable waveform in the CRT display and correct horizontal synchronising waveform (in phase with the input waveform), this control is used.

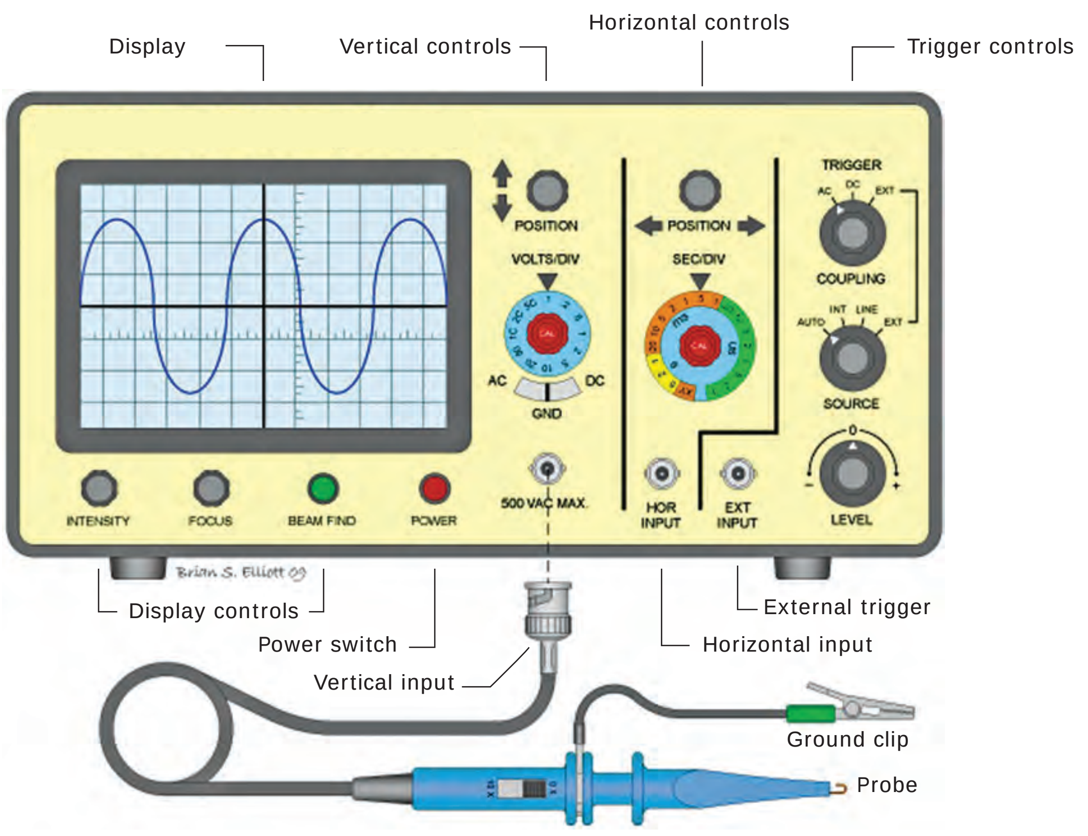


Figure 10.20 Front panel of a Cathode Ray Oscilloscope

❍ Horizontal Position knob: Controls horizontal position of waveform on the screen.

Trigger controls

The trigger control delays the time base circuit operation. This makes the moving wave appears to be static (unmoved) on the screen. The frequency, wave length and amplitude can be measured, when it is unmoved (locked).

10.3.1. Working of CRO

Figure 10.21 shows block diagram of a CRO. As like TV Receivers, a Vacuum cathode Ray tube is employed as a screen in a C.R.O. The cathode of the CRT is heated using the filament. Due to thermionic emission electron ray emitted from cathode. This electron ray is controlled by the first grid/anode. The second grid accelerates the speed of the electron and the third grid focusing the electron ray at the centre of the screen. Next to the third grid, there are two pair of plates named as X and Y. These plates are termed as horizontal and vertical deflection plates. By giving a voltage to these plates the electron ray can be deflected. This is known as Electrostatic Deflection.

The X plates are connected with time base circuits. This circuit generates saw tooth wave. This saw tooth wave makes to move the (electron ray) bright spot from left to right on the screen. This is termed as X axis on the screen. The amplifier connected with Y plates, moves the ray up and down. This is termed as Y axis on the screen. The signal wave to be measured is given at the input. The switch ac/dc must be in off state. Through the capacitor the wave is amplified by the Y amplifier and fed to the Y plates.

The power of the Y amplifier can be controlled through the front panel control Volts/Div. Due to this, the wave form appears on the screen can be maximized

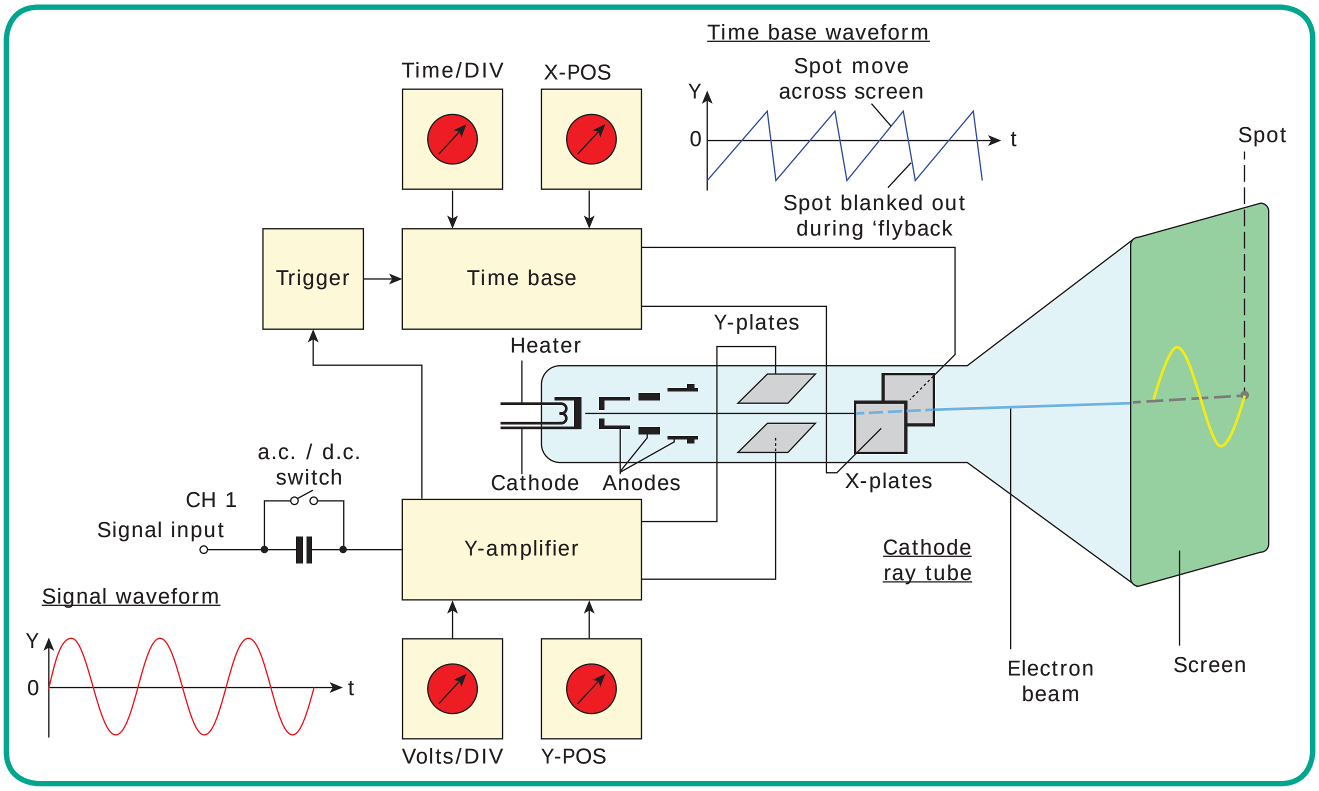


Figure 10.21 Block Diagram of a CRO

or minimized. The trigger circuit delays the time base circuit operation. This makes the moving wave appears to be static (unmoved) on the screen. The frequency, wave length and amplitude can be measured, when it is unmoved (locked).

10.3.2. Classifications of C.R.O

1. Analog C.R.O
2. Digital C.R.O

10.3.3. Types of digital CRO

1. Digital Storage Oscilloscope
2. Digital Phosphor Oscilloscope
3. Sampling Oscilloscope
4. PC Based Oscilloscope

10.3.4. C.R.O Probes

A cable which is used to connect CRO and the circuit under test is known as CRO probe.

10.3.5. Applications of CRO

1. Various waveforms with reference to time can be measured.
2. It is used to align all the parts of TV receivers.
3. Signal voltage can be measured.
4. Used to rectify the faults in TV receivers.
5. Frequency of the Signal can be measured.
6. Faults in DVD can be rectified.
7. Phase shift of a signal can be measured.

10.4. SIGNAL GENERATOR

This instrument generates Audio Frequency (AF) and Radio Frequency (RF) signals. Hence, it is also called as AF and RF signal generator.

It is of two types

1. Analog Signal Generator
2. Digital Signal Generator

10.4.1. (a) Analog signal generator

It consists of the following sections.

RF Oscillator: This section generates fixed RF waves. This wave is known as carrier waves. Frequency of this wave can be altered by adjusting the variable capacitor (Gang).

RF Amplifier: It amplifies the RF signal.

AF Amplifier: This stage amplifies the AF signal. An output can be obtained through the socket AF-OUT, which is used to find faults appeared in audio stages of any receiver. The strength of AF can be altered by means of a potentiometer.

AF Oscillator: This will generate noiseless audio wave.

AM Modulator: In this section, the sound wave amplitude is modulated.

RF Amplifier: This amplifies the modulated signal and fed to the RF out.

In Radio receivers, faults can be rectified by using the modulated RF waves, when injecting into the RF and IF stages of Radio receivers. The strength of the signal can be varied through potentiometer.

10.4.1. (b) Front panel and handling methods of analog signal generator

Figure 10.22 shows the front panel of an analog signal generator. The functional description of each function of the signal generator is summarized as follows.

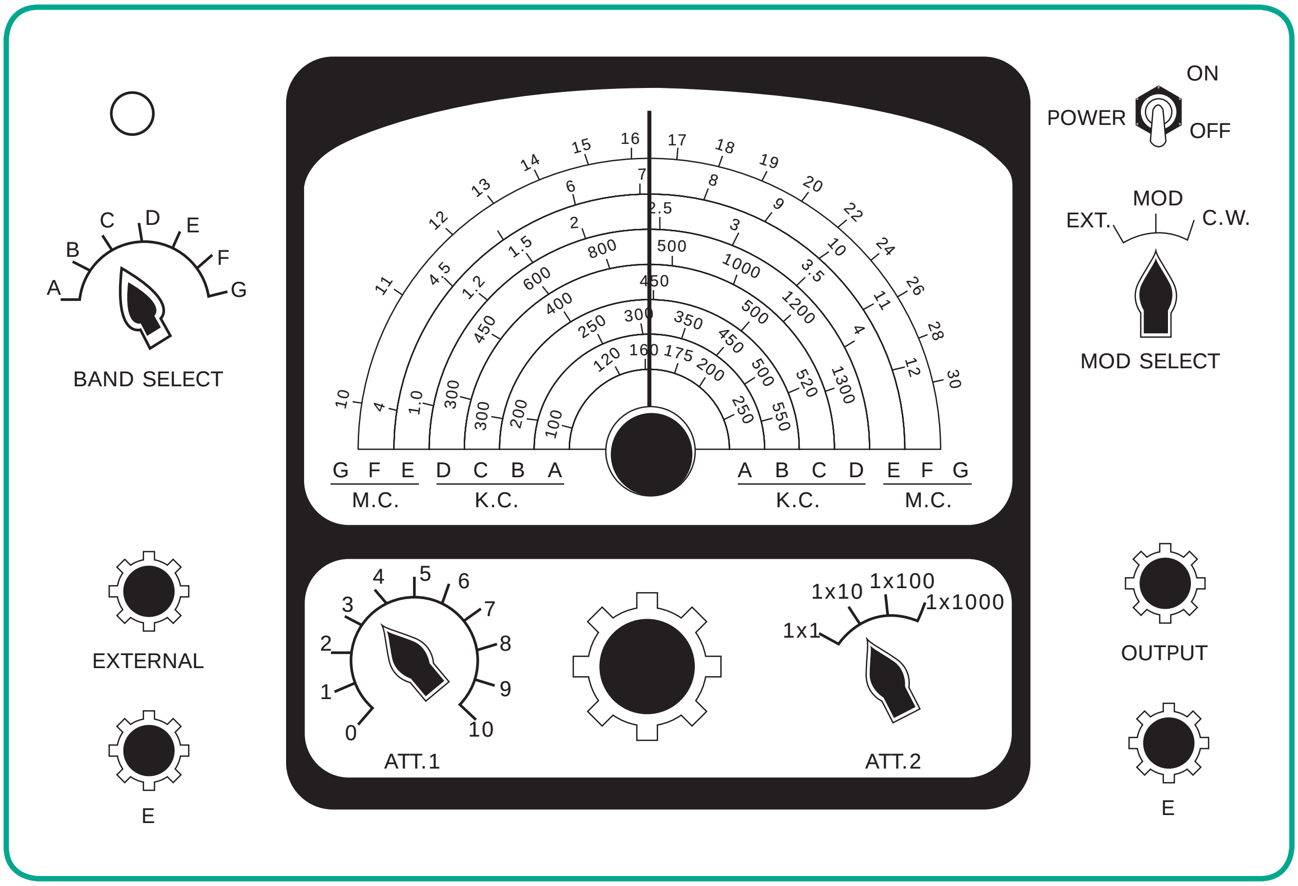


Figure 10.22 Front Panel of an Analog Signal generator

This is like a small A.M transmitting circuit.

1. **On/Off switch:** This is used to on/off the generator.
2. Mode Selector

   This is a three modes switch
   1. Carrier Wave Mode
   2. Modulated Wave Mode
   3. Audio Wave Mode

   The respective wave will appear at the output on selecting the required mode.
3. **Band Selector:** This is used to select the band appears on the dial gauge. This is also called as Range selector. By using this, various frequencies of different bands in a radio receiver can be checked.
4. **Frequency Selector:** By employing a variable capacitor, different ranges of frequencies are generated.
5. **Gain Control:** The gain (strength) of the RF and AF signals are controlled by the potentiometers.
6. **Output Socket:** The signal selected through the mode selector is obtained at this socket. The signal is taken out through a co-axial cable. Radio receivers can be checked by using this signal.

10.4.2. Applications

1. It is used to check audio stages in Radio and TV receivers
2. RF and IF stages can be aligned
3. Faults in RF and IF stages can be found

Figure 10.23 Front panel of a Digital Signal Generator

10.4.3. Digital RF Signal Generator

Now a days RF signal generator consists of LCD display (instead of needle) which shows frequencies and bands selected by the user in digits. This avoids manual errors when selecting frequencies and bands. Figure 10.23 shows the front panel of a digital signal generator.

Advantages

1. Accuracy
2. Affordable cost
3. We can easily select frequencies and bands using feather touch micro switches

10.5. FUNCTION GENERATOR

Function generator is a testing instrument that produces different types of signals consisting of specified frequency, shape and amplitude. Figure 10.24(a) shows the front-panel of a digital function generator. Figure 10.24(b) shows the various standard waveforms generated by the function generator.

10.5.1. Simple Working Principle of function generator

Figure 10.25 shows block diagram of function generator. A function generator contains the following circuits.

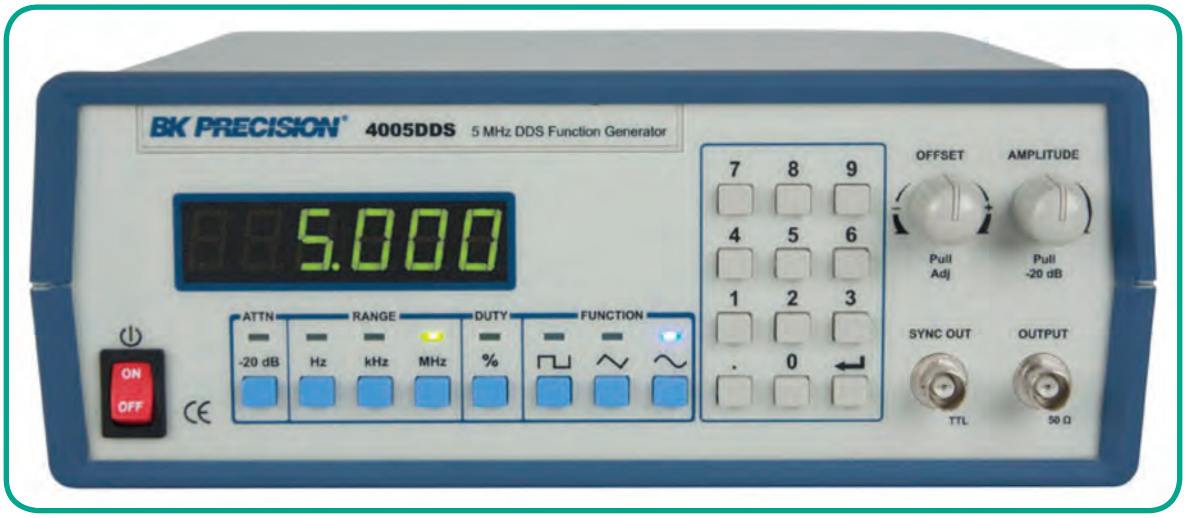


Figure 10.24(a) Front panel of a Function Generator

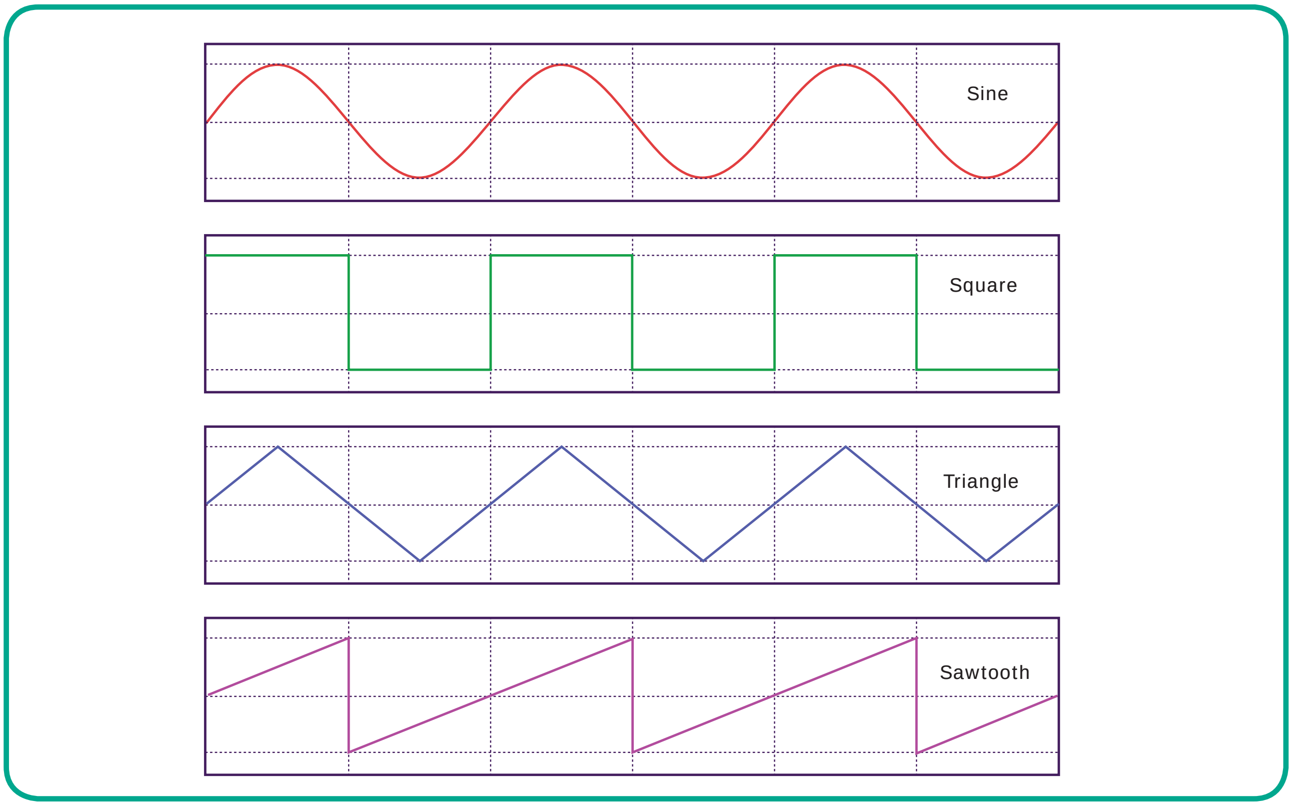


Figure 10.24(b) Waveforms produced by Function Generator

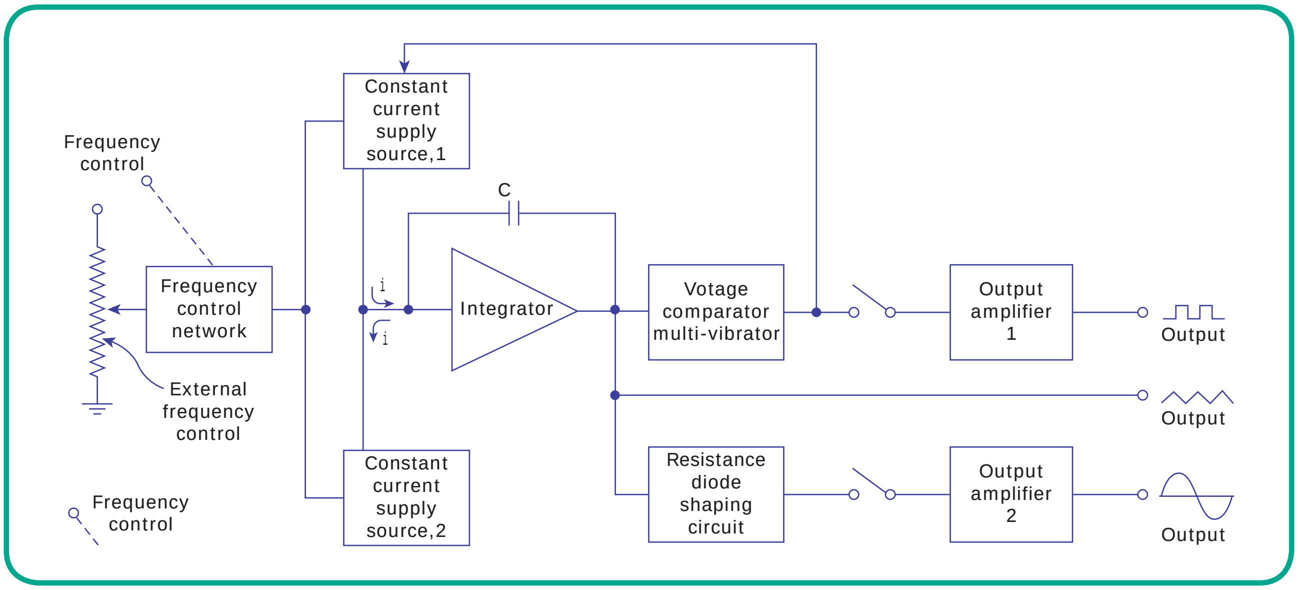


Figure 10.25 Block Diagram of Function Generator

1. Voltage comparator and multivibrator circuit.
2. Constant current source circuits.
3. Resistance and diode shaping circuit.
4. Frequency control network
5. Output amplifiers

Using these circuits, a function generator produces various signals and are listed below.

1. Sine Waves
2. Triangular Waves
3. Square Waves
4. Saw Tooth Waves

Uses

1. Used in electronic laboratories.
2. Used to test and align electronics equipment.
3. Used to rectify faults in Radio and television receivers.
4. It can produce signals having frequencies from 0.01 Hz to 100 MHz.

10.6. SPECTRUM ANALYSER

An instrument, which can analyse the parameters (frequency, phase etc.,) of a signal, is known as spectrum analyser.

Signals can be seen in the display of the spectrum analyser that can be analysed by the user. It works on the basis of super heterodyning principle. Figure 10.26 shows the front panel of a spectrum analyser.

10.6.1. Functions

A Spectrum Analyser can analyse

- Time domain signals
- Frequency domain signals and
- Modulation of signals

Time Domain Analysis

- Changes in time of a signal can be seen

Frequency Domain Analysis

- Each frequency component of a complex signal can be separated easily
- Low level distortion signals can be detected
- Spurious signal can be found out

Modulation of signals - Analysis

- Changes in frequency can be seen
- The modulation accuracy can be analysed but changes in amplitude cannot be seen

10.6.2 Applications

It is used for signal analysis in:

1. Mobile phone transmitters
2. Satellite communication
3. T.V transmitters and receivers
4. Cable TV broadcasting
5. Internet broadband transmission and reception

Figure 10.26 Front panel of a Spectrum Analyser

10.7. LOGIC PROBE

A logic probe is used to analyse and troubleshoot the logical states (0 or 1) of a digital circuit

Figure 10.27 shows a simple logic probe used to test the logical operations of basic gate circuits.

Figure 10.27 Logic probe

Red and green LEDs are used in this probe to indicate high (1) and low (0) states, respectively. Yellow LED is used to indicate narrow pulses. When the logic probe is connected to either an invalid logic level (that is a fault condition) or a tri-stated output or not connected at all, none of the LEDs will lit up. Some logic probes have a separate audible tone for each of the logical states. Logic probe can test a signal at a time. When many logic levels need to be tested at a time, a logical analyzer is used.

Uses

1. Logic probe is used to check individual gates of the TTL, DTL and CMOS ICS.
2. It is used to detect memory functions in digital equipment like computer.
3. It is also used to identify narrow pulses.

10.8. IC TESTER

Integrated circuit (shortly IC) Tester is an instrument which tests integrated chips.

IC testers are classified into three types.

1. Logic IC Tester
2. Memory IC Tester
3. Analog IC Tester

All types of ICs cannot be tested using these IC testers. Few types of ICs can be tested using these testers.

10.8.1 Testing a Logic IC Using Logic IC Tester

Figures 10.28 (a) and (b) show an AND gate and Hex INVERTER ICs being tested by an IC Tester.

(a) AND gate Using IC Tester

(b) HEX Inverter using Logic IC Tester

Figure 10.28 IC Tester

1. First we should insert the logic IC (to be tested) in the base and it should be locked properly.
2. Enter the IC number using the key-pad and press Enter key. The LED display shows the IC number being typed.
3. If IC is in good condition, the display will show "IC IS GOOD".
4. If IC is faulty, the display will show "IC is BAD".
5. To test another IC, we should 'RESET' the IC tester.

10.9. DIGITAL ENERGY METER

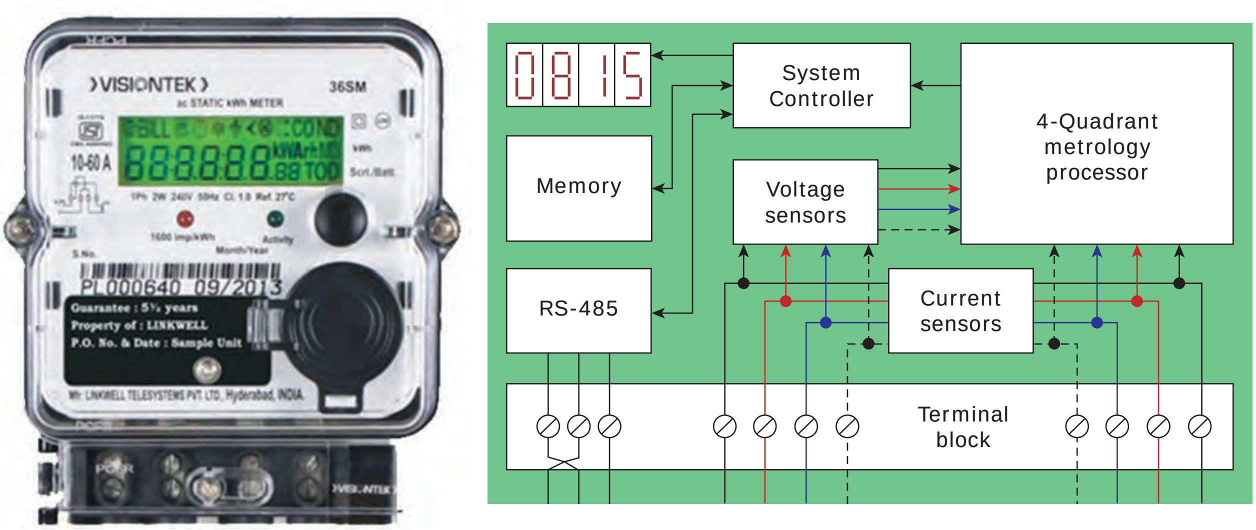
Electricity charge is one of the main expenses in every body's home budget. Every consumer has of the opinion that the consumed electrical energy value may be lesser than the caluculated value in the old tranditional meter. Presently , digital energy meters are widely used in homes and industries, which clears the doubt of the consumer by calculating minimum power consumption and also shows the readings in LCD display.

It is an instrument which measures electrical energy consumed in our homes and industries and shows the reading in digital form is called digital energy meter.

Digital energy meter displays the energy consumed by the user on the LCD display and transmits the readings to remote places via Wi-Fi. In addition to measuring consumed energy, these meters can also record other parameters of the load and supply such as instantaneous and maximum demands, voltage, power factor and three phase availability. They can also support to record the amount of energy used during on-peak and off-peak hours. The front panel of a digital energy meter is shown in Figure 10.29 (a).

ACTIVITY 10.1

Observe the Energy meter reading in your home daily in a notebook. Using this, you can calculate the daily usage of electricity consumption in your home.



(a) Front Panel of DEM
(b) Block Diagram of DEM

Figure 10.29 Digital Energy Meter (DEM)

Explanation of block diagram of digital energy meter

The digital meter has a power supply, metering circuit, a processing and communication circuits containing a microcontroller and real time clock circuit as shown in Figure 10.29 (b).

It has also current sensor and voltage sensor circuits to measure the current and voltage consumed by the users. Power is calculated by multiplying voltage and current. The time duration of consumption is multiplied with the voltage and current, in order to calculate the power consumption in kilowatt hour (kwh) and it is commercially called it as ' Unit'. It is periodically stored in memory circuit from time to time and added with the previously stored consumed values. We can see often, the latest number of units consumed, in the display.

LEARNING OUTCOMES

A student will understand the working principle of the following instruments after reading this Chapter.

1. **Multimeter (Analog & Digital)**
2. **Cathode Ray Oscilloscope (C.R.O.)**
3. **Signal Generator**
4. **Function Generator**
5. **Spectrum analyser**
6. **Logic probe**
7. **IC tester**
8. **Digital energy meter**

GLOSSARY

S. No	Terms	Explanation
1	**Function generator**	Signal generator that can produce sine, triangle and sawtooth output waveforms
2	**Ohm meter**	An instrument which is used for measuring ohms.
3	**Cathode Ray oscilloscope**	It is an electronic device in which various types of waveforms can be seen on the screen.
4	**Digital Meter**	An instrument that uses counting methods
5	**Calibration**	To adjust the correct value of a reading by comparison to a standard
6	**Continuity**	Occurs when a complete path for current exists
7	**Multimeter**	Electronic test equipment that can perform multiple tasks. Typical one is capable of measuring voltage, current and resistance.
8	**Spectrum analyser**	Instrument used to display the frequency domain of a waveform by plotting amplitude against frequency
9	**Energy meter**	Instrument used to measure electrical energy in units
10	**Voltmeter**	Instrument used to measure difference in potential between two points

QUESTIONS

PART A

I. Choose the best answer from the four options given to each question. Each question carries One Mark

T5M9FL

1. Sensitivity of a multimeter is determined by

   a) Ω b) k Ω/V c) Watt d) none of these

2. A multimeter cannot measure ....

   a) Voltage b) Current c) Ohm d) Watt

3. Another name of the multimeter is

   a) Voltmeter b) Ammeter c) Ohm meter d) AVO meter

4. In a multimeter, we should not measure voltage or current in

   a) Ohm's range b) Voltage range c) Current range d) any range

5. A CRO is used to measure

   a) Voltage b) Frequency c) Phase d) All of these

6. Multimeter was invented by

   a) Donald Macadie b) D'ARSONVAL c) Marconi d) Nikola tesla

7. Which LED is used to indicate High level (1) in a logic probe?

   a) White b) Red c) Yellow d) Green

8. Which type of multimeter is more accurate?

   a) Analog multimeter b) Micro Multimeter
   c) Digital Multimeter d) None of these

9. A spectrum analyser can analyse

   a) Ohm b) Frequency c) watt d) coulomb

10. The commercial name for kilowatt hour is

    a) Kilo b) Watt c) Hour d) Unit

PART B

II. Answer in a Few Sentences. Each Question Carries Three Marks

1. Name the three important electrical parameters measured by a multimeter.
2. Define sensitivity of an analog multimeter.
3. Explain briefly about calibrating an analog multimeter.
4. What are the three major circuits in a digital meter?
5. Name any three applications of a CRO

PART C

III. Explain in a Paragraph. Each Question Carries Five Marks

1. Write the uses of analog multimeter.
2. List out any five functions of a multimeter
3. Write any five applications of CRO.

PART D

IV. Explain in About a Page. Each Question Carries Ten Marks

1. What are the precautions to be taken while handling an Analog Multimeter?
2. Compare Digital and Analog multimeters
3. Explain front panel of analog multimeter with neat diagram
4. Draw a block diagram of a CRO and explain.

ANSWERS

1. **(b)**	2. **(d)**	3. **(d)**	4. **(a)**	5. **(d)**
6. **(a)**	7. **(b)**	8. **(c)**	9. **(b)**	10. **(d)**

CASE STUDY

P.ANAND,
Asst. Engineer,
MTPS (TNEB-TANGEDCO),
Mettur Dam-636401.

I am P.ANAND proud to say that I have studied +1,+2 opting Vocational Subject Electronics Equipment as the course in Government Higher Secondary School, Mettur Dam of Salem District, during 2002-03. This Vocational group helps me to do my engineering graduation, besides giving basic knowledge about general engineering and technology. I am ever in debt to this school and my teachers, particularly

From my point of view it will be more appreciable if these Vocational subjects are introduced even from High School level, which can help the students and also for the parents and teachers to identify their own talent and the field of interest.

Now I am working in Mettur Thermal Power Plant (TANGEDCO) as Assistant Engineer. I am immensely happy and thankful to present myself as case study for future Vocational students.

M.PRABHU,
Sr.Engineer,
MEGAWIN SWITCH GEARS
(P) LTD.,
SALEM

I am M.Prabhu., presently working in MEGAWIN SWITCH GEARS (P) LTD., SALEM, as a Senior Engineer, elated to share the following few words.

I did my +1, +2 opting Vocational Subject Electronics Equipment as the course in Government Higher Secondary School, Mettur Dam of Salem District, during 2001-02.

This course of study played vital role in my career development. I done my Diploma in Engineering with very good academic record. Because of having gained basic Electrical and Electronics Knowledge at School level, helps me to do many R&D (Research & Development) at my work place, where I succeeded in many. In turn its changed my life style.

Now I am having the confidence to guide others to gain knowledge in this Electronics field. I feel very proud and thankful for including me too in this case study.

M.PRABHU

G.T.Kannan
Old student Electronics group
Mannar Higher secondary school
Chief Executive Officer - Omega Groups
Sivagangai – 630561

My name is **G.T.Kannan**. I studied at Sivagangai Mannar Higher secondary school, established by Sivagangai Rajah Shri Bodhagurusamy (II) in 1856, in Vocational – Engineering and technology Group – Electronics as optional subject (1989 -1991). My subject teachers taught the **Electronics** theory and practical subjects well which made electronics as my passion. After the completion of **+2**, I engaged myself intensively on trouble shooting of Radio, television and other electronics equipments. After few years , I started a shop namely **Omega mobiles** in which we have been selling and servicing of mobile phones and got succeeded. With the help of my wife Mrs **K.Thilagavathi (Chairperson**,**Omega Groups**) now we are doing the following jobs successfully.

1. On contract basis, in Government and Private departments, we installed hundreds of Electric and Solar - High mast L.E.D. type lamp posts and R.O. – water purifier plants at rural and urban areas.
2. Besides Sales, installation and servicing of Un-Interruptible Power Supplies.
3. Solar cells based U.P.S. – production, maintenance and servicing.
4. Running " L.E.D. Televisions and Electronic equipments Sales and service show room".

Now, there are more than 40 technicians working with us. We are ready to offer training for my school students and Old students.

I am very proud to say in this case study that, "All my endeavor in this electronics field is just because of the course of the **vocational education on basic Electronics which I had from my school".**

Thanking you
G.T.Kannan
Sivagangai.

MODEL QUESTION PAPER

Time: 2 1/2 hours Total marks: 90

I. Choose the correct answer from the given four options. Answer all the questions.

15 X 1 =15

1. The unit of current is

   a) Volt b) Ampere c) Ohms d) None of these

2. If two resistors 1 kΩ and 1 kΩ are connected in parallel, the total resistance is

   a) 50Ω b) 100 Ω c) 500Ω d) 75 Ω

3. Which of the following is a transducer?

   a) Resistor b) Condenser c) Transformer d) Microphone

4. The formula for inductive reactance is

   a) $X_L = 2\pi fL$ b) $X_L = \frac{1}{2\pi fL}$ c) $X_L = 2\pi\sqrt{fL}$ d) $X_L = \frac{1}{2\pi LC}$

5. Which of the following element does not have five valence electrons?

   (a) Phosphorous (b) Arsenic (c) Antimony (d) Indium

6. Center tapped transformer is used in a ………….. rectifier.

   a) Bridge type b) Half-wave c) Full-wave d) None

7. A transistor has …………PN junction

   a) One b) Two c) Three d) Four

8. The emitter of a transistor is ………….. doped

   a) Lightly b) Heavily c) Moderately d)None of these

9. The control element of an SCR is …………..

   a) Cathode b) Anode c) Anode supply d) Gate

10. An IGBT is also known as

    a) MOIGT b) COMFET c) GEMFET d) All of these

11. An oscillator produces ……… oscillations

    a) Damped b) Un-damped c) Modulated d) None of these

12. The number of levels in digital signal is

    a) One b) Two c) Eight d)Ten

13. How many digits in octal system

    a) 10 b)2 c)8 d)16

14. Write the Odd one from the following.

    a) Monitor (b) Printer (c) Mouse (d) Plotter

15. A multimeter cannot measure ………

    a) Voltage b) Current c) Ohm d) Watt

II. Answer any 10 questions (including Question No.17 compulsory) in few sentences.

10 X 3 =30

16. Define Ohm's law.
17. If 100 Ohms and 150 Ohms are connected in parallel in a circuit, calculate the total resistance of the circuit.
18. What is a transformer?
19. What is atomic weight?
20. What is called half-wave rectifier?
21. Write short notes on SMD transistor.
22. How will you display number 3 in seven segment display?
23. What is meant by piezo electric effect?
24. What are the three basic logic gates?
25. Why digital system is reliable?
26. Define the working of ROM & RAM.
27. Define computer.
28. Write the uses of Logic Probe.

III. Explain any 5 questions (including Question No.31 compulsory) in a Paragraph

5 X 5 =25

29. Draw and explain about electrolytic capacitors.
30. Explain Dynamic microphone with neat diagram.
31. Draw the circuit diagram of bridge rectifier and explain its working function
32. Explain the working principles of NPN transistor
33. Explain Binary number system.
34. Write short notes on (i) Keyboard (ii) Plotter (iii) Hard disk (iv) Pen Drive
35. List out any five functions of a multimeter

IV. Explain in about a page. 2 X 10 = 20

36. (a) In a series circuit, two resistors 150 Ω and 100 Ω are connected with 125 V supply. Prove that the sum of the voltage drops across the resistors is equal to the EMF applied in the circuit.

    (OR)

    (b) Explain the working principle of RC phase shift oscillator with circuit diagram.

37. (a) Explain the construction and working of an IGBT

    (OR)

    (b) Explain the working of CPU with neat diagram.

REFERENCES

1. S. M. Sze, 1988, VLSI Fabrication Technology, McGraw Hill.
2. S. K. Gandhi, 1983, Si/GaAs Devices Fabrication Technology, John Wiley Ltd.
3. S. M. Sze, "Physics of semiconductor devices" 2nd edition (John Wiley& Sons, New York, 1981)
4. P.Y. Yu & M. Cardona, "Fundamentals of Semiconductors, Physics and Materials Properties" 2nd edition (Springer, Berlin, 1999)
5. Ruska, 1988, Devices Fabrication Technology, McGraw Hill.
6. D. K. Schroder, 1990, Semiconductor Material and Device Characterization, Wiley, NY.
7. M.S. Tyagi, Introduction to Semiconductor Devices, Wiley.
8. Deboo and Burrous, 1987, Integrated Electronics and Semiconductor Devices, Theory and Applications, McGraw-Hill International Ed.
9. Malvino and Leach, Digital Principles and Applications, 4th Ed., McGraw-Hill.
10. Millman and Halkias, 1972, Integrated Electronics, McGraw-Hill.
11. M. M. Mano, 1995, Digital Design, Prentice-Hall of India, New Delhi.
12. A.S. Bouwens, 2000, Digital Instrumentation, TMH.
13. T. L. Floyd, 1993, Digital Fundamentals, *5h Ed., Macmillan.*
14. Taub and Shilling, Digital Electronics.
15. Ahmed, Power Electronics for Technology, Pearson Education, PHI, NJ, 1999.
16. G.K. Dubey, S.R. Doradla, A. Joshi, and R.M.K. Sinha, Thyristorised Power Controllers, New Age International, New Delhi, 1986.
17. P.C. Sen, Power Electronics, Tata McGraw-Hill, New Delhi, 1987.
18. M. Ramamoorthy, An Introduction to Thyristors and Their Applications, 2nd Ed., Affiliated East West, New Delhi, 1991.
19. M.D. Singh and K.B. Khanchandani, Power Electronics, TMH, New Delhi, 1998.
20. P.S. Bimbhra, Power Electronics, 3rd, Ed., Khanna, New Delhi, 1999.
21. R.K. Sugandhi and K.K. Sugandhi, Thyristors – Theory and Applications, 2nd Ed., Wiley Eastern, New Delhi, 1981.
22. N. Mohan, T.M. Undeland, and W.P. Robbins, Power Electronics – Converters, Applications, and Design, 2nd Ed., Wiley, NY 2001.
23. B.W. Williams, Power Electronics –Devices, Drivers, Application, and Passive Components, 2nd Ed., Macmillan, London, 1992.
24. J.N. Ross, The Essence of Power Electronics, Prentice-Hall, London, 1997.
25. S.B. Dewan and A. Stranghen, Power Semiconductor Circuits, Wiley, NY, 1975.
26. M.H. Rashid, Power Electronics – Circuits, Devices, and Application, 2nd Ed., Prentice-Hall of India, New Delhi, 1999.
27. S. Rama Reddy, Fundamentals of Power Electronics, Narosa, New Delhi, 2000.
28. Ghosh T. K., "Computer Organization and Architecture", Tata McGraw-Hill, Third Edition, 2011.
29. William Stallings, "Computer Organization and Architecture – Designing for Performance", Pearson Education, Seventh Edition, 2006.
30. Behrooz Parahami, "Computer Architecture", Oxford University Press, Eighth Impression, 2011.
31. David A. Patterson and John L. Hennessy, "Computer Architecture-A Quantitative Approach", Elsevier, a division of reed India Private Limited, Fifth edition, 2012.
32. John P. Hayes, "Computer Architecture and Organization", Tata McGraw Hill, Third Edition, 1998.
33. Carl Hamacher, ZvonkoVranesic, SafwatZaky, "Computer Organization", McGraw-Hill, Fifth Edition, Reprint 2012.
34. C. S. Rangan, G. R. Sarma and V. S. V. Mani, 1999, Instrumentation Devices and Systems, Tata McGraw-Hill, New Delhi.
35. A. D. Helfrick and W. D. Copper, 1992, Modern Electronic Instrumentation and measurement Techniques, Prentice-Hall of India, New Delhi.
36. A. K. Sawhney, A Course in Electrical and Electronic Measurement and Instrumentation, DhanpatRai& Sons.
37. E. O. Doebelin, 1983, Measurement Systems Application and Design, International Edition, 3rd Ed., McGraw-Hill, NY.
38. D. V. S. Moorthy, 1995, Transducer and Instrumentation, Prentice-Hall of India, NewDelhi.
39. J. W. Dalley, W. F. Riley and K. G. McConnel, 1993, Instrumentation for Measurements, Wiley, NY.
40. B. C. Nakre and K. K. Chaudry, Instrumentation Measurements and Analysis, Tata McGraw-Hill, New Delhi.
41. D. A. Skoog, Principles of Instrumental Analysis, 3rd Ed., Saunders College Publishing.

Basic Electronics Engineering

PRACTICAL

CONTENTS

1 SOLDERING AND ITS TECHNIQUES

Aim:

To study about different types of Soldering Iron, its parts, Soldering procedure and itsworkingfunction.

Apparatus / Components Required :

S.No	Name of the apparatus / Components	Range / Value	Quantity
1.	Soldering Iron	25 watts	1No
2.	Soldering lead	-	Required quantity
3.	Soldering paste (flux)	-	Required quantity

Constructional details of Soldering Iron (25 W):

Fig 1.1 Soldering Iron (25W)

The soldering Iron has five main parts.

1. Handle
2. Element (or) filament
3. Body
4. Soldering bit
5. Mains cord

1. Handle

This is usually made of PVC materials.

2. Element (or) filament

This is the important part of a Soldering Iron (Converts electrical energy into heat energy).

3. Body

It connects the filament and soldering bit.

4. Soldering bit:

The bits are made up of copper, because it is good conductor of heat. It is used to make and break the joints. There are three types of bits generally available. They are,

i. Pencil bit

ii. Oval bit

iii. Bent bit

The selection of the bit depends upon the place and heat requirement.

5. Mains cord

This wire can be used to supply the input voltage (230V AC) to the Soldering Iron.

12 volts DC soldering Iron

It is used for soldering in Mobile PCBs and LED TV mother boards.

Fig 1.2 Soldering iron (12V DC)

Activity 1 :

Construct some models using hookup wires, flexible wires in soldering methods

Activity 2 :

Soldering practice using leg strips, Group boards and General purpose board in soldering methods

Soldering Station

Figure 1.3 Soldering Station

A soldering station, is an invariably temperature-controlled device. It consists of an electrical power supply, control circuitry with provision for user adjustment of temperature and display. The soldering iron or soldering head is also attached with a tip temperature sensor. The station will normally have a stand for the hot iron when not in use, and a wet sponge for cleaning. It is most commonly used for soldering and desoldering electronic components.

Desoldering pump

A *desoldering pump*, colloquially known as a *solder sucker*, is a manually-operated device which is used to remove solder from a printed circuit board. Suction pumps are used to suck away molten solder, leaving previously joined terminals disconnected. They are primarily used to release through-hole connections from a PCB.

Figure 1.4 Desoldering Pump

Activity 3 :

Remove and Resolder some components in given old printed circuit board using soldering iron and desoldering pump

Figure 1.5 Soldering Iron with Desoldering Pump

Desolder wick (copper shield wire)

Desoldering braid, also known as desoldering wick or solder wick, is finely braided as 18 to 42 SWG(Standard Wire Gauge) copper wire coated with resin flux, usually supplied on a roll.

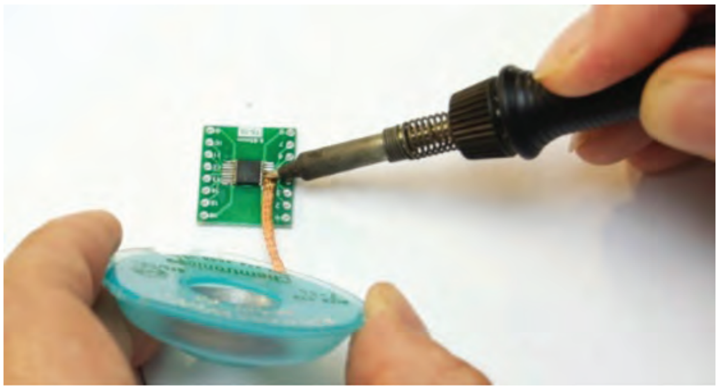


Figure 1.6 Wick

The end of a length of braid is placed over the soldered connections of a component being removed. The connections are heated with a soldering iron until the solder melts and is wicked into the braid by capillary action. The braid is removed while the solder is still molten, its used section cut off and discarded when cool. Short lengths of cut braid will prevent heat being carried away by the braid instead of heating the joint.

Soldering paste (flux):

During soldering, the Soldering paste or flux is used for the following reason.

1. Prevention of oxidation of molten solder.
2. Protect the heated surface against oxidation and the part which is to be soldered.
3. It helps in the flow of molten solder.

Soldering wire:

This is made up of an alloy of lead and Tin which is available in the form of wire in size of 16 to 18 SWG. The percentage of tin and lead is 60% and 40% respectively. Little amount of Paste is inserted internally in the solder wire. Solder wire without paste inside, is also available.

Safety Precautions

1. Plug in the Soldering iron into the relevant plug point and wait for few minutes to heat up.
2. Keep the Soldering iron always in its stand while not in use.
3. Keep a small piece of wet sponge. This is used to clean the tip of the iron and also helps you to do first aid in case of heat wound happens on the finger.
4. Touch the tip of the iron with soldering wire, see that it melts, to check the iron sufficiently heated.
5. Don't touch the tip of the soldering iron, as this heats upto 400˚C.
6. Bit of smoke will come out during soldering. Don't inhale the smoke.
7. Wash your hands after soldering work finished, because the soldering material contains some harmful materials.

Soldering procedure:

1. The melting point of the solder wire should be about 60º C.
2. The solder must be well melted with good flow, so that it can fill up the gaps between the joints.
3. A solder must have sufficient corrosion resistance, so that the joint may not be open due to corrosion.
4. The bit of the iron should always be kept neat and clean.
5. Due to the oxide formation the tip of the soldering iron becomes black and dirty. So the tip surface should be filed and cleaned before soldering is started.
6. The surface of the wire to be soldered should be clean.
7. A joint should be secured by removing the insulation on the wires and twisting them together before soldering.
8. The excessive paste and solder should not be used for joint because it may cause dry soldering.
9. When soldering in a congested place, care must be taken such that, the insulation of wires and other components are not burnt.
10. While soldering ICs, care should be taken that excessive heat does not pass through the leads and pins of IC should not get short.

Result:

The functions of soldering iron, different types of soldering iron, its working function are learnt.

2 APPLICATIONS OF MULTIMETER

Aim:

To study the functions, precautions and uses of analog and digital multimeter.

Apparatus required

S.No.	Apparatus required	Quantity
1	Analog multimeter	1
2	Digital multimeter	1

Working of Multimeter

Figure 2.1 Analog Multimeter

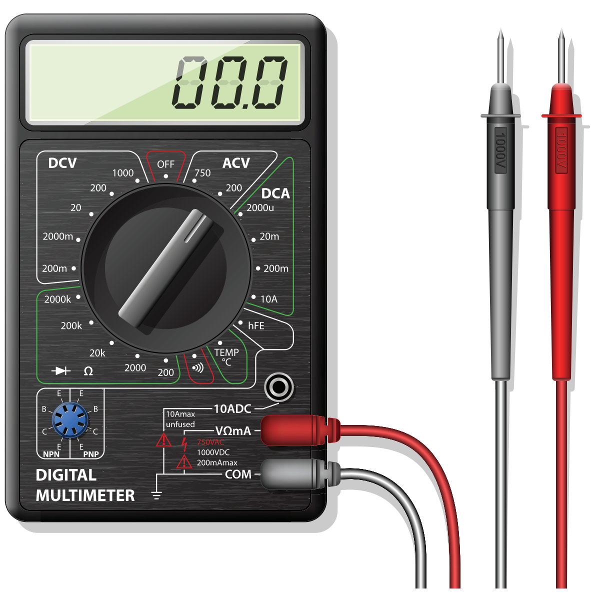


Figure 2.2 Digital Multimeter

A multimeter has one **positive probe (Red colour)** and a **negative probe (black colour)** to measure parameters as shown in Figure.

Functions of a Multimeter

It can measure the following electrical and electronic quantities.

1. DC Voltage
2. DC Current
3. AC Voltage
4. AC Current
5. Resistance
6. Continuity Test
7. Checking the Transistor (NPN or PNP)
8. Collector Emitter Leakage Current (I_{CEO}) of a transistor (when base kept unmeasured)
9. Capacitance up to 20 μF (available in few meters only)
10. Frequency up to 20 kHz (available in few meters only)
11. h_{FE} that is forward current gain (ratio of the Ic/Ib) (available in few meters only)

S.No	Checking Components	Range / Value	Key using in multimeter	Results
1	Resistor	1______M⊠ 2 ______K⊠ 3 _______⊠		
2	Capacitance Power	1______MFd 2________pf		
3	Transistor (hFE Test) NPN PNP	________ ________		
4	Transistor (Continuity / ⊠) NPN PNP	________ ________		
5	Diode	________		
6	DC Voltage	Battery / Eliminator		
7	DC Current	Battery / Eliminator		

8	AC Voltage	AC Supply		

Precautions:

1. When measuring DC voltage, care must be taken while connecting the two probes of the meter with the DC source. It should be connected with correct polarities in parallel connection with DC supply. That is, positive probe of the meter should be connected to positive terminal of the DC supply and negative probe to negative terminal of the DC supply.
2. When measuring DC current, multimeter should be connected in series with the DC supply and the load with correct polarities. That is, positive probe should be connected with positive terminal of the supply and negative probe to the load.
3. In the above two measurements, if we wrongly connect the probes, the meter needle will get reversed and subsequently the meter will get damaged.
4. While measuring AC voltages, it should be connected in parallel but polarity need not be considered.
5. While measuring AC current, as like the measurement of DC current, the meter should be connected in series with the supply and the load. Polarity need not be considered as like in measuring DC voltage.
6. We should not measure voltage or current in ohm's range. Otherwise, the meter will become faulty.
7. While measuring, the angle of vision towards the meter should be straight. Otherwise, parallax error will result in the measuring quantities.
8. We should not measure high voltage or current by keeping one probe at the supply and the other probe's metal point in contact with our hand, which will result in fatal electric shock.
9. We should presume the voltage and current to be measured at a point of circuit. If any doubt arises, Keep the meter in high range and then measure. If it is a low voltage, then we can select the lower ranges for measuring.
10. High voltage must not be measured using low voltage range. Otherwise the meter will become faulty.
11. Before measuring Ohms, both probes have to be short circuited and adjust pointer to 0 Ω, in order to get accurate values.
12. Select X 1 range to check continuity of a power cord or any wire.
13. In meters, DC is denoted by ⎓.
14. In digital multimeters, if we measure negative voltage or current, it shows reading with a negative sign. In analog meters, negative values should be measured by reversing the meter probes.

15. In digital multimeter, if we measure higher voltage or current value than the selected range, it shows '1' in the leftmost of the LCD display which means overload. But in ohm's range, '1' denotes ∞ Ω.
16. If it shows 1 in lower range, change the selector switch to the next higher range and measure. Even after the selector switch is opted in the highest range, the meter shows 1, it denotes the component becomes open.
17. For continuous better performance of mutimeter the batteries should be replaced often.

Uses of Multimeter

1. It is used in trouble shooting Radio, TV and all other electronics equipment.
2. It is also used to check electrical appliances.
3. It is used in assembling of electronics equipment.
4. It is used in installation of electronics equipment.
5. It is used to measure AC and DC voltage, current and resistance.

Result

Through this, I came to understand the functions, precautions and uses of analog and digital multi-meter.

3 MEASURING AC, DC VOLTAGES AND DC CURRENT

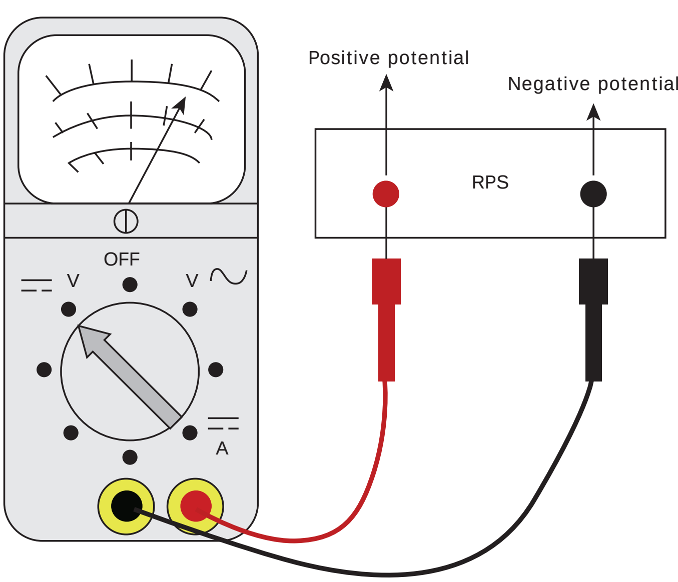
Aim:

To measure the AC, DC voltages and DC current by using multimeter.

Apparatus / Components required:

S.No	Name of the apparatus / components	Range / Value	Quantity
1.	Multimeter	---	1 No
2.	Regulated DC power supply or multi voltage range eliminator	0-30V/2Amps or 1.5 V to 12 V DC	1 No
3.	FM Radio or 6V or 12 V mini motor	---	1 No
4.	Transformer	0-12V 1Amp	1 No

Measurement of DC voltage



S. No	Selected Range	DC Voltage - Meter reading	
		Without Load	With Load
1			
2			
3			
4			
5			
6			
7			

Fig 3.1 **Measurement of DC voltage**

Measuring DC voltages:

1. Connect the Regulated Power Supply (RPS) with Multimeter as shown in Fig 3.1.
2. Vary the potentiometer in RPS to get three different voltage values.
3. Tabulate the voltage values.

Measuring DC current

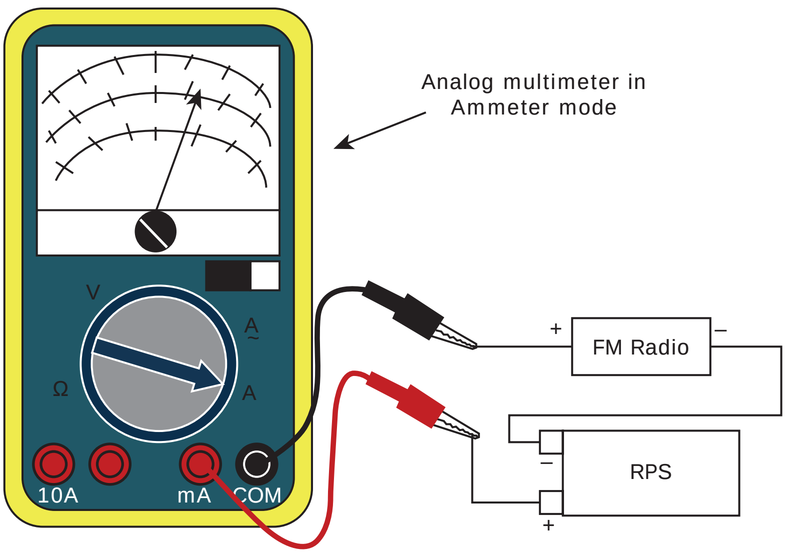


Fig 3.2 **Measuring DC current**

S. No	Selected Range	DC Voltage - Meter reading	
		Without Load	With Load
1			
2			
3			
4			
5			
6			
7			

1. Select 250 mA range in multimeter.
2. Connect the Regulated Power Supply (RPS) with Multimeter via an FM radio as shown in Fig 3.2.
3. Vary the DC supply voltage from 6 to 12 volts by varying potentiometer in RPS, to get three different current values.
4. Tabulate the DC current values.

Measuring AC voltage

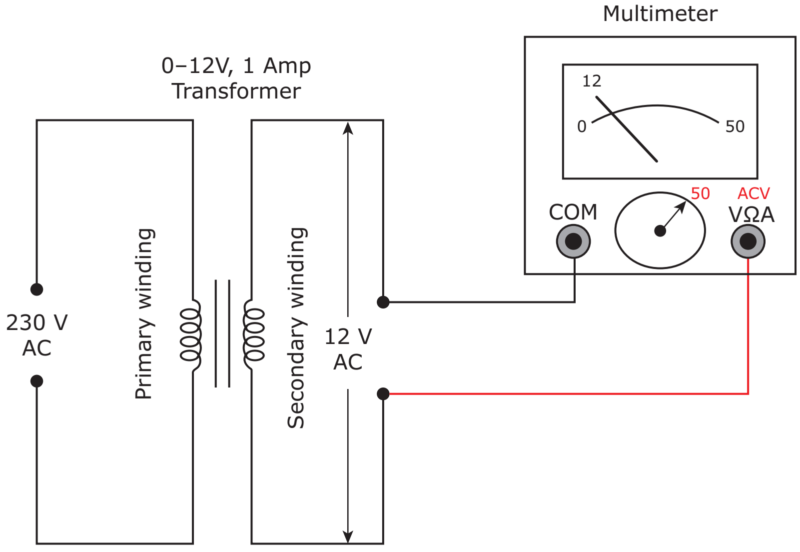


Fig 3.3 **Measuring AC voltage**

1. Connect the AC mains with primary coil of the transformer.
2. Connect the multimeter (in 0 – 50 AC voltage range) with transformer secondary coil as shown in fig 3.3
3. Switch 'ON' and measure the secondary AC voltage reading and tabulate the same.

S. No	Selected Range	DC Voltage - Meter reading	
		Without Load	With Load
1			
2			
3			
4			
5			
6			
7			

Result:

Thus the AC, DC voltages and DC currents are measured through multimeter.

FINDING RESISTANCE VALUES

COLOUR CODING AND MULTIMETER

4

Aim :

To find resistance values using Colour coding and compare the values with Multimeter measurements.

Apparatus Required

SI.No	Apparatus Required	Range/ Values	Quantity
1.	Resistors	½ watt	10 different values
2.	Multimeter	-	1

Diagram

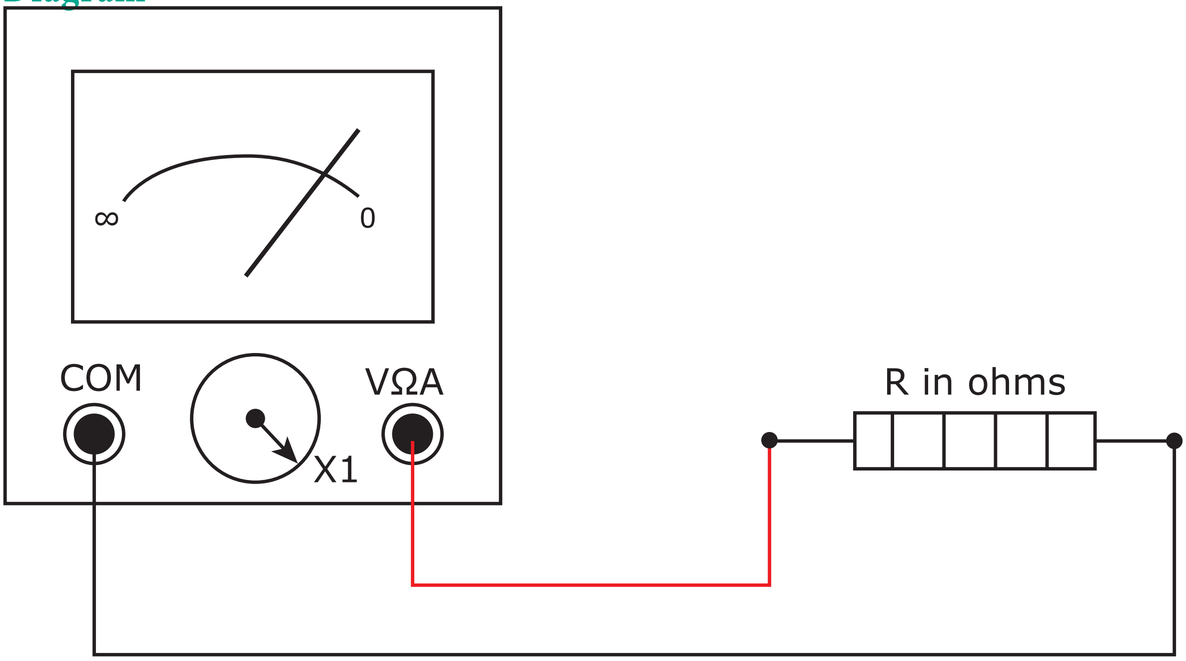


Fig 4.1 Testing of Resistor

Procedure

1. Find the values of given 10 resistors using colour coding and tabulate the same.
2. Select the required ohm's range in the multimeter whenever required. First, set 0 Ω adjustment.
3. Measure the value of resistors one by one using multimeter and tabulate the same.
4. If both values are nearly same, the resistor is said to be in working condition.
5. If meter shows , that is, the needle remain unmoved, the resistor is said to be open. This resistor should not be used in circuits.
6. If meter shows some ohmic value higher than the resistance value, the resistor is 'the high value resistance'. This resistor should not be used in circuits.

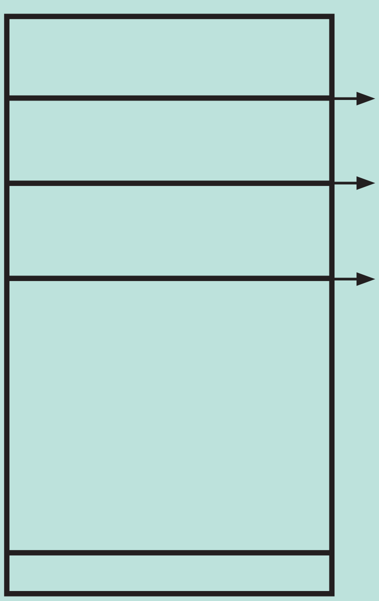
Model Tabular Column

Sl.No.	Colour coding	Value (using colour coding)	Selector switch position	Meter Reading	Result
Model 1	Brown Black Brown	100 Ω	X 1	98 Ω	Good
Model 2	Yellow Violet Gold	4.7 Ω	From X 1 to X 10 K Ω	∞ Ω	Open

Tabular Column

Sl.No.	Colour coding	Value (using colour coding)	Selector switch position	Meter Reading	Result
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

Activity: Calculate the values of any five resistors



	colour	prescribed value
I ring	________	________
II ring	________	________
III ring	________	________

Calculation

Total resistance ________

Result:

The comparison of the resistor values using colour coding and Multimeter testing is studied.

TESTING OF RESISTORS - SERIES AND PARALLEL

5

Aim:

To study the voltage and current level, when resistors are connected in series and parallel.

Apparatus / Components required

S.No	Name of the apparatus / Components	Range / value	Quantity
1.	Regulated power supply	0-30 V DC	1 No
2.	Voltmeter	0-30 V DC	3 No
3.	Ammeter	0-100 mA	4 No
4.	Resistors	Three different values	1 each

Resistors in series

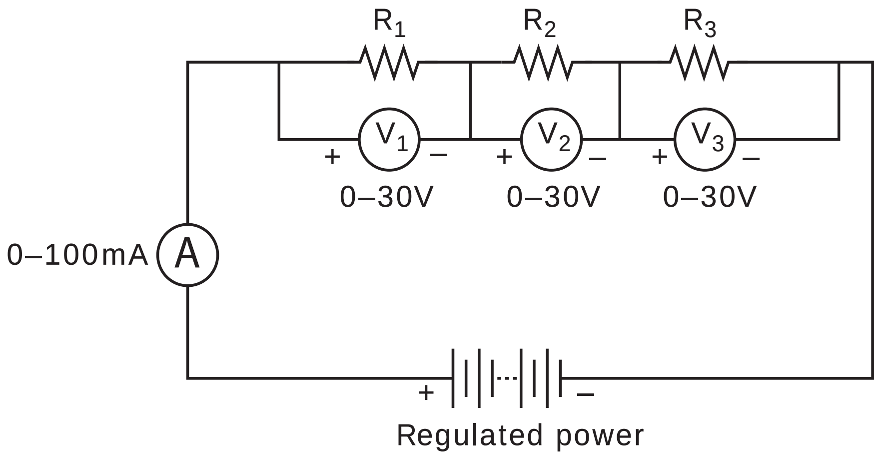


Fig 5,1 **Resistors in Series**

Given resistors	Value
R_1	
R_2	
R_3	
Total resistance	

Calculate the values

Procedure:

Resistors in series:

1. Connect the components as per the circuit diagram.
2. Switch ON the power supply.
3. Measure the voltage across each resistor (V_1,V_2,V_3).
4. Measure the total current (I).
5. Repeat the same procedure for different input DC voltages.
6. Tabulate the readings.

S.No	V_{in} (Volts)	V_1	V_2	V_3	I
1.	2				
2.	4				
3.	6				
4.	8				
5.	10				

Resistors in parallel

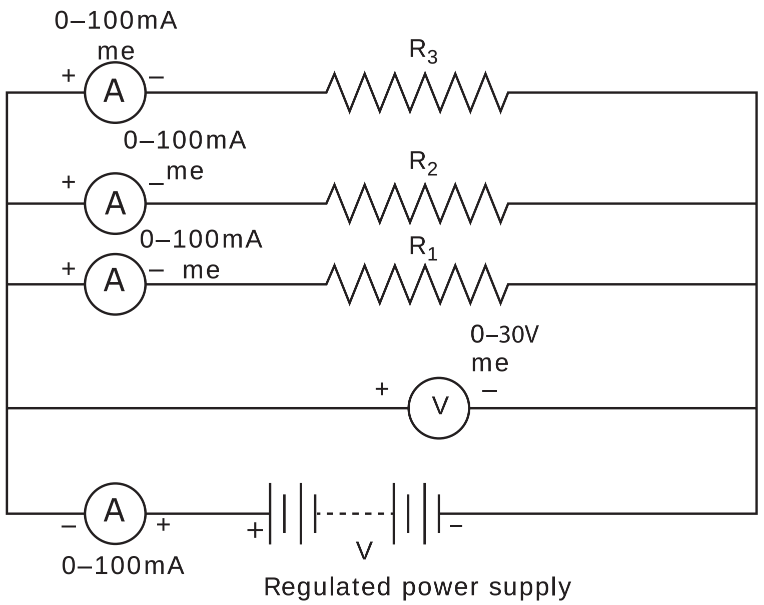


Fig 5.2 Resistors in Parallel

1. Connect the components as per the circuit diagram.
2. Switch ON the power supply and give fixed DC voltage to the circuit.
3. Measure the current flow through each resistor (I_1, I_2,I_3).
4. Measure the supply voltage (V).
5. Repeat the same procedure for different input DC voltages.
6. Tabulate the readings

S.No	V_{in} (Volts)	I_1	I_2	I_3	I
1.	2				
2.	4				
3.	6				
4.	8				
5.	10				

Result:

The different voltage and current values are measured when resistors are connected in series and parallel.

Activity :

Relationship between the voltage, current and resistance using a graph diagram.

TESTING OF CAPACITOR–INDUCTOR–TRANSFORMER-RELAY & SPEAKER

6

Aim:

To know the testing of capacitor, Inductor, Transformer, Relay and Speaker.

Apparatus Required

S.No.	Apparatus / Components required	Range/Value	Quantity
1	Capacitor	1000 µF/25 V	1
2	Inductor	----	1
3	Transformer	0 – 6 V/ 500 mA	1
4	Relay	12 volts	1
5	Speaker	-----	1

Testing of Capacitor

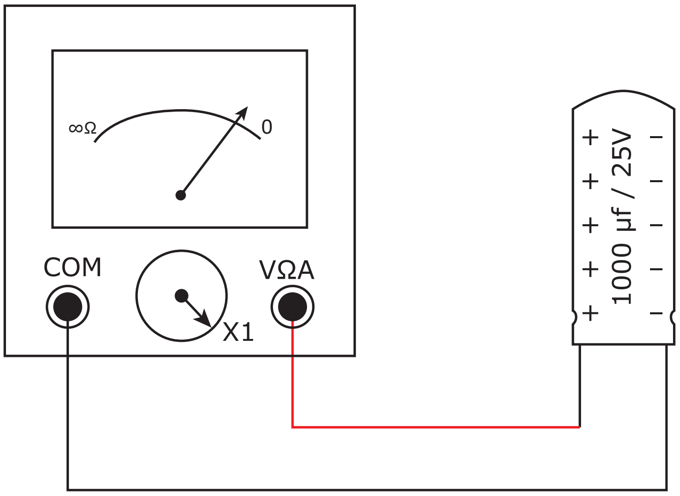


Fig 6.1 Testing of Capacitor

1. Select the multimeter selector switch in the X 1 ohm's range.
2. Connect the red probe with positive terminal of electrolytic capacitor and black probe to negative terminal. Observe the value of meter reading.

3. If the needle of the meter, suddenly move to the right end (ie. Charging of current) and slowly move to the left end, the capacitor is in working condition.
4. If meter reading shows 0 Ω, the capacitor is said to be short.
5. If meter reading shows ∞ Ω, the capacitor is said to be open.
6. If meter reading shows some ohms and the needle remains unmoved at that point, the capacitor is said to be leaky.

Testing of Inductor

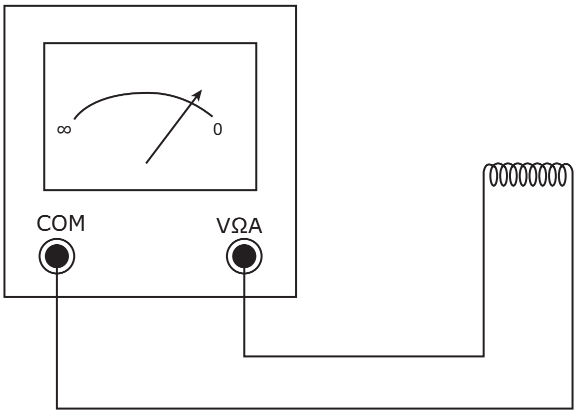


Fig 6.2 Testing of Inductor

1. Select the multimeter in X 1 ohm's range.
2. Connect both probes with both ends of the coil. Observe the value of meter reading.
3. If the needle of the meter shows nearly zero, the coil is said to be in good condition.
4. If the needle of the meter shows ∞ Ω, the coil is said to be open.

Testing of transformer

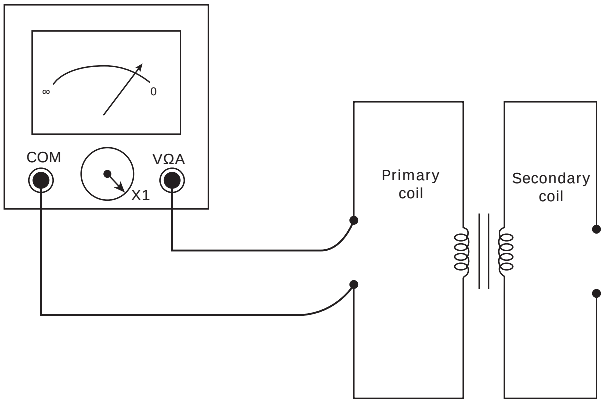


Fig 6.3 Testing of transformer

1. Select the multimeter in X 1 ohm's range.
2. Connect both probes with both ends of the primary coil. Observe the value of meter reading.
3. If the needle of the meter shows few hundred ohms, the primary coil is said to be in good condition.
4. If the needle of the meter shows ∞ Ω, the primary coil is said to be open.
5. Connect both probes with both ends of the secondary coil. Observe the value of meter reading.
6. If the needle of the meter shows few ohms, the secondary coil is said to be in good condition.
7. If the needle of the meter shows ∞ Ω, the secondary coil is said to be open.

Testing of Relay Contacts

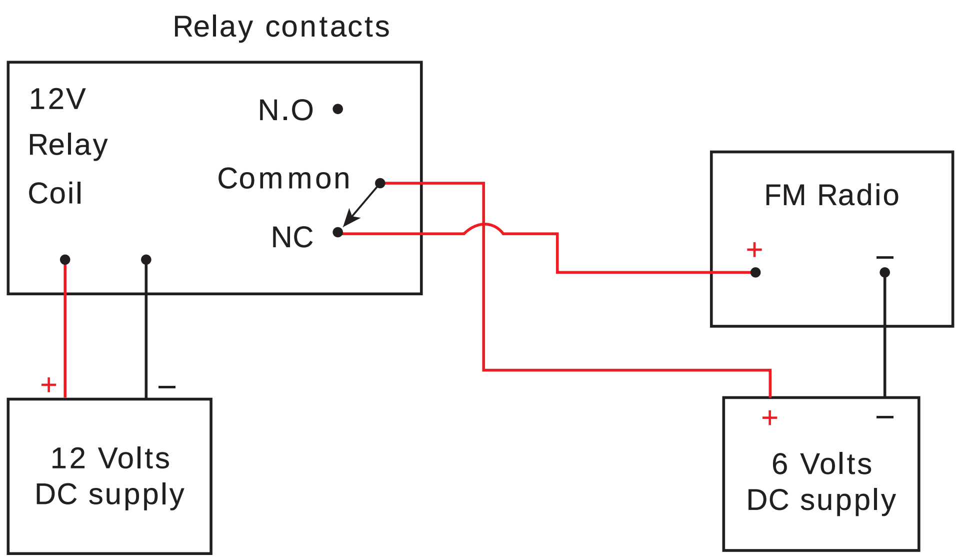


Fig 6.4 **Testing of Relay**

1. Connect the relay coil with 12 volts dc supply.
2. Connect the relay N.C. switch with +ve input of FM radio (Load).
3. While giving the 12V supply, the Relay coil gets magnetized. Coil attracts the small metal lever, which brings the relay contacts to ON position.
4. You can hear the click sound from relay. It denotes the N.C terminal gets on.
5. The FM radio will work, after the relay turns on the relay switch.

Testing of Speaker

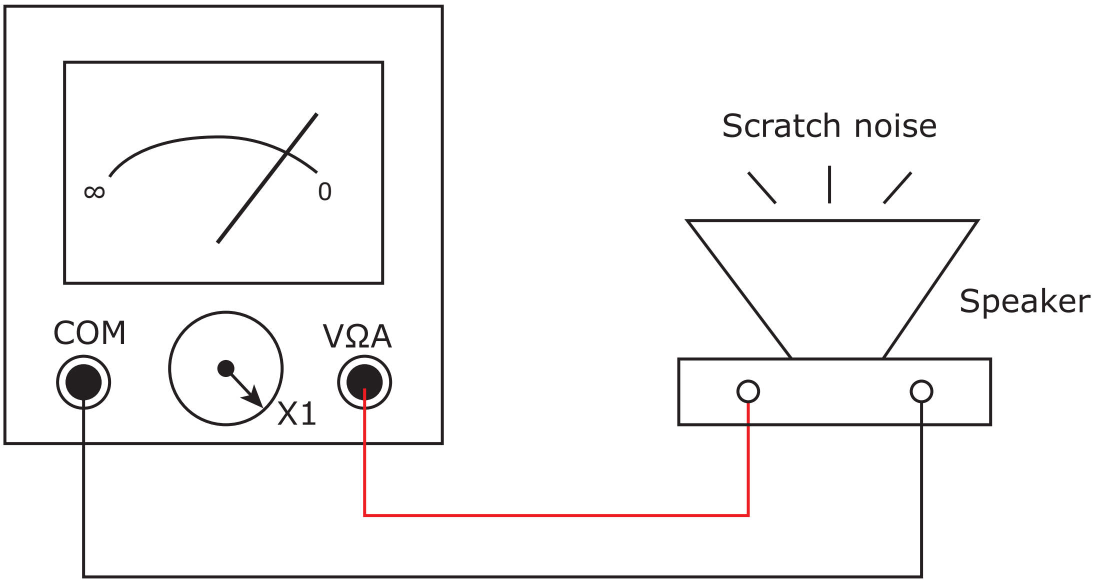


Fig 6.5 Testing of Speaker

1. Select X 1 ohm's range in multimeter.
2. Touch the speaker terminals with meter probes.
3. A scratch noise is heard from the speaker. It denotes that the speaker is in good condition.
4. It no scratch noise is heard from speaker, the speaker may be faulty (open).

S.No	Checking components	Value	Key using in multimeter	Result
1	Electrolyte capacitor	________MFd		
2	Choke	________		
3	Transformer primary secondary	 ________ ________		
4	Relay coil N/O N/C	 ________ ________		
5	Speaker	________		

Result:

The testing of capacitor, inductor, transformer, relay and speaker are studied.

7 TESTING OF DIODES AND TRANSISTORS

Aim

Testing of diodes and transistors using Analog Multimeter

Apparatus required

S.No	Name of the apparatus / Component	Range/Value	Quantity
1.	Multimeter (Analog)	--	1 No
2.	Diode	IN 4007	1 No
3.	Zener Diode	6V or 12 V	1 No
4.	Transistor	BC 548 (NPN)	1
5.	Transistor	BC 558 (PNP)	1

Circuit Diagram

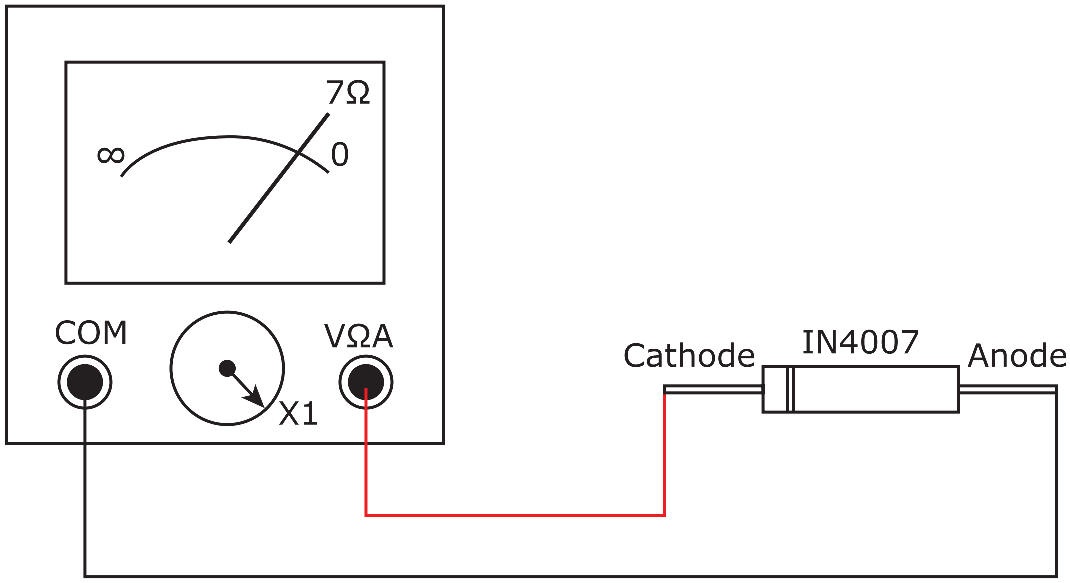


Fig 7.1 Diode testing

Procedure

Testing of a Semiconductor diode/ zener diode using Analog multimeter:

1. Select X1 Ohm's range and set 0 Ω adjustment.
2. Connect Anode with Black test probe and Cathode with Red test probe. If the meter reading is approximately 7 Ω, the diode is said to be in **good condition.** This is known as ***forward bias testing***.

   If the meter reading shows 0 Ω, diode is said to be ***short***.

   If the meter reading shows ∞ Ω , i.e., the needle does not move, diode is said to be ***Open.***

   If the meter reading shows some reading above 7 Ω , i.e., 100 Ω or 5k Ω, it means the diode has high ***'forward bias resistance'.***

> **Note**
>
> Diodes with the following conditions ***cannot be used*** in circuits.
>
> 1. Open (or)
> 2. Short circuit (or)
> 3. Forward bias resistance becomes high.

3. Connect Anode with Red test probe and Cathode with black test probe. If the meter reading is ∞ Ω, the diode is said to be in ***good*** condition. This is known as ***reverse bias testing***.

   If the meter reading shows 0 Ω, diode is said to be ***short***.

   If meter reading shows some reading that is 300 Ω or 6 k Ω, diode is said to be ***Leaky.***

> **Note**
>
> Leaky Diodes ***cannot be used*** in circuits.

Tabular column: (Draw separate tabular column and do test for each diode)

S.No.	Testing	Meter selector switch position	Anode	Cathode	Meter Reading	Result
1	Forward bias	X 1	- ve probe	+ ve probe		
2	Reverse bias	From X 1 to X 1 K	+ ve probe	- ve probe		
Final Result :						

Testing of transistors

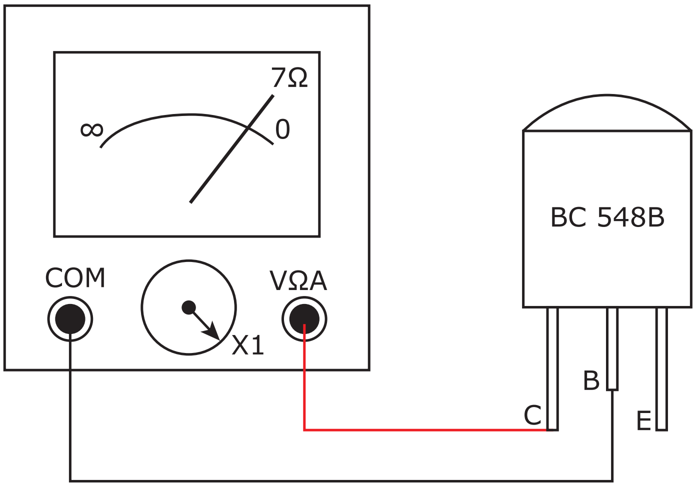


Fig 7.2 Transistor testing

Testing of transistor

Take an NPN transistor.

1. Select X1 in Ohm's range and set 0 Ω adjustment.
   Connect Base with black test probe and Emitter with Red test probe. If the meter reading is approximately 7 Ω, the transistor is said to be in ***good*** condition.

2. Connect Base with black test probe and collector with Red test probe. If the meter reading is approximately 7 Ω, the transistor is said to be in ***good*** condition.

   Now, select X 1K in Ohm's range and set 0 Ω adjustment.

3. Connect Base with Red test probe and collector with Black test probe. If the needle remains unmoved, that is, meter reading is ∞ Ω, the transistor is said to be in ***good*** condition.
4. Connect Base with Red test probe and Emitter with Black test probe. If the needle remains unmoved, that is, meter reading is ∞ Ω, the transistor is said to be in ***good*** condition.
5. Connect Collector with Red test probe and Emitter with Black test probe. If the needle remains unmoved, that is, meter reading is ∞ Ω, the transistor is said to be in ***good*** condition.
6. Connect Collector with Black test probe and Emitter with Red test probe. If the needle remains unmoved, i.e., meter reading is ∞ Ω, the transistor is said to be in ***good*** condition.

   In the above test 3 to 6 , if the meter reading is 0 Ω, the transistor is said to be ***short***.

   In the above test 3 to 6 , if the meter reading shows some ohms such as 100 Ω or 2 kΩ, the transistor is said to be ***leaky***.

   For a PNP transistor, change the polarities while testing.

Model Tabular column for an NPN Transistor using Analog Multimeter

S.No.	Selector switch position	Emitter	Base	Collector	Meter Reading	Result
1	X 1	+ve probe	-ve Probe	----	7 Ω	Good
2	X 1	----	-ve Probe	+ve probe	7 Ω	Good
3	X 1 K	-ve Probe	+ve probe	----	∞ Ω	Good
4	X 1 K	----	+ve probe	-ve Probe	∞ Ω	Good
5	X 1 K	-ve Probe	----	+ve probe	∞ Ω	Good
6	X 1 K	+ve probe	----	-ve Probe	∞ Ω	Good
Final Result: Good condition. This transistor can be used in circuits.						

Tabular column for transistor testing (NPN – BC 548)

S.No.	Selector switch position	Emitter	Base	Collector	Meter Reading	Result
1	X 1	+ve probe	-ve Probe	----		
2	X 1	----	-ve Probe	+ve probe		
3	X 1 K	-ve Probe	+ve probe	----		
4	X 1 K	----	+ve probe	-ve Probe		
5	X 1 K	-ve Probe	----	+ve probe		
6	X 1 K	+ve probe	----	-ve Probe		
Final Result:						

Tabular column for transistor testing (PNP – BC 558)

S.No.	Selector switch position	Emitter	Base	Collector	Meter Reading	Result
1	X 1	-ve Probe	+ve probe	----		
2	X 1	----	+ve probe	-ve Probe		
3	X 1 K	+ve probe	-ve Probe	----		
4	X 1 K	----	-ve Probe	+ve probe		
5	X 1 K	-ve Probe	----	+ve probe		
6	X 1 K	+ve probe	----	-ve Probe		
Final Result:						

Result:

The testing of semiconductor diode, zener diode, NPN and PNP transistors are studied.

CONSTRUCTION OF 6V DC POWER SUPPLY (BRIDGE RECTIFIER)

8

Aim:

To construct the 6V DC power supply (bridge rectifier) and measure the input AC main voltage and output DC voltage.

Apparatus / Components Required:

S. No	Name of the apparatus / Components	Range / Value	Quality
1.	Multimeter	-	1 No.
2.	Step down transformer	0 – 6V, 1A	1 No.
3.	Mains cord	-	1 No.
4.	Diode	IN 4007	4 Nos.
5.	Resistor	100Ω, 1W	1 No.
6.	Electrolytic capacitor	1000μ*F* / 25V	2 Nos

CIRCUIT DIAGRAM

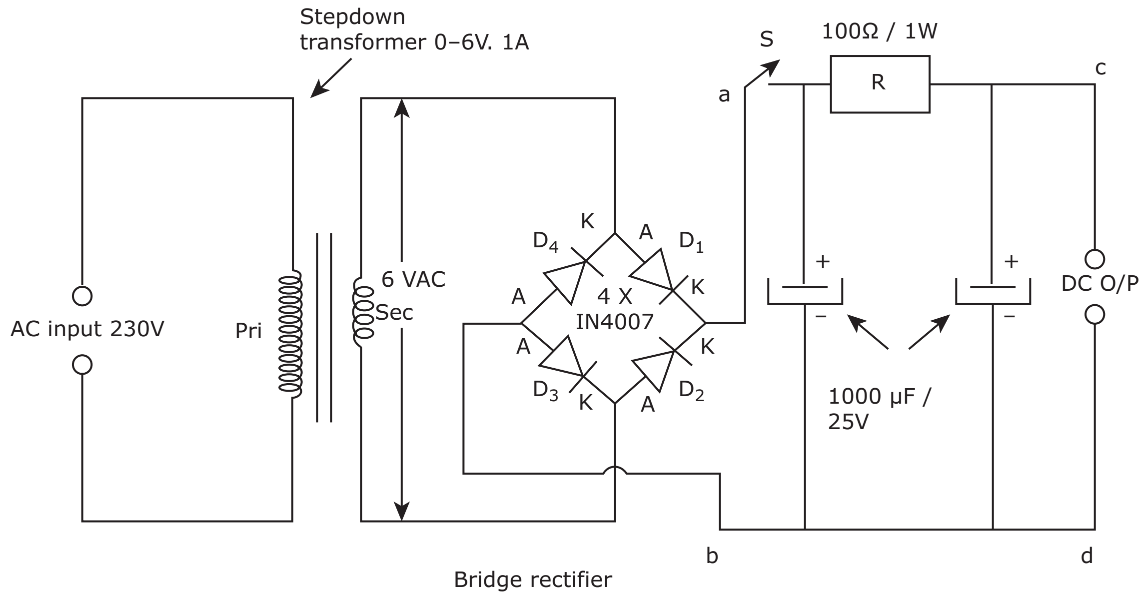


Fig 8.1 **Power supply Circuit**

Procedure:

1. Construct the circuit as per the circuit diagram.
2. Switch ON the power supply.
3. Measure the input AC secondary voltage and output DC voltage using multimeter.
4. Then switch off the power supply and disconnect the circuit.

S.No	Voltage	Meter Reading
1	AC Input voltage (Secondary)	
2	DC Output voltage (with out filter)	
3	DC Output voltage (with filter)	

Activity :

Assemble an eleminator using 1.5V to 12V tapped transformer and 4 diodes, measure the voltage

Voltage terminal	Output Voltage	
	Without load	With load

Result:

The Construction of Bridge rectifier is done and input/output voltages are measured.

9

VOLTAGE REGULATOR USING IC 7812

Aim:

To construct the IC based voltage regulator.

Apparatus / Component's required:

S.No	Name of apparatus / components	Range / value	Quantity
1.	Regulated power supply	0-30 V DC	1 No.
2.	Multimeter	-	2 No.
3.	IC 7812	-	1 No.
4.	Electrolytic capacitor	100 µF / 25V	1 No.
5.	Disc capacitor	0.1 µF	1 No.

CIRCUIT DIAGRAM

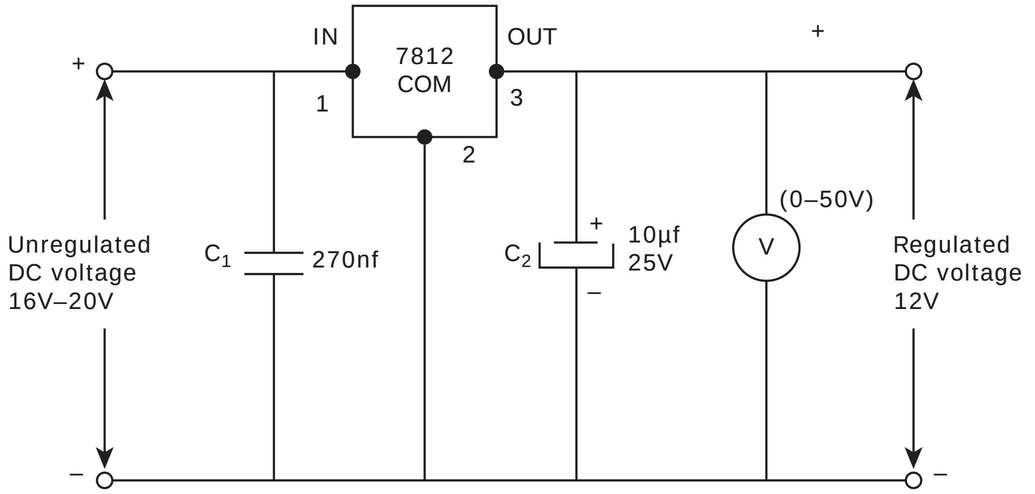


Fig 9.1 **IC-Voltage Regulator**

Procedure:

1. Connect the components as per the circuit diagram
2. Apply 16 to 20 volts unregulated dc voltage to the first pin (input) of IC to get 5 different readings.
3. Measure and tabulate the unregulated input voltage and regulated output voltage.
4. Switch OFF the supply and disconnect the circuit.

Tabular column

S.No	DC input voltage in volts	DC Output voltage in volts
1.		
2.		
3.		
4.		
5.		

Result:

Thus, the IC based voltage regulator is constructed and input, output voltages are tabulated.

CONSTRUCTION OF COMMON EMITTER (CE) AMPLIFIER CIRCUIT

10

Aim :

To Construct the Common Emitter (CE - NPN) amplifier circuit

Apparatus Required

S.No	Apparatus/components Required	Range/ Value	Quantity
1	Transistor	BC 548	1
2	Resistor	47 KΩ, 10KΩ, 820Ω, 180Ω	Each one
3	Regulated Power supply	0 – 30 V DC, 1 A	1
4	Bread board	----	1
5	Electrolytic capacitor	100 µF/16 V	1
6	Electrolytic capacitor	1 µF/16 V	2
7	Multimeter	----	1

Procedure

1. Connect the components in bread board as per the circuit diagram.
2. Give supply to the circuit.
3. Measure and tabulate the voltages of B + , Emitter , Base , Collector.

Circuit diagram

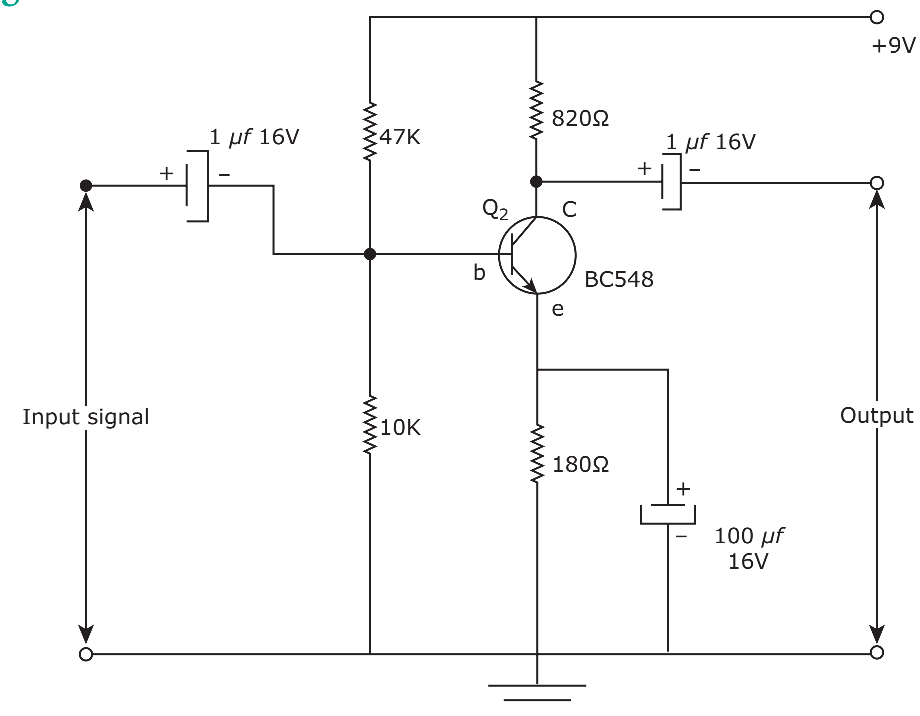


Fig 10.1 Common Emitter amplifier circuit – single stage

Tabular Column

Sl.No.	Terminals to be measured	Meter Reading
1	B +	
2	- ve to Emitter	
3	- ve to Base	
4	- ve to Collector	
5	Emitter to Base	
6	Emitter to collector	

Activity :

Connect a speaker and check its sound, find the waveform using oscilloscope.

Result:

The construction and measuring of Common Emitter (CE) amplifier circuit is studied.

V-I CHARACTERISTICS OF ZENER DIODE

11

Aim:

To study the V-I characteristics of zener diode and its break down voltage.

Apparatus / Components required:

S. No	Name of the apparatus / Components	Range / Value	Quantity
1.	Regulated power supply	0-30 V DC, 2A	1 No.
2.	Multimeter	-	2 No.
3.	Zener diode	6.3V	1 No.
4.	Resistor	1kΩ, ½ W	1 No.
5.	Bread board	-	1 No.
6.	Single strand wire	-	Required quantity

Circuit Diagram

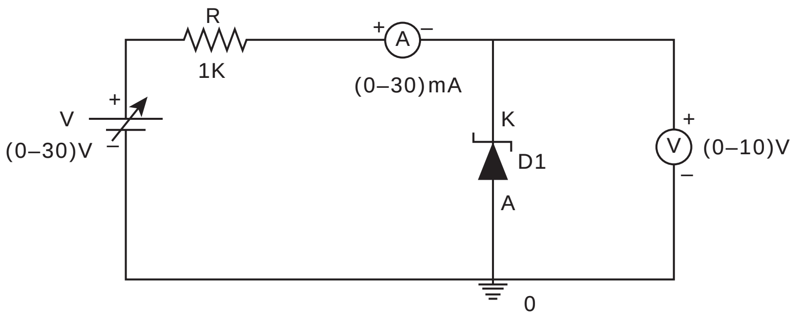
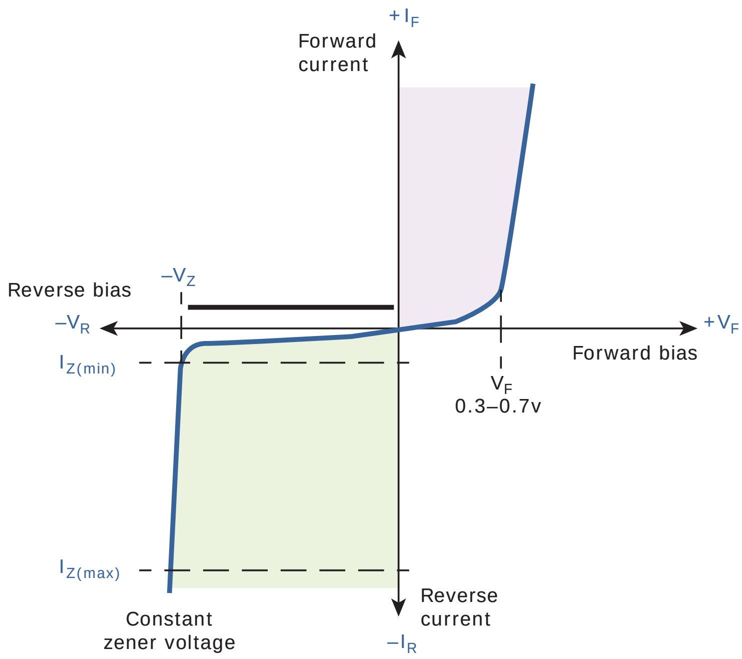


Fig 11.1 Regulator circuit

Procedure:

1. Connect the circuit as per the circuit diagram using the breadboard.
2. Vary the supply voltage in such a way that the readings are taken in steps of 0.5V.
3. Note down the corresponding ammeter readings (I_R).
4. Find out the reverse bias voltage (V_R).
5. Plot a graph between V_R & I_R.
6. Tabulate the values of V_R & I_R.



S.No	Voltage (V_R) in volts	Current (I_R) in mA
1	0.5	
2	1.0	
3	1.5	
4	2.0	
5	2.5	
6	3.0	
7	3.5	
8	4.0	
9	4.5	
10	5.0	
11	5.5	
12	6.0	
13	6.5	
14	7.0	

Activity :

Draw a graph using the tabulated voltages and ponit out the break down voltage.

Result

Thus the V-I characteristics of Zener diode is studied.

CONSTRUCTION OF BASIC LOGIC GATES

12

Aim:

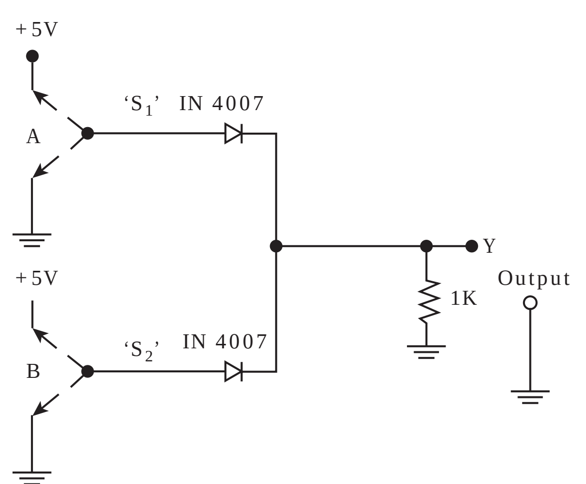
To Construct Logic Gates AND, OR, NOT by using Diodes, Transistor and Verify their Truth Table.

Apparatus / Components required:

S.No	Name of the apparatus / components	**Range / Value**	**Quantity**
1.	DC Regulated power supply	0-30V 1 A	3 No
2.	Diodes	IN 4007	4 No
3.	Transistor	BC 548	1 No
4.	LED	-	3 No
5.	Resistor	1K Ω,10K Ω, 200Ω	3 Nos
6.	Switches	SPDT	2 No
7.	Bread board	-	3 Nos
8.	Wire	Single strand	Required quantity

Circuit diagram

OR Gate



TRUTH TABLE

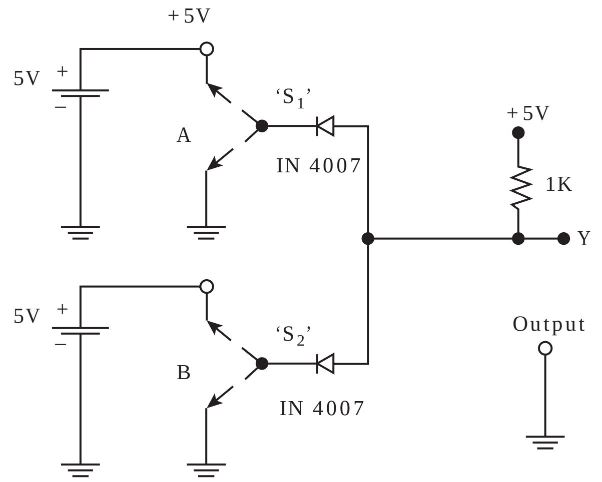
OR - Gate		
Input		Output
A	**B**	**Y=A+B**
0	0	0
0	1	1
1	0	1
1	1	1

Fig 12.1 **OR Gate**

Procedure:

1. Connect the components as per the OR, AND, NOT gate circuit in the bread board without loose contact .
2. Power supply voltage should not exceed 5V.
3. Verify the relevant truth table.

AND Gate

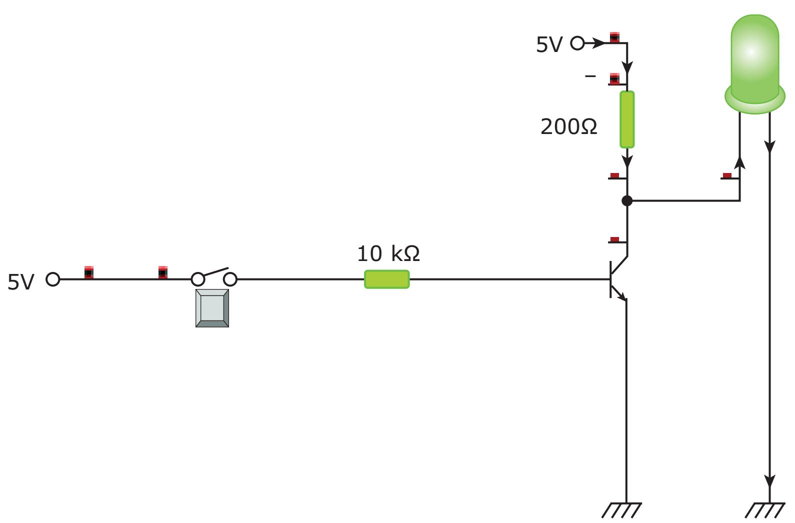


TRUTH TABLE

AND - Gate		
Input		Output
A	B	Y=A·B
0	0	0
0	1	0
1	0	0
1	1	1

Fig 12.2 **AND Gate**

NOT Gate



TRUTH TABLE

NOT - Gate	
Input A	Output $Y=\bar{A}$
0	1
1	0

Fig 12.3 **NOT Gate**

Activity :
Construct the above gates. check and compare with truth table.

Result:

Thus AND, OR, NOT gates are constructed and their truth tables verified.

Any one of the following ideas may be selected as Project to be done. (5 Marks)

1. 1. Blinking LED decorative lamps using Astable multivibrator (transistorised circuit).
2. 2. Logic Probe Tester.
3. 3. To display Numbers from 0 to 9 in a Seven segment display.
4. 4. To display any 5 Tamil letters in an LED matrix display.
5. 5. To display any 5 English letters in an LED matrix display.

OR

1. Any other project, the concerned vocational teacher is willing to do.

Higher Secondary – Class XI – Basic Electronics Engineering
List of Authors and Reviewers

Acadamic Advisor & Expert

Dr. P. Kumar,
Joint Director (Syllabus),
State Council of Educational Research and Training,
Chennai.

Chair Person

Dr. D. Nedumaran,
Professor & Head
Central Instrumentation & Service Laboratory,
University of Madras,
Guindy Campus, Chennai.

Reviewer

Dr. A. Vimala Juliet,
Professor & Head,
Department of Electronics and Instrumentation Engineering,
SRM Institute of Science & Technology,
Kattankulathur.

Authors

Mr. A. Idayaselvan,
Vocational Teacher,
Govt. Hr. Sec. School,
Mettur Dam, Salem District.

Mrs. S. Rama,
Vocational Teacher,
Govt. Boys Hr. Sec. School,
Vriddhachalam, Cuddalore Dist.

Mr. V. Ramana Sundaram,
Vocational Teacher,
General Cariappa Hr. Sec. School,
Saligramam, Chennai.

Mr. C. Vengatagiri,
Vocational Teacher,
Mannar Hr. Sec. School,
Sivagangai.

Mrs. G. Anbarasi,
Vocational Teacher,
Govt. Hr. Sec. School,
Mangalampet, Cuddlore District.

Academic Coordinators

A. Ilangovan,
Lecturer, DIET, Thirur,
Thiruvallur District.

K. Ravichandran,
P.G. Assistant,
Thanthai Periyar Govt. Hr. Sec. School, Puzhuthivakkam,
Kancheepuram District.

P. Malarvizhi,
B.T. Assistant,
PUMS, Padiyanallur,
Thiruvallur District.

Art and Design Team

Layout Designing and Illustration)

Kamatchi Balan Arumugam
Arockiam Felix, Chennai.

Wrapper Design

Kathir Arumugam

Quality Control

S. Gopu, Eye Think Creations, Chennai.

Coordination

Ramesh Munisamy

QR Code Management Team

R. Jaganathan
S.G. Asst., (SPOC)
PUMS Ganesapuram - Polur, Thiruvannamalai Dist.

N. Jagan
B.T. Asst.,
GBHSS Uthiramerur, Kanchipuram Dist.

J.F. Paul Edwin Roy
B.T. Asst.,
PUMS Rakkipatti, Salem Dist.

This book has been printed on 80 G.S.M.
Elegant Maplitho paper.

Printed by offset at: