

Basic Electronic Components & Hardware - I

TEM - 1



Centre for Electronics Design & Technology of India
A Scientific Society under Department of Electronics,
Govt. of India, New Delhi

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FOREWORD

The Information Technology and Telecom sectors have suddenly opened up avenues, which require a very large specially trained manpower. These sectors are highly dynamic and need training and re-training of manpower at a rapid rate. The growing gap of requirement of the industry and its fulfilment has created a challenging situation before manpower training institutes of the country. To meet this challenge most effectively, Centre for Electronics Design and Technology of India (CEDTI) has launched its nation-wide franchising scheme.

Centre for Electronics Design and Technology of India (CEDTI) is an Autonomous Scientific Society under the Govt. of India, Department of Electronics with its Headquarters at New Delhi. It operates seven centres located at Aurangabad, Calicut, Gorakhpur, Imphal, Mohali, Jammu and Tezpur. The scheme will be implemented and coordinated by these centres.

The scheme endeavours to promote high quality computer and information technology education in the country at an affordable cost while ensuring uniform standards in order to build a national resource of trained manpower. Low course fees will make this education available to people in relatively small, semi urban and rural areas. State-of-the-art training will be provided keeping in view the existing and emerging needs of the industrial and Govt. sectors. The examinations will be conducted by CEDTI and certificates will also be awarded by CEDTI. The scheme will be operated through all the seven centres of CEDTI.

The CEDTI functions under the overall control and guidance of the Governing Council with Secretary, Department of Electronics as its Chairman. The members of the council are drawn from scientific, government and industrial sectors. The Centres have separate executive committees headed by Director General, CEDTI. The members of these committees are from academic/professional institutes, state governments, industry and department of electronics.

CEDTI is a quality conscious organisation and has taken steps to formally get recognition of the quality and standards in various activities. CEDTI, Mohali was granted the prestigious ISO 9002 certificate in 1997. The other centres have taken steps to obtain the certification as early as possible. This quality consciousness will assist CEDTI in globalizing some of its activities. In keeping with its philosophy of 'Quality in every Activity', CEDTI will endeavour to impart state of the art – computer and IT training through its franchising scheme.

The thrust of the Software Courses is to train the students at various levels to carry out the Management Information System functions of a medium sized establishment, manufacture Software for domestic and export use, make multimedia presentations for management and effectively produce various manufacturing and architectural designs.

The thrust of the Hardware Courses at Technician and Telecommunication Equipment Maintenance Course levels is to train the students to diagnose the faults and carry out repairs at card level in computers, instruments, EPABX, Fax etc. and other office equipment. At Engineer and Network Engineer levels the thrust is to train them as System Engineers to install and supervise the Window NT, Netware and Unix Networking Systems and repair Microcontrollers / Microprocessor based electronic applications.

An Advisory Committee comprising eminent and expert personalities from the Information Technology field have been constituted to advise CEDTI on introduction of new courses and revising the syllabus of existing courses to meet the changing IT needs of the trade, industry and service sectors. The ultimate objective is to provide industry-specific quality education in modular form to supplement the formal education.

The study material has been prepared by the CEDTI, document centre. It is based on the vast and rich instructional experience of all the CEDTI centres. Any suggestions on the improvement of the study material will be most welcome.

(R. S. Khandpur)
Director General (CEDTI)

PREFACE

The primary objective of this book is to serve as a text in Basic Electronic Components and Hardware Courses (Specially for TEM Course) for Electronics students. Our approach is to stress the fundamental concepts of Basic Electronic Components. We hope to convey both the substance and flavor of the subject. The breadth and depth of treatment also makes this volume a valuable adjunct to continuing education of practicing technicians, engineers and computer engineers.

This book has substantial amount of new material that has been added to reflect changes in technology and curricula. This book helps where you need it, offering useful and practical suggestions. Each chapter is short in length, so that the student is not burdened by the amount of material presented.

The chapter one deals with conducting material. It covers Basic properties of materials. Chapters two, three, four, five focus on Basic Electronic Components e.g. Resistance, Fuse, Capacitor, Inductor and Transformer. Chapter Six consist of fundamental concepts of AC circuit, Kirchoff's Law and Stress is also given over measuring equipment such as digital voltmeter. Chapter Seven deals with Cells and Batteries. Chapter Eight deals with Relays and different switches and Chapter Nine deals with Oscillators. Chapter ten deals with active components such as Diode, Zener diode, UJT, FET, SCR etc. Chapters Eleven ,twelve and Thirteen deal with the Power Amplifiers, Linear ICs, Power Supply, Chapter fourteen and fifteen deals with Test & Measuring Equipment, Soldering & Desoldering Techniques and Tools & Aids.

The review questions are given at the end of each chapter. These questions will help the students to gain qualitative knowledge of the text material. The material of this book is collection of articles from various books mentioned in Bibliography.

CEDTI

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CHAPTER ONE

CONDUCTING MATERIALS

Features:

- 1.1 Introduction
- 1.2 Classification and Properties of Material
- 1.3 Quality and Reliability

1.1 INTRODUCTION :

The most important solid conducting materials used in the electrical and the electronics engineering are metal and their alloys. Among the metal conductors, one can distinguish high conductivity metals, of which resistivity at room temperature should not be more than 0.1 micro ohmmeter (μ ohm m) and high resistivity alloys with a resistivity at normal temperature should not be less than 0.3 (μ ohm/m). The first type is used for manufacturing wire, cables, connectors and coils of electrical machines and transformer. The second type of the metal is used for the manufacturing of the resistors, the electrical heaters etc. The choice of a good conductor material depends on the following factors.

- (i) The resistance of conducting material against corrosion
- (ii) Its oxidation characteristics.
- (iii) The strength durability and its cost.
- (iv) The temperature co-efficient of resistance.
- (v) The resistance to chemicals.

1.2 CLASSIFICATION AND PROPERTIES OF MATERIAL:

The common conducting material may be classified into two groups.

- (a) High conductivity materials.
- (b) High resistivity materials.

(a) High Conductivity Materials:

High Conductivity Materials should have low resistivity so that desired power can be sent through it without considerable loss in it. These materials are selected on following factors.

- (i) The resistivity of the material.
- (ii) The temperature coefficient of resistance.
- (iii) The resistance against corrosion.
- (iv) The oxidation characteristics.
- (v) Ease in soldering and welding.
- (vi) The capacity to be drawn, rolled (etc.)
- (vii) Mechanical strength.
- (viii) Flexibility and abundance.
- (ix) Durability and low cost.
- (x) Resistivity to chemicals and weather.

A conductor is a material, which has a large number of free electrons on its surface. These free electrons contribute to conduction process. High conductivity materials are also known as conductor material elements. Few examples of high conductivity materials are as follows:

- | | |
|-------------------------|-----------------------|
| (1) Copper Material | (2) Aluminum Material |
| (3) Silver Material | (4) Tungsten Material |
| (5) Molybdenum Material | (6) Platinum Material |
| (7) Tantalum Material | (8) Nickel Material |

(9) Carbon Conducting Material

(10) Lead Conducting Material

Before discussing the basic properties of these materials let us first discuss about the term Resistivity and Conductivity. The resistance of a conductor material depends upon the type of material; shape of material, size of the material and temperature of the material. The Resistivity ρ of the material is given by the following relation:

$$R = \rho L/A \quad \text{-- (1)}$$

Where R is the resistance of the conductor in Ohms. 'L' is the length of the conductor in meter and 'A' its cross-sectional area in m². If we select a conductor of unit length (L=1) and of unit cross-sectional area (A=1) then equation (1) becomes:

$$R = \rho \cdot 1/1 \text{ i.e. } R = \rho \quad \text{-- (2)}$$

Thus the resistivity ρ can be defined as the resistance of a material of which length is unity and which has a unit cross-sectional area. The resistivity is measured in ohmmeter.

The conductivity 'g' can be defined as the reciprocal of the resistivity. Its unit is mho that is,

$$\text{Conductivity (g)} = 1/\text{Resistivity } (\rho) \quad \text{-- (3)}$$

The resistivity is a function of temperature and the relation gives it.

$$\rho = \rho_0 (1 + \alpha (T - T_0)) \quad \text{-- (4)}$$

- Where T = Temperature of the material
- T₀ = Reference temperature
- ρ_0 = Resistivity at T₀
- α = Temperature coefficient of resistivity.

(1) Copper Materials (Cu):

The resistivity of Cu is $1.75 \times 10^{-2} \mu\Omega\text{m}$. Its temperature co-efficient of resistivity α is 0.004/°C. It is rather hard, extremely tough, durable and highly ductile. Wire can be drawn from copper; its rolled sheet and plates are also manufactured. It has high resistance against corrosion and has no oxidation. It can withstand damp air and high temperature. Its specific weight is 8.96 per cm³. Its melting point is 1083°C. Its boiling point is 2595°C. Following types of copper conductor material are used.

- (i) Hard copper (cold drawn) copper conductor.
- (ii) Annealed copper conductor material.
- (iii) Commutator copper material.
- (iv) Alloy copper conductor materials.
- (v) Ordinary copper material.
- (vi) Band copper conductor.

(2) Aluminum Conductor Materials (Al):

This metal is used extensively in different branches of engineering. Its melting point is 657°C, while its boiling point is 1800°C. It can be easily rolled, drawn forged. Its resistivity is $2.87 \times 10^{-2} \mu\Omega\text{m}$. Its temperature co-efficient of resistance $\alpha=0.004/^\circ\text{C}$.

Following types of aluminum conductor material are available for use.

- (i) Hard aluminum material
- (ii) Soft aluminum material
- (iii) Cast aluminum material
- (iv) Extra hard aluminum
- (v) Alloys of aluminum (Mn, Si, Fe)
- (vi) Pure aluminum.

(3) Silver Conductor Materials (Ag):

Silver is costlier than copper and aluminum. Though the silver has a greater conductivity than the copper, the cost of the silver restricts its application for electrical and electronic engineering devices. Its resistivity at room temperature is $1.629 \times 10^{-2} \mu\Omega\text{m}$. Its specific weight is 10.5 g/cm³. Its melting point is 961°C. Its temperature coefficient of resistance is 0.004/°C, same as that of copper. Rolled sheets and plates are manufactured from silver also. It is strong, rather hard, durable and highly ductile.

(4) Tungsten Material:

The tungsten is a very heavy grey metal. It has the highest melting point as compared to other metals. Its melting point is 3140°C and its boiling point 5900°C. Tungsten is one of the most important metallic materials used in electronic and vacuum engineering. This material can work up to 2000°C and higher in a good vacuum or in an inert gas atmosphere. Tungsten is obtained by very complicated chemical process. Its specific weight is 20 g/cm³ and its temperature co-efficient of expansion is $4.4 \times 10^{-9/10} \text{ m}/^\circ\text{C}$. Its resistivity is $5.5 \times 10^{-2} \mu\Omega\text{m}$. Temperature co-efficient of resistance is 0.005/°C.

(5) Molybdenum Material:

It is used as the target in x-ray tubes and structural members in high vacuum electron tubes because of its ability to form a tight seal with glass. It is used for high temperature applications in a refractory element. Its specific weight is 10.2 g/cm³. It boils at 3700°C while it melts at 2620°C. Its resistivity is 0.48 $\mu\Omega\text{m}$. Its temperature co-efficient of resistance is 0.047 per degree.

(6) Platinum Conducting Material:

Its specific weight is 21.4 g/cm³. Melting point is 1775°C and boiling point is 453°C. Its resistivity is 0.11 $\mu\Omega\text{m}$. Its temperature co-efficient of resistance is 0.00307/°C. This can be drawn in thin filament and used in different electrical devices.

(7) Tantalum Material (Ta):

It is used as refractory material in modern engineering. It is also used in manufacturing electrolytic condensers. It melts at 297°C. Its resistivity is 0.135 $\mu\Omega\text{m}$. Its specific weight is 16.6 g/cm³. Tantalum electrolytic capacitors are widely used in computers because of their small size.

(8) Niobium Material:

It is used as a refractory material in modern engineering. Its melting point is 1950 °C and its boiling point is 3300°C. It is also known as Columbium (cb). Its resistivity is 0.18 micro-ohm meter ($\mu\Omega\text{m}$)

(9) Carbon Conducting Material (C) :

Carbon conducting materials are used for:

- I. Brushes in electric Machine.
- II. Resistor of carbon.
- III. Rheostats of carbon.
- IV. Electrodes in arc ovens.
- V. Electrodes in lamps.
- VI. Electrodes in galvanic bath.
- VII. Component in electronic industries.
- VIII. Communication equipment.

(10) Lead Conductor Material (Pb):

Its melting point is 327°C. Its specific weight is 11.34 g/cm³. Its resistivity is 0.21 $\mu\Omega\text{m}$. It is used for cylindrical in cable engineering, which protects cables from moisture, dirt etc. Lead is a bluish-gray metal. It is also used as plates of storage batteries, safety fuses, etc. Sheet lead is widely used for radiation shielding because it strongly absorbs x-rays.

B) HIGH RESISTIVITY MATERIALS:

High resistivity Material alloys (materials) are used for:

- I. Resistors in electric heating device.
- II. Control apparatus.
- III. Load rheostats.
- IV. Reference resistors.

For above purposes, the resistivity of material should be high and independent of temperature. Temperature co-efficient of resistor should be low. The materials used for resistors in heating appliances are to withstand high temperature for a long time without melting or oxidising. High resistivity alloys such as Tungsten, Magnesium, Nichrome satisfy these requirements. Let us discuss their characteristics.

(1) Constantan or Eureka:

This material is an alloy of copper and nickel. The alloy is given the name constantan for its constant resistivity with varying temperature. At normal temperature, the resistivity of constantan is 0.48 to 0.52 $\mu\Omega\text{m}$. Its temperature co-efficient of resistance ranges from $-5 \times 10^{-6} \text{ }^\circ\text{C}$ to $-25 \times 10^{-6} \text{ }^\circ\text{C}$. The tensile strength ranges between 40 to 50 kg/mm^2 and elongation between 20 to 40%.

(2) Manganin:

This is most typical and widely used alloy for production of reference resistors and other such elements. It contains approximately 85% copper, 12% manganese and 3% nickel. It derives its name from manganese. The resistivity is 0.42 to 0.48 $\mu\Omega\text{m}$. Its temperature co-efficient of resistance is rather small, about $5 \text{ to } 3 \times 10^{-6} \text{ }^\circ\text{C}$. Manganin has a tensile strength of $45 \times 6 \text{ Kg/mm}^2$ and ultimate elongation 15 to 30%.

(3) Nichrome:

It is mainly used for electrical heating elements. Combination of Iron, nickel & manganese is known as nichrome. It contains 1.5% Mn, 75% Ni, 20% Cr. and 3.5% Fe or 1.5% Mn, 75% Ni, 23% Cr and 0.5% Fe. Its resistivity is 1.2 to 1.4 $\mu\Omega\text{m}$. Its temperature co-efficient of resistance is $10 \times 10^{-6} \text{ }^\circ\text{C}$ to $20 \times 10^{-6} \text{ }^\circ\text{C}$.

(4) Gold (Au):

A yellowish metal of a very high plasticity, with tensile strength is 15 kg.mm^2 and elongation at rupture of 40%. Its use in electrical engineering includes corrosion resistant oats, photocell electrodes; vacuum deposited thin film microcircuit etc. Its melting point is 1063°C and boiling point is 2950°C . Its resistivity is 0.024 $\mu\Omega\text{m}$.

1.3 QUALITY AND RELIABILITY

In the previous sections we have looked at some of the basic physical considerations that apply to electronic components and their performance. An equally important aspect of performance has to do with the retention of these properties with time.

Reliability is the measure of the performance of a device or equipment in the time domain. Obviously, since a device or equipment is made up of materials, its reliability has a lot to do with the properties of the materials that go into its making as well as the processes that go into its making.

In more concrete terms, we define reliability as the probability that a piece of equipment, device or service will perform its intended or stated function under given stipulated conditions, for a specified period of time. It is thus expressed as a probability, which obviously is a dimensionless fraction lying between 0 and 1. Often, for convenience, it is expressed as a percentage, in which case the number lies between 0 and 100. Thus, while the reliability is intimately linked to the expected life of the equipment under consideration, it does not directly predict its life expectancy. In other words, if the reliability of an object is 0.95 under given operating conditions for 1000 operating hours,

it means that, there is a 95% probability that the equipment will perform as per the specifications, under the stated conditions for 1000 operating hours.

Obviously, there is a close relation between the quality of equipment and its reliability. However, the two terms are not synonymous. Quality, as Juran points out, is “the fitness for use” of an object and is a ‘total’ concept. If one sits and lists out all the desirable properties, attributes and characteristics that a piece of equipment should have, then the degree to which it meets all such properties is a measure of its quality. It is obvious that in any such list, ‘reliability’ would figure prominently.

Quality is thus not an easily quantifiable quantity. The product is designed to fulfil certain specific needs of the user, and therefore does depend on the requirements and expectations of the user. How well the product meets these requirements and expectations, both at the present time and in future, is a measure of this quality.

Failure Rate and Screening Tests

Reliability is closely linked to failure – equipment of poor reliability is prone to failure and a low failure rate means high reliability. Another important term is maintainability. If an equipment is designed such that repairs on it can be speedily done, the ‘down time’ of the equipment can be substantially reduced, thus enhancing its quality.

Consider the case when a number of identical components are in simultaneous operation. We can define the failure rate of a component as the ratio of the number of components failing in unit time to the total number of components in operation. It is usually denoted by the Greek Symbol λ and has the units of $[1/(\text{time})]$. Another useful term is MTBF or the Mean Time Between Failures. It is a measure of the average or mean time taken for a component to fail. Consider again the simultaneous operation of a number of components. The MTBF is given by the ratio of the product of the total number of components under test and the time of test to the number of components failing in that time. It is easy to see that λ and MTBF are reciprocally related i.e. one is the inverse of the other.

The point at which the failure rate starts increasing rapidly is called the useful life period, normal life or life expectancy of the component. The normal failure rate is the failure rate during the normal life span is usually associated with the quality of design of the component, whereas the life expectancy is usually correlated with the quality of the materials used in the product. During this time, the failures are ‘random’ in nature and usually not associated with a particular defect mechanism.

In infancy, it is much more prone to diseases and predators, and therefore has a high rate of mortality. This is infant mortality; in fact, the nomenclature of reliability is largely derived from such anthropological terms. The same is true for equipment as well. It is seen that some of the equipment fails in a very short time. Such failure has little to do with the inherent design and choice of materials for the component; it is a result of errors during production usually due to human error during assembly.

The failure rate of an equipment, component or device is very high during the early stages of its life. These are usually related to production faults associated with human error and needs to be sorted out by appropriate testing before the product leaves the

factory premises. These are called screening tests. Without such testing, the image of the product will be very adversely affected and cause large maintenance and servicing problems.

Thus, screening is a set of tests performed on the 'fresh' components, which causes such defective pieces to fail. These are then removed from the lot; the reliability of the marketed components is thus improved substantially.

Consider that the infancy period for a particular device is 5 normal working hours and its useful life period is 1000 hours. It is important that the 'screen' is the screening tests eliminate all devices with incipient defects, which would cause early failures. However, testing all devices is tested for 5 hours at normal working conditions can be a very expensive and time-consuming proposition. To avoid this problem, we perform burn-in tests for screening.

In burn-in, the components or devices are first subjected to thermal stress according to a suitable model. This reduces the infancy period perhaps to 15 minutes. The devices are then tested. The entire process is thus substantially reduced in time.

While thermal stressing is one common method of accelerating the failure, it is not the only one. Other stresses can also be effective and are also used, often in combination. Other commonly used stresses are Electric field or 'voltage stresses, Temperature cycling, Vibration, Humidity, etc.

Review Questions

1. What are the uses of high resistivity material?
2. Explain - Variation of resistivity on different factors.
3. Explain the properties of high conductivity material.
4. What are the alloys of Aluminum?
5. Give Notes on -
 - a) Eureka
 - b) Niobium
 - c) Tungsten material

Note: *The objective of this chapter was to give awareness about materials. Therefore various values given above need not be remembered, as they are available in data sheets.*

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CHAPTER TWO

RESISTORS (RESISTANCE)

Features:

- 2.1 Introduction
- 2.2 Types of Resistor
- 2.3 Resistor colour coding
- 2.4 Thermistor

2.1 INTRODUCTION

In electronic circuits Copper, Aluminum materials are known as conductors, which are having negligible resistance. Other materials like paper, ceramic are known as insulators which are having very high resistance. Other materials like carbon with certain value of resistance are used to manufacture resistor. The value of resistance varies from very low to very high value, almost from the value of conductor to insulator. The value of resistance is measured in ohms (Ω). Resistance is the opposition to the flow of electrons or simply opposition to the electric current. Resistance is required in electronic circuits to limit the current, to drop the voltage and to divide the voltage. In combination with capacitor it is used as filter or it can be used to achieve the time constant and so on. Hence resistor is one of the important component you can observe, in any particular circuit. Usually there are more number of resistors than any other type of components used in circuit.

ELECTRONIC COMPONENTS

Active Component:

The device can be used for amplification, rectification or change of energy from one to another.

Example: Transistor, Diode.

For example LED converts electrical energy into light energy.

Passive Components:

The device can be used to complete a circuit with voltage and current sources and active components.

Example: Resistor, Capacitor, Inductor, and Transformer.

What are passive components?

These components are called passive because they by themselves are not capable of amplifying or processing an electrical signal. However these components are as important as active components (e.g. transistor). Without the aid of these components a transistor cannot be made to amplify signals.

Resistor:

It offers resistance to the flow of current. The two main characteristics of resistors are its Resistance (R) in ohm and Power rating (W) in watts. In electronic circuits, the resistors with higher 'R' values have lower wattage rating because they have less current.

2.2 TYPES OF RESISTORS

Carbon Resistors:

This type of resistor is made up of finely divided Carbon or graphite mixed on the powdered insulating material as a binder, in proportion to the desired 'R' value. The resistive element is enclosed in a plastic case for insulation and mechanical strength.

Carbon resistors are available in resistance values of 1Ω to $20\text{ M}\Omega$. Power rating generally available is $1/4, 1/2$ and 2 W .

FAILURE IN RESISTORS

Generally resistors are very reliable and have a very low failure rate. But failures occur due to passage of time, heat, applied voltage, humidity, and mechanical stress.

Carbon Composition Type Resistor

These types of resistors have poor stability and poor temperature coefficient. The possible failures and their causes are:

a) OPEN CIRCUIT

1. Burning of resistor center due to excess heat.
2. Fracturing of resistor due to mechanical stress.

a) HIGH VALUE

1. Heat, voltage or moisture can cause movement of carbon or binder.
2. Separation of carbon particles due to swelling caused by absorption of water.

Wire Wound Resistors:

In this a special type of wire called resistance wire is wrapped around an insulating core. The length of the wire and specific resistivity determines resistance of the unit. The types of resistance wire include Tungsten and Manganin. The insulated core is commonly porcelain or cement.

These are used for generally high current applications with low resistance and appreciable power. The resistance are available in wattage rating from 5 W to 100 W . The resistance can be less than 1 ohm and upto several thousand ohms.

Film type resistors:

There are two kinds of film type resistor. The carbon film type has thin coating around an insulator; the metal film resistor has spiral winding around a ceramic substrate. The advantage of metal film resistor over carbon type resistor is its more precise value of resistance.

Metal Film Resistors

These resistors exhibit low temperature coefficient and good stability. The metal resistors are available in power ratings of 250 mw to 2 W . The possible failures are:

a) OPEN CIRCUIT

1. Scratching of film.
2. High voltage or temperature causing disintegration.
3. Open circuit failure occurs in higher value of resistors due to thin resistance spiral.

a) HIGH NOISE

1. Bad contact of end connectors due to poor assembly on the circuit.

Chip resistors:

These have carbon coating filled into a solid ceramic substrate. The purpose is to have more precise resistance volume and greater stability with temperature.

Fusible resistor:

This is wire wound resistor type. It burns open easily when power rating is exceeded. It serves dual purpose of a fuse and also a resistor to limit the current.

2.3 RESISTOR COLOUR CODING

Resistor colour coding is used to calculate the value of resistance as per the colour codes given below.

Colour Code

Colour	Value	Colour	Value
Black	0	Green	5
Brown	1	Blue	6
Red	2	Violet	7
Orange	3	Gray	8
Yellow	4	White	9

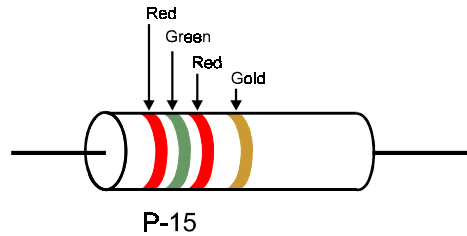
Calculating resistance value using colour codes:

The colour bands or rings are printed at one end of the insulating body. Reading from left to right. The first band close to the edge gives first digit in the numerical value of resistor, the next band marks second digit. The third band is the decimal multiplier.

Example:

- 1st band - Red
- 2nd band - Green
- 3rd band - Red

$$R = 2500 \Omega = 5\% \text{ (Tolerance limit)}$$



The value of resistor is

Red	Green		Red		
2	5	x	10^2	=	2500Ω

Resistors under 10Ω:

For these values, the third band is either gold or silver indicating a fractional decimal multiplier. Multiplication factor for gold and silver are 0.1 and 0.001 respectively.

Example:

- 1st stripe -Red
- 2nd stripe-Green
- 3rd stripe -Gold

The value of resistor is	Red		Green		Gold		
	2		5	X	0.1	=	2.5Ω

Resistor Tolerance:

The amount by which the actual resistor is different from its colour-coded value is the tolerance, usually given in percent. The fourth band on the resistor indicates the tolerance of the resistor. Gold band indicate +5% tolerance, Silver indicates the tolerance of + 10%.

Some resistors have five bands instead of four, in this case, the first three stripes give three digits followed by the decimal multiplier that is the fourth stripe and tolerance is fifth stripe. These resistors have more precise values with tolerance of 0.1 to 2 percent.

Fifth stripe	Tolerance (%)
Black	1.00
Brown	2.00
Green	0.50
Blue	0.25
Violet	0.10

Power Rating:

This is the maximum power, which can be developed in a resistor without damage occurring by overheating. For most electronic circuits 0.25W or 0.5W ratings are

adequate. The greater the physical size of a resistor the greater is its rating. For power supply of other application circuits 1W, 2W, 5W are common.

Stability:

This is the ability to keep the same value with changes of temperature and age.

Types of Resistors

Resistors are made of many forms, but all belong to either of the two groups.

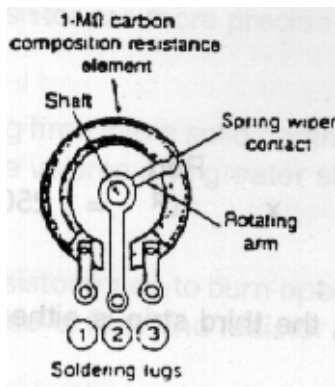
- (i) Fixed Resistors
- (ii) Variable Resistors

(i) Fixed Resistors

Several types of fixed resistors, are discussed in Sr. No. 2.2

(ii) Variable Resistors:

The variable resistors can be wire wound or carbon type. It can be a thin coating on pressed paper or a moulded carbon disc. These are joined to the two external soldering leg terminals 1 and 3. The middle terminal is connected to the variable arm that contacts the resistor element by metal spring wiper. As the shaft of the control is turned, the variable arm moves to make contact at different points on the resistor element. When the contact moves closer to one end, the resistance between that terminal and the variable arm decreases.



Rheostat and Potentiometers:

A rheostat is a variable resistance having its two terminal connected in series with load. The potentiometer has three terminals. The fixed resistance or maximum "R" across the two ends is connected across a voltage source. The variable arm is used to vary the voltage division between their centre terminal and the ends.

Resistance measurements:

When measuring a resistance in a circuit, it is important to be sure, there are no parallel paths across the resistor being measured. Otherwise resistance value can be much lower than actual value. When measuring very high resistance, it is important not to touch the Ohmmeter leads, as the body resistance of 50K comes in parallel, thus lowering the actual value of the resistance being measured.

2.4 THERMISTOR:

Specifications & Properties

A Thermistor is a semiconductor device whose resistance varies with temperature but change in temperature is non-linear. Conductor shows very small change in resistance with temperature change but Thermistor can increase or decrease its resistance by more value. Hence Thermistor can be NTC or PTC. When resistance decreases with increase in temperature then it is called as "Negative Temperature Coefficient" (NTC). If it increases then it is called as "Positive Temperature Co-efficient" of resistance (PTC). Thermistors are used in many applications like measurement by temperature, temperature control, temperature compensation etc.

Thermistors can be directly heated or indirectly heated when they are vacuum mounted in a glass envelope. It is often necessary to solder mount brackets or connect leads to provide efficient thermal contact. Thermistors are used in an application as excess current limiters, temperature sensors and protection devices against overheating. The thermistors are used in all kind of apparatus such as electric motors, washing machines and Alarm installations.

They are prepared from the oxides of the iron group of transition elements like Cr, Mn, Fe, Co or Ni. These oxides have a high resistivity in the pure state but can be transformed into Semiconductors by adding small amounts of foreign ions.

Review Questions

1. Explain the colour coding of Resistor?
2. Give a short note on Thermistor?
3. Explain different types of Resistor?
4. Explain the Tolerance in Resistor?

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CHAPTER THREE

FUSES

Features:

- 3.1 Introduction
- 3.2 Specification, Properties & Applications
- 3.3 Types of Fuses

3.1 INTRODUCTION

The current drawn by any machine or appliance in a circuit gets exceeded from rated (predetermined) value due to increase of load condition, short circuit, leakage from the mains. This current can be limited by a short length of wire known as fuse, which automatically melts due to this excessive current, and thus the circuit is broken. This is how the wiring or any appliance is protected. Otherwise the wiring and the appliance will be damaged due to the excessive flow of the current in the circuit.

Shortly, it can be stated that the fuse is a device used to prevent overheating due to excessive current. This in turn protects the insulation of the wire, machine or the appliances from over heating and damage.

3.2 SPECIFICATION, PROPERTIES & APPLICATIONS

Following points should be noted about the fuse.

- (1) The fuse is put in the live wire (+ve phase) in the main board and at the sub branches.
- (2) The size of the fuse wire should be based on the value of current and not on the melting current value.
- (3) If the fuse of proper rating is not provided in the circuit and any fault develops due to overload or short circuit, the flow of heavy current will heat up the wires and fire may take place.

Rated Current of Fuse:

By rated current we mean the current that can be carried safely for an indefinite period without undue heating and melting the fuse wire. This rated value also depends upon types of fuse holder, temperature and fuse contacts.

Fusing Current of Fuse:

It means the value of current at which the fusing wire melts, when current passes through it even for a fraction of second. The rated current is approximately half of the fusing current.

$$\text{Fusing factor} = \frac{\text{Minimum fusing current}}{\text{Rated current of the fusing element}}$$

Properties & Applications

Fuse unit should have following properties:

1. Easy isolation or separation from terminals.
2. Box/case, which holds the fuse wire, should be insulating material such as porcelain.
3. Ease of replacement.

The fuse basically consists of a current –carrying element, which melts when heated to temperatures above 170 F. The melting action opens the circuit thereby removing the

source of voltage from the circuit. The fuse will heat and remain intact provided the applied current does not produce heat that exceeds the melting point of the metal. It is, therefore important that the material used as a fusing element is engineered to accurate thickness, lengths and widths to carry specific voltage and current loads. Obviously, the basic laws of electricity are applied for selection of fuse ratings for a specific circuit taking into consideration the current required to maintain the normal circuit operation, total energy dissipation and voltage requirements. A short circuit in the equipment will melt a circuit fuse instantaneously. When a fuse needs to be replaced the exact replacement of a fuse with both proper voltage and current ratings must be used.

The blown up fuse can indicate the type of service problem in non-functional electronic equipment. Usually if the glass case of the fuse appears clear and there are broken pieces of the centre conductor, the problem has been caused by a slow, gradual overload on the power supply.

If the glass cover of the fuse is discolored and the centre conductor is almost missing, it shows that the fault was caused due to a short circuit. It also indicates that there may be other problem that produced a lot of current to flow very quickly and destroying the fuse violently with the production of a lot of heat.

Fuse is a vital component in equipment. It is used as an indicator of a defect in the system. It protects the equipment from the over current/ over loading.

Fuse unit should have following features:

1. Easy isolation or separation from terminals.
2. Box / case which holds the fuse wire, should be made of insulating material such as porcelain.
3. Ease of replacement.

3.3 TYPES OF FUSES:

1. Round type fuse unit (cut out) (Rewirable)
2. Kit-kat type fuse unit (Rewirable)
3. Catridge type fuse unit.

1. Round Type (cut out):

It looks similar to a ceiling Rose. It is made up of Bakelite or porcelain material. Its base is fixed on a wooden board with screw. There are two terminals on the base in which the fuse element is fitted. Threads are provided on the box as well as on the cover for placing and replacing purposes. Small holes are provided on the cover, for air entrance. The holes also provide a passage for gases formed due to melting (burning) of fuse element.

Following are disadvantages of this type of fuse.

1. One of the terminals is always energised with live (+ve) wire of the supply.
2. Due to above reason it is difficult to replace the fuse element with mains on. Main switch must be open.

3. When fuse blows off there is too much arcing and the unit may damaged.

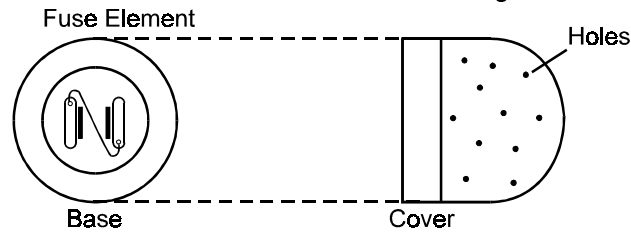


Fig. 3.1

2. Kit-Kat type Fuse Unit:

This is semi-closed type unit. Neither it is kept in free air nor it is completely enclosed. These are used for house hold or laboratory purpose mostly.

This type of fuse unit can be rewired; even the cut out terminals are energised without taking any safety precautions. This can be fitted on wooden blocks or boards or also used in iron-boxes. (In Iron-clad switch.)

Following terms are used in connections with this type of units.

- (a) Fuse links: - This part consists of fuse element.
- (b) Fuse carrier: - This carries fuse link.
- (c) Fuse base: - It is fixed part carrying fixed contact terminals.

Fuse base carriers are made of porcelain, whereas contacts and terminals are of hard bronze materials. Fuse carrier on which the fuse link is kept can be taken out very easily and safely (even with the switch in ON position). Fix contacts are fitted to the base.

Both terminals and wires are fitted to the top terminal. No fuse element is kept in neutral wire. For this purpose Neutral Link (copper or bronze) is provided in D.P.I.C. switches. When fuse bridge with fuse element is inserted and switch is made "on" then only the circuit is completed. These fuse units are rated as 5,15,30 upto 300 Amps

These types of fuse units are very simple in operation and very cheap and easy for replacement.

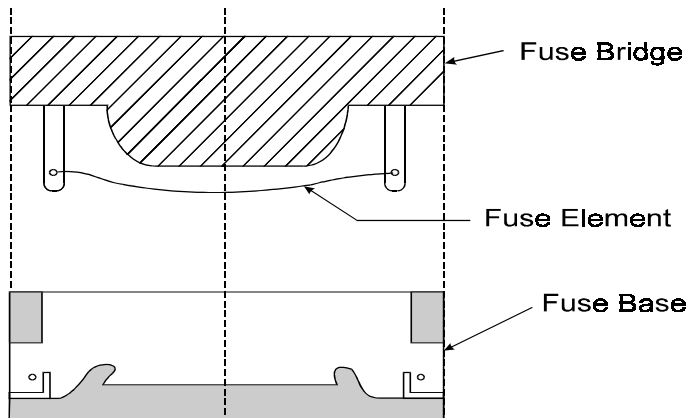
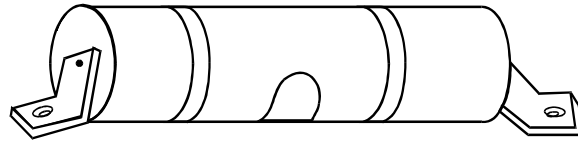


Fig. 3.2 Kit-Kat Rewirable Fuse Unit

3. Cartridge Type fuse unit :

These types of fuse units are completely enclosed. The fuse element is kept in a peculiar shape just like bucket known as cartridge. This container is filled with the materials "quarth". The container is heat resistant; good insulating material and it is

sealed completely. If the fuse goes off the complete unit is to be replaced. Therefore it is costly. It cannot be rewired (in some types, rewiring is possible). There is index circle on the container, which under normal condition is clear, but when fuse blows off it becomes



dark. These fuses are fixed in fuse carriers just like kit-kat fuse in D.P.I.C. unit.

Fig. 3.3

4. H.R.C. Tube Fuse Unit:

H.R. means high rupturing capacity. These are similar in construction to cartridge types with the exception that the fuse wire can carry heavy current for a known short time period. This heavy current can be much more than the normal rated current. During this time if the fault is removed, its use does not blow off otherwise it blows off and breaks the continuity of the circuit. Thus these fuses are sometimes also called as Slow Blow Fuses. The cartridge of H.R. type is either made of glass or some other chemical compound and has air tight construction to avoid the effect of atmospheric air on the fuse material (results in lowering its rated capacity due to continuous slow oxidation of the wire material). These fuses are available in 2A to 800 Amps. Capacity ranges. Fuse element used here is silver. Most popularly used fuses in electronic circuits are of 2 amp to 5 amp.

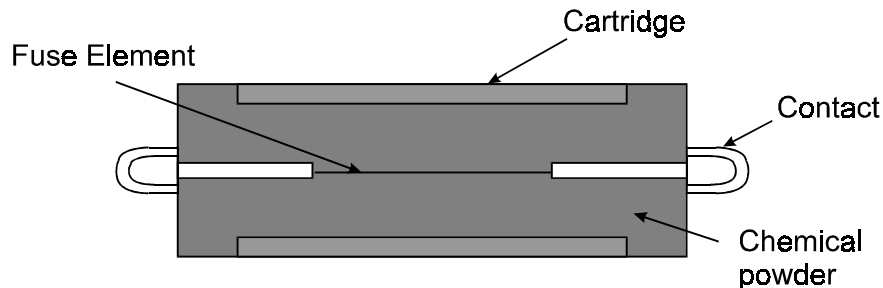


Fig 3.4

Some other types of fuses are: -

5. Automatic Cut Out
6. Plug type
7. Expulsion fuse
8. Liquid fuse
9. Drop out fuse.
10. Mini Circuit Breaker

Summary:

The fuse basically consists of a current carrying element, which melts when heated to temperatures above 170°F. The melting action opens the circuit thereby removing the source of voltage from the circuit.

The fuse normally heats up and remains intact provided the applied current does not produce heat that exceeds the melting point of the fuse metal wire. It is therefore

important, that the material used as a fusing element is engineered to accurate thickness, lengths and widths to carry specific voltage and current loads.

For this the basic laws of electricity are applied for selection of fuse ratings for a specific circuit, taking into consideration the current required to maintain the normal circuit operation, total energy dissipation and voltage requirements. A short circuit in the equipment will melt the circuit fuse instantaneously. When a fuse needs to be replaced the exact replacement of a fuse with respect to both proper voltage and current ratings must be used.

The blown up fuse can indicate the type of service problem in non-functional electronic equipment. Usually if the glass case of the fuse appears clear and there are broken pieces of the centre conductor, the problem has been caused by a slow, gradual overload on the power supply.

If the glass cover of the fuse is discolored and the centre conductor is almost missing, it shows that the fault was caused due to a short circuit or other problem that produced a lot of current to flow very quickly and destroying the fuse violently with the production of lot of heat. Fuse is a vital component in any equipment. It is used as an indicator of a defect in the system. It protects the equipment from over current or over loading.

Review Questions

1. Define fuse element, fusing current, current rating of a fuse ?
2. What is the importance of fuse ?
3. Explain Kit-kat fuse ?
4. Give Notes on
 - (a) Cartridge type fuse.
 - (b) H.R.C. Type fuse

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CHAPTER FOUR

CAPACITORS

Features :

- 4.1 Introduction
- 4.2 Capacitor operation
- 4.3 Charge Storage
- 4.4 Relation between C, Q & V
- 4.5 Unit of Capacitance
- 4.6 Types of Capacitors
- 4.7 Colour Coding of Capacitor
- 4.8 Failure in Capacitors
- 4.9 Applications

4.1 INTRODUCTION

Capacitor is another important passive component commonly observed in electrical and electronic circuits. Some times it is also called a condenser. Basically it is used to store electrical energy (by charging) and to supply this stored energy when required (by discharging). This component has property of storing charge across its two plates; hence it is also named as capacitor. They are available in fixed and variable types; their capacity is measured in unit "Farad". Typically they are available in microFarads.

The capacitor utilization is very high in any analog circuit.

Characteristics of a Capacitor:

It can store an electrical charge.

It will not permit any voltage to exist on its terminals until some of the voltage charge is moved from one of its plates to another plate.

4.2 CAPACITOR OPERATION

It consist of two parallel plates, insulating material called dielectric separates the plates. Each plate has an equal quantity of positive and negative charges when it is neutral. When the voltage source is connected to the plates of the capacitor, the charge is redistributed. The negative charges of the upper plate are attracted to the positive electrodes of the power source. The positive charges on the lowest plate are attracted towards the negative electrodes of the power supply. The result of this action is a device containing a positively charged plate and a negatively charged plate.

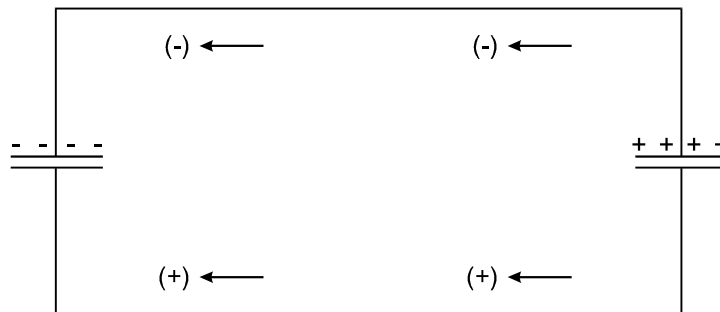


Fig 4.1.

4.3 CHARGE STORAGE

The charges on the plates of a capacitor develop an energy field in the dielectric material and are known as electric field. It consists of lines of force between the charged plates of capacitor. The lines of force are concentrated in the dielectric material; they therefore store energy in the dielectric material.

4.4 RELATION BETWEEN C, Q AND V

$$C = Q/V$$

C = Capacitance of capacitor in Farad

Q = Charge on plate of capacitor in Coulombs

V = Voltage across the capacitor in Volts.

4.5 UNIT OF CAPACITANCE

The basic unit of capacitance is Farad. The application of the capacitor in electrical and electronic devices usually requires a unit with value much less than 1 Farad. Typical units of capacitance are the microfarad (10^{-6} F) and picofarad (10^{-12} F)

4.6 TYPE OF CAPACITORS

Electrolytic Capacitors:

The electrolytic capacitors are made of metal foil with a thin surface of metal oxide film. One of these plates is coated with aluminium oxide material. This becomes the positive plate of capacitor. The oxide layer acts as a dielectric material for the capacitor.

The electrolytic capacitor has polarity marking on their case. While installing an electrolytic capacitor, the positive lead must always be connected to the most positive lead of the two connections. When connected in reverse polarity, electrolytic capacitors emit gas, which expands in its sealed container resulting in explosion and damage of capacitor.

Leakage current: The electrolytic capacitor has high leakage current, since the oxide film is not a perfect insulator. The leakage current is typically 0.1 to 0.5 mA/ μ F.

Tantalum Capacitor

This is another form of an electrolytic capacitor. It uses tantalum instead of aluminium.

The features of tantalum capacitor are

- Larger Capacitance (C) in smaller size
- Larger shelf life
- Less leakage current

Non Electrolytic Capacitors:

Ceramic Capacitors:

A thin plate of ceramic is metallized on both sides to make a ceramic capacitor. Connecting leads are also soldered to the metallized area. The body of the capacitor is coated with varnish to give a hard and glossy look and marked with capacitance value—either using numerals or color-coding. The color-coding is the same as used for the resistors. This type of capacitor features capacitance values up to 0.01 μ f. This capacitor has the same applications as mica capacitors but are smaller.

Mica Capacitor:

The mica sheets as dielectric are stacked between tinfoil sections for the conducting plates to provide the required capacitance. Alternate strips of tin foil are connected together and brought out as one terminal for one set of plates, while opposite terminals connect to other set of interlaced plates. Entire unit is molded in Bakelite case.

Mica capacitors are used for small capacitance value of 50pF to 500 pF.

Paper Capacitor:

In this, two rolls of tinfoil conductor separated by a tissue paper as insulator are rolled into a compact cylinder. Each outside lead connects to roll of tin foil as a plate. The

entire cylinder is generally placed in cardboard container coated with wax or enclosed in plastic.

Paper capacitors are always used for medium capacitance values of 0.001 μ F to 1.0 μ F.

Plastic film Capacitor:

Plastic film is used in place of tissue paper as dielectric. This type is available in 0.001 μ F to 1.0 μ F values like paper capacitor.

VARIABLE CAPACITORS

In tuning circuits, the value of the capacitance needs to be changed. In such capacitors, air is the dielectric and such capacitors are called air gang capacitors. By rotating the shaft at one end, we can change the common area between the movable and fixed set of plates. The greater the common area the greater is the capacitance.

Marking and coding:

Capacitors have two specifications of importance, one is value of capacitance and other is voltage rating. Voltage rating is the maximum value of DC voltage that can be applied across the device. Any voltage higher than this rating is capable of destroying the dielectric material resulting in failure of capacitor. Capacitor values are marked on the body of the capacitor.

In ceramic capacitor the capacitance value is indicated like "104". In this the value is read like 10 \times 10⁴pF. Sometimes a letter such as "R" may be used in place of decimal point indicating the value such as 3R3 which is equivalent to 3.3 pF.

4.7 COLOUR CODING OF CAPACITORS

The system of colour coding is similar to the colour code system of resistors, only difference is the addition of a temperature coefficient. Some times working voltage is indicated by colour code.

There are different methods of colour code as illustrated.

Color	Digit	Multiplier	Tolerance	Class of Characteristics
Black	0	1	20%	A
Brown	1	10	1%	B
Red	2	100	2%	C
Orange	3	1000	3%	D
Yellow	4	10000		E
Green	5		5%	F
Blue	6			
Violet	7			
Grey	8			
White	9			

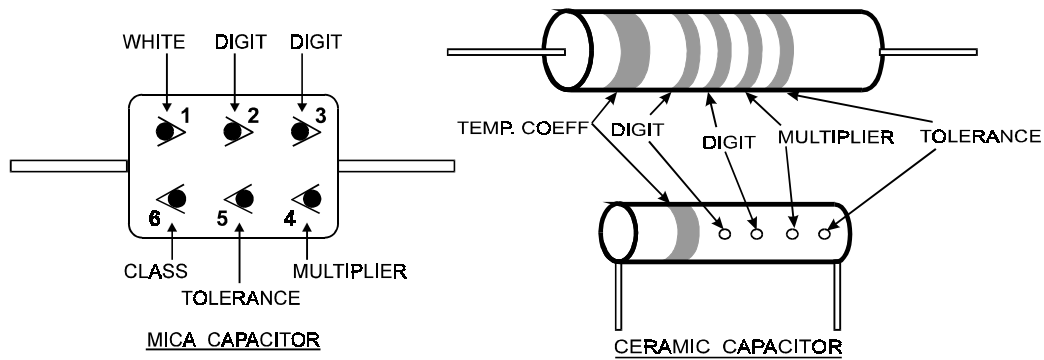


Fig. 4.2

4.8 FAILURE IN CAPACITORS

1. Open circuit problems
2. Short circuit problems
 - I. Due to dielectric breakdown
 - II. Environmental shock
 - III. Mechanical shock
 - IV. Thermal shock
 - V. Humidity
 - VI. Misuse-poor assembly
 - VII. Prolonged storage
 - VIII. Manufacturing imperfection
 - IX. Impurities in electrolytic

TESTING OF CAPACITORS:

Electrolytic and high value capacitors can be checked for open circuit, short circuit and leaky behavior by means of an ohmmeter operated on the highest scale.

If ok the capacitor will slowly charge to show a high value of resistance. In case of open circuit the charging action would be absent.

Troubles in Capacitors

Capacitor can become open or short-circuited. In either case, this capacitor is useless because it cannot store charge leaky capacitor is equivalent to a partial short circuit where the dielectric gradually loses its insulating properties under the stress of applied voltage, lowering its resistance. A good capacitor has very high resistance of the order of megaohms. A short-circuited capacitor has zero ohm resistance, or continuity. The resistance of a leaky capacitor is lower than normal.

Open Capacitors: In addition to the possibility of an open connection in any type of capacitor, electrolytic develop high resistance in the electrolyte with age, particularly at high temperatures. After service of a few years, if the electrolyte dries up, the capacitor will be partially open. Much of the capacitor action is gone, and the capacitor should be replaced.

Leaky Capacitors: A leaky capacitor reads R less than normal with an ohmmeter. However, D.C voltage tests are more definite. In a circuit the D.C. voltage at one terminal of the capacitor should not affect the dc voltage at the other terminal.

Shelf Life: Except for electrolytic, capacitors do not deteriorate with age while stored, since there is no applied voltage. Electrolytic capacitors, like the dry cells should be used fresh from manufacture. The reason is the wet electrolyte.

4.9 APPLICATIONS

A capacitor offers low impedance to AC, but very high impedance to DC. Hence capacitors are used when we want to couple alternating voltage from one circuit to another, while at the same time blocking the DC voltage from reaching the next part of the circuit. The capacitor is also used as a bypass capacitor, where it bypasses the AC through it without letting the AC signal to go across the circuit. Capacitors are also used in tuned circuits in series or parallel with an inductor.

Electrolytic capacitors are used in circuits that have a combination of DC voltage and AC voltage. The DC voltage maintains the required polarity across the electrolytic capacitor. A common application is Electrolytic filter capacitors eliminate 60 Hz AC ripples in a DC power supply. Another use is for audio coupling capacitors in transistor amplifiers.

Review Questions

1. Give the Characteristic of a Capacitor?
2. Explain Capacitor charging operation?
3. What are the different types of Capacitor?
4. Explain the colour coding of Capacitor?
5. Write a short note on
 - a) Charge Storage
 - b) Unit of capacitance
- a) Relation between C, Q & V.

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CHAPTER FIVE

INDUCTIVE COMPONENT

Features:

- 5.1 Introduction to Magnetic Material.
- 5.2 Magnetic Properties.
- 5.3 Inductor
- 5.4 Properties
- 5.5 Types and Applications
- 5.6 Troubles in Coils
- 5.7 Transformer.
- 5.8 Types of Transformer.
- 5.9 Efficiency of a transformer
- 5.10 Turn Ratio
- 5.11 Coefficient of coupling
- 5.12 Comparison of step up and step down transformer

5.1 INTRODUCTION TO MAGNETIC MATERIAL

The magnetic material are those in which a state of magnetization can be induced. When it is magnetized, it creates a magnetic field in the surrounding space. Magnetic materials play an important role in electronic engineering. Magnetic materials are used in magnetic circuits, in electromagnets, machines, transformer, saturable reactors, relays and many instruments. The electronic engineers must be well versed with the characteristics of the magnetic materials, so that they choose the proper material for the construction of a desired device.

All the substance found in nature posses some magnetic properties and interacts with an external magnetic field. The magnetic properties of a substance depend on the magnetic properties of the individual elementary particles, the structure of atoms and molecules and their groupings. Studies on the magnetic properties of micro particles reveal that the magnetic behaviour of atoms largely depends on that of electrons. The magnetism of other particles is insignificant. Thus the magnetic moment of the atomic nucleus of approximately one thousandth to that of the electronic shell of the atom. The magnetic moment of an electron arises due to its orbital, revolution and twining (spin) motion.

5.2 MAGNETIC PROPERTIES

Magnetic Permeability:

The permeability for the magnetic materials is the criteria for selecting them.

For dielectric material

$$D = \epsilon_0 \epsilon E$$

$$\epsilon_0 = \text{Absolute permitivity for free space } 8.854 \times 10^{-12} \text{ flm,}$$

$$\epsilon = \text{Absolute permitivity,}$$

$$E = \text{Electric intensity E is volt / meter)}$$

$$D = \text{Electric displacement,}$$

And similarly for the magnetic material we have

$$B = \mu_0 \mu_r \epsilon H$$

Where

$$\mu_r = \mu / \mu_0$$

$$\mu_r = \text{Relative permeability}$$

$$\mu_0 = \text{Permeability of vacuum}$$

$$\mu = \text{Permeability of the medium in henry per meter.}$$

$$\mu_0 = 4 \times 10^{-7} \text{ henry per meter.}$$

$$B = \text{Magnetic flux density in Weber / m}^2$$

If a magnetization curve of magnetic material specimen between the flux density B and the field intensity H is plotted by making the use of the following circuit.

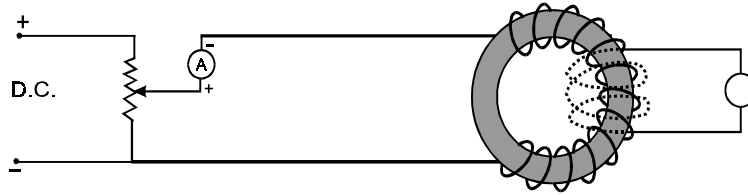


Fig. 5.1

The flux linked is ϕ . If "A" is the cross-sectional area of the specimen anchor ring then,

$$B = \phi/A$$

$$A = \text{Area in m}^2$$

$$\text{And } H = NI/L_m$$

H = uniform magnetic field of strength in Newton/wb

L_m = Mean length of magnetic flux

The flat section of the B - H curve is represented by an equation given by

$$B = H / (a+bH)$$

B = flux density in wb/m²

Where,

a = hardness constant is the measure of the value H, necessary to attain given fraction saturation.

$$b = 1/B_s$$

Where B_s is the saturation density of the material.

Retentivity: The residual flux density B_r on the loop is called retentivity.

Coercivity: The coercive force, which is required to reduce B to zero, is called the coercivity.

Energy Product: The maximum BH product is known as energy product. It is the quantity of importance for permanent magnetic materials.

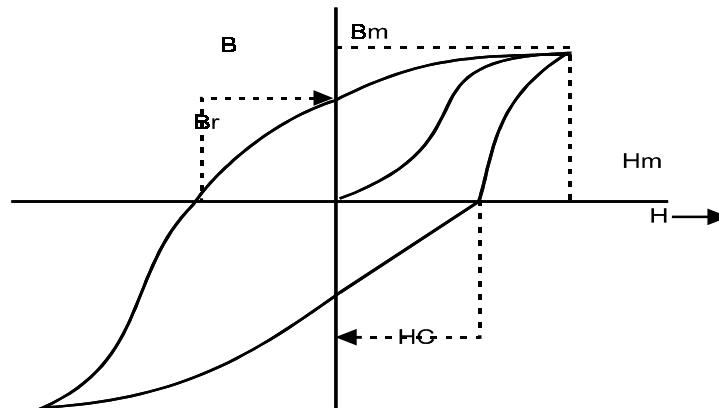


Fig 5.2

Where, N = Number of turns on the specimen
 L_m = Mean length of magnetic flux

$$l = \pi D \quad (D = \text{Diameter of Ring})$$

$$I = \text{Current in ammeter.}$$

The graph of "B' against "H' is shown.

$$\mu_r = \frac{B}{\mu_0 H}$$

$$= \frac{B}{4\pi \times 10^{-7} H}$$

$$\mu_{\text{max}} = \frac{B_m \text{ at point A}}{H_m}$$

Permeability of a magnetic material is

$$\mu = B/H \quad \text{Where } \mu = \text{Absolute permeability in Henry/m}$$

$$\mu = \mu_0 \mu_r \quad \mu_0 = \text{Absolute permeability } 4\pi \times 10^{-7} \text{ H/m}$$

Reluctivity:

The ratio $1/\mu_0 \mu_r$ is called the reluctivity of a magnetic material.

5.3 INDUCTOR

Induced voltage is the result of flux cutting across a conductor. This action can be produced by physical motion of either the magnetic field or the conductor. When the current in a conductor varies in amplitude. The variations of current and its associated magnetic field are equivalent to motion of the flux. As the current increases in value, the magnetic field expands outward from the conductor. When the current decreases, the field collapses into the conductor. As the field expands and collapses with changes of current, the flux effectively expands and collapses. With changes of current the flux is effectively in motion. Therefore a varying current can produce induced voltage without the need for motion of the conductor.

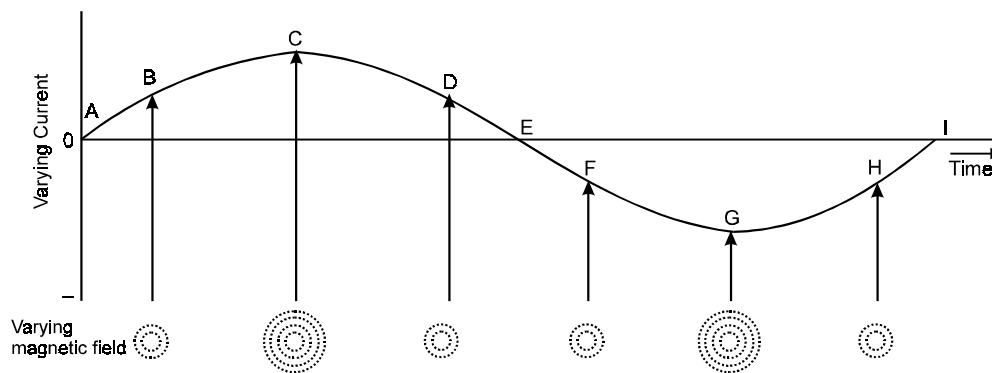


Fig. 5.3

This moving flux cuts across the conductor that is providing the current, producing induced voltage in the wire itself. Furthermore any other conductor in the field, whether carrying current or not, also is cut by the varying flux and has induced voltage.

It is important to note that induction by a varying current results from the change in current, not the current value itself. The current must change to provide motion of the

flux. Since inductance is a measure of induced voltage, the amount of inductance has an important effect in any circuit in which the current changes.

Self-Inductance L

The ability of a conductor to induce voltage in itself when the current changes is its self-inductance (or simple inductance). The symbol for inductance is L, and its unit is the Henry (H). One Henry is the amount of inductance that allows one volt to be induced when the current changes at the rate of one ampere per second. The formula is

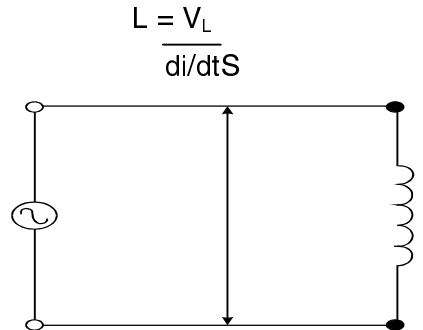


Fig. 5.4

Where V_L is in volts and di/dt is the current change in amperes per second. The self-induced voltage across an inductance L produced by a change in current di/dt can be stated as

$$V_L = L di/dt$$

Where V_L is in Volts, L is in Henrys, and di/dt in Amperes per second.

The moving flux cuts across the conductor providing the current that produces induced voltage in the wire itself. Further any other conductor in the field, whether carrying the current or not is also cut by the varying flux and has induced voltage. It is important to note that, induction by a varying current results from the change in current not the current value itself. The current must change to provide motion to the flux.

Since inductance is a measure of induced voltage, the amount of inductance has an important effect in any circuit in which the current changes.

Inductance of Coil:

In terms of physical construction of an inductor, the inductance depends on how a coil is wound.

1. A greater number of turns (N), increases 'L' because more voltage can be induced. Actually 'L' increases in proportion to N^2 . Double the number of turns in the same area and length, increases the inductance four times.
2. More area 'A' enclosed by each turn increases 'L'. This means a coil with larger turns has more inductance. The 'L' increases in direct proportion to 'A' and as the square of the diameter of each turn.

3. The 'L' increases with the permeability of the core (μ). For an air core, μ is zero. With a magnetic core, 'L' is increased by μ factor, as the magnetic flux is concentrated in the coil.
4. The 'L' decreases with more length for the same number of turns as the magnetic field then gets less concentrated.

Mutual inductance L_M :

When the current in an inductor changes, the varying flux can cut across any other inductor nearby. This produces induced voltage in both inductors. In figure below, the coil L_1 is connected to a generator that produces varying current in the turns. The winding L_2 is not connected to L_1 but the turns are linked by the magnetic field. A varying current in L_1 therefore induces voltage across L_1 and thereby also in L_2 .

If all flux of the current in L_1 links all the turns of the coil L_2 , then each turn in L_2 will have the same amount of induced voltage as each turn has in L_1 . Further the induced voltage V_{L_2} can produce current in a load resistance connected across L_2 .

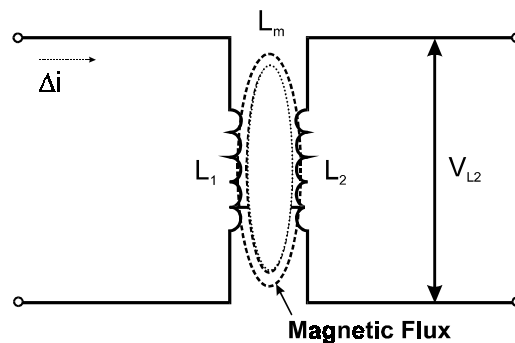


Fig. 5.5

When the induced voltage produces current L_2 , its varying magnetic field induces voltage in L_1 . The two coils L_1 and L_2 have mutual inductance, therefore current in one can induce voltage in the other.

5.4 PROPERTIES

It is important to note that induction by a varying current results from the change in current, not the current value itself. The current must change to provide motion to the flux. Example: A large value of DC current say 1000A, cannot produce any induced voltage as long as the current value is constant. Whereas a current of $1\mu\text{A}$ changing to $2\mu\text{A}$, however does induce a little voltage.

The characteristics of inductance are considered to be important in:

1. AC circuits: Here the current is continuously changing and producing induced voltage. Lower frequencies of alternating current require more inductance to produce the same amount of induced voltage as a higher frequency current. The current can have any waveform as long as the amplitude is changing.

2. **DC circuits in which the current changes in value:** It is not necessary for the current to reverse direction. One example is a DC circuit being turned on or off. When the direct current is changing between zero and its steady value, the inductance affects the circuit at the time of switching. This effect with a sudden change is called the transient response. A steady direct current that does not change in value is not affected by inductance, because there can be no induced voltage without a change in current.

5.5 TYPES & APPLICATIONS

All inductors are listed under two categories: Fixed and Variable. Inductors that are used in power supplies for smoothing the pulsating current are known as filter chokes. Audio frequency chokes are used to provide high impedance to audio frequencies. Variable inductors are used in tuning circuits for radio frequencies.

Inductance has been one of the important passive elements, used in frequency selective electrical networks. It has been in use since the beginning of telecommunication engineering. It is an important constituent in a wide variety of electronic equipment ranging from telephony to domestic radio, television. An inductor is a single winding on a magnetic core. At audio and low carrier frequencies, inductors have iron cores using a shell type of core built up of EI, UV or TU types of laminations. Such cores can provide sufficiently large inductance and low DC resistance in reasonable sizes. However, laminated core inductors have low Q factors and the value of inductance value is imprecise.

5.6 TROUBLES IN COILS

The most common trouble in coils is an open winding. An ohmmeter connected across the coil reads infinite resistance for the open circuit. It does not matter whether the coil has an air core or an iron core. Since the coil is open, it cannot conduct current and therefore has no inductance, because it cannot produce induced voltage. When the resistance is checked, the coil should be disconnected from the external circuit to eliminate any parallel paths that could affect the resistance readings.

DC Resistance of a coil A coil has dc resistance equal to the resistance of the wire used in the winding. The amount of resistance is less with heavier wire and fewer turns. For RF coils with inductance values up to several milli-henry, requiring 10 to 100 turns of fine wire, the dc resistance is 1 to 20, approximately. Inductors for 60 Hz and audio frequencies with several hundred turns may have resistance values of 10 to 500ohms, depending on the wire size.

Open Coil An open winding has infinite resistance, as indicated by an ohmmeter. With a transformer that has four leads or more, check the resistance across the two leads for the primary, across the two leads for the secondary, and across any other pairs of leads for additional secondary windings. For an auto-transformer with three leads, check the resistance from one lead to each of the other two.

When the open circuit is inside the winding, it is usually not practical to repair the coil, and the entire unit is replaced. In some case, an open connection at the terminals can be re-soldered.

Open Primary Winding When the primary of a transformer is open, no primary current can flow and there is no voltage induced in any of the secondary windings.

Open Secondary Winding When the secondary of a transformer is open, it cannot supply power to any load resistance across the open winding. With no current in the secondary, the primary current is also practically zero, as though the primary winding were open. The only primary current needed is the small magnetizing current to sustain the field producing induced voltage across the secondary without any load. If the transformer has several secondary windings, an open winding in one secondary does not affect transformer operation for the secondary circuits that are normal.

Short across Secondary Winding In this case excessive primary current flows, as though it were short-circuited, often burning out the primary winding. The reason is that the large secondary current has a strong field that opposes the flux of the self induced voltage across the primary, making it draw more current from the generator.

5.7 TRANSFORMER

Transformer basically consists of two inductors. One of these inductors is meant for supplying alternating current from an external source and is referred as a Primary Winding. The other coil, in which Primary Winding induces the voltage, is known as Secondary Winding.

In transformer the change in current in one coil can induce an E.M.F. in the second coil. A transformer works on the principle of mutual inductance. Hence it is a device which transfers alternating currents of high voltage and vice-versa from one winding to other. Transformers can also be a step-up transformer or a step-down transformer.

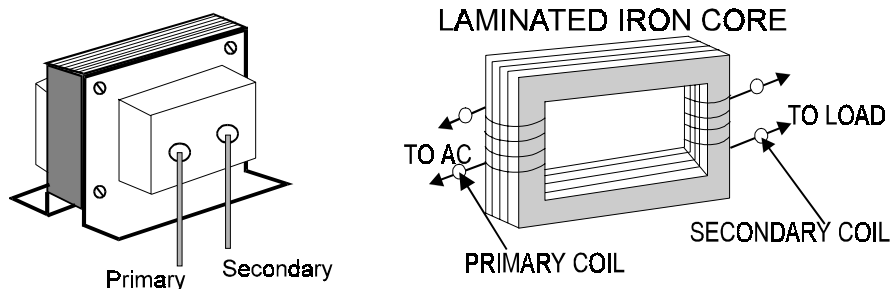


Fig. 5.6

A special type of transformer which has output voltage same as the input voltage is known as " Isolation-Transformer". It is used for isolation of voltage from the main line. This is useful in cases where mains supply voltages may cause problem.

Principle of Operation: If two coils are placed near each other, the change in flux in one coil will cut the turns of the other coil and will induce a voltage in it. Then these two coils are said to have mutual inductance.

5.8 TYPES OF TRANSFORMER

(1) Power Transformer

Power transformer is also called as main transformer i.e. it is meant to operate having AC mains supply applied to its primary winding. They have one primary and several secondary windings as shown in figure. These secondary windings provide various values of operating voltages, depending upon the secondary winding turns. These voltages are required for the functioning of circuits in radio and other electronic equipment.

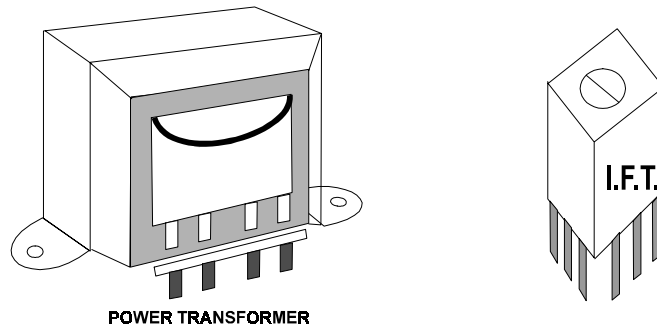


Fig. 5.7

(2) Audio Frequency Transformer (AFT)

Audio frequency transformer is made to operate at audio frequencies in the range of 20 Hz to 20 kHz. They are similar to the power transformers but differ in the constructions and material of the core. They are always used to couple one stage to another. These transformers are used in audio amplifiers. They are available in both types as step up as well as step down transformers. In power output stage of radio receiver a step down audio frequency transformer is used to match high output impedance of the amplifier to the low input impedance of the speaker. Since transformer can serve as a step up or step down device for current, it can also serve as a step up or step down device for impedance because impedance is a ratio of voltage to current.

(3) Radio Frequency Transformer (RFT)

Radio frequency (RF) transformers operate at very high frequencies. They are generally used with capacitor to form resonant circuits. At higher frequencies the Eddy Current becomes excessive.

To reduce Eddy Current losses, the RF transformer's core is made of air. Radio frequency transformer is also used for interstage coupling in electronic circuits, and for coupling a signal to and from antenna.

(4) Intermediate Frequency Transformer (IFT)

Intermediate frequency range lies between the audio frequency and radio frequency range. These transformers are meant to operate at a fixed frequency, known as intermediate frequency. In radio-receiver circuits, the intermediate frequency commonly used is 455 kHz. IFT Transformers are also used in the inter-carrier (TV Receiver) sound section of television. Other I.F. transformers with center frequency of the range of 39 MHz to 48 MHz are used in the video I.F. section of Television (TV Receiver).

(5) Auto Transformer

In autotransformer, same coil is used to provide turns for the primary as well as for the secondary. If whole part of the coil is used as a primary winding and small part of coil is used as a secondary winding, then it is called as step-down transformer.

If small portion of the entire winding is used as a primary winding and entire winding is used as a secondary winding, then it is known as step-up transformer. They are also provided with fixed or variable taps for varying the secondary voltage as shown in the fig.

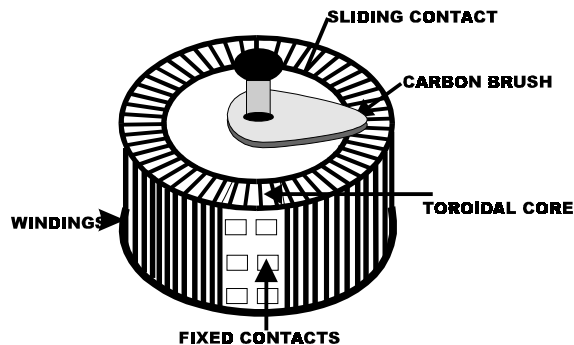


Fig. 5.8

(6) Isolation Transformer

When the number of turns of the primary winding are made equal to the number of turns of the secondary winding, then the transformer formed is known as isolation transformer. It has two coils having 1 to 1 turn ratio. It reduces the possibility of electric shock from the equipment. It is also used in audio frequency equipment and to block the DC component.

(7) Driver Transformer

Driver transformers are similar to interstage transformers but they are required to supply current (or base current) to the driver stage. Driver transformers are rated for primary and secondary impedance ratio. Low value resistance designs it. They are also rated for maximum frequency and winding resistance. Generally the secondary winding is center-tapped, since driver transformers are used in Class- B amplifier. The primary of the transformer may be center-taped in some particular cases.

5.9 EFFICIENCY OF TRANSFORMER

Transformer efficiency is another factor used for the design purposes. Efficiency is expressed as a percentage. The basic Expression of efficiency is

$$\text{Efficiency} = \frac{\text{Output}}{\text{Input}} \times 100$$

The efficiency rating for a transformer is also given by above formula. Since both voltage and current are required for transformer action. Efficiency is normally described by comparing input power and output power. The formula for this

$$\text{Efficiency} = \frac{\text{Output}}{\text{Input}} \times 100$$

Power transformer's efficiency ranges between 80% to 90%. It is possible to produce transformers having higher efficiency ratings, but this is not economical or always practical. Any primary power that is not used by the secondary of a transformer gets converted into heat in the transformer. The power lost in this manner is not productive.

5.10 TURN RATIO

The formula for turns ratio is

$$\text{Turns ratio} = \frac{N_p}{N_s}$$

Where,

N_s is the number of turns of wire in the secondary windings and N_p is the number of turns of wire in the primary windings. This ratio is important when we consider that this relationship is directly related to the quantity of induced voltage.

5.11 COEFFICIENT OF COUPLING

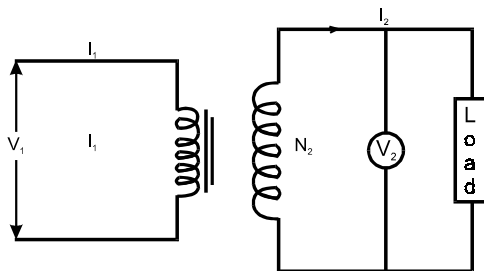
The quantity of the total flux developed in one coil of conductor that links a second is known as the coefficient of coupling.

The letter K is used to express this value

$$K = \frac{\text{Flux lines between } L_1 \text{ and } L_2}{L_1 \text{ flux}}$$

5.12 COMPARISON OF STEP UP AND STEP DOWN TRANSFORMER

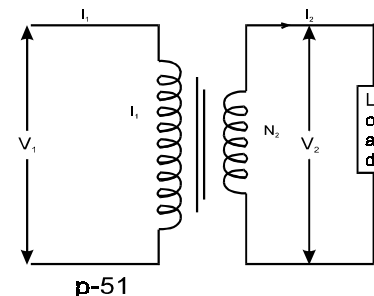
Step Up Transformer



Step Up Transformer

1. Secondary voltage is more than primary voltage.

Step down Transformer



Step down Transformer

1. Secondary voltage is less than Primary voltage.

- | | |
|--|---|
| 2. $(N_2 > N_1)$
No. of Secondary Turns = N_2
No. of Primary Turns = N_1 | 2. $N_2 < N_1$ |
| 3. $I_2 < I_1$
I_2 = Current in Secondary Winding
I_1 = Current in Primary Winding | 3. $I_2 > I_1$ |
| 4. Transformer ratio
$K = V_2 / V_1$ is more than 1 | 4. Transformer ratio is less than 1 |
| 5. Power transformer at a Power Generating Station is an example of this type. | 5. Distribution transformer is an Example of this type. |

Review Questions

1. Explain the Basic principle of transformer ?
2. What is the purpose of a step up and a step down transformer?
3. Give short notes on
 - a) Efficiency of transformer
 - b) Turns ratio
 - c) Coupling coefficient
4. State the different magnetic properties of the material.

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CHAPTER SIX

CIRCUIT ANALYSIS

Features:

- 6.1 Fundamental of AC Circuit and its Applications
- 6.2 A.C. Circuit with Resistance
- 6.3 A.C. Circuit with Reactance
- 6.4 A.C. Circuit with Capacitance
- 6.5 Power in a Reactive Circuit
- 6.6 Filters
- 6.7 Kirchoff's Law
- 6.8 Study of Voltmeter

6.1 FUNDAMENTALS OF AC CIRCUIT & ITS APPLICATIONS

AC circuit containing both inductive and capacitive reactance is called resonant circuit. This circuit is designed to operate at a frequency or a group of frequencies. It is used to either accept or reject the desired frequency or frequencies. Resonant circuits are most commonly used in the tuner section in radios and television receivers. Resonant or tuned circuits are also used to generate and amplify radio frequency signals. The use of the resonant circuit restricts the signal to the specific frequency for proper operation.

Many circuits have an AC voltage applied to them. The factors influencing current and voltage drops apply to these circuits. Both inductive reactance and capacitive reactance introduce a phase shift. This phase shift factor must also be taken into consideration while attempting to solve the AC circuit for a voltage drop and current flow calculations. This chapter deals with methods for solving AC circuit problems.

The AC resistive circuits have no phase shift between voltage and current. In this case voltage and current signals are in phase with each other. In a purely resistive AC circuit there is a zero phase shift. This is because there are no reactive components in the circuit.

6.2 A.C. CIRCUIT WITH RESISTANCE

Combinations of series and parallel resistance are shown in fig.

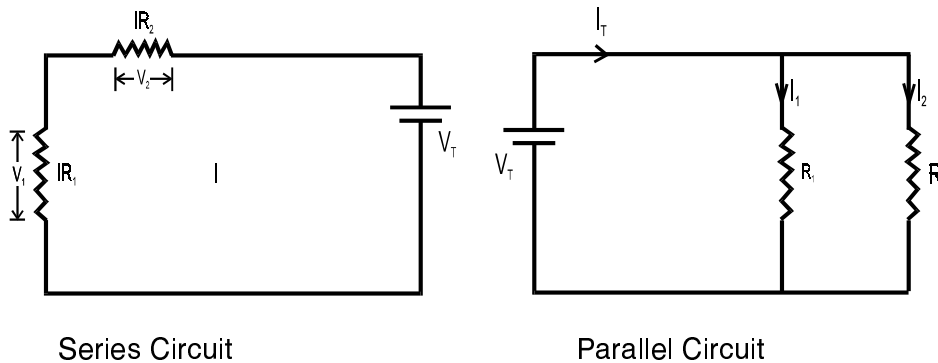


Fig 6.1

Series Resistance: for the series circuit

$$R_S = R_1 + R_2$$

Where R_S = Total resistance of circuit

$$I = V_T / R_T$$

$$V_1 = IR_1$$

$$V_2 = IR_2$$

Note that the series resistance R_1 and R_2 serve as a voltage divider, in a D.C. circuit. The voltage drop V_1 and V_2 are both in phase with the series current I , which is common reference.

Parallel Resistance: For the parallel circuit

$$I_1 = \frac{V_T}{R_1}, \quad I_2 = \frac{V_T}{R_2}$$

$$I_T = I_1 + I_2$$

With a total current of I_T in the main line from the V_T source, the combined

$$\text{Parallel resistance is } R_p = \frac{R_1 + R_2}{R_1 + R_2} \text{ ohm}$$

Each branch current has the same phase as the applied voltage. Voltage V_T is the reference because it is common to both branches.

6.3 A.C CIRCUIT WITH REACTANCE

Following circuits show reactive element or inductor in series and parallel combinations.

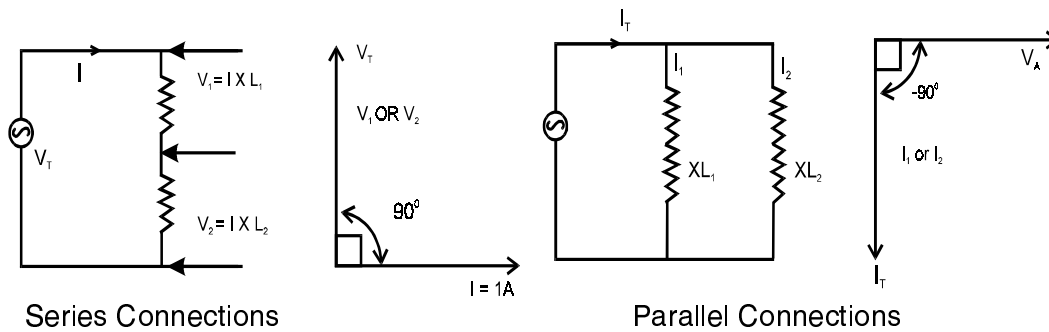


Fig. 6.2

Although X_L is a phasor quantity with a 90° phase angle. In this example, one type of reactive element is used. Therefore without any R or X_C , the series ohms of X_L can be combined directly. Similarly, the parallel I_L current can be added.

X_L values in series

$$X_{L_T} = X_{L_1} + X_{L_2}, \quad I = \frac{V_T}{X_{L_T}}$$

$$V_1 = I X_{L_1}$$

$$V_2 = I X_{L_2}$$

With regard to the phase angle for the inductive reactance, the voltage across any X_L always leads the current through it by 90° . I is the reference phasor because it is

common to all the series components. Therefore, the voltage phasor for V_1 and V_2 across either reactance, or V_T across both reactance, are shown leading I by 90° .

I_L -values in parallel

$$I_1 = V_A / X_{L1}, \quad I_2 = V_A / X_{L2} \quad I_T = I_1 + I_2$$

These two branches can be added because they both have the same phase. This angle is 90° lagging the voltage reference phasor.

Since the voltage V_A is common to the branches this voltage is across X_{L1} and X_{L2} . Therefore V_A is the reference phasor for parallel circuits.

6.4 A.C CIRCUIT WITH CAPACITANCE

Combination of series and parallel capacitance is shown below.

X_C values in series:

Calculation for V_1 and V_2 are the same as before in reactance circuit. With regards to the phase angle for the capacitive reactance, the voltage across any X_C always lags its capacitive charge and discharge current I by 90° for the series circuit, whereas I is the reference phasor. The capacitive current leads by 90° or we can say that each voltage lags I by -90° .

I_C values in parallel:

Here V_A is the reference phasor. The calculation for I_1 and I_2 are the same. However now each of the capacitive branch currents, I_T leads V_A by 90° .

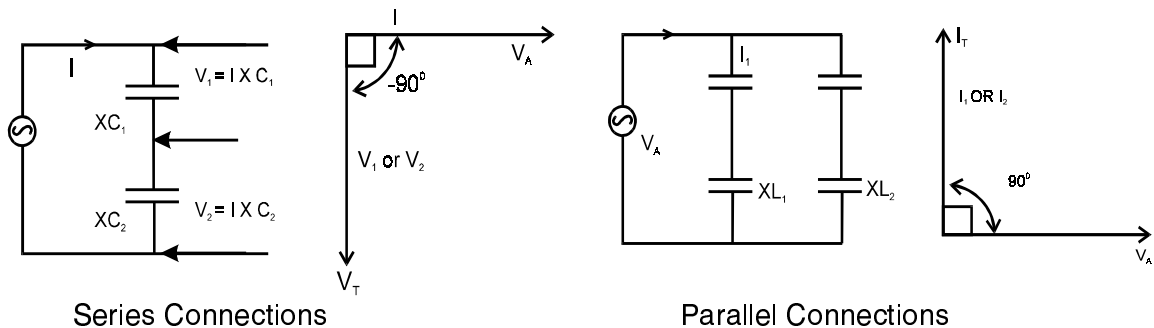


Fig. 6.3

6.5 POWER IN REACTIVE CIRCUIT

In a resistive circuit the voltage and the current are in phase with each other. Power in a circuit such as this is the product of voltage and current. When a circuit contains reactive components the voltage and current are not in phase with each other. In one extreme set of circumstances the voltage may be low when the current is high. In another

instance the opposite may be true in the circuit. When attempting to calculate power in the resistive circuit the formula to use is

$$P = VI$$

To find power in a reactive circuit, another formula is used.

$$P = I^2R$$

This formula produces a value known as the real power in the circuit.

Apparent Power:

The factor of reactance in a circuit produces an out-of-phase condition. If this factor is ignored, the amount of power in the circuit is determined by the use of formula $P = VI$. This is known as apparent power and the term volt amp (VA) is used to describe it. The term watt is used to describe unit of real power in the circuit.

Power factor:

This term is used to indicate the numerical ratio of the factors influencing power in a circuit. In series circuit, the following formula is used.

$$\text{Power factor} = R/Z$$

In parallel circuit

$$\text{Power factor} = IR / It$$

6.6 FILTER

A Rectifier is required to produce pure D.C. supply at various places in the electronic circuits. However, the output of a rectifier has pulsating character i.e. it contains a.c. and D.C. components. The a.c. component is undesirable and must be kept away from the load. To do so, a filter circuit is used which removes (or filters out) the a.c. component and allows only the D.C. component to reach the load.

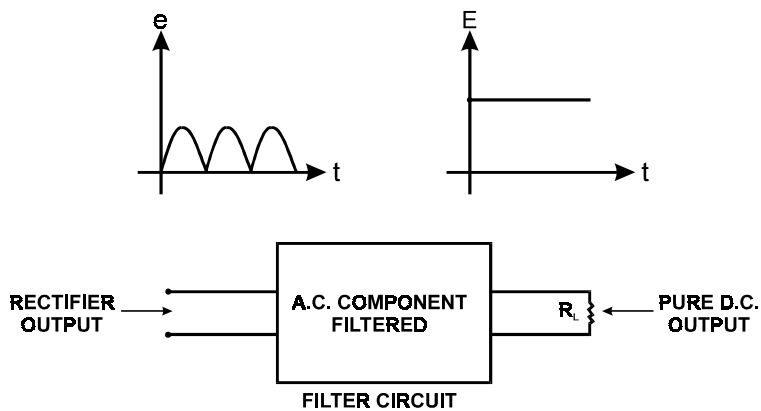


Fig 6.4

A filter circuit is a device that removes the a.c. component of rectifier output but allows the d.c. component to reach the load opposes a.c. but allows that suitable network of L and C can effectively remove that a.c. component, allowing the d.c. component to reach the load.

A filter circuit should be installed between the rectifier and the load as shown in the above fig. A filter circuit is generally a combination of inductor (L) and capacitor (C). The filtering action of L and C depends upon the basic electrical principles. A capacitor passes a.c. readily but does not pass d.c. at all. On the other hand, an inductor opposes a.c. but allows that suitable network of L and C can effectively remove that a.c. component, allowing the d.c. component to reach the load.

RC Filter:

Figure shows the typical RC filter. It is also called as capacitor filter. It consist of a capacitor "C" placed across the rectifier output in parallel with load R_L . The pulsating direct voltage of the rectifier is applied across the capacitor. As the rectifier voltage increases, it charges the capacitor and also supplies current to the load. At the end of quarter cycle the capacitor is charged to the peak value V_m of the rectifier voltage. Now, the rectifier voltage starts to decrease. As this occur, the capacitor discharges through the load and the voltage across it decreases as shown by line AB in fig (ii). The voltage across load will decrease slightly because immediately the next voltage peak comes and recharges the capacitor. This process is repeated again and again and the output voltage waveform becomes ABCDEFG. It may be seen that very little ripple is left in the output. Moreover, output voltage is higher as it remains substantially near the peak value of rectifier output voltage.

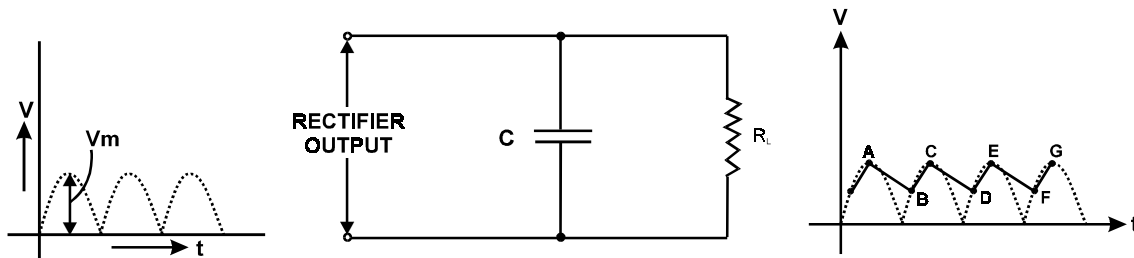


Fig. 6.5

LC Filter:

Figure shows the typical LC filter. It is also called as choke input filter. It consists of a choke connected in series with the rectifier output and a filter capacitor "C" across the load. Only a single filter section is shown, but several identical sections are often used to reduce the pulsation as effectively as possible.

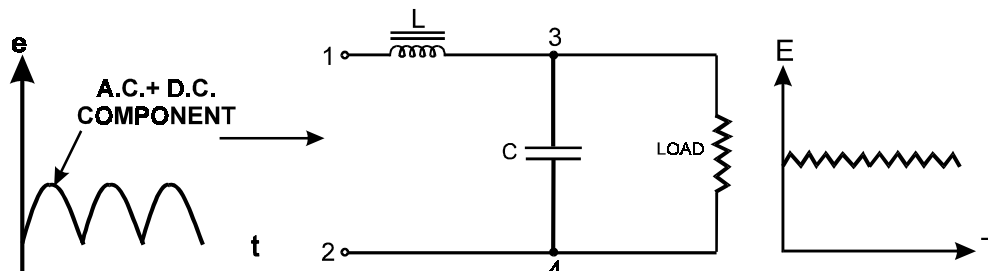


Fig. 6.6

The pulsating output of the rectifier is applied across terminals 1 and 2 of the filter circuit. As discussed before, the pulsating output of rectifier contains a.c. and d.c. component. The choke offers high opposition to a passage of a.c. component but negligible opposition to the d.c. component. The result is that most of the a.c. component appears

across the choke while whole of d.c. component passes through the choke on its way to load. This results in the reduced pulsation at terminal 3.

At terminal 3, the rectifier output contains d.c. components and the remaining part of a.c. component which has managed to pass through the choke. Now, the low reactance of filter capacitor bypasses the a.c. component but prevents the d.c. components to flow through it. Therefore, only d.c. component reaches the load. In this way, filter circuit allows d.c. component and filters a.c. component.

6.7 KIRCHOFF'S LAW

Many types of circuit have components that are not in series, in parallel or in series-parallel. For example, a circuit may have two voltages applied in different branches. Another example is an unbalanced bridge circuit, where the rules of series and parallel circuit cannot be applied. Hence more general methods of analysis become necessary. These methods include the application of Kirchoff's laws.

Kirchoff's current Law:

The algebraic sum of the current entering and leaving any point in a circuit must be equal to zero or the algebraic sum of currents into any point of the circuit must equal the algebraic sum of the currents out of that point.

Algebraic Signs:

In using Kirchoff's law to solve circuits, it is necessary to adopt conventions that determine the algebraic signs for current and voltage terms. A convenient system for currents is to consider all currents into a branch point as positive and all currents directed away from that point as negative.

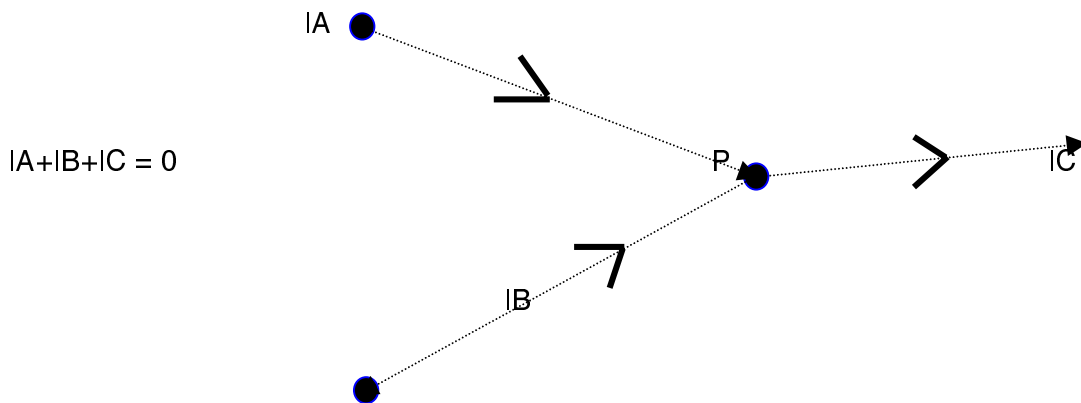


Fig. 6.7

Current I_A and I_B are positive terms because there is current flow into p, but I_C , directed out, is negative.

Kirchoff's Voltage Law (KVL):

The algebraic sum of the voltages around any closed path is zero. If you start from any point at one potential and come back to the same point and potential, the difference of potential must be zero.

Algebraic Signs:

In determining the algebraic signs for voltage terms in KVL equations, first mark the polarity of each voltage. A convenient system then is to consider the closed path and consider that voltage whose negative terminal is reached first as a negative term. Similarly any voltage whose positive terminal is reached first consider it as a positive term. This method applies to IR Voltage drops and Voltage source. The direction can be clockwise or counter clockwise.

Remember that electrons flowing into a resistor make that end negative with respect to the other end. For a voltage source, the direction of electrons returning to the positive terminal is the normal direction for electron flow, which means the source, should be a positive term in the voltage equations.

When you go around the closed path and come back to the starting point, the algebraic sum of all the voltage terms must be zero. There cannot be a potential difference for one point. If you do not come back to the start, then the algebraic sum is the voltage between the start and finish point.

You can follow any closed path. The reason is that the voltage between any two points in a circuit is the same regardless of the path used in determining the potential difference.

Loop equations:

Any closed path is called loop, starting from point "A' at the top, through CEFDB, and back to A, includes the voltage drops V_1 , V_4 , V_5 and V_2 and the Source V_T .

The inside loop ACDBA includes V_1 , V_3 , V_2 and V_T . The other inside loop, CEFDC with V_4 , V_5 and V_3 does not include the voltage source.

Consider the voltage equation for the inside loop with V_T . In clockwise direction, starting from point A, the algebraic sum of the voltage is

$$-V_1, -V_3, -V_2 + V_T = 0$$

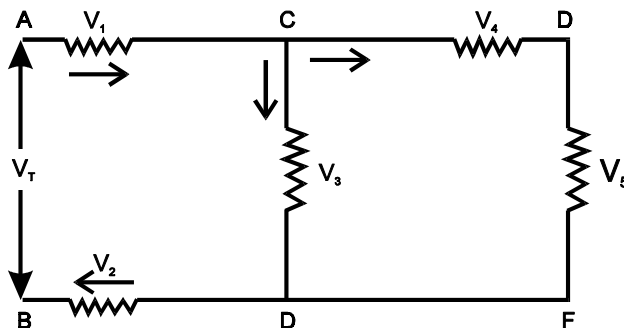


Fig. 6.8

Voltage V_1 , V_3 and V_2 have the negative sign, because for each of these voltages the negative terminal is reached first. However, the source V_T is a positive term because its plus terminal is reached first, going in the same direction.

For the opposite direction, going counter clockwise in the same loop from point B, V_2 , V_3 and V_1 have positive values and V_T is negative, then

$$V_2 + V_3 + V_1 - V_T = 0$$

6.8 STUDY OF VOLTMETER

The basic meter movement is a current sensitive device. It reacts to the flow of current through its armature windings. We have seen how the current is shifted or bypassed around the armature when a quantity greater than the maximum limit is measured. In this type of measurement the voltage applied to the parallel bank of the meter and its shunt is a constant value. It is also a very low value. The voltage required for full-scale deflection of an ammeter is usually less than 1V.

The basic meter movement is also used to measure voltage. If placing a resistance in parallel extends the current range of the meter, placing a resistance in series with the armature of the meter will extend the voltage range. A meter used to measure voltage is shown. This meter is placed in parallel with the points in the circuit where the measurement is to be taken.

The voltmeter is used to measure the difference in electrical potential, or voltage, between two points in a circuit. The series resistance establishes a voltage drop across the series string consisting of the meter (R_M) and the series resistance ($R_{M \text{ volt}}$). The resistance placed in series is called a multiplier resistor (R_{mult}). It multiplies, or extends, the voltage range of the meter movement.

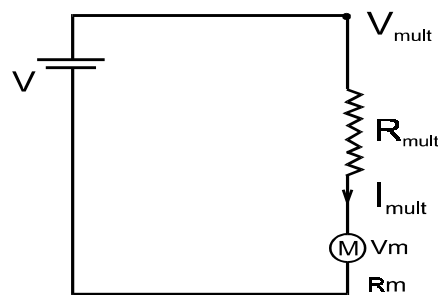


Fig. 6.9

The determination of the value of the multiplier resistance is done by use of Ohm's and Kirchoff's law. It may be done as a two-step operation or a combined one-step calculation.

Range Extension:

Changing the value of the multiplier resistance extends the voltmeter's range. Following figure shows three-multiplier resistance in use. One is selected for each specific range. Since each multiplier resistance has a different ohmic value, the meter will also measure different values of each range.

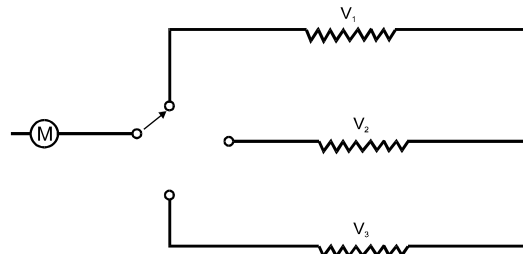


Fig. 6.10

Reading the dial:

Most multirange meters use either one or two scales for the voltmeter range. One of these is shown in figure. It is calibrated, or marked, with values between 0 & 1. Each major division is marked from 0 on the left and increasing in units of 0.1 V. There are five minor divisions, or markings, between each number. Each of these has a value one-fifth of the difference between the major values.

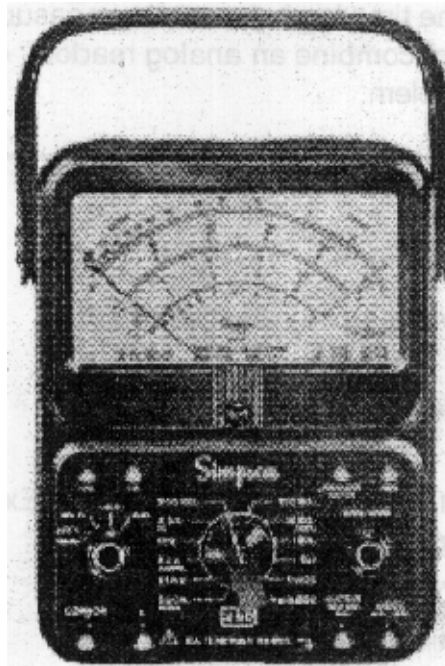


Fig. 6.11 Multimeter

Voltmeter Resistance:

Voltmeter resistance is a term used to describe the total resistance for a voltmeter circuit. This value is the ohmic value for the meter and its multiplier resistance. This value will be different for each range of the multiple-range voltmeter.

Voltmeter loading:

Effect of internal resistance of voltmeter on circuit values when making measurements.

Digital Multimeter:

There are several different types of multiple-function meters. Some of these use a meter movement as an output indicator. Such devices are classified as analog unit.

Further technological advances have provided us with a solid-state electronic instrument having a digital readout. Digital term describing meter output indicator-displaying numbers instead of a calibrated dial scale. The values given in this readout are usually very accurate. We have a tendency to feel that a value of, say 19.8 V is not acceptable when the circuit diagram calls for a value of 20.0 V. The inaccuracy may be due to tolerance values of the meter or the circuit and all may be working correctly. A judgement factor of 2 to 5% errors should be included when making comparisons between the circuit and circuit diagram. One problem usually occurs while using a CVM. This problem is related to the lack of an instant response, or read out, when attempting to adjust a circuit for a maximum or minimum value. It is very possible to adjust the system to a point either before or after the peak, due to the time lag between the measurement and the display on the meter. Some instruments combine an analog readout device with digital read out to compensate for this problem.

Review Questions

1. Discuss the following term in reactive circuit?
 - a) Real power
 - b) Apparent power
 - c) Power factor
2. What is a filter? Why it is necessary? Explain with circuit diagram?
3. Explain RC filter & LC filter?
4. State the Kirchoff's voltage and current law?
5. Write a short note on
 - a) Voltmeter
 - b) Digital Multimeter

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CHAPTER SEVEN

CELLS & BATTERIES

Features:

- 7.1 Introduction
- 7.2 Principle of Operation
- 7.3 Classification of Cells & Batteries
- 7.4 Features of Batteries
- 7.5 Measuring Cell Voltage
- 7.6 Cells in combination
- 7.7 Types of Cells
 - a) Carbon - Zinc Cell
 - b) Zinc Chloride Cell
 - c) Nickel Cadmium Cell
 - d) Wet Cell
- 7.8 Charging of Dry Cell
- 7.9 Voltage and Current in Power Source
- 7.10 Troubleshooting

7.1 INTRODUCTION

Electrical power sources have become integral accessory in the modern life style. There are various types of electrical power sources being used in the home, office and industry and their application areas are ever expanding.

An ideal electric voltage (or current) source is the one which gives optimum performance under all operating conditions . It gives constant voltage (current) for all loads, has zero internal resistance (infinite internal resistance for current source), has infinite capacity and can operate over full range of temperature and environmental conditions. Such an ideal voltage or current source (shown in fig 7.1 &7.2) is, of course, still a dream.

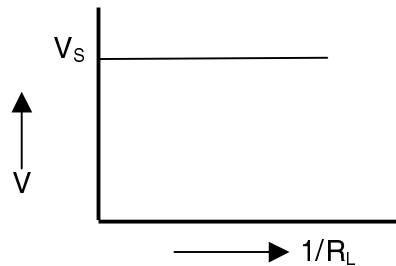


Fig –7.1 - Characteristics of Ideal Voltage Source

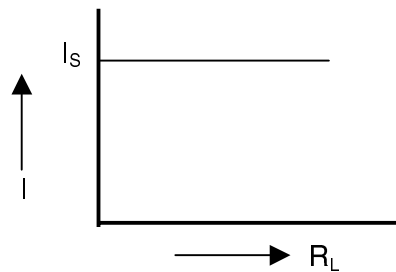


Fig –7.2 - Characteristics of Ideal current source

A practical constant voltage source has finite internal resistance. The presence of this resistance causes drop in terminal voltage of the source on load. Usually the internal resistance is much smaller than the load resistance, this voltage drop is small, hence, and the terminal voltage remains approximately constant from no load to full load. This change in voltage from no load to full load is termed as load regulation. A practical constant current source on the other hand has a high internal resistance. So far as the load resistance is small compared to the source resistance the load current remains more or less constant.

The load characteristics of a practical voltage or current source are shown fig. 7.3. There is also an upper limit of load called full load which a constant voltage or current source can deliver without violating the specified performance limits. Moreover, the performance of the practical sources is affected by other electrical and environmental conditions like change in input source parameter change in temperature etc.

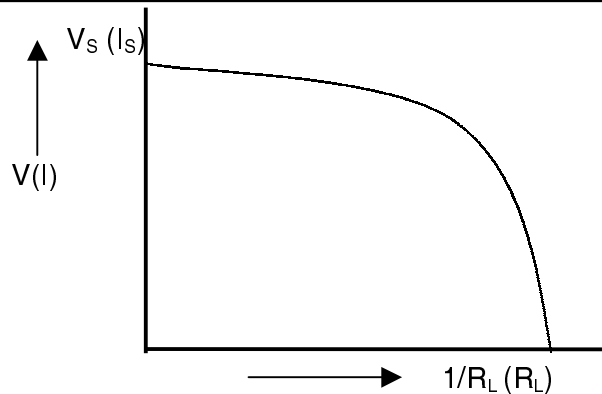


Fig-7.3 – Characteristics of constant Voltage (Current) Source

Many types of practical DC sources are available for diverse applications. Cells and batteries, electrical generators, and electronic power supplies are a few examples of the sources. These sources exhibit a wide range of capability and characteristics to suit different applications. The cell and batteries have been a popular source of portable electrical power and find their applications in home and industry alike. In the following sections operating principles, type, characteristics and applications of some well-known batteries will be discussed.

A battery can be defined as a device that converts the chemical energy contained in its active material directly into electrical energy. This is accomplished by Electro chemical oxidation-reduction reaction. The basic electrochemical unit is called a “Cell”. A battery is one or more of these cells, connected in series of parallel, or both. Basic cell consists of three major components anode, cathode and electrolyte.

The anode and cathode electrodes are electrically isolated in the cell and are surrounded by the electrolyte. A separator material is used to mechanically separate the anode and cathode electrodes; the separator material is used to mechanically separate the anode and cathode electrodes; the separator, is permeable to the electrolyte in order to maintain the desired ionic conductivity.

7.2 PRINCIPLE OF OPERATION

Discharge Process

During discharge the cell is connected to an external load; the conventional current flows from the positive electrode through the external load to the negative electrode and electrons flow from the negative electrode through the external load to the positive electrode. Inside the cell, the electrical circuit is completed in the electrolyte by the flow of negative to the negative electrode and the positive ions to the positive electrode respectively.

Charging Process

During the recharge of a rechargeable battery, the current flow in the battery is reversed of the energy is supplied to the battery. In this case the conventional current flows from the negative electrode through external source to the positive electrode of the battery or

the electrons flow from the positive electrode through the external source to the negative electrode of the battery. Inside the cell, the negative ions flow towards the positive electrode and the positive ions flow towards the negative electrode. During the charging process, the oxidation takes place at the positive electrode and reduction at the negative electrode.

After recharge, the secondary battery reverts to its original chemical state and is ready for further discharge. The cells are designed such that the chemical reaction does not take place when the cell is open; and completion of the cell causes the reaction to take place resulting in flow of current to the external circuit during discharge and flow of current in to the cell during charge.

The use of the terms anode and cathode for the positive and negative electrodes needs explanation as the actions of anode and cathode are reversed during the charging process as opposed to the discharge process. The classical definition of the anode is the electrode that oxidizes and the cathode is the electrode that reduces during an electrochemical reaction.

From the example given above, it is clear that during discharge reaction, the negative electrode acts as anode and the positive electrode acts as the cathode. On the contrary, during charge reaction, the positive electrode acts as anode and the negative electrode acts as cathode

As both charge and discharge processes are associated with secondary batteries, to avoid confusion, the terms anode and cathode are seldom used for secondary batteries, and the electrodes are designated as positive and negative electrodes.

As the primary batteries to through the discharge cycle only, for the primary batteries the Cathode is the positive Electrode, and the anode is the negative electrode.

7.3 CLASSIFICATION OF CELLS AND BATTERIES

As discussed above, the cells and batteries are available in two categories – primary (non-rechargeable) or secondary (rechargeable) batteries, depending on their capacity of being electrically recharged.

Primary Cells or Batteries

These cells can not be easily recharged and, therefore, are discharged once and discarded. The primary battery is popularly uses as source of power for portable electronic and electrical equipment. The advantage of primary batteries are good shelf life, good performance at low to moderate current loads, almost no maintenance, low cost, and ease of use. Majority of primary batteries are available as cylindrical and flat cells.

Secondary or Rechargeable Cells or Batteries

Unlike the primary batteries, these can be recharged electrically to their original condition by passing current through them in the opposite direction to that of the discharge current. These are also known as “storage batteries” or accumulators” The

secondary batteries find their applications in automobiles, aircraft, emergency no fail power sources, uninterrupted power systems and as primary or standby power in telephone and telegraph systems.

Advantage of the secondary batteries is high power density, high capacity, high discharge rate, flat discharge curve and good low temperature performance. The secondary batteries generally have energy densities lower than those of primary batteries. The charge retention of the secondary batteries also is poorer, however, the charge lost by itself discharge can be restored by recharging.

In the following sections, some of the most popular types of primary and secondary batteries are described in detail.

7.4 FEATURES OF BATTERIES

One or more chemical cells are used to produce a finished product known as a battery. The battery is housed in a container containing some chemicals. The chemicals interact to produce a voltage level, as low as 1.0 V for a single-cell battery to well over 100 V for a multiple-cell battery.

Batteries are used to produce a direct-current flow through the load. The output connections of the battery have commonly accepted terminals to connect them to the load. These include clips, buttons, and snap fittings. There are various sizes of batteries available. A voltage rating specifies all batteries.

Batteries are generally classified into two groups: primary cells and secondary cells. The difference between the two groups is simple. Primary cells are not normally rechargeable. Once their chemistry is exhausted, the cell must be replaced. Secondary cells are rechargeable. They may be used over a long period of time by keeping the charge "up" in the cells. Typical primary cells include a large group of cells, made primarily from a combination of lead and zinc. Secondary cells include lead-acid (automobile) batteries, nickel-cadmium, and some types of batteries made from a manganese dioxide mixture.

In the early days of radio, batteries were used to supply the operating power. There were three categories for these batteries. They were identified as A, B and C battery. The "A" battery was used to heat the filaments of the vacuum tubes in the radio. "B" batteries were used for the d.c. plate voltage of the tubes, and the "C" battery established a point of operation for the control elements of the tube. Even though tube-type radios requiring batteries are obsolete now, the terminology relating to the battery class function is still partially in use.

The "**A**" **battery** is a low-voltage source (still identified for its original purpose of heating vacuum tube filaments). The term "'B+' refers to the positive voltage obtained from an electronic power source, while "'B-' is used to indicate circuit ground. These terms should not be confused with an "**A**" **cell** or **type "A" cell**, which is a specific type or size of battery, not power source.

The type of chemical mix used to create the terminal voltage can also classify batteries. In a dry cell the chemical mix is moist but not in liquid form. A wet cell, on the other hand, contains a form of liquid as its electrolyte.

7.5 MEASURING CELL VOLTAGE

The operating characteristics of the cell must be tested under loaded conditions. The terminal voltage of a cell or battery that is not connected to its normal load will provide a false reading. When the open terminal voltage is measured, the terminal voltage will reflect the cell voltage without any current flowing in the circuit. When there is no current flow, there are no voltage drops across any resistance's in the circuit.

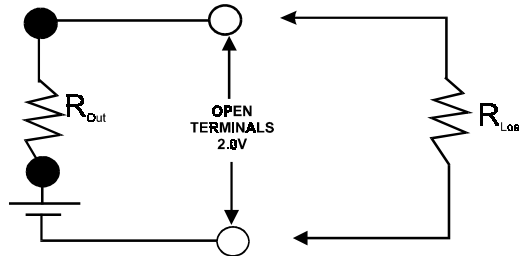


Figure 7.4 Voltage drop across the internal resistance of the cell can be determined only when the cell is connected to a load and its terminal voltage measured.

Consequently, the value of R_{int} is not reflected in the terminal voltage reading. This open circuit test is shown in Figure 7.4 Connecting the load to the terminals of the cell completes the circuit. Current will now flow and thus terminal voltage of the cell can be accurately measured. When the terminal voltage is close to the design value (2.0V in

above example), the cell is useful for practical purposes. When the terminal voltage drops to less than about 60 to 65%, it should be replaced. The exact value for replacement depends on the manufacturer's specification and also the application.

7.6 CELLS IN COMBINATION

All cells are rated for optimum terminal voltage and current. When the voltage requirement for a power source is greater than the capability of a single cell, several cells should be connected in series. This series combination will create a terminal voltage for the group of cells that is equal to the sum of the individual cell voltages.

For example, when if a 9.0V source is required, the battery manufacturer builds a battery containing six 1.5V cells, since $6 \times 1.5V = 9.0V$. Cells are also wired in parallel when current values larger than those available from a single cell are required. The rules established by Kirchoff are applied for the series voltage drops and parallel current paths. Since series voltage drops add, we can also state that series voltage sources also add in a closed-loop circuit. The same is valid for parallel circuits. Parallel current sources also add to equal total current flow.

The circuit of Figure 7.3 illustrates a series cell connection. Each cell has a value of 1.5 V and 0.5 A. When they are wired in series a voltage produced by each cell adds up to make voltage equal to 6.0V . The current flow in this configuration has only one path. It

is limited to the maximum current flow of any one cell. In this example if one cell had a current rating of 0.1 A, the maximum current flow in the series circuit would also be limited to 0.1 A.

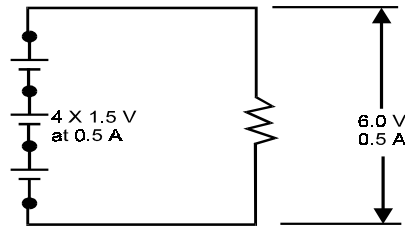


Figure 7.5 Series cells produce the sum of the individual cell voltages and a current value limited to the lowest single-cell current value.

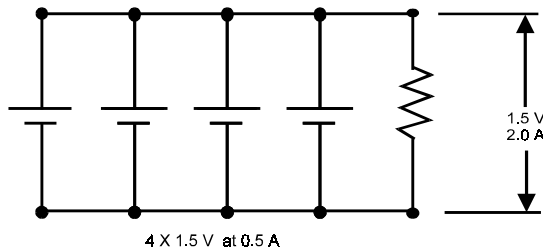


Figure 7.6 Parallel cells produce the voltage of a single cell and the sum of the individual cell current values.

lowest single-cell current value

When cells are wired in parallel (Figure 7-4), their terminal voltages have same value. In this circuit the voltage is 1.5 V for all the parallel cells. The number of parallel current sources increases the current capabilities for this parallel cell bank in the system. When four cells, each having the capacity of producing a 0.5A current, are placed in parallel, their total current capacity is equal to the sum of the current value of each. If the cells have the same terminal voltage but have different current ratings, the total current capacity is still the sum of the current capacity of each cell.

Cells are rated in terms of Ampere-Hours. This term is used to specify the amount of current available for one hour of operation. The Ampere-Hour capacity of the battery is its current rating for a specific number of hours of operation.

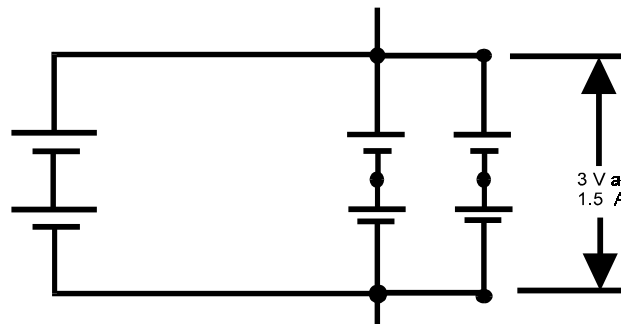


Figure 7.7 : Cells may be combined in both series and parallel to achieve a specific value of voltage and current.

Cells may also be connected in series-parallel combinations. One such arrangement is shown in Figure 7.5 This figure shows three series strings. Each string has two 1.5 V cells. The total voltage and current for each string is 3.0V and 0.5 A. When three of the strings are connected in parallel bank, the total voltage and current of the package is 3.0V and 1.5 A. Any number of different combinations of cells is possible. The cell manufacturer forms cell combinations into battery packages. The package rating has a total voltage and current capacity printed. Cells and individual batteries can also placed in series, parallel, or series-parallel combinations by the user. When a specific voltage is not readily available from the battery manufacturer, the user can create the voltage. If one requires an 18 V source, it is possible to connect two 9.0 V batteries in series. The popular 9.0 V batteries used in portable radios and calculators are readily available and are low in cost. An 18 V battery could be much more expensive and more difficult to obtain than two 9.0 V batteries. Any type of cell may be used in combination to create a battery.

7.7 TYPES OF CELLS

a) Carbon Zinc cell :

The Carbon-Zinc cell has been one of the most often used types. It has a formal name, the Leclanche cell, named after its inventor. A cutaway view of the carbon-zinc cell is shown in Figure 7.6 This cell has an anode made of zinc. Its cathode is made of a manganese dioxide mixture, and the electrolyte is a mix of ammonium chloride and zinc chloride dissolved in water. A carbon rod is used as a mean of improving conductivity and to provide electrical conductivity for cathode. The case of this cell is a zinc can. The terminals for its electrodes are located at the top and at the bottom of the case. The positive (+) terminal has a button-like terminal. The negative (-) terminal is also a formed metal piece. It normally has an indentation in its center.

The terminal voltage of the carbon-zinc cell is 1.5V It may be placed in combination to obtain 1.5 voltage of the carbon-zinc cell. The Leclanche cell is available in two basic forms. One of these is the previously shown round cell. These are available in a variety of sizes. They may be assembled and wired in combination to create a specific battery. The second form for this cell is called a flat cell. The Flat- Cell (button cells) construction is shown in Figure 7.7. Flat cells are available only as multiple-cell batteries. The major difference between round and flat cells is in their physical sizes. They both have the same chemical composition.

The carbon-zinc cell has the following major characteristics:

Cell voltage: 1.5 V
Type: Primary

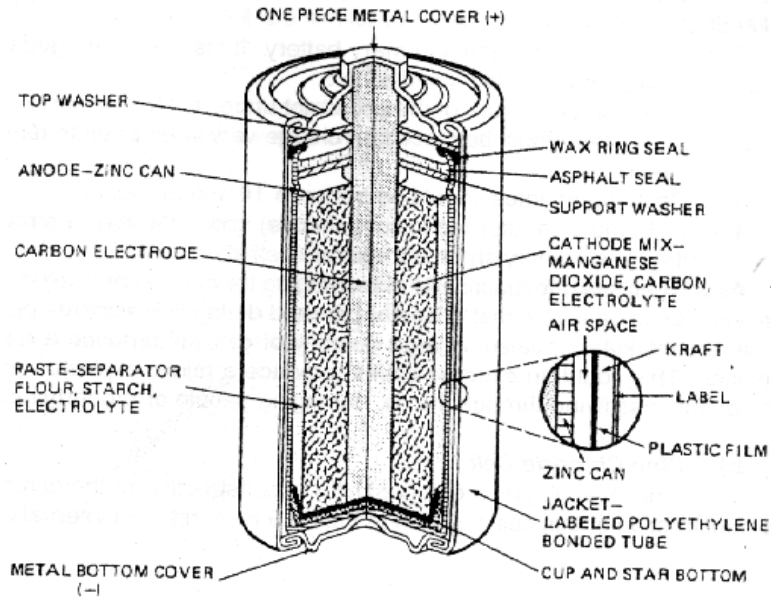


Figure 7.8 Cutaway view of a carbon-zinc cell, showing its internal construction. (Courtesy Eveready Battery Company, Inc.)

- Rechargeability: poor
- Number of Cycles: 10 to 20
- Capacity: 60 mA to 30 Ah (Ampere-hour)
- Temperature: poor low-temperature efficiency
- Operating cost: low

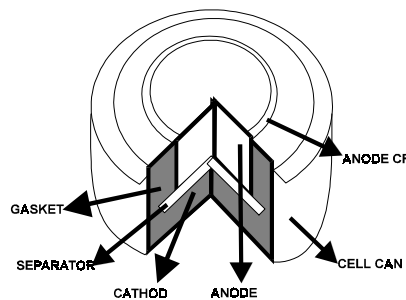


Figure 7.9 Cutaway view of a flat cell, showing its internal construction (Courtesy Eveready Battery Company inc.)

Recharging of carbon-zinc cells is not a normally accepted procedure. One may purchase a recharging unit for these cells but recharging carbon-zinc cells is not cost effective and thus is rarely recharged. A term that better describes this process is "rejuvenating" rather than "recharging ". If one wishes to utilize one of these rejuvenating unit, the U.S. National Bureau of Standards has made the following statement (National Bureau of Standard L C 965):

The dry cell is considered a primary battery. It may be recharged for a limited number of cycles under certain conditions:

1. Open-circuit voltage of the cell is not under 1.0 V.
2. The battery must be placed on charge very soon after its removal from service.
3. Recharging times should be between 16 and 20 hours.
4. Cells must be returned to service (use) soon after they are recharged, as they have a very short storage, or shelf life.

As it can be seen from above points that practicality of recharging of the carbon-zinc cell is very limited. One also has to be aware that gases are formed during the recharge period. When the cell's container is sealed, a large quantity of gas will produce a rupture of the container. This could, in extreme case, produce a minor explosion and result in parts of the case flying through the air, damaging people or property near them.

Applications

The zinc carbon dry cell is the most widely available cell and is extensively used for consumer products like flashlights, torches, transistor radio receivers, wall clocks and toys. This cell is also used in industry for battery back up, real time clock and controllers etc. mainly due to easy availability and low per unit cost.

Major advantage of the zinc carbon batteries over other primary batteries are low cell cost, low per unit energy cost, easy off the self availability of large variety of shapes and sizes and proven reliability. The disadvantage of these cells are low energy density, poor leakage resistance under bad conditions, poor low temperature performance, low efficiency under high discharge, poor shelf life and steady fall of voltage with discharge. The Alkaline Manganese Dioxide (Zinc/ Potassium Hydroxide / Manganese Dioxide) cell is getting more popular as the consumer battery mainly because its performance under high discharge conditions is much better than the zinc carbon battery.

b) Zinc Chloride Cell : Zinc chloride cell is very similar in construction to the carbon-zinc cell. The construction of this cell is shown in Figure 7.10. A different internal construction

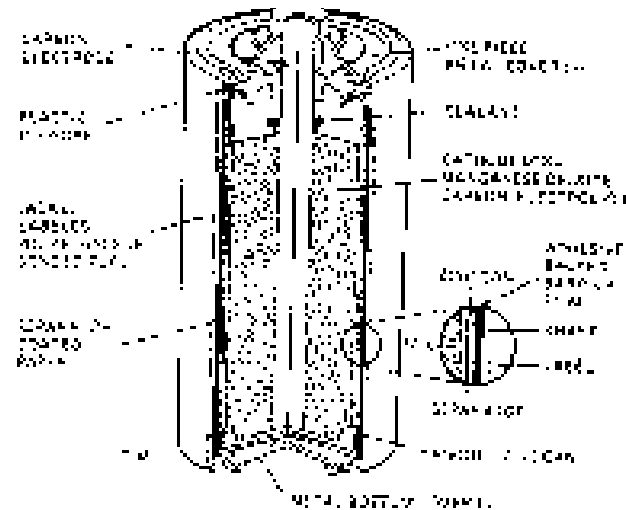


Figure 7.10 Cutaway view of a zinc-chloride cell, showing its internal construction. (Courtesy Eveready Battery Company, Inc.)

is required because of the change in the electrolyte for this type of cell. Removal of the ammonium chloride from the electrolyte permits a higher current output for a longer time period than is available from the carbon-zinc cell. Another feature is the cell's ability to maintain its operating voltage, under load for a greater time. The characteristics of this cell are similar to those of the carbon-zinc cell, except for the following:

- Capacity: Several hundred m A to 9 Ah
- Temperature: Maintains a low-temperature operation
- Cost: Low to medium

c) Nickel-Cadmium cell: Nickel-Cadmium cells have the reputation of being one of the best of the rechargeable cells. The cells are assembled into a variety of packages. The output voltage for the package ranges from 1.2 V to 14.0 V. The construction of the Ni-Cd cell, as it is called, is shown in Figure 7.9. It uses two sheets of electrodes, one positive and one negative, rolled together and separated by an electrolyte.

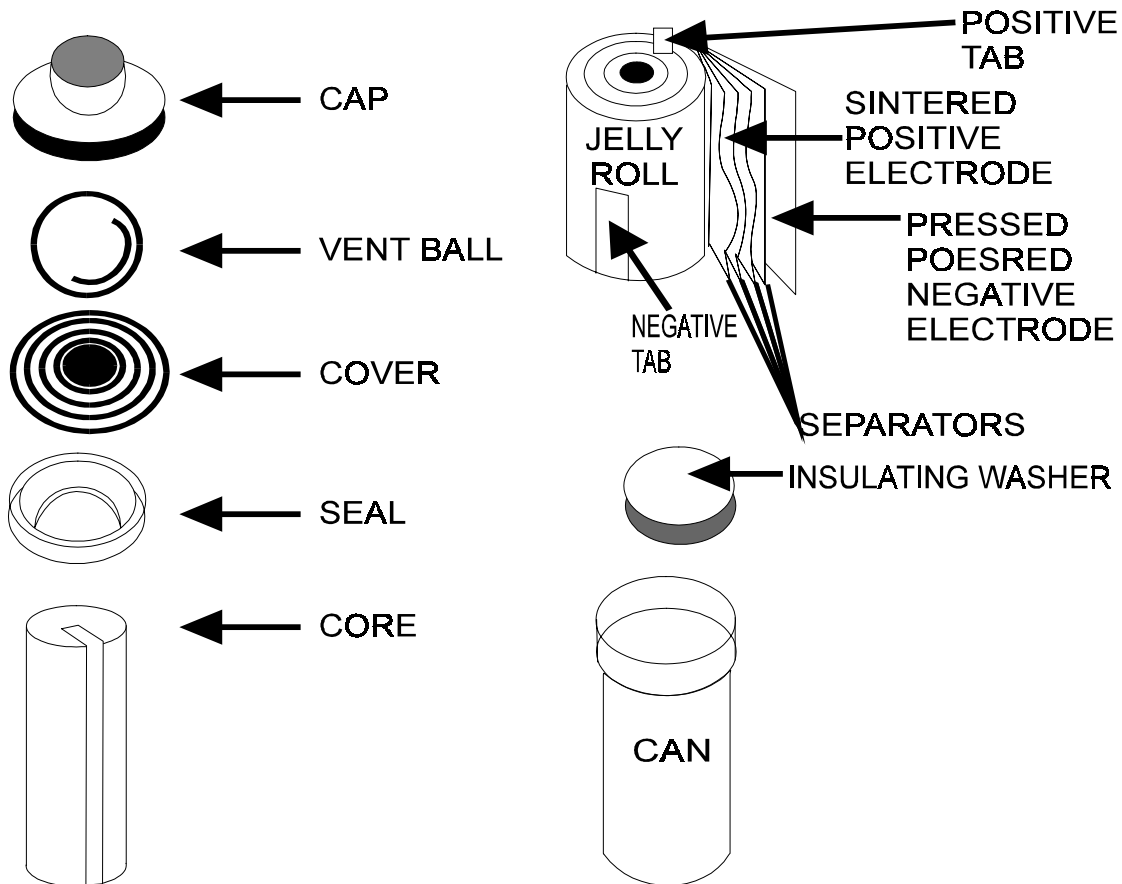


Fig. 7.9 Cutaway view of a nickel-cadmium cell, showing its internal construction (Courtesy Eveready Battery Company, Inc .)

Terminal connections maybe solder tabs or the package may use the standard cell configuration.

The chemistry of the Ni-Cd cell uses nickel hydroxide for the positive electrode. The negative electrode is cadmium hydroxide and the electrolyte is potassium hydroxide. The cell creates a normal terminal voltage of 1.2 V. These cells represent the best features of a rechargeable chemical cell.

There is a negative characteristic of the Ni-Cd cell. When the cell is connected in a series voltage source string, the rate of discharge for each of the cells in the string is slightly different. When the cells are completely discharged during operation it may create a reverse polarity condition in the first cell which then gets fully discharged. Polarity reversal results in the formation of gas in the cell as the current is forced through it (this is a negative effect). This could result in a cell rupture. A solution to this problem is to use the cell in such a manner that it does not get fully discharged.

The characteristics of the nickel-cadmium cell are :

- Voltage: 1.2V
- Type: secondary
- Rechargeable: yes
- Number of cycles: 300 to 2000
- Capacity: 20 mA to 4 Ah
- Temperature: Very good efficiency at low temperatures, poor at high temp.
- Operating cost: Low

Mercuric Oxide Cells: Mercuric Oxide Cells are made using a Mercuric Oxide Cathode, Zinc Anode, and an electrolyte of either Potassium Hydroxide or sodium hydroxide. The terminal voltage for this cell is 1.35 V. The construction of this cell is shown in Figure 7.10. These cells are commercially packaged in batteries with voltages ranging up to 97.4 V A characteristic of this cell is that its output voltage remains almost constant until

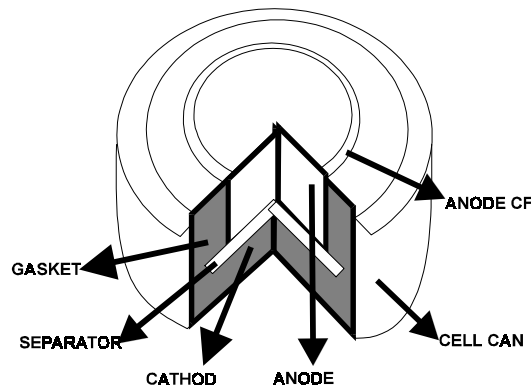


Figure 7.10 Cutaway view of the mercuric oxide cell, showing its internal construction. (Courtesy Eveready Battery Company, Inc.)

it is fully discharged. The mercuric oxide cell is classified as a primary, nonrechargeable type. Its major characteristics are :

- Cell Voltage: 1.35V
- Type: Primary
- Rechargeable: no
- Capacity: 16 mA to 28 Ah

Temperature: Poor efficiency at low temperatures, good at high temperatures
Operating cost: High

Batteries made of mercuric-oxide cells are used in television receivers, radios, test equipment, hearing aids, and electronic watches. These are just a few of the wide range of applications for this cell.

Silver oxide cells are also classified as primary cells. Their construction is the same as the mercuric oxide cell except that they have a Silver Oxide anode. This cell is capable of a terminal voltage of 1.5 V. Almost all of these cells are packaged in either 1.5 or 6.0 V output batteries. This cell is very similar in many ways to the mercuric oxide cell. It has a few characteristics that differ.

These characteristics are:
Cell Voltage: 1.5 V
Capacity: 35 mA to 210 Ah
Temperature: Good efficiency at low-temperature.
Operating cost: High

Silver oxide cells are used in a number of small electronic devices. These include photoelectric exposure units, hearing aids, electronic watches, and test instruments.

d) Wet Cell: One of the most commonly used cells where large capacities of current are required is the wet cell.

Lead acid batteries

General: The lead-acid battery is the most widely used secondary battery and its market is continuously expanding. The lead acid battery in its present form is the result of innovations in battery & its production technology in last hundred years. These batteries are extensively used for automobiles, boats, and planes (to provide the energy for engine starting, vehicle Lighting, and Engine Ignition hence the term SLI), telephone systems, power tools, communication devices, emergency lighting systems, mining & material – handling equipment, electric vehicles, emergency power systems and solar energy storage equipment. The lead-acid batteries are available in many design ,sizes and capacities. Such a wide popularity of these batteries is due to their low price, ease of manufacture, and ease of maintenance.

Operation

The positive electrode of the lead-acid battery consists of lead dioxide as the active material and the negative electrode consists of highly reactive porous form of metallic lead as the active material and the electrolyte used is a sulphuric acid solution. During discharge, both electrodes are converted to lead sulphate and the process reverses on charge.

This cell is commonly used in the automobiles. Its construction is illustrated in Figure 7.11 the plates of this cell are made of an alloy of Lead and Antimony. The electrolyte is concentrated Sulfuric Acid in water. The positive plate is Lead Peroxide and the negative plate is a spongy lead material. The chemical interaction of these materials forms a

positive electrode and a negative electrode. The discharge of the cell dilutes the water-acid electrolyte. The cell has to be recharged when this occurs. The recharging process reverses the chemical action and the plates are once again charged properly. The terminal voltage for a wet cell is 2.0 V.

Typical cell combination for the wet cell is in-groups of three or six units. These are series connected and the resulting battery terminal voltages are 6 and 12 V respectively. The ratings of these cell combinations are in terms of the Ampere-hour (Ah). This

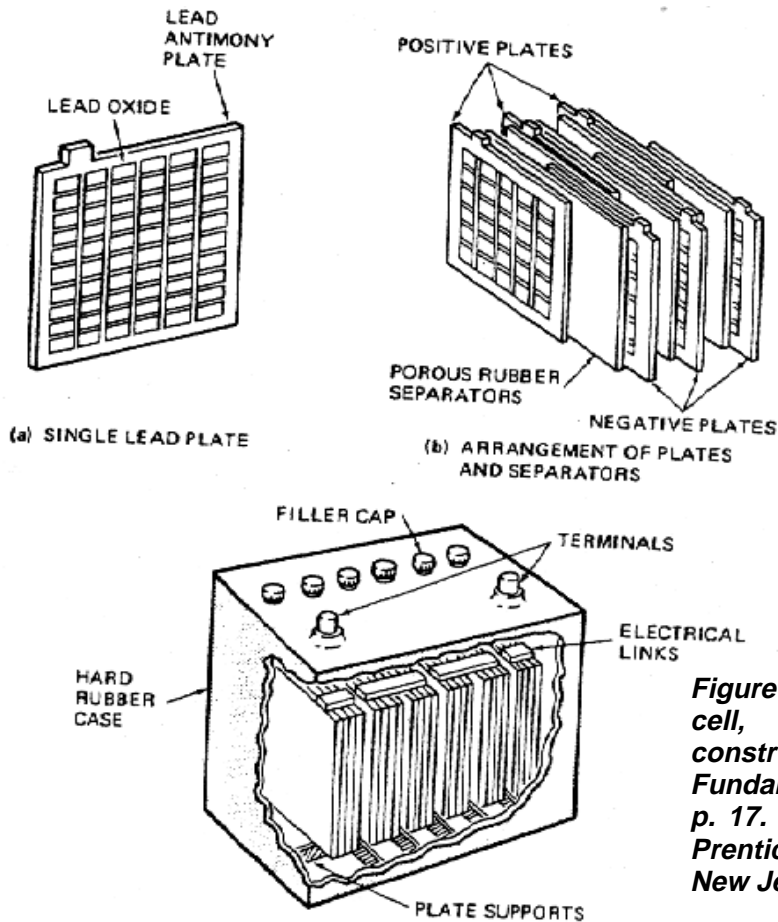


Figure 7.11 Cutaway view of a wet cell, showing its internal construction (From Joel Goldberg, *Fundamentals of electricity*, 1981, p. 17. Reprinted by permission of Prentice Hall, Englewood Cliffs, New Jersey)

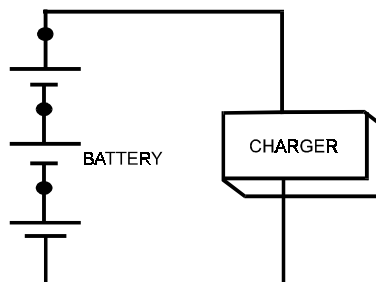


Figure 7.12 Use of a charging system to maintain terminal voltage in the wet cell battery.

terminology describes the quantity of current available for 1 h of continuous use. A battery capable of producing its rated voltage for 1 h might be rated as having a 100-Ah

capacity. This battery could also produce 200 A for 1/2 h or 25 A for 4 h before being discharged.

Charging a wet cell when discharged, the battery is connected to a charging system (Fig 7.12). The voltage source of the charger will create a reverse current flow through the cells of the battery. This action reforms the original chemical composition of the cells. The value of the charging voltage has to be slightly higher than the terminal voltage of the battery when it is fully charged or this system will not work properly. Usually, a value of around 15V will recharge a 12V battery. The system of charging will operate successfully using either a dc source or an ac operated source. The dc source most often used is the generating system of the automobile since most wet cell batteries are used in application with an internal combustion engine. It is possible, and often done, to use charging system operated from the home or business power line. The charger is actually an electrical system used to convert to an alternating current from the electric company into a direct current and for charging the battery.

The ability to recharge a cell or any other rechargeable cell is dependent on its construction. The automobile battery in recent years has undergone a design change. Batteries in new production cars require a high current output for initial motor cranking. The battery's requirements after this startup are minimal. The construction of this battery doesn't permit its recharge when it is fully discharged. When this condition occurs, The battery must be replaced.

Batteries designed for truck, boat or recreational vehicles do not have the same limitation as automobile batteries. These batteries may be run on, and then when recharged, they will accept a full charge. The best thing to do is to check the manufacturer's literature to see what conditions are required for recharging the battery.

7.8 CHARGING THE DRY CELL

The purpose of any cell or battery is to develop a potential voltaic source. The cell uses chemical energy principles to accomplish this purpose. The electrical energy is then used to perform some form of useful work. The work is performed when a load is connected to the terminals of the cell. Some of the dry cells described in this chapter are constructed from chemical systems that may be reversed. The reversal process will restore the original voltaic charge to cell. We know this process as battery or cell recharging.

The primary requirements for any battery recharging system is a dc voltage source. The source must be capable of producing a voltage that is higher than the voltage obtained from a fully charged battery. The purpose of this dc voltage is to force a current through the battery in reversal from normal direction. The electrical circuit for this was shown in Fig. 7.12.

The charging time for a dry cell will depend on the specific chemical makeup of the cell or battery. Typically, the charging rate for Ni -Cad and alkaline cell is around 20h. The methods of charging include a constant voltage, constant current and taper current processes. Specific procedures are discussed in the technical material available from battery manufacturers.

In general, the constant-voltage process indicates the presence of a fixed voltage value from the charger. This voltage is maintained during the entire charging period, usually within 1%. Current flow will be heavy during the entire charge period. This type of charger is not normally used because of its high cost and circuit complexity.

The constant - current charging source is the simplest method to use. Current between the charging source and the battery is limited by placing a large resistance in series with the cell being charged (fig. 7.13). The addition of the series resistance will aid in the maintenance of a constant current flow from the charger to the cell.

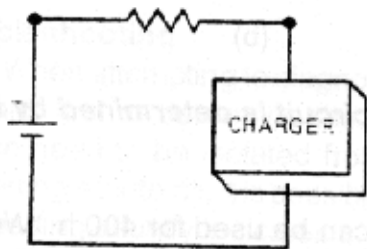


Figure 7.13 Addition of a current-limiting series resistance reduces current flow during the charging period.

The final charging method is the taper current process. This process has a high current at the beginning of the charge. Current tapers, or declines, during charging period. The characteristics of the taper, its amount and charge rate, depend on the requirements of the cell or battery. Many of less expensive types of taper chargers require adjustments by the person during the charging.

Another method of maintaining battery voltage is called trickle charge process. Most batteries have a tendency to discharge when they are not in use. This effect is true for batteries installed in equipment as well as new batteries sitting in a box or on a shelf waiting to be used. In some situations the batteries are on a "standby" basis. Equipment such as emergency lighting systems or two-way radios need to have these batteries kept in a fully charged condition. A trickle charge is connected to the terminal of the battery. A low value of voltage or current charger is placed across the battery terminals. This slow charge will maintain the battery's full capabilities and keep it ready for immediate use at all times.

7.9 VOLTAGE AND CURRENT IN A POWER SOURCE

The concept of an ideal power source is easy to understand. The ideal power source has a constant voltage output. This source also has a constant-current output. The ideal power source also has unlimited quantities of both voltage and current available. This condition exists only in textbooks. Almost all power sources have voltage and current limitations. The term ampere-hour was introduced earlier in this chapter. What occurs when the limits of the source are reached and what occurs when load demands go beyond this rating are topics of this section.

Load current values will vary depending on the value of load resistance (Figure 7.14). This factor is based on the relationships identified by Ohm. Current is 25 ma with a load of 240 ohm connected to a 6.0-V source [Figure 7.14 (a)]. The current rises to a value of 2.5 A when the load resistance is reduced to 2.4 ohm [Figure 7.14 (b)]. If the source is rated at 10.0Ah, the 240 ohm load can be used for 400 h. We calculate this by dividing the load current into the A h rating. A load of 2.4 will operate for slightly more than 4 h.

The useful life of this battery is determined by its rating and the demands of the loads it services

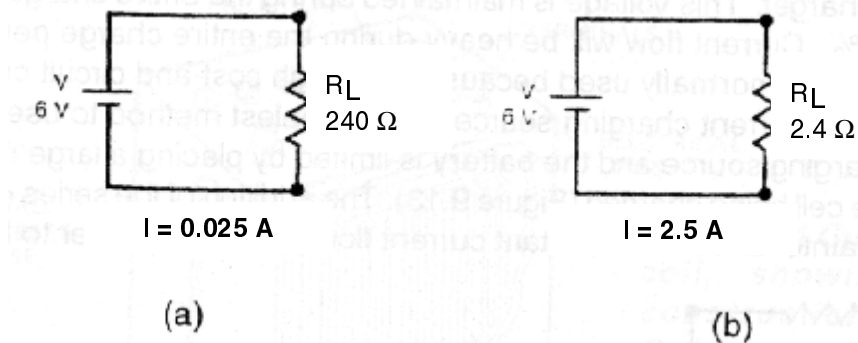


Figure 7.14 Load current in a battery circuit is determined by load resistance.

The limitations of batteries or any other type of power source include a maximum power rating factor. Power in electrical term is the relationship of voltage and current. The power formula is $P = V \times I$

Exceeding the capabilities of the power source will create a decrease in the output level of voltage from the source. This factor is explained when one considers the internal resistance. The circuit illustrated in Figure 7.15 shows this concept. A load is connected to a 50V source. The internal resistance (R_{int}) of the source is a value of 100Ω . The effect of varying loads on the output voltage of the source is described as follows: When the load resistance is $10 \text{ k}\Omega$, the current flow in the circuit is 495 mA. Voltage drop across the internal resistance of the source is 0.495 V and the terminal voltage is 49.01 V, almost the same value as the unloaded source.

When a heavy load (low resistance-high current demand) of 10Ω is used, the circuit current rises to 0.45 A. Under this condition the IR voltage drop across the internal source resistance is 45V. Since this is a series circuit, the voltage drop across the load is the difference between the source voltage and all other voltage drops. The 50 V source and its -45V internal IR drop gives a value of 5.0 V for the load. Should the load resistance decrease to 1Ω , the output voltage of the source is reduced further. The new value of output voltage is now less than $1/2 \text{ V}$.

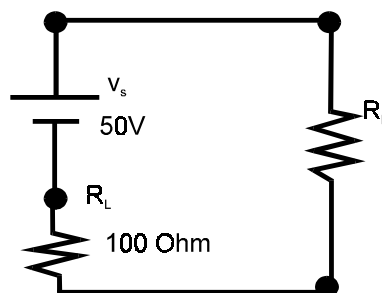


Figure 7.15 The internal resistance of the battery source is a factor in the availability of current for load operation

The concept of a voltage drop due to excess circuit current flow is one requiring acceptance by those learning all about electricity. All power sources presently known to humankind are affected by this concept. The design of a power source for any electrical

device includes its normal operating conditions. When the internal resistance of the load exceeds the design factors for the source, the output voltage of the source decreases. The effect will occur when the load circuit has a total or partial short circuit. The result is a drop in the terminal voltage from the source.

7.10 TROUBLESHOOTING

When attempting to diagnose and repair a system having a low operating voltage, one has to first determine the source of the trouble. The load and source need to be isolated from each other. When the source is a power supply converting A.C into D.C, it is possible to measure the resistance of the load. An extremely low reading usually indicates a short-circuit path in the section of the device having the resistance value below normal.

Power Transfer A voltage drop due to the value of internal resistance of the source can have an adverse effect. The purpose of the power source is to provide a maximum quantity of power to the load. When the source resistance is equal to the load resistance, a maximum quantity of power is transferred from the source to the load.

Maximum power transfer occurs when the load resistance and the source resistance are equal. This, of course, has to be some realistic value. A battery having an internal resistance of the order of 1Ω would soon be depleted when a 1Ω load was placed across its terminals. Any difference in the values of the two resistance demands the use of power. The power consumed by the extra resistance is subtracted from the total power value of the circuit. If the mismatch or unbalance occurs in the source, the difference is subtracted from the total power. The difference is the quantity remaining to perform the load's work. When the imbalance is in the load it also dissipates power and is not available to perform the required work. The undesirable power loss is often in the form of heat. The mismatched units create heat as a form of energy. This heat is dissipated into the air and is not available for useful work in the load.

One example of this is the matching of the output of a radio transmitter to its antenna system. A properly matched system delivers all the power created in the transmitter to the antenna. An improperly matched system ""reflects" the power created by the mismatch back into the transmitter. It is a negative force and its value opposes the delivery of all of the power to the antenna system. The result is the loss in the amount of power radiated from the antenna and the possibility of overheating the output stage of the transmitter. Overheating the output stage often destroys the transistors comprising this section of the transmitter.

The process of maximum power transfer is necessary for all types of machinery and electrical devices. The friction between moving parts normally creates power loss in machine. Machine designers attempt to minimize friction, as it produces heat. Energy is required to overcome the effects of friction. This energy cannot be considered as doing useful work under these circumstances.

This effect is seen in electrical circuitry in a very similar manner.

Energy is required to force electrons through a conductor. When the conductor is small the electrons bump into each other and create heat. This is a result of wasted energy.

Often a large conducting path minimizes conductor resistance and reduces the built up heat due to friction. A final example of this concept deals with the addition of speakers to audio amplifying systems. Both the audio amplifier and the speakers exhibit the qualities of resistance. When the values of the two devices are close to matching , sound reproduced by the speakers is at its loudest level. Any mismatching of values between speakers and amplifier results in a loss of level of audio output. An excess in mismatch can result in destroying the output stage transistors in the amplifier unit. What is being said can be stated in the form of a formula.

$$P_{out} = P_{in}$$

Either of the power (P) units must include analysis due to friction. This formula could be modified as follows and still be correct :

$$P_{out} + P_{loss} = P_{in} + P_{load}$$

the loss in this example being the power required to overcome electrical friction.

Review Questions

1. Explain the features of Batteries ?
2. Explain the following terms
 - a) Measuring cell voltage.
 - b) Cells in combination.
 - c) Charging of Dry cell.
 - d) Voltage and current in power source.
3. What are the different types of cells? Briefly explain Carbon Zinc cell?
4. Give a short note on.
 - a) Nickel-Cadmium Cell.

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CHAPTER EIGHT

RELAYS, SWITCHES AND PANEL COMPONENTS

Features:

- 8.1 Introduction to Relays
- 8.2 Relay Construction
- 8.3 Relays Classification
- 8.4 Characteristics of a Relay
- 8.5 Types of Relays
- 8.6 Introduction to Switches
- 8.7 Types of Switches
- 8.8 Applications of switches

Relays

8.1 INTRODUCTION

Relay is an electrical device and it functions as an electrically operated switch. Most relays are operated Electro-magnetically. When current flows through a coil, electromagnetic field is generated. The generated electrical field attracts the armature, which in turn opens or closes the electrical contacts. The time taken by a relay for this operation is in milli-second range.

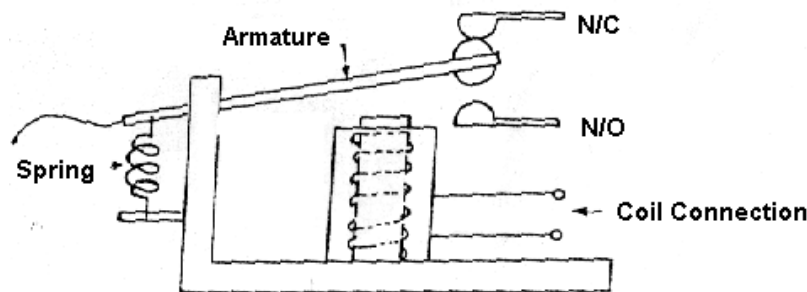


Fig 8.1 Electrical Relays

A Common type of relay having a normally open and otherwise a closed contact is shown in fig. 8.1 The normally closed contact provides a continuity between the armature and the upper contact. The spring holds the armature as shown in fig. When a desired voltage is applied to the coil, the armature is attracted to the coil and it is drawn downwards.

This breaks the normally closed contact and makes the contact open. Now the continuity exists between the armature and the normally open contact. A wide variety of sizes for relays are available.

8.2 RELAY CONSTRUCTION

The definition of relay implies that relay consists of three basic elements.

1. An actuating or exciting coil
2. Mechanical linkage to transfer the excitation /de-excitation of the coil into output.
3. Contact switching.

It consists of a coil wound over a magnetic core or rod. One face of the core is attached to a base plate that is extended to the other face of the coil. A movable plate extending to the open face of the core is attached to the base plate such that a small gap remains between the movable plate and the core. The movable contacts are attached to this plate. The fixed contacts are constructed opposite to the moving contacts. Suitable gap is maintained between the two contacts. The contact arrangement is such that when the movable plate is in contact with the core face, the contacts also get closed. The coil, when energized, produces magnetic field in the core. The open face becomes a pole of the electromagnet and attracts the movable plate. The movable plate comes in contact

of the pole face and is held firmly there, as the magnetic circuit remains close through the base plate. The contacts attached to the movable plate are now firmly held to the fixed contacts. Thus actuation of the coil causes the normally open contacts to close. The normally closed contacts are placed in such a way that they remain closed when the coil is not energized and get open actuation of the coil. A spring is fitted to the movable plate that brings the movable plate and the contacts back to their original position when the coil is de-actuated.

8.3 RELAY CLASSIFICATION

Several types of relays have been developed to perform different types of duties. They can be classified in a number of ways. In general, they are classified according to the mechanism that operates the contacts. Some of the common types are the clapper, ratchet stepper, solenoid, meter, reed, thermal and solid state relays. Relays can also be classified according to their coil design and contact structure. Following fig. 8.2 shows some of the common types of electromagnetic relays used in practice.

Relays can also be classified according to their use. For instance, relays with contact that normally carries 30A of current or more are called contractors. A relay used in motor control circuit to control the starting current is called a motor starter. Relays used as protective device to interrupt circuits, when they become overloaded are called circuit breakers. In following figure,

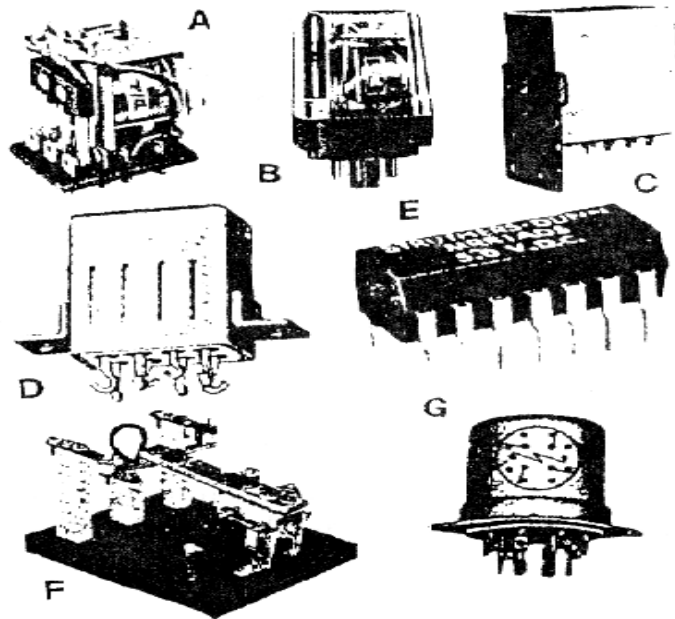


Fig 8.2 Various Types of Relays

Fig. 8.2 A = Open type of relay with solder contacts.

Fig. 8.2 B = Plug-in type of relay with a plastic dust cover.

Fig. 8.2 C = Enclosed type with solder contacts.

Fig. 8.2 D = Hermetically sealed relay for working in chemical atmosphere.

Fig. 8.2 E = Small DIP relay for directly soldering on a Printed Circuit Board.

Fig. 8.2 F = High voltage relay.

Fig. 8.2 G = Hermetically sealed type of relay with rigid specifications for military application.

8.4 CHARACTERISTICS OF RELAY

Solid state relays now occupy an important position in the field of relay application. They are slowly replacing the conventional electromagnetic relays in many applications such as telephone exchanges and power switching. In spite of this, the electromagnetic relay continues to hold a very important place in electronics and electrical engineering. Following are some different characteristics of relay.

(a) Electrical isolation of input from output: In electromagnetic relays the resistance between the input and output circuits is at least $100M\Omega$. This is about 1000 times that of semiconductor device, and is almost independent of supply voltage, time, temperature and exposure to radiation. This is not in the case with solid-state relays. Thus, the solid-state relays are a poor performer as far as the isolation characteristics are concerned.

(b) Contact resistance: The conventional electromagnetic relays and reed relays offer near infinite open circuit resistance and near zero resistance when contacts close. It thus offers distinct "on" and "off" conditions independent of temperature and supply voltage. With the solid state relays, the "contact resistance" varies with load current, temperature etc.

(c) Multiple contact arrangement: Often there is a requirement to switch many circuits with one relay closure. For example, one switch will start the motor, the second one will change the illuminated indicator from off to on, and the third will prevent other circuit indicator from operation or interference. This can be achieved with a conventional three-pole electromagnetic relay easily and inexpensively. One form A contact to switch on the motor, one form C contact to change over the indicator, and one form B contact for operation of the second circuit.

(d) Contact Sequence: Limited only by space and ease of wiring to an optimum combination of usually up to 8 contacts, the electromagnetic relay offers the facility of allowing mechanical layering between contacts.

(e) Tolerance to overloads: The conventional electromagnetic relay offers an optimum solution to the problems posed by temporary overloads. Coils can be designed to function on various supply voltages and even take continuous overloads depending on their design.

(f) Operating power range: Electromagnetic relays are available for operation on power ratings anywhere from milli-watts to watts. Both reed relays and solid-state relays usually rated for low power operation.

(g) Noise free operation: Electromagnetic relays make or break a.c. circuit at any time during the ac cycle, and this random change in state can result in an arc on contact

opening. Electromagnetic relays also generate acoustic noise, which sometimes becomes objectionable. If a large number of relays are involved solid state relays operate silently.

8.5 TYPES OF RELAYS

(a) The General Purpose Relay: The General-purpose relay has been described. These relays are low cost and are readily available. The major disadvantages of these types of relays are that they are position sensitive, have low service life, can be easily tempered with, and have poor shock and vibration resistance. General-purpose relays are used primarily in consumer electronics goods, voltage stabilizers and household electrical appliances.

(b) Power Type Relay: The power type relays are larger and rugged version of the general-purpose relays. The relay contacts are designed for heavy current (20 to 25 Amp. and more) and inductive loads primarily motors. The main disadvantages of these relays are that they are position sensitive, have poor resistance to shock or vibration and are less sensitive. The merits are that they can handle heavy loads, are easy to repair and the condition of the contacts can be determined by visual inspection. Power type relays find their applications in air-conditioning and heating equipment, household electrical appliances, and electric power control.

(c) The Telephone Type Relay: Telephone type relays are used for applications where contacts are required to operate on open circuit as well as on the capacity power. These relays are now available in many different designs offering a variety of contact forms, contact materials and variation in timing. The telephone type relays provide high mounting density, contact reliability and good sensitivity. These relays are generally insensitive to mounting position and have moderate shock and vibration resistance.

Telephone type relays are generally used for medium power loads like telephone and wired communications systems, office machines, radios computer peripherals, data processing equipment, laboratory instruments and also military systems.

(d) The Dry-Reed Relay: In the dry reed relay, the relay coil surrounds the contacts and generates a flux that acts directly on the contacts without the use of the armature. The contacts are made of magnetic materials and are enclosed in a sealed glass envelope. When the coil is energized these contacts are attracted to each other to form a closed contact. The basic reed switches are available in different forms and sizes. To obtain normally closed contacts, the contacts are biased using a permanent magnet. The sizes available can be described as regular, miniature and micro-miniature. Dry-reed relays are available in a wide variety of assemblies like open assembly, enclosed relays, potted or moulded relays, and hermetically sealed relays. The potted/moulded or sealed relays are available in various shapes and sizes like box type, Dual-In-Line Package (DIP), Single-In-Line Package.

The dry-reed relays, as the construction suggests, are susceptible to external magnetic fields. For this reason, and to improve magnetic coupling of the coil to the switches, many relays incorporate some form of magnetic shielding. Metal cases serve this function, as do internal wraps or plates affixed to the coil. In some designs, the magnetic shield is connected to a terminal, which may be grounded to provide electrostatic

shielding, but in most cases the electrostatic shield is nonferrous and separate from the magnetic shield.

Switches

8.6 INTRODUCTION TO SWITCHES

An electrical switch is a device usually used to open or close an electrical circuit. Mostly switches are manually operated devices. Switches play an important role in electronics, to stop the flow of current or send the current.

8.7 TYPES OF SWITCHES

(1) **Single Pole Single Throw (SPST) Switch:** This type of switch can connect or disconnect only a single wire circuit. These are of two types - slide type and toggle type. A typical slide type of SPST is shown in fig. 8.3. Its current rating is from 0.5 to 6A and voltage from 6V to 30 V. It is primarily used as an On-Off switch in small electrical appliances.

The common type toggle switch has a current rating approximately as 3 A of 125 V. It has wide application in low current solid state device, instruments, test apparatus and computers. Its function is to On-Off the instrument.

(2) **Single Pole Double Throw (SPDT) Switch:** This type of switch has two ON positions. SPDT are also of two types- slide type and toggle SPDT switch.

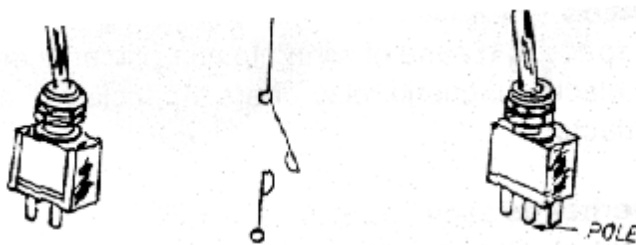


Fig. 8.3 (SPST)

Fig.8.4(SPDT)

The slide type SPDT is used for PCB mounting but toggle SPDT is used in low current devices as in SPST. Slide type SPDT is available in 1A, 4A for a voltage range of 30 V to 6V. Toggle type SPDT has a current rating of 1A, 1.5A for a voltage range of 30V and 30V.

(3) **Double Pole Single Throw (DPST) Switch:** Such a type of switch has only one position of closure but two contacts simultaneously as shown in fig.

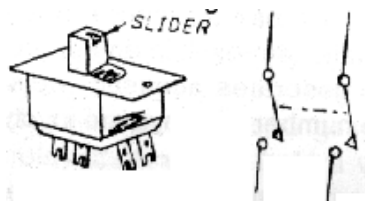


Fig 8.5 DPST Switch

It is similar to a SPST switch. The major difference in DPST switch is that both side of a two-wire line are switched at once.

(4) Double Pole Double Throw (DPDT) Switch:

This type of switch has two poles and can be moved on either side that is to the right or to the left as shown.

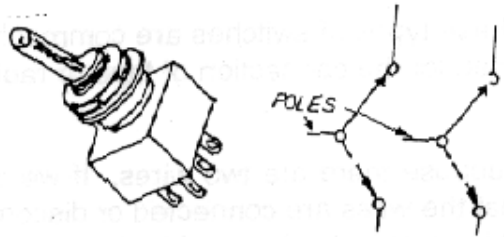


Fig. 8.6 DPDT Switch

Two DPST switches connected together can also be used as a DPDT switch. There are two types of DPDT switches

(i) Toggle type

(ii) Slide type DPDT.

(5) Micro Switches: Micro switches are various types. Basically they can be classified as illuminated rocker switches and subminiature rocker switch. But all the switches discussed above are toggle micro-switches. They are suitable for both low level and high level (power switching) applications. Normally these switches are enclosed in a nylon case. This nylon construction provides a double insulation for extra safety. This insulation resistance is generally greater than 10 M Ω . The temperature rating of micro-switches is between - 25⁰C to 70⁰C. Fig. shows different types of micro switches.

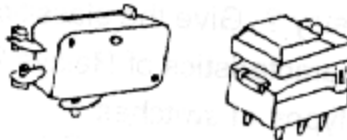


Fig. 8.7

(6) Band Switches: These switches are used in instrument such as Radio, TV, and Tape recorder to select a desired circuit. Mostly a three-band radio receiver set requires a three-position band switch. These switches are of different types-slide type or rotary type Following figure shows the band switches. Industrial grade rotary switches are suitable for all types of test and industrial equipment and heavy use consumer product.

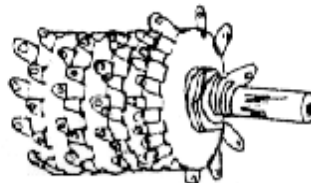


Fig. 8.8

(7) **Push Button Switches:** Both locking or latching (contacts remaining operated after the button is pressed) and non locking (contacts release after removal of the finger) designs are available. Other design variations have multiple contacts, snap action and wiper action. In most designs, state of the switch (operated or not) is determined by visual observation only. Some designs have an indication light either self-contained or separate.

(8) **Keyboards:** A wide variety of keyboards or key pads are used for providing manual input to electronic instruments such as telephone sets and adding machines. The most commonly available keyboard has a 12-button (4 rows and 3 columns) arrangement identical to the telephone instruments although keyboards with 16 and 20 button arrangement are also available.

8.8 APPLICATION OF THE SWITCHES

- (1) SPST: - The mains line switch used in the house for the on off of tube-lights. Bulbs etc. are of the type of SPST.
- (2) SPDT: - These types of switches are commonly observed in tape-recorders. They are used for the connection of tape or radio as per requirement.
- (3) DPST: - This type is known as a DPST. It is commonly observed in doorbell.
- (4) Micro switches: - Such types of switches are generally observed in our T.V.sets, in place of on-off switch etc.
- (5) Band switches: - These switches find an application in our radio receiver sets. When we want to select a particular band, say MW or SW1, or SW2 we adjust this band switch with the help of a knob.

Causes of Malfunctioning of Switches: Defects occurring in various switches used in electronic equipment most often are as follows.

- a) Broken contact
 - b) Burned contact
 - c) Shorted contact
 - d) Defective spring
 - e) Burned switch body
-

Review Questions

1. What do you mean by Relay? Give the classification of Relays?
 2. What are the different characteristics of Relays?
 3. Briefly, Explain different types of switches?
 4. What are the different applications of switches?
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CHAPTER NINE

OSCILLATORS

Features:

- 9.1 Introduction
- 9.2 Types of Oscillators
- 9.3 RC Oscillators
- 9.4 LC Oscillators
- 9.5 Crystal Oscillators
- 9.6 Timer Circuit

9.1 INTRODUCTION

Any circuit that generates an alternating voltage is called an oscillator. To generate ac voltage, the circuit is supplied energy from a dc source. The oscillators have a variety of applications. In some applications we need voltages of low frequencies, in others of very high frequencies. For example to test the performance of a stereo amplifier, we need a signal of variable frequency in the audio range (20 Hz-20KHz). The commercial oscillator available in the market for this purpose is called audio signal generator.

Next to amplifiers, oscillators are the most important analog circuit block. Oscillators can be found in almost every imaginable electronic system. For example all radio receiving systems must have a local oscillator. All transmitting systems require oscillators to define the carrier frequency. Similarly, most digital systems are clocked and require a master clock oscillator to operate. Signal sources, which are essential for testing electronic systems are also precise oscillators whose frequency and amplitude can be accurately set according to the requirement. A frequency and amplitude can be accurately set according to the requirement. A working knowledge of oscillators, their construction and operating characteristics is therefore essential to analog electronics. This module is intended to introduce the reader to oscillator types, their characteristics and considerations for their behaviour.

9.2 OSCILLATOR TYPES

Although some application may require oscillators with a very specific type of output, most applications are met via oscillators of the following types :

- 1. Sine wave oscillators :** This type of oscillator is the basic type, and is required in a very large range of applications. The main requirements from a sine wave oscillator are : frequency stability and signal purity (low harmonic content). Sine wave oscillators are used from frequencies of a few Hz to tens of GHz and to at power levels of milliwatts to hundreds of kilowatts. Therefore, a variety of circuit techniques are available depending on the frequency range and power level required.
- 2. Square wave types :** Square or rectangular wave oscillators are typically required for testing digital systems, measurement of transient response of circuits and for timing/counting applications.
- 3. Triangle and function generators :** For general laboratory use, it is often required to generate three common waveshapes: sine, triangle and square. Circuits that can generate these waveforms simultaneously are generally referred to a function generator circuits. Most such circuits produce a primary triangle wave from which the sine and square waves can be generated. Some function circuits can also produce the sawtooth or ramp waveforms.
- 4. Voltage controlled oscillators :** These are sine or square wave oscillators whose frequency can be changed in response to a voltage (or current) signal. These oscillators have become rather important in recent years as they are the basic component in all modern radio/TV and communication systems.

The following sections will discuss the basic techniques used for constructing each of these oscillator types.

9.3 RC OSCILLATORS

For application at low frequencies of upto a few hundred KHz, LC oscillators are not convenient to construct because of the large inductor values required. In this frequency range, oscillators based on R-C circuits can be used. Low frequency A very extensively used configuration is the Wien Bridge oscillator to be discussed shortly. For general applications not requiring very high purity sine waves, it is more convenient to use function generators, as various types of waveforms become simultaneously available. Another advantage of function generator is their easy voltage controlled frequency modulation. For high quality sine waves, such as those required to test distortion in an audio amplifier, for example, the wien bridge oscillator provides superior performance.

Wien Bridge Oscillator :

This oscillator is based on the Wien bridge feedback network shown in Fig 9.1. The circuit is easier to analyse if the two resistors and capacitors are assumed equal. In actual circuits also, the condition is generally followed. Setting the reactance of the two capacitors to X, the “gain” of the network (i.e. output voltage divided by input voltage) may be written as :

$$B = \frac{\frac{RjX}{(R + jX)}}{R + jX + \frac{RjX}{(R + jX)}} = \frac{jXR}{R^2 - X^2 + 3jXR}$$

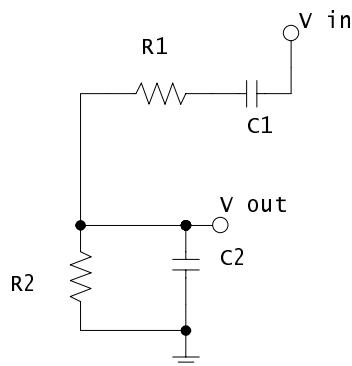


Fig. 9.1

At low frequencies, $X > R$, and the above equation indicates a phase shift of -90° indicating leading phase. At high frequencies, the phase shift is 90° lagging. This is also apparent from fig 9.1 as it can be seen that at low frequencies, the shunt capacitor can be neglected, and then the feedback is via a series capacitor which will give a leading phase shift. Similarly, at high frequencies, the series capacitor can be considered as a short and the shunt capacitor forms a low pass filter with a lagging phase. At a frequency

such that $X=R$, the gain of the network is maximum and is $1/3$, and the phase shift is zero. This corresponds to a frequency of :

$$\omega = 1/RC$$

The Wien network, therefore, satisfies the necessary conditions for providing feedback around an amplifier to construct an oscillator. The voltage transmission of the Wien network changes very slowly with frequency, and therefore the selectivity of the network is low.

A circuit using a non-inverting opamp based amplifier to create an oscillator is shown in Fig 9.2. For oscillations to begin, the gain of the opamp must exceed 3. However, once the oscillation are initiated, the gain must be reduced to exactly 3, else the oscillation amplitude continues to build up until the output voltage clips. This is a problem in all linear oscillators including LC Types. Separate circuit techniques are required to deal with this problem. In the circuit of Fig 9.2, amplitude stabilisation will require that either R2 is increased or R1 is reduced as the oscillation amplitude builds up.

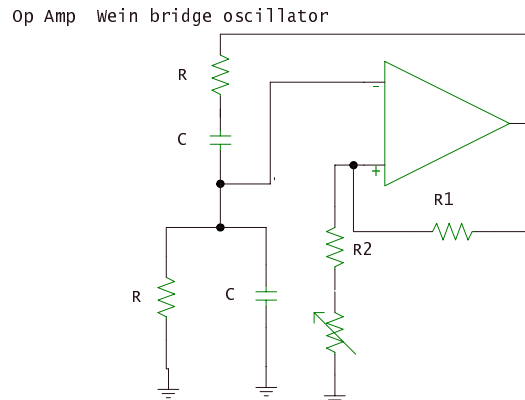


Fig. 9.2

Historically, the most popular technique is the one where R2 contains an incandescent bulb in series with it. As the oscillation amplitude builds up, the bulb heats and its resistance increases. The process stabilises at a signal amplitude where the loop gain of the circuit becomes exactly 1. This technique can produce oscillators with distortion level below 0.01%. A disadvantage is that the amplifier must be able to drive the low bulb resistance. Standard opamps cannot do this, and a buffer amplifier is required. A similar technique is to add a thermistor with R1. The higher sensitivity of the thermistor allows operation without a buffer amplifier, but an open thermistor will have a thermal time constant of tens of seconds. Hence the amplitude control will be rather sluggish.

Another technique which is easily implemented involves adding a Zener diode clipper across R1. As the oscillation amplitude rises beyond the Zener's breakdown voltage, R1 is shunted by the Zener series resistance and the amplifier gain is therefore reduced. The abrupt operation of the Zeners introduces a kink in the sine wave, and therefore distortion cannot be generally reduced below 3% with this technique. More elaborate techniques using JFETs or MOSFETs for gain control have also been used in many circuits. Nevertheless, the incandescent bulb technique still remains a favourite. Some of these techniques are to be investigated in a laboratory experiment attached with this module.

Laboratory low frequency oscillators typically cover the frequency range from a few Hz to at least 100 KHz. Wien bridges circuits can be made to cover this range by using a dual potentiometer for the two resistances and range selection switches to select different pairs of capacitors.

9.4 SINE WAVE OSCILLATORS – LC Oscillators:

Sine wave oscillators can be understood by approximation as linear systems. The classical equivalent circuit of a sine wave oscillator is shown in fig 9.3. In this model, the oscillator is considered as an amplifier of gain A with integral feedback by a factor B . Since generally, the gain A and feedback factor B will also involve phase shifts, these quantities cannot be considered to be just real numbers. A more convenient way of understanding the basic nature of the model of Fig. 9.3 is as follows :

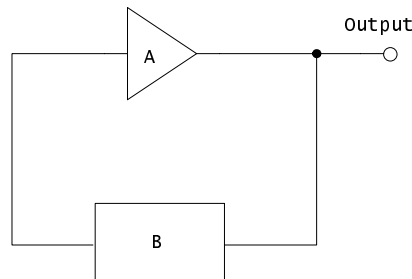


Fig. 9.3

If we imagine a signal created at the input of the amplifier (say by noise then this signal is amplified by a factor A at the output. This signal is now being fed back to the input after reduction by a factor B . If the gain around the loop is more than one, then the signal returning to the input after traversing the loop in phase with the original signal, then the signal is reinforced (positive feedback), and the output signal will go on increasing as it travels around the loop. This requirement is often called the Barkhausen criterion and can be stated as follows :

For oscillations to be sustained in an amplifier of gain A with a feedback network with a factor B , the following condition must be satisfied :

Where A and B are normally considered to be complex numbers to take account of phase.

Even if the above is satisfied, the signal cannot go on increasing for ever; it will be limited by the available power supply for example. We do not worry about the amplitude limiting mechanisms for the moment. If we wish to produce a sine wave with low distortion, then it means that the above condition must be satisfied at only one frequency. Therefore, the design of a sine wave oscillator can be viewed as consisting of two parts : design of an amplifier, and design of a feedback network which will satisfy the oscillator condition at only one frequency. In most oscillator circuits, the feedback network is a passive circuit with frequency dependent reactive components. The best performance is achieved with L-C tuned circuits as these can be easily made with high

selectivity (meaning high Q values). At low frequencies, however, the construction of inductors becomes rather difficult, and therefore the required networks must be synthesised with resistors and capacitors. Sine wave oscillators may therefore be divided into two basic types : L-C tuned and R-C tuned. The basic concepts, however, are the same for both these types.

L-C tuned oscillators can be found in any system operating above 300 KHz. Thus they are exclusively used in all radio transmitting and receiving equipment. Many L-C oscillator configurations have been used over the last 85 years or so of electronic circuits. However, they can all be viewed in a unified manner to be discussed below. To begin with, it is to be noted that the amplifier that is at the heart of the oscillator will generally be an inverting or non-inverting type, meaning that generally speaking, the feedback network is required to provide a phase shift of around 0 or 180°. This means that standard tuned circuit can be used, as these can be easily set up for such phase shifts.

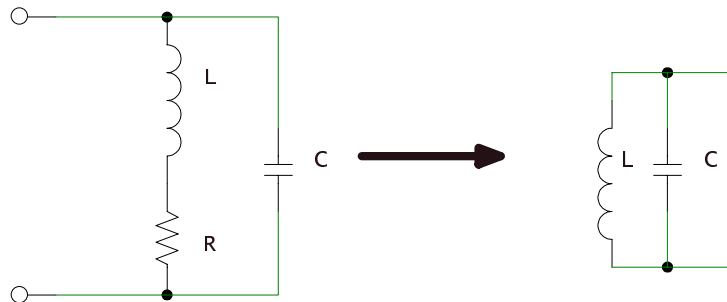


Fig. 9.4 Tuned circuit configurations

The basic parallel tuned circuit is shown in Fig 9.4. All practical tuned circuits have parasitic loss creating components caused by the resistance of the inductor windings and losses in the capacitor. It is convenient to combine these losses into a series resistor r with the inductor or a parallel resistance R with the capacitor. These two representations are equivalent, and one can freely change from one to the other. Such a configuration is frequently used in oscillator circuits for providing feedback. At resonance. The impedance seen looking into C2 may be written as :

$$Z_2 = \frac{-jX_2 \cdot (-jX_1 + jX_L + r)}{-jX_2 - jX_1 + jX_L + r}$$

At resonance, L resonates with series combination of C1 and C2. Therefore

$$jX_L = jX_1 + jX_2$$

and we get,

$$Z_2 = \frac{-jX_2(-jX_2 + r)}{r} = \frac{X_2^2}{r} \quad \dots\dots (9.1)$$

Where r is neglected in comparison with X_2
 Similarly, the impedance seen looking into C1 is

$$Z_1 = \frac{X_2}{r} \quad \dots\dots(9.2)$$

If the loading at C1 and C2 is small compared with the resonant current flowing through them, then it is also evident that the voltages across C1 and C2 are in the ratio of C2 and C1.

All L-C oscillators use a feedback network derived from the basic tapped tuned circuits shown above. The Pierce configuration is perhaps the most widely used L-C oscillator.

9.5 Quartz Crystal Oscillators

A piezo electric crystal has the property that mechanical strains and electric fields in the crystal are coupled together. As a result mechanical or acoustic resonance in the crystal can be excited by applying an electric voltage of the current frequency on the crystal. The device therefore appears as an electric resonator. Quartz technology has evolved substantially in the last 50 years. It is possible to construct quartz crystal oscillators with frequency stabilities of 1 part in 10^9 over months. Better stability can be obtained only by atomic maser based oscillator. The electrical equivalent circuit of a piezoelectric resonator is shown in fig 9.5. C_0 is essentially the package and lead capacitance. R, C and L are modelled electrical variables as there is no inductance or capacitor inside the crystal. For a 10MHz crystal, the crystal impedance exhibits a minimum impedance at a frequency below its specified frequency of 10 MHz. This frequency f_s corresponds to series resonance of the notional inductance and capacitance L and C. The terminal impedance is essentially the loss resistance R.

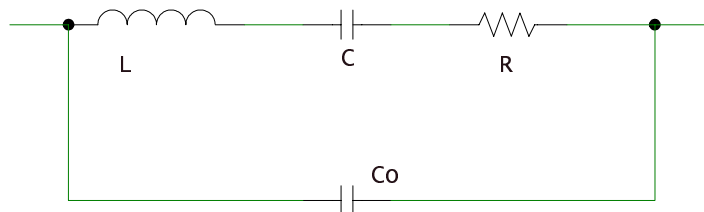


Fig. 9.5 Crystal Equivalent Circuit

At frequencies above the series resonant frequency, the impedance of the crystal is inductive as shown by the phase angle of 90 degree of the crystal impedance. As the frequency is raised, a parallel resonance is seen as a frequency f_p . This frequency corresponds to the situation where the terminal capacitance C_0 resonates with the inductive result of the series combination of L and C. At frequencies beyond f_p , the crystal impedance becomes capacitive again, primarily because of terminal capacitance C_0 . The useful operating range of a quartz crystal is the frequency band between the series and parallel frequencies where the crystal impedance is inductive. In fact, replacement of an inductor in a tuned circuit with a crystal will generally result in the circuit oscillating at some frequency in this range, provided enough gain is available in the circuit. The exact frequency is determined by the net shunt capacitance applied across the crystal by the circuit. Commercial crystal are one of two types :

- (a) parallel resonant and
- (b) series resonant.

The former types are designed to oscillate at the specified frequency when loaded with a specified shunt capacitance (an accepted standard is 32 pF). The series are designed for operation at series resonance with essentially zero shunt capacitance. It must be noted that every crystal, irrespective of its type has a series and parallel resonance frequency. The difference is only in the way the crystal frequency is specified. Also, at the specified frequency of 10.00 MHz, the crystal impedance is inductive with a reactance of 558Ω . This reactance corresponds to a capacitance of 28 pF at 10 MHz, very close to the specified 32pF. In any practical circuit, the crystal frequency needs to be adjusted to its nominal value via a variable capacitance across it. Usually, variation of only a few pF is all that is required.

It is apparent that none of the L-C oscillator circuits shown so far can oscillate at the crystal's series resonant frequency because all those circuits require a tapped capacitor to be connected across the crystal. This is one reason for the lesser popularity of the series resonant crystal types.

9.6 TIMER Circuit - 555

No discussion of oscillators can be completed without a discussion of the NE555 timer IC. Developed in the early seventies, this chip rivals the 741 opamp in its popularity with generations of designers. A schematic diagram of the chip is shown in fig. 9.6. The circuit consists essentially of an S-R flip-flop, two voltage comparators and a few gates.

The internal logic is organised as follows : The output is high when Q in the internal S-R flip-flop is high. The flip-flop can be set via comparator C1 when the Trigger input goes below $V_{cc}/3$. Similarly, the flip-flop can be set low by C2 when the THRESHOLD input goes above $2V_{cc}/3$. When the output is low, the DISCHARGE pin is pulled low by internal transistor Q1. The RESET input when taken below the power supply by about 0.6V turns on the internal pnp transistor which forces the flip flop into the reset state, and forces the output low. In this mode, the circuit is locked out and the flip-flop cannot be flipped by external signals. The RESET input therefore can also be viewed as a "DISABLE" input.

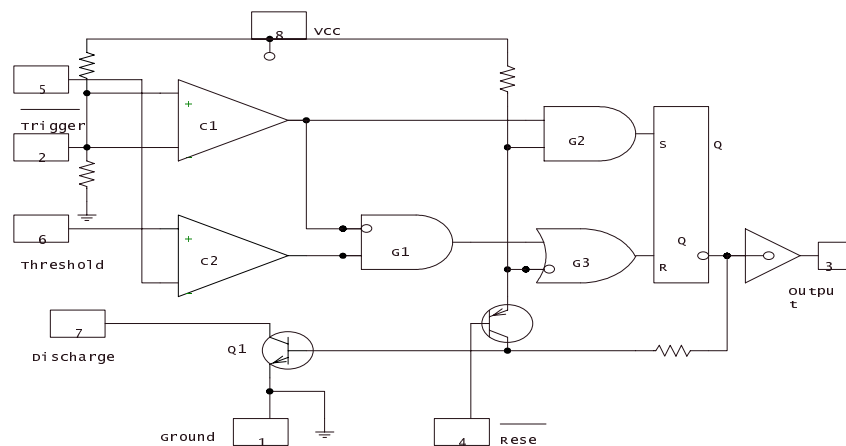


Fig. 9.6 Schematic of 555 timer IC

The simplest use of the 555 is as a monostable multivibrator shown in Fig. 9.7. Notice that the THRESHOLD and Discharge pins are strapped together and a capacitor C

connected to ground. In the reset state, C is kept discharged by the internal transistor Q1. When an external signal is applied to the TRIGGER input that takes it below $V_{cc}/3$, the flip-flop is set, the output goes high and Q1 is turned off. C then begins to charge towards V_{cc} through R. When the capacitor voltage reaches $2V_{cc}/3$, the threshold comparator C2 clears the flip-flop that switches the output low and turns on Q1 which discharges C. The circuit then returns to its stand by state. A pulse is therefore produced at the output. The duration of this pulse is simply the time it takes for an RC circuit to charge up to $2/3$ of its supply voltage. This time is given by :

$$T = RC \ln \left[\frac{1}{1 - \frac{2}{3}} \right] = RC \ln 3 = 1.1 RC$$

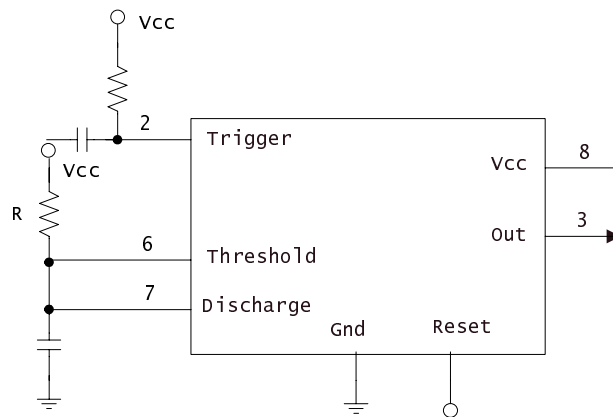


Fig. 9.7 Monostable multivibrator using 555 IC

Note that the pulse period is independent of the power supply. In fact it depends only one aspect of the 555's internal circuit, and that is the threshold voltage's deviation from $2/3 V_{cc}$. As shown in Fig. 9.6, the threshold voltage is obtained by a voltage divider that uses 3 identical 5K resistors on the chip. While the absolute value of these resistors cannot be controlled, being on the same chip, temperature. Therefore, the above equation for the pulse duration is generally accurate to within about 2% even if the 555 IC is changed. A very important reason for the 555 circuit's continued popularity even about 25 years after its design is this predictability of its timing at low cost. When this chip was introduced around 1971, it represented a quantum jump in the design of accurate low cost timer circuits.

The $2V_{cc}/3$ reference voltage inside the 555 is also brought out to pin 5 of the IC. This serves two functions. Firstly, the timing can be made stable with respect to supply voltage noise by adding a capacitor from this pin to ground. Secondly, the internal threshold and trigger voltages can be modified by driving this pin via an external voltage. The 555 timing periods can therefore be voltage modulated.

The output circuit of the 555 can sink or source more than 100mA of current with a supply voltage as low as 4.5V. The data sheets specify the device for operation from supply voltages of 4.5V to 16V, but in fact the chip works reliably down to 3V or so, and is partially functional even at 2.5V!

By today's standards, the power consumption of the 555 is rather high as it consumes several mA of current for internal circuit operation. Furthermore, the 555 also has a drawback in that when the output stage changes state, it draws a pulse of high current from the power supply due to simultaneous conduction of the output stage source and sink transistors. In practical circuits, the 555's power supply must therefore be buffered with a few μF of capacitance across the supply placed physically close to the 555. These two problems have been overcome by a new generation of 555 "clones" (much like IBM PC clones!). These circuits are generally CMOS types and therefore consume only a few μA of current (they of course lack the drive capability of the original 555) and are free of the supply current pulse. Being CMOS devices. The THRESHOLD input draws only picoamperes of current, hence timing resistors as high as $1000\text{ M}\Omega$ can be used leading to timing possibilities of hours with capacitors of a few μF . Realisation of such circuits, however requires very careful layout to keep stray current leakages low. A popular CMOS version of the 555 is the 7555 introduced by INTERSIL but presently manufactured by many vendors worldwide.

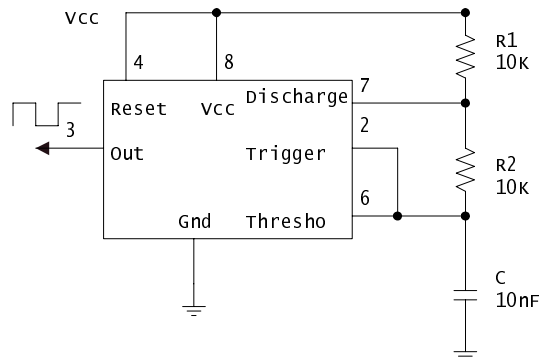


Fig. 9.8 Astable multivibrator

555 as astable multivibrator is shown in Fig. 9.8. If we assume that the voltage across C is zero., the input is low and output is high. Then the internal discharge transistor is off and C charges up. The output goes low when capacitor reaches $2V_{cc}/3$ and discharge transistor turns on. Through R_2 the capacitor C discharge and when the capacitor voltage reaches $V_{cc}/3$, the output goes high. The capacitor voltage cycles between $V_{cc}/3$ & $2V_{cc}/3$.

Setting $V(t) = 2V_{cc}/3$ and solving for the time period we get the charging time as :

$$T_1 = (R_1 + R_2) C \ln 2 = 0.69 (R_1 + R_2) C$$

Setting $V(t) = V_{cc}/3$, the discharge time can be written as :

$$T_2 = R_2 C \ln 2 = 0.69 R_2 C$$

Adding the charge and discharge times, the total time period of oscillation is :

$$T = 0.69 (2R_2 + R_1) C$$

Review Questions

- Q-1 Construct a square wave oscillator using 555 timer.
- Q-2 Explain the electrical characteristics of quartz crystals.
- Q-3 What is the basic principle of operation of an RC oscillator?
- Q-4 Draw a crystal controlled oscillator circuit. State some of its applications.

NOTES

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CHAPTER TEN

ACTIVE COMPONENTS

Features :

- 10.1 Semiconductors
- 10.2 Semiconductor Diodes
- 10.3 Causes of failures in Semiconductors
- 10.4 Zener Diode
- 10.5 Introduction to Bipolar transistor & Its Application.
- 10.6 Uni- Junction Transistor
- 10.7 Field Effect Transistor
- 10.8 Metal Oxide Semiconductor FET (MOSFET)
- 10.9 Silicon Control Rectifier
- 10.10 Rectifier Circuits
- 10.11 Testing of Transistors.
- 10.12 Testing of Semiconductor diode.
- 10.13 OPTO Devices

10.1 SEMICONDUCTORS

Germanium (Ge) and Silicon (Si) are examples of semiconductor materials that are neither conductors nor insulators. Their electrical conductivity is between that of a conductor and insulator. When isolated germanium and Silicon atoms have four valence electrons (i.e. electrons in the outer orbit).

Semiconductors are divided into two types:

INTRINSIC SEMICONDUCTORS- A semiconductor in the pure form is called intrinsic semiconductor (for example pure silicon and germanium). At room temperature the number of free electrons and holes in an intrinsic semiconductor is insufficient for practical applications.

EXTRINSIC SEMICONDUCTORS- Since intrinsic semiconductors are of little use, impurities have to be added for better results. Doping semiconductors with impurities does this.

N-TYPE SEMICONDUCTOR- By doping Si or Ge with pentavalent impurity for example, Phosphorus, Arsenic or Antimony we get N type semiconductors. By doping with a pentavalent impurity the number of electrons increase and hence there is excess of electrons. These excess electrons contribute to the flow of current.

P-TYPE SEMICONDUCTOR- By adding trivalent impurity for example, Boron, Aluminium, Gallium or Indium to an intrinsic semiconductor, we get p-type semiconductor. This increases the number of holes and therefore these holes contribute to the current.

P N JUNCTION- A P N junction is formed by combining a P-type material and an N-type material together.

A P N junction has the ability to conduct in one direction only .In the reverse direction it offers very high resistance. As soon as a P N junction is formed, the following takes place.

Holes from P region diffuse into the N region and combine with the free holes. This occurs due to thermal energy and difference in concentration .The diffusion of holes and free electrons occurs for a very short time.

The electrons in the P-type region and holes in the N-type region, in the neighborhood of the junction form a barrier.

This is called the depletion region because there is a depletion of mobile charges .An electric field is created at the barrier. The barrier potential is about 0.7V for silicon whereas it is 0.3V for Ge. The barrier does not allow the majority carriers to diffuse any further.

10.2 SEMICONDUCTOR DIODES

When a piece of P-type Semiconductor material is combined with N-type material then the junction of the two materials is known as a P N Junction.

Forward Biased P N Junction: The P N junction forms a voltage-polarity-sensitive resistance. Fig. 10.1 shows the positive element of the power source connected to the P-type material and the negative element of the power source connected to the N-type material. The negative charges, known as Electrons are forced towards the P N junction in N-type material. Whereas the positive charges, known as Holes, are forced toward the P N junction in P-type material. The meeting of these two opposite charges effectively neutralizes the junction. The result is a very low resistance across the P N junction. This type of junction with its voltage polarity is called a forward biased junction.

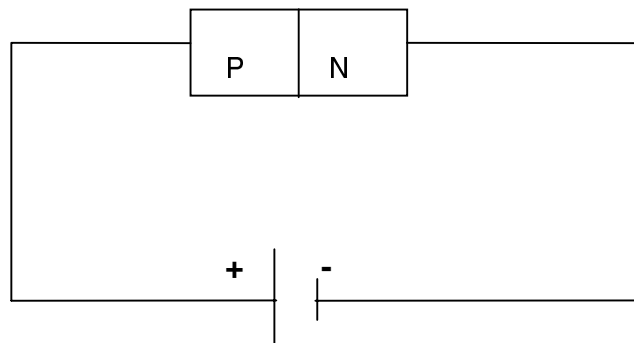


FIG. 10.1 Forward Bias

The forward-biased P N junction exhibits a very low resistance. When a voltage is applied to this junction, it forces a current flow through the semiconductor device. Since the junction has a relatively low resistance, a low value of voltage will permit a relatively large current flow. When a silicon semiconductor junction is forward biased the voltage drop occurring across it amounts to about 0.7 V. Similarly, a germanium P N Junction has a voltage drop of about 0.2 V, when it is forward biased. When the polarity of the applied voltage is reversed, the charges in both the P-type material and N-type material move away from the P N junction. They move towards the connections to the power source. This forms an area at the P N junction that has a lack of charges. The P N junction becomes an insulator under these conditions. This is known as a reverse-biased junction.

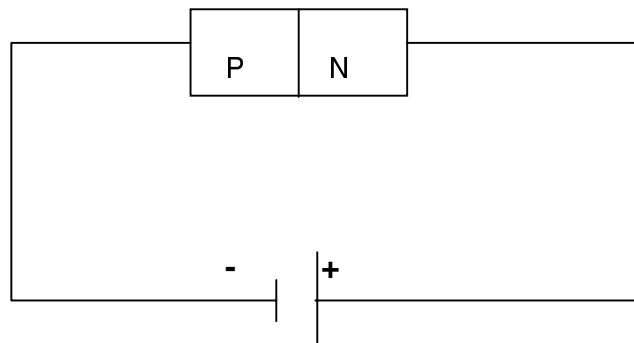


FIG. 10.2 Reverse Bias

The internal resistance of this junction is extremely high. There is little, if any current flow through the P N junction when it is reverse biased. The voltage drop that develops across the junction is very high under these conditions.

Diode Characteristics: The semiconductor has certain basic characteristics. The fundamental characteristics are (1) Forward current and (2) Reverse voltage.

Forward Current: Describes the maximum quantity of current that can safely be allowed to flow through the diode and its junction.

Reverse Voltage. Reverse voltage is a term applied to conditions existing when the diode is reverse biased. The diode exhibits a very high resistance when it is reverse biased. The voltage drop developed across its terminals is also very high. The diode has a breakdown voltage rating. This rating is the maximum voltage that can be applied to the diode when it is reverse biased without its insulation breaking down. When the insulation of the diode breaks down, it becomes a conductor.

Diode Elements and Symbols: The diode has two elements. The two elements of the diode are known as the anode and the cathode. The schematic symbol for the solid-state diode is shown below.

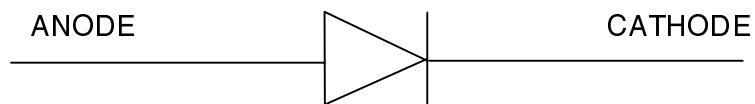


Fig 10.3 Symbol of Diode

When the diode cathode has negative voltage charge on it and the anode has a positive voltage charge, the diode is forward biased. The internal resistance of the diode is very low. It is of the order of 10Ω to about 1000Ω for low current rated diodes and less for diodes rated 1A or higher. When a voltage is applied to the diode's element the polarity of the applied voltage determines the internal resistance of the diode.

When the polarity of the voltage is reversed, the negative terminal of the source is applied to the anode of the diode. The diode is reverse biased under this condition. The internal resistance of the diode becomes infinitely high.

10.3 CAUSES OF FAILURES IN SEMICONDUCTORS

- a) The device may have inherent weakness due to improper manufacturing.
- b) Failures can be caused by misuse.
- c) By exceeding the maximum rated value of voltage, current and power for a particular semiconductor device.
- d) Electrical interference is one of the causes of premature failures.

Testing Semiconductor Diodes: Since the semiconductor is a voltage-dependent resistance it is possible to test its resistance to determine if it is in working condition. The process for using the ohmmeter to test a diode is very simple. The positive, or red, lead of the ohmmeter is usually connected to the positive lead of its internal battery. When the two leads of the ohmmeter are connected across the terminals of the diode, a bias

voltage is applied to the diode. If the diode is forward biased the resistance reading will be under 5 K Ω . The specific value depends on the range setting of the ohmmeter. Usually, a range of R \times 1 K Ω is used for this test. If the diode is forward biased, the voltage at the test leads of the ohmmeter will produce a current flow and the meter will read a resistance value.

When the test leads, or the diode leads, are reversed, the diode is reverse biased. Its internal resistance is very high, but when current flow occurs it gets low under the condition when the test leads are connected. The ohmmeter will indicate an infinitely high value of resistance. In many tests the ohmmeter will not indicate any reading of resistance. The diode test is therefore a test of its resistance under forward and reverse-biased conditions. If the diode shows the similar resistance values in both directions, the diode has failed.

10.4 ZENER DIODES

When a constant-voltage output from a DC power source is required, a device known as Zener diode may be used. This device looks the same as any other diode. It is denoted

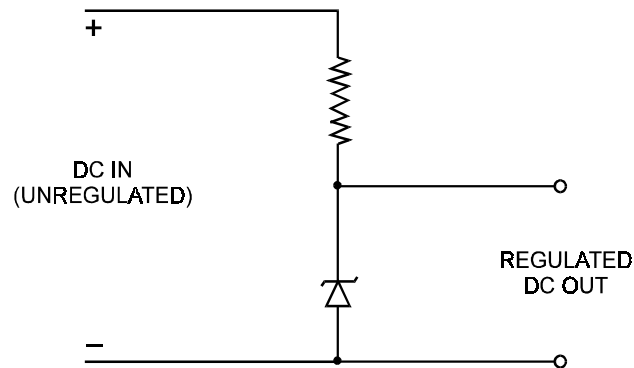


Fig 10.4 Zener Diode

by the special schematic symbol, shown within the basic circuit diagram of the above figure 10.4. To make a DC voltage regulator, the Zener diode is connected in reverse bias. Its anode is connected to circuit common and its cathode is connected through a series resistance to the positive terminal of the power source. The resistance of the Zener diode will vary during circuit operation. It attempts to maintain a constant voltage across its terminals under varying current conditions in the circuit. In this manner it acts as a voltage regulator. The Zener diode is placed in parallel with the load. When the load resistance decreases, the Zener diode's internal resistance will increase. This will restore the voltage to its original value. When the load resistance increases, the Zener resistance will decrease. This also restores the output voltage to its original value.

Zener diodes Characteristics: It is just like an ordinary silicon diode. In the leakage region (between zero and breakdown), it has only a small leakage or reverse current through Zener diode, the breakdown has a very sharp knee, followed by an almost vertical increase in current. Note that voltage is almost constant. Approximately it equals V_z over most of the breakdown region.

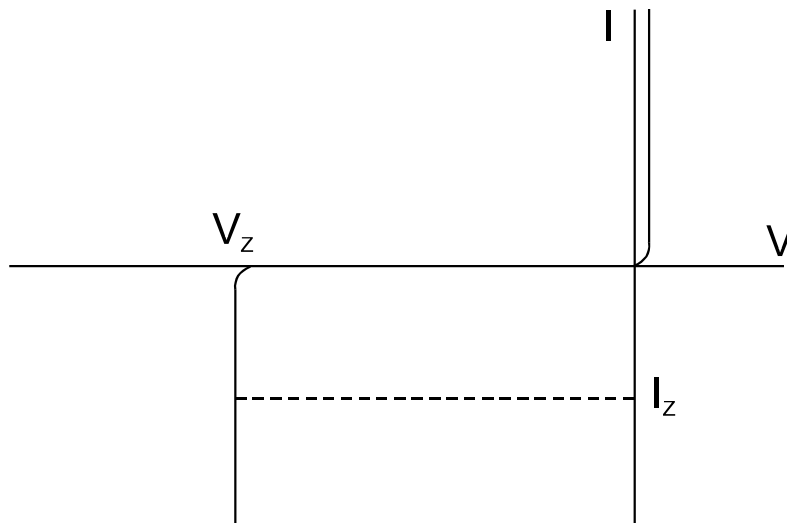


Fig. 10.5 Zener Diodes Characteristics

The Schottky Diode: At lower frequencies an ordinary diode can easily turn off when bias changes from forward to reverse. At higher frequencies, it can not turn off fast enough to prevent noticeable current during part of the reverse half cycle. The above problem can be solved using Schottky diode.

The Schottky diode uses a metal like gold, silver or platinum on one side of the junction and doped silicon (typically "N" type) on the other side. When the diode is forward biased, free electrons on the N type semiconductor side can gain enough energy to travel in larger orbits. Because of this free electrons can cross the junction and enter the metal producing a large forward current. Since the metal has no holes, there is no charge storage and no reverse recovery time. So lack of charge storage means that Schottky diode can be switched off faster than P-N Junction diode.

The important application of Schottky diode is in digital computer where fast switching of logic circuit is required. The following fig. shows the symbols for Schottky diode.

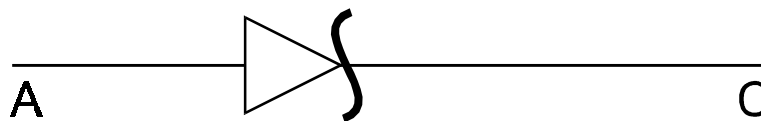


Fig 10.6 Symbol of Schottky Diode

10.5 INTRODUCTION TO BIPOLAR TRANSISTOR & ITS APPLICATION

When a third doped element is added to a crystal diode in such a way that two P-N junctions are formed, the resulting device is known as a transistor. The transistor is capable of achieving amplification of weak signals. Transistors are far smaller than vacuum tubes, have no filament and hence do not need power to heat the filament. They are mechanically strong, have practically more life and can do some jobs better than vacuum tubes.

Transistors: A transistor consists of two P N junctions formed by sandwiching either P-type or N-type semiconductor between a pair of opposite types. Accordingly there are two types of transistors:

i) N-P-N transistor

ii) P-N-P transistor

An N-P-N transistor is composed of two N-type semiconductors separated by a thin section of P-type as shown. However, a P-N-P transistor is formed by two P-sections separated by a thin section of N-type semiconductor.

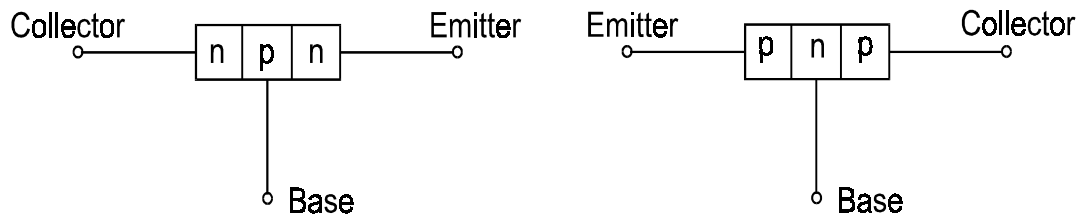


Fig 10.7 N-P-N Transistor & P-N-P Transistor

In each type of transistor, the following points may be noted.

- (i) There are two P N junctions. Therefore, a transistor may be regarded as a combination of two diodes connected back to back.
- (ii) There are three terminals, one each taken from each type of semiconductor.
- (iii) The middle section is a very thin layer. This layer is very important.

Naming the transistor terminal: A transistor (P-N-P or N-P-N) has three sections of doped semiconductors. The section on one side is the emitter and the section on the opposite side is the collector. The middle section is called the base and forms two junctions between the emitter and collector.

(i) Emitter: The section on one side that supplies charge carries (electrons and holes) is called the emitter. The emitter is always forward biased with respect to the base so that it can supply large number of majority carriers. In fig. (a) the emitter (P-type) of PNP transistor is forward biased and supplies hole charges to its junction with the base. Similarly in fig. (b), the emitter (N-type) of NPN transistor has forward bias and supplies free electrons to its junction with the base.

(ii) Collector: The section on the other side that collects the charges is called the collector. The collector is always reverse biased. Its function is to remove charges from collector-base junction. In fig. 10.8 the collector (P-type) of PNP transistor has reverse bias and receives hole charges that flow in the output circuit. Similarly in fig 10.9 the collector (N-type) of NPN transistor has reverse bias and receives electrons.

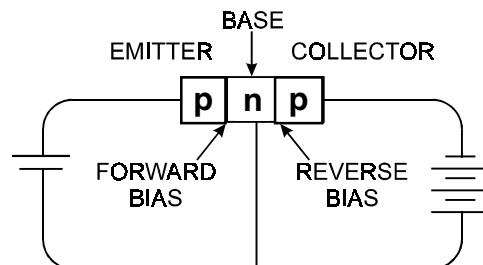


Fig 10.8

(iii) **Base:** The middle section which forms two PN junctions between emitter and collector is called base. The base emitter junction is forward biased, allowing low resistance for the emitter circuit. The base collector junction is reverse biased and provides high resistance in the collector circuit.

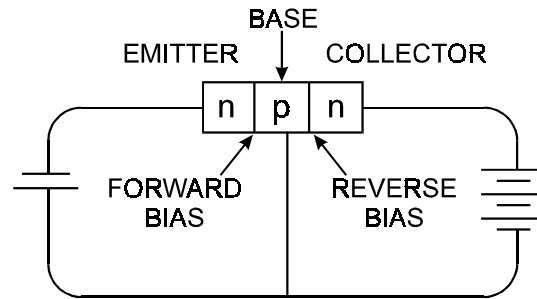


Fig 10.9

Transistor as a Switch

Saturation: In this case the emitter junction as well as the collector junction are forward biased. The collector current becomes independent of the base current. In such a case the transistor acts like a closed switch. It is called saturation region because now collector current no longer depends on input current (base current).

Cut Off Operation: In this type of operation the emitter and collector junctions are reverse biased as shown in fig. The emitter does not emit carriers into the base. There are no carriers to be collected by the collector. The collector current is thus zero. The transistor in this case acts like an open switch.

Transistor as an amplifier:

A transistor raises the strength of a weak signal and thus acts as an amplifier. The weak signal is applied between emitter-base junction and output is taken across the load R_C connected in the collector circuit. In order to achieve amplification, the input circuit should always remain forward biased. To do so, a D.C. voltage V_{EE} is applied in the input circuit at base in addition to the signal as shown. This D.C. voltage is known as bias voltage and its magnitude is such that it always keeps the input circuit forward biased, regardless of the polarity of the signal.

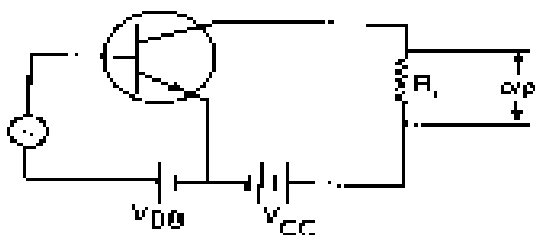


Fig. 10.10 Transistor as CE Amplifier

As the input circuit has low resistance, therefore a small change in signal voltage causes an appreciable change in emitter current. This causes almost the same change in collector current due to transistor action. The collector current flowing through a high load resistance R_C produces a large voltage across it. Thus, a weak signal applied in

the input circuit appears in the amplified form in the collector circuit. In this transistor acts as an amplifier. Transistor is a current amplification device.

$$I_C = \beta I_B$$

Where I_C = Collector current, β = Amplification factor, I_B = Base current

Transistor Data Sheets: To analyze or design a transistor circuit one must have sufficient information about the transistor. This information is obtained from the manufacturer's DATA SHEETS. The data sheets also give information on maximum power dissipation, max. allowable collector base voltage, current gain etc.

They also give the orientation of leads in a transistor. While substituting for transistors, following points are to be considered.

- * The NPN transistor replaces a PNP transistor.
- * A Ge transistor replaces a Germanium (Ge) transistor.
- * The most important characteristic is the transistor current gain which must be nearly same.
- * The transistor casing and size should match in order to fit back into the circuit.

THERMAL RUNAWAY AND HEAT SINK

If the temperature of the collector base junction increase, the collector leakage current I_{CBO} increase. Because of this, collector current increases. The increase in collector current produces an increase in the power dissipated at the collector junction. This in turn further increases the temperature of the junction and so gives further increase in collector current. The process is cumulative. It may lead to the eventual destruction of the transistor. This is described as the thermal runaway of the transistor. In practice, thermal runaway is prevented in a well-designed circuit by the use of stabilization circuitry.

For transistors handling small signals, the power dissipated at the collector is small. Such transistors have little chances of thermal runaway. However in power transistors, the power dissipated at the collector junction is larger. This may cause the junction temperature to rise to a dangerous level. We can increase the power handling capacity of a transistor if we make a suitable provision for rapid conduction of heat away from the junction. This is achieved by using a sheet of metal called heat sink. Connecting a heat sink to a transistor increases the area from which heat is to be transferred to the atmosphere. Heat moves from the transistor to the heat sink by conduction and then it is removed from the sink to the ambient by convection and radiation.

TROUBLESHOOTING A TRANSISTOR

Many things go wrong with a transistor. Since it contains two diodes, exceeding any of the breakdown ratings, maximum current damage either or both diodes. The troubles can include shorts, opens, high leakage currents etc.

One way to test a transistor is with an ohmmeter. You can begin measuring the resistance between the collector and emitter. This should be very high (of the order of M ohms) in both directions because the collector and emitter diodes are back to back connected. One of the common troubles is collector emitter short, produced by exceeding the power rating. If the reading is between zero to few thousands Ohms the transistor is no longer usable and should be thrown off.

If the collector emitter reading is very high (M ohms) in both the directions, you must now check the forward and reverse resistance of the emitter and collector diodes respectively. The forward resistance in case of the emitter diode should be low while the collector diode shows a high resistance when it is reverse biased.

Some analog meters produce enough currents on low ranges of resistance which can damage the transistor, hence while checking small signal transistors one must use a higher range such as $R \times 100$. In this range the internal resistance of ohmmeter prevents excessive currents through the transistor.

After all these checks also the transistor may have some faults, because the ohmmeter only tests each junction under dc conditions. Certain faults like too much leakage current, low B_{DC} can be tested using commercial transistor testers.

In- circuit tests : You can test the transistor voltages with respect to ground .For instance measuring the collector voltage V_C and the emitter voltage V_e .The difference $V_C - V_e$ should be more than 1V but less than V_{CC} . If the reading is less than 1 V the transistor may be shorted .If the reading equals V_{CC} the transistor may be open. Such tests usually pin down the problem if it exists . One can also test the voltage V_{be} as follows: Measure the base voltage V_b with respect to ground and the emitter voltage V_e with respect to ground .The difference of this reading is V_{be} which should be equal 0.6 to 0.7V for small signal transistors operating in the active region.

10.6 (UJT) UNIJUNCTION TRANSISTOR

Introduction: A unijunction transistor is a three terminal semiconductor-switching device. This device has a unique characteristic that when it is triggered, the emitter current increases regeneratively until it is limited by emitter power supply. Due to this characteristic, the unijunction transistor can be employed in a variety of applications e.g. switching, pulse generators, saw-tooth waveform generator.

Construction: Fig. shows the basic structure of a unijunction transistor. It consists of an N-type silicon bar with an electrical connection on each end. The leads to these connections are called base leads - base one B_1 and base two B_2 . Part way along the bar between the two bases nearer to B_2 than B_1 , a P N junction is formed between a P-type emitter and the Bar. The lead to this junction is called the emitter lead E. Fig. 10.11 shows the symbol of unijunction transistor. Note that emitter is closer to B_2 than B_1 .

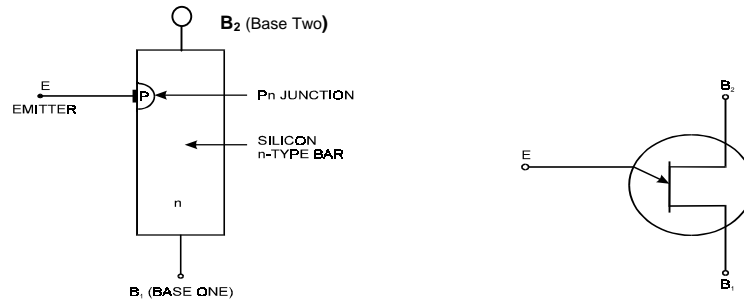


Fig 10.11

Principle of Operation: Following fig.10.12 shows the basic circuit operation of unijunction transistor. The device has normally B_2 positive with respect to B_1 .

(i) If the voltage is applied at V_{BB} with the emitter left open, a voltage gradient is established along the N-type bar. Since the emitter is located nearer to B_2 , more than half of V_{BB} appears between the emitter and B_1 . The voltage V_1 between emitter and B_1 establishes a reverse bias on the P N junction and the emitter current is cut off. Of course, a small leakage current flows from B_2 to emitter due to minority carriers.

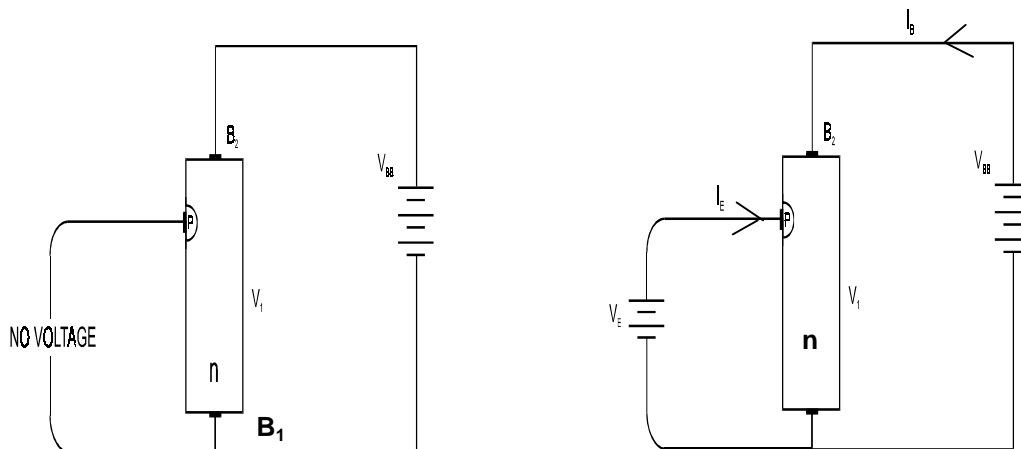


Fig 10.12

(ii) If a positive voltage is applied at the emitter, the P N junction will remain reverse biased so long as the input voltage is less than V_1 . If the input voltage to the emitter exceeds V_1 , the P N junction becomes forward biased. Under these conditions, holes are injected from P-type material into N-type bar. These holes are repelled by positive B_2 terminal and they are attracted towards B_1 terminal of the Bar. This accumulation of holes in the emitter to B_1 region results in the decrease of resistance in this section of the bar, this results in a internal voltage drop from emitter to B_1 and hence the emitter current I_E increases. As more holes are injected, a condition of

saturation will ultimately be reached. At this point, the emitter current is limited by emitter power supply only. The device is now in the ON state.

- (iii) If a negative pulse is applied to the emitter, the P N junction is reverse biased and the emitter current is cut off. The device is then said to be in the OFF state.

UJT Characteristics: Fig. shows the curve between the emitter voltage (V_E) and emitter current (I_E) of a UJT at a given voltage V_{BB} between base. This is known as emitter characteristics of UJT.

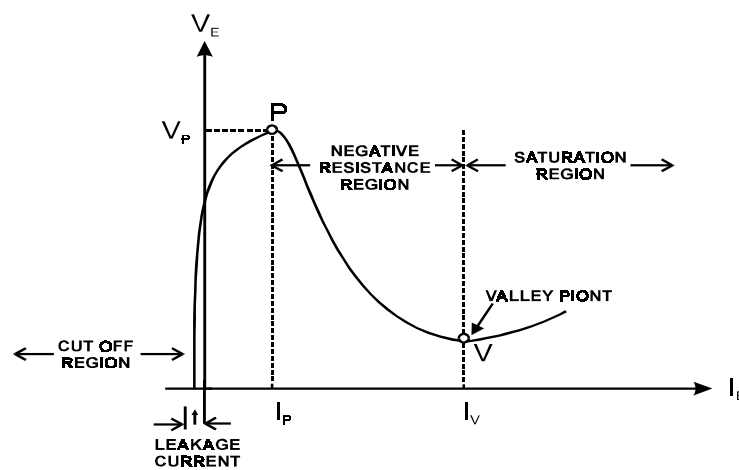


Fig 10.13 UJT Characteristics

Applications of UJT: Unijunction transistors are used extensively in oscillator circuits, pulse and voltage sensing circuits.

(1) **UJT as a relaxation oscillator :** A UJT relaxation oscillator, where the discharging of a capacitor through UJT can develop a saw-tooth output waveform is shown below.

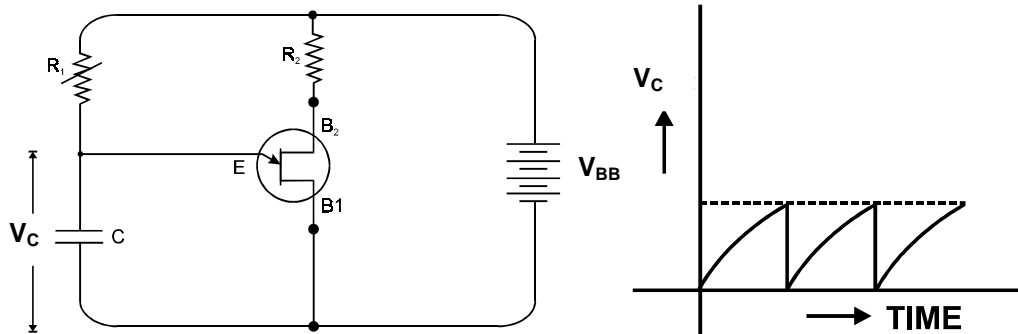


Fig. 10.14 (a) UJT Relaxation

(b) Saw tooth wave form oscillator

When battery V_{BB} is turned on, the capacitor C charges through resistor R_1 . During the charging period, the voltage across the capacitor rises in an exponential manner until it reaches the peak-point voltage. At this instant of time, the UJT switches to its low resistance-conducting mode and the capacitor is discharged between E and B_1 . As the capacitor voltage comes back to zero, the emitter ceases to conduct and the UJT is switched off. The next cycle then begins, allowing the capacitor C to charge again. The frequency of the output saw-tooth wave can be varied by changing the value of R_1 since it controls the time constant R_1C of the capacitor charging circuit.

10.7 FIELD EFFECT TRANSISTOR

A Field Effect Transistor is a three terminal semiconductor device in which current conduction is by one type of carrier i.e. electrons or holes. In FET, the current conduction is either by electrons or holes and is controlled by means of an electric field between the gate electrode and the conducting channel of the device. The FET has high input impedance and low noise level.

Construction: A FET consists of P-type and N-type silicon bar containing two P N junctions at the sides as shown. The bar forms the conducting channel for the charge carriers. If the bar is of N-type, it is called N-channel FET and if the bar is of P-type, it is called a P-channel FET. The two P N junction-forming diodes are connected internally and a common terminal called gate is taken out. Other terminals are source and drain taken out from the bar as shown. This FET has essentially three terminals, Gate (G), Source (S) and Drain (D).

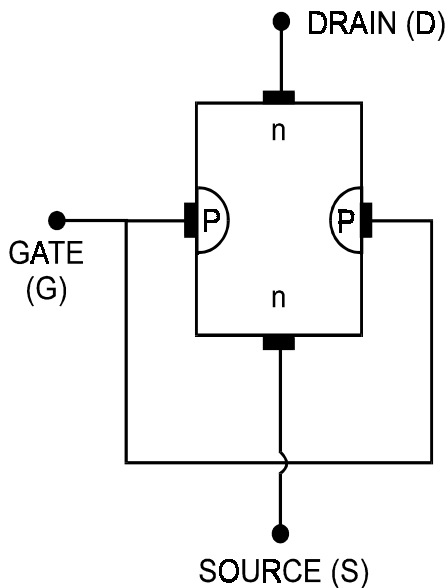


Fig. 10.15 (I)

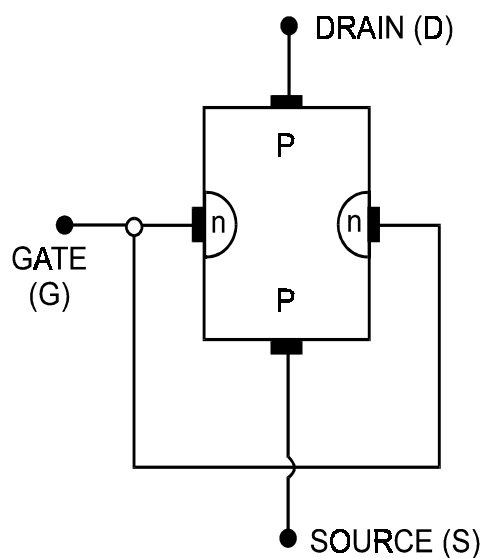
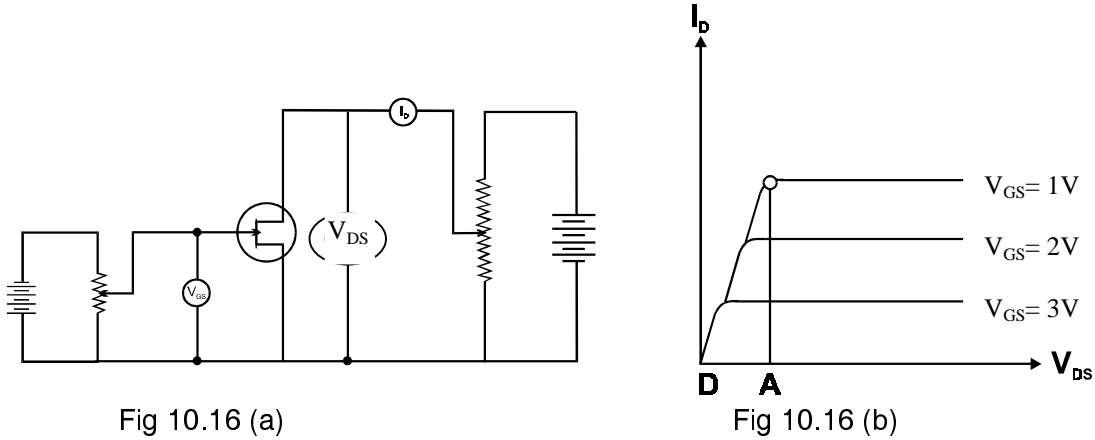


Fig. 10.15 (II)

Output Characteristics of FET : The curve between drain current (I_D) and drain source voltage (V_{DS}) of a FET at constant gate-source voltage (V_{GS}) is known as output characteristics of FET. Following figure shows the circuit for determining the output

characteristics of FET keeping V_{GS} fixed at as some value, say 1V, the drain source voltage is changed in steps. Corresponding to each value of V_{DS} , the drain current I_D is noted. A plot of these values gives the output characteristics of FET at $V_{GS}=1V$. Repeating similar procedure, output characteristics at other gate-source voltages can be drawn.



Application :

FET as an amplifier : Figure shows FET amplifier Circuit. The weak signal is applied between gate and source and amplified output is obtained in the drain source circuit. The input circuit is always reverse biased. A small change in the reverse bias on the gate produces a large change in drain current. This fact makes FET capable of raising the strength of a weak signal. During the positive half of signal, the reverse bias on the gate decreases. This increases the channel width and hence the drain current. During the -ve half cycle of the signal, the reverse voltage on the gate increases. Consequently the drain current decreases. The result is that small change in voltage at the gate produces a large change in drain current. These large variations in drain current produce large output across the load R_L . In this way FET acts as an amplifier.

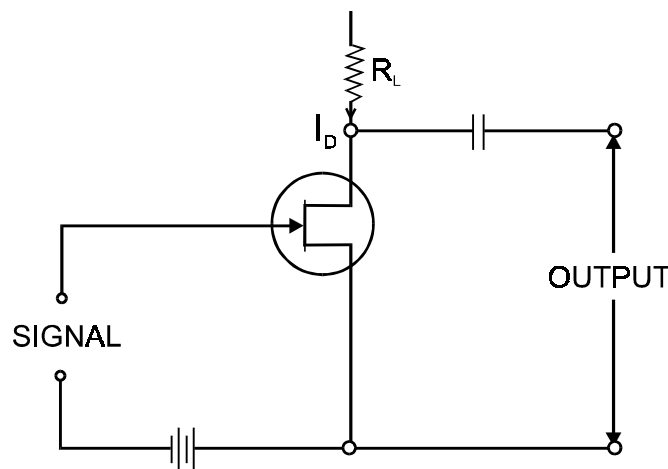


Fig. 10.17 FET (Amplifier)

10.8. METAL OXIDE SEMICONDUCTOR FET (MOSFET)

MOSFET is an important semiconductor device and is widely used in many circuit applications. The input impedance of a MOSFET is much more than that of a FET because of very small gate leakage current. The MOSFET can be used in any of the circuits as the FET. Therefore, all the equations apply equally well to the MOSFET and FET in amplifier connection.

Construction :

Figure 10.18 shows the construction details of N-channel MOSFET. It is similar to FET except with following modifications.

- (i) There is only a single P-region. This region is called substrate.
- (ii) A thin layer of metal oxide (usually silicon dioxide) is deposited over the left side of the channel. A metallic gate is deposited over the oxide layer. As silicon dioxide is an insulator, therefore, gate is insulated from the channel. For this reason, MOSFET is sometimes called insulated gate FET.
- (iii) Like FET, a MOSFET has three terminals viz. Source, Gate and Drain.

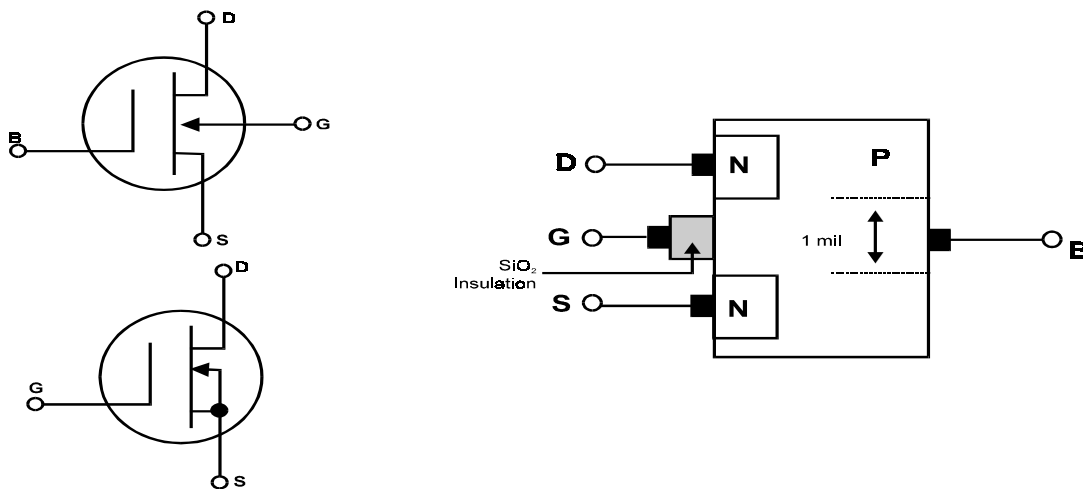


Fig. 10.18 Symbol of MOSFET

TESTING OF MOSFET

Before testing a MOSFET one must know the following

- a) Is it a JFET or MOSFET.
- b) Is it n-channel or p-channel
- c) Is it enhancement type or depletion type.

Precautions to be taken with a MOSFET

- a) Before the MOSFET is inserted into the circuit, the device lead should be shorted. The gate lead should not be open as it can induce static charges from florescent

light. Due to this the capacitor between the gate and channel can get charged , so always short the leads of the MOSFET.

- b) Soldering must be done carefully. An ohmmeter can be used to check the MOSFET. The gate to source insulation is checked with the highest range of the ohmmeter .A infinite reading is normally obtained for both polarities of test voltage.

10.9. SILICON CONTROL RECTIFIER

It is a semiconductor device which acts as a true electronic switch. It can change alternating current into direct current and at the same time can control the amount of power fed to load. It is a P-N-P-N device. It can be considered as combination of two transistor.

The difference between gate control of the current in a thyristor and the control of current in a transistor amplifier is that the thyristor gate electrode serves only as trigger to start the current.

This electrode can not vary the anode current. In fact, after the forward current has started, reducing the gate voltage will not turn off conduction. The current can be turned off only when the anode voltage is reduced or become negative.

The SCR is considered as a reverse blocking triode thyristor, meaning that it does not conduct with negative voltage at the anode, which can conduct for either polarity of applied voltage.

The gate voltage is usually a train of pulses. Once the SCR is turned on, it stays on even after the gate pulse has been removed. The SCR holds the anode current until the anode voltage is low enough to reduce the current to 3 to 10 mA for about 50 μ s for a medium power SCR. This minimum value of anode current needed to sustain conduction is the holding current. The latching current is the value needed to switch the anode circuit on from the off conditions. The latching current is typically about three times more than holding current.

Diac: This thyristor is a two terminal device without a gate electrode, as shown in following fig. The Diac is used as a bi-directional trigger diode. Current can flow either way when enough voltage is supplied for break-over. Typically, the firing potential is about 30 V, in either direction. The Diac is in its off state until the voltage across MT_1 and MT_2 exceeds the break-over voltage. In power control circuits a Diac can be used for more effective control of the turn-on point for the gate electrode of a Triac or the SCR.

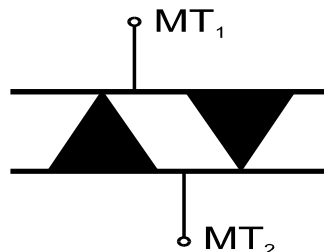


Fig. 10.19 (a) Symbol

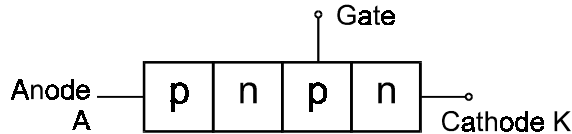


Fig. 10.19 (b)

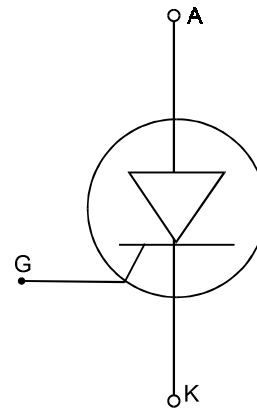


Fig. 10.19 (c)

V-I Characteristics of SCR : It is the curve between anode to cathode voltage and anode current of an SCR.

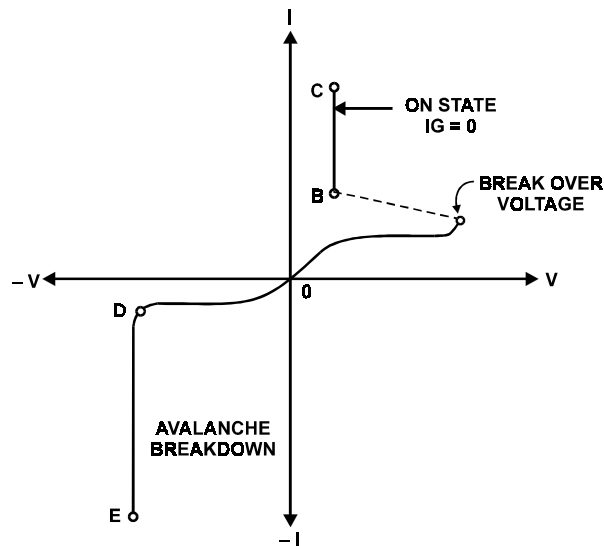


Fig. 10.20 Characteristics of SCR

1) **Forward Characteristics :** When anode is positive with respect to cathode, the curve between V and I is called forward characteristics. In fig. OABC is the forward characteristics of SCR at Gate Current ($I_G = 0$).

2) **Reverse Characteristics :** When anode is negative with respect to cathode the curve between V and I is known as reverse characteristics. The reverse voltage does not come across SCR when it is operated with a.c. supply.

Difference Between FET and Bipolar Transistor :

1. The gate is reverse biased in case of FET while the base is forward biased in a BJT (Bipolar Junction Transistor)

2. The JFET is a voltage controlled device because the input voltage alone controls the output current.
3. The input resistance of a JFET is quite large, of the order of 10M ohm. Thus applications in which a high input resistance is needed, the JFET is preferred over the bipolar transistor. For example the input stage of a measuring instrument like an oscilloscope or electronic volt meter often uses a JFET.
4. The JFET is less sensitive to changes in input voltage than a bipolar transistor. In a JFET, an input voltage change of 0.1V produces an output current change of less than 10MA. In a bipolar transistor, a change of 0.1V in V_{BE} can easily produce a change of more than 10MA in collector current. This means that JFET produces less voltage gain than a bipolar transistor.
5. JFET is less noisy than Bipolar Transistors.
6. JFET is simpler to fabricate and occupy less space.

10.10 RECTIFIER CIRCUITS

For reasons associated with economics of generation and transmission, the electric power available is usually an A.C. supply. The supply varies sinusoidal and has a frequency of 50 Hz. It is used for industrial and domestic purposes such as lighting, heating and running electrical motors. But there are many applications (e.g. electronic circuit) where D.C. supply is needed. When such a D.C. supply is required, the mains a.c. supply is rectified by using crystal diodes. The following two rectifier circuit can be used.

(i) Half wave rectifier

(ii) Full wave rectifier.

In half wave rectification, the rectifier conducts current only during the positive half cycles of input A.C. supply. The negative half-cycle of A.C. supply are suppressed i.e. during negative half-cycles, no current is conducted and hence no voltage appears across the load. Therefore, current always flows in one direction (i.e. d.c.) through the load though after every half-cycle.

Circuit details : Fig. shows the circuit where a single crystal diode acts as a half-wave rectifier. The a.c. supply to be rectified is applied in series with the diode and load resistance R_L . Generally, a.c. supply is given through a transformer permits two advantages. It allows use to step-up or step down the a.c. input voltage as the situation demands.

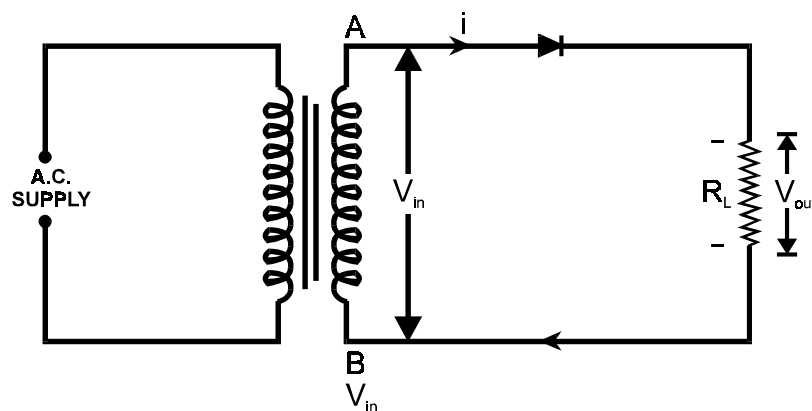


Fig 10.21 Half Wave rectifier Schematic

OPERATION : The a.c. voltage across the secondary windings AB changes polarities after every half-cycle. During the positive half cycle of input a.c. voltage, end A becomes positive with respect to end B. This makes the diode forward biased and hence it conducts current. During the negative half cycle, end A is negative with respect to end B under this condition, the diode is reverse biased and it conducts no current, therefore, current flows through the diode during positive half cycles of input a.c. voltage only; It is blocked during the negative half-cycles. In this way, current flows through load RC always in the same direction. Hence d.c. output is obtained across RC. It may be noted that output across load is pulsating d.c.

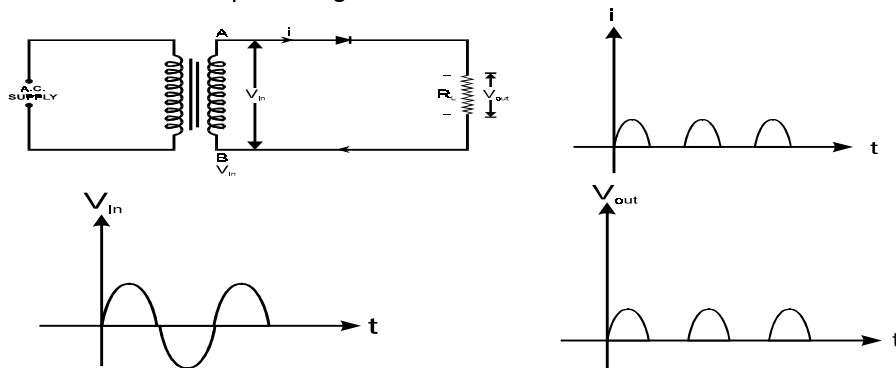


Fig. 10.22 Wave form of Half wave Rectifier

Full wave rectifier : In full wave rectification, current flows through the load in the same direction for both half -cycles of input a.c. voltage. This can be achieved with two diodes working alternatively. For the positive half-cycle of input voltage, one diode supplies current to the load and for the negative half cycle, the other diode does s, current being always in the same direction through the load. Therefore, a full wave rectifier utilizes both half-cycle of input a.c. voltage to produce the a.c. output. The following two circuits are commonly used for full wave rectification.

- (i) Centre-tap Full-wave rectifier
- (ii) Full wave bridge rectifier centre-tap Full wave rectifier.

The circuit employees two diodes D1 and D2 as shown. A center tapped secondary windings AB is used with two diodes connected so that each use one half-cycle of input a.c. voltage. Diode C1 utilizes the a.c. voltage appearing across the upper half (OA) of secondary windings for rectification while diode dD2 uses the lower half winding OB.

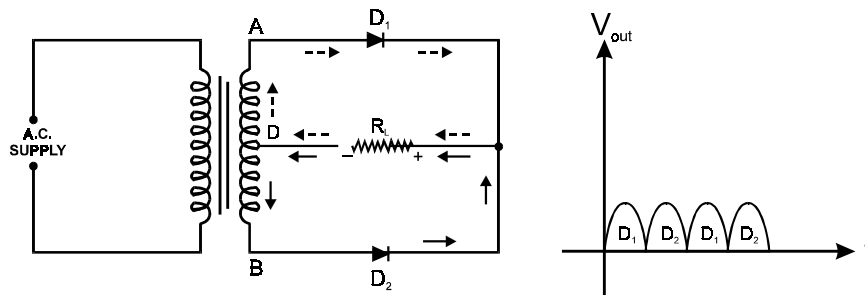


Fig 10.23 a) Full wave Rectifier

b) Wave form of full wave Rectifier

Operation : During the positive half cycle of secondary voltage, the end A of the secondary windings becomes positive and end B negative. This makes the diode D1 forward biased and diode D2 reverse biased. Therefore, diode D1 conducts while diode D2 does not. The conventional current flow is through diode D 1 load resistor R L and the upper half of secondary windings as shown by dotted arrows. During the negative half cycle, end A of the secondary windings becomes negative and B positive. Therefore diode D 2 conducts while diode D 1 does not. The conventional current flow is through diode D2 load R L and lower half windings.

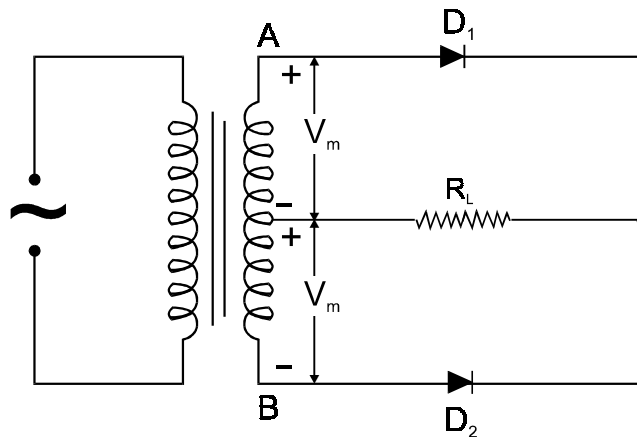


Fig. 10.24

Full wave bridge rectifier. The need for a centre tapped power transformer is eliminated in the bridge rectifier. It contains four diode D1, D2, D3 and D 4 connected to form bridge as shown in :

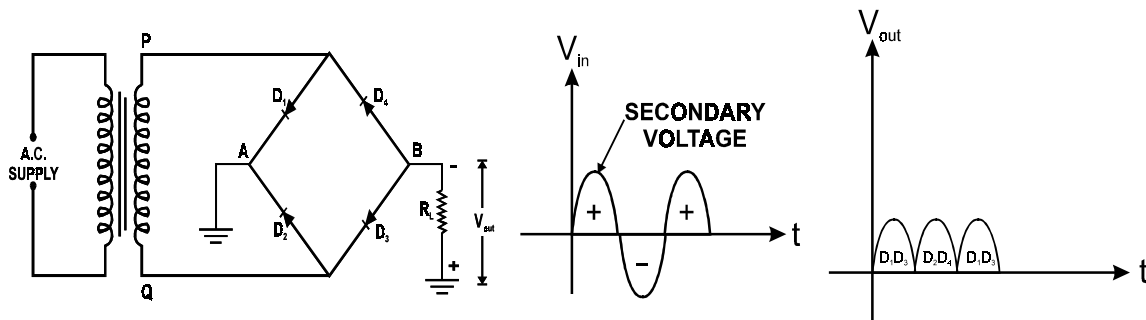


Fig 10.25 (a) Bridge Wave Rectifier

(B) Wave form of Bridge Wave Rectifier

The a.c. supply to be rectified is applied to the diagonally opposite ends of the bridge through the transformer between other two ends of the bridge the load resistance R L is connected.

Operation: During the positive half cycle of secondary voltage, the end P of the secondary winding becomes positive and end Q negative. This makes diodes D1 and D2 forward biased while diodes D2 and D4 are reverse biased. Therefore, only diodes D1 and D3 conduct. These two diodes will be in series through the load R L as shown.

Dotted arrows show the conventional current flow. It maybe seen that current flows from A and B through load R L

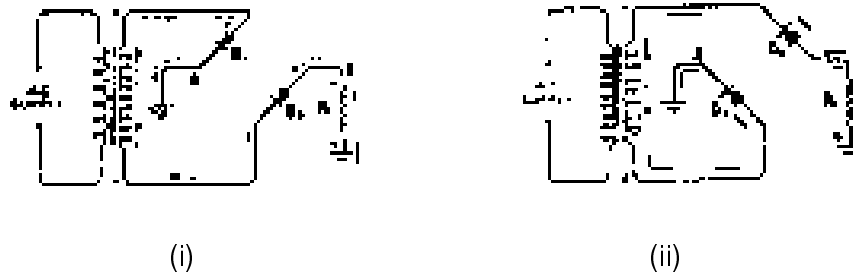


Figure 10.26

During the negative half-cycle of secondary voltage, end P becomes negative and end Q positive. This makes diode D 2 and D4 forward biased whereas diodes D1 and D3 are reversed biased. Therefore only diodes D2 and D4 conduct. These two diodes will be in series through the load R L. It may be seen that again current flows from A to B through the load. i.e. in the same direction as for the positive half-cycle. Therefore, d.c. output is obtained across load R L.

10.11 TESTING OF TRANSISTORS

Troubleshooting Application : The bipolar transistor may be checked by use of an ohmmeter. Since this device is constructed of two diodes, it can be tested using the same techniques as those used for the diode. The ohmmeter connected between the emitter and base will test for the validity of this junction. Resistance values should be low in one direction and high when the ohmmeter leads are reversed. this is also true for the base-to-collector junction. Readings that are the same ohmic value when the leads are reversed at one junction indicate defective transistor.

When the ohmic value is low in both directions across one junction, the junction is short-circuited. When the ohmic value is high in both directions across the same junction, the junction is open. In either of the tests, the transistor must be replaced with a functionally good unit.

Another test one may make on the bipolar transistor is one using a voltmeter. This test is conducted with the operating voltage turned on for the system. The difference in voltage measured between the emitter and the base of the transistor would be about -0.7 V if the transistor is a silicon type (and most of them are). This is not an exact value. It may vary by as much as 0.3V in either direction from the ideal voltage value. If this voltage is zero, the transistor's emitter-to-base junction is shorted. If the voltage is much higher, the transistor has an internal condition known as leakage. Leakage creates an abnormally high resistance between emitter and base. The abnormally high voltage measured between these two elements can identify this.

There are two ways of measuring the voltage drop between emitter and base (fig.a). One of these places the negative lead of the voltmeter directly on the emitter led or its connection to the circuit board. The other meter lead is placed on the base lead or its connection to the circuit board. This method provides a direct reading of the emitter-to-base voltage drop (fig.a). The selection method requires two reading and a slight amount of mathematics. One reading is made between the emitter element and circuit common. This reading is noted and the second reading measures the voltage drop between the

base and circuit common. The difference between these two voltage values is the emitter-to-base voltage drop. (See Fig.(b) The selection of the specific method is left to the person conducting the test.

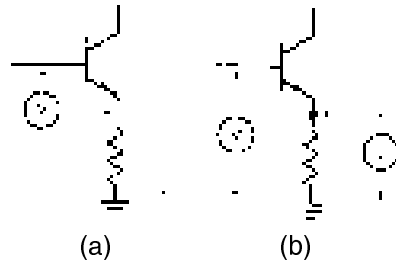


Fig. 10.27 Measurement of the voltage difference between base and emitter is accomplished using either of these methods

10.12 TESTING SEMICONDUCTOR DIODES

Troubleshooting Applications: Since the semiconductor diode is a voltage-dependent resistance it is possible to test its resistance to determine if it is in working condition. The ohmmeter is a very dependable device for this purpose. The ohmmeter has a built-in power source. This is a d.c source and has a constant polarity. The process for using the ohmmeter to test a diode is very simple. The positive, or red, lead of ohmmeter is usually connected to the positive lead of its internal battery. When the two leads of ohmmeter are connected across the terminals of the diode, a bias voltage is applied to the diode. If the diode is forward biased the resistance reading will be under 5 k Ohm. The specific value depends on he range setting of the ohmmeter. Usually, a range of R x 1 K Ohm is used for this test. If the diode is forward biased, the voltage at the test leads of the ohmmeter will produce a current flow and the meter will read a resistance value.

When the test leas, or the diode lead, are reversed, the diode is reverse biased. Its internal resistance becomes a very high. Little, if any, current flow occurs under this condition. The ohmmeter will indicate an infinitely high value of resistance. In many tests the ohmmeter will not indicate any leading of resistance.

The diode test is therefore a test of its resistance under forward and reverse biased conditions. If the diode test indicate the same resistance values in both directions, the diode has failed. It must be replaced if its internal resistance is the same when it is forward biased and when it is reverse biased. This is true when the resistance is low in both directions and also when it is high in both directions.

10.13 OPTODEVICES- LED & Optocouplers

LED: A light emitting diode is basically a PN junction that emits light when forward biased .The schematic symbol for a light emitting diode is as shown in fig10.28

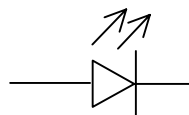


Fig 10.28 Light Emitting Diode-Symbol

WHY DOES A LED RADIATE LIGHT

When a diode is forward biased, free electrons recombine with holes near the junction. Since the free electrons fall from a high energy level to low energy level, they radiate energy. In case of a rectifier diode the radiated energy is in the form of heat while in LED's the energy radiates as light. LED's have replaced incandescent lamps in many applications because the LED's have a low operating voltage, long life and fast on-off switching speed. LED emit visible radiation when the PN junction is diffused in GaAsP, infrared if it is constructed from GaAs.

OPTOCOUPLER : In an optocoupler the emitter and the sensor are placed in the same package, provides an output current proportional to input current, with a high degree of isolation. Typical isolation resistance between emitter and detector is 10^{11} ohms with isolation voltages upto 2500 V. Output current in phototransistor-coupled pairs is typically 35% of the LED input current with a linear relation between the two. The symbol of the optocoupler when emitter is LED and detector is phototransistor is shown in fig.

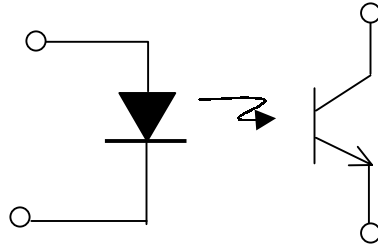


Fig. 10.29 Optocoupler symbol

The optocoupler is most commonly used to couple one circuit to another providing a high level of isolation.

Review Questions

1. Briefly Explain the operation of a full wave bridge rectifier circuit ?
2. Explain the diode characteristic ?
3. Give the short note on Zener diode with characteristic ?
4. Explain, transistor act as an amplifier ?
5. Give the short note on
 - a) Unijunction Transistor.
 - b) Field Effect Transistor.
 - c) MOSFET.

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CHAPTER ELEVEN

AMPLIFIER

Features:

- 11.1 Introduction
- 11.2 Power Amplifier - Class A,B & push Pull

11.1 INTRODUCTION

As we have studied transistor as an amplifier. Transistor is used for the purpose of voltage amplification in audio amplifiers. In this case the small voltage signal are used whereas the power amplifiers are large signal amplifiers.

Almost no electronic system can work without an amplifier. No gathering can be addressed or entertained if the PA (Public Address) system fails. It is only because of the amplification of the signal picked up by microphone that we can enjoy a music orchestra. We are able to hear the news or the cricket commentary on our radio, simply because the amplifier in the radio amplifies the weak signals received by its antenna. The signal can only be of any use if it is amplified to give a suitable output.

Once the transistor is biased in the active region, it can work as an amplifier. We apply an ac voltage between the base and emitter terminals to produce fluctuations in the collector current. An amplified output signal is obtained when this fluctuating collector current flows through a collector resistor R_C . When the input signal is so weak as to produce small fluctuations in the collector current compared to its quiescent value, the amplifier is **called small signal amplifier(voltage amplifier)**. Such an amplifier is used as the first stage of the amplifier used in receivers(TV and radio),tape recorders, stereos and measuring instruments.

To what extent an amplifier enlarges signals is expressed in terms of its voltage gain. The voltage gain of an amplifier is given as

$$A_v = \frac{\text{output ac voltage}}{\text{Input ac voltage}} = \frac{V_o}{V_i}$$

The other quantities of interest for a voltage amplifier are current gain (A_i), input impedance (Z_i), and output impedance (Z_o).

Multi Stage Amplifiers

An amplifier is the basic building block of most electronic systems. Just as one brick does not make a house, a single stage amplifier is not sufficient to build a practical electronic system. Although the gain of an amplifier does depend on the device parameters and circuit components, there exists an upper theoretical limit for the gain obtainable from one stage. The gain of single stage is not sufficient for practical applications. The voltage level of a signal can be raised to the desired level if we use more than one stage. When a number of amplifier stages are used in succession it is called a multi-stage amplifier or a cascaded amplifier. Much higher gains can be obtained from the multi stage amplifiers.

11.2 POWER AMPLIFIER

In almost all electronic systems, the last stage has to be a power amplifier. For example, in a public address system, it is the power amplifier that drives the loudspeakers. When a person speaks into a microphone, the sound waves are converted by it into electrical signal. This electrical signal is very low voltage (a few mV). This signal, if fed directly, cannot drive loudspeakers, to give sound output. The voltage level of this signal is first

raised to sufficiently high values by passing it through a multistage voltage amplifier. This voltage is then used to drive the power amplifier.

There are three classes of power amplifiers : Class A, Class B, Class C & Push Pull.

CLASS A :The class A push-pull amplifier reduces the harmonic distortion to a larger extent, whereas the conversion efficiency is still only 50%. A method of increasing this efficiency and also the input power for a given transistor dissipation capability is found in the class B push-pull amplifier.

Class A amplifier is used in the following three configurations :

1. Class A direct-coupled resistive load.
2. Transformer-Coupled Resistive Load.
3. Class A Push-Pull.

1. **Class A Direct-coupled Resistive Load** : This amplifier shows the conversion efficiency η of only 25%. Conversion efficiency has been defined as follows :

$$\eta = \frac{\text{ac power delivered to load}}{\text{dc power supplied by battery}} \times 100\%$$

$$= \frac{P_L}{P_B} \times 100\%$$

A class A amplifier with a direct-coupled load can supply only one-half the amount of ac power to the load that its transistor can dissipate, and the dc power input is four times the amount of ac signal power in the load.

2. **Transformer-Coupled Resistive Load** :The conversion efficiency can be increased by a factor of two by eliminating the dc power dissipated in the load. This is accomplished by coupling the load resistor to the transistor collector circuit by means of a transformer. Since the primary of this transformer has negligible dc resistance, there is negligible dc power lost at this point. The ac power is, however, coupled magnetically across the transformer into the load R_L . This coupling method also prevents a large dc current from flowing in the load, which otherwise could be harmful if the load were a loudspeaker, since this would cause saturation of the magnetic circuit and impair the reproduction of the audio signal. Refer Fig. 11.1

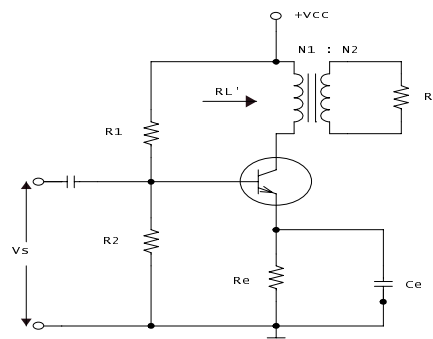


Fig 11.1

Conversion efficiency $\eta = \frac{P_L'}{P_B}$

where, $P_L' = V_{c1}I_c$, $P_B' = V_{CC}I_c$

$V_{CC} = \sqrt{2}V_c$, $I_c = \sqrt{2}I_c$

Hence, $\eta = \frac{V_{c1}I_c}{2V_{c1}I_c} \times 100\%$

= 50%

Disadvantages of a Single-Ended Transformer-Coupled Amplifier

- i) The output transformer is subject to saturation problems due to the dc current in the primary.
- ii) The amplifier is designed to work into a load that minimizes distortion with a resulting sacrifice in output power.
- iii) The total harmonic distortion is unacceptably high.

3. Push-Pull Amplifiers :

A method to accomplish this second harmonic cancellation is found in the push-pull circuit, which employs two active devices, requires two input signals 180° out of phase with each other, and usually needs a center-tapped output transformer. This type of circuit effectively eliminates all of the three disadvantages. Fig. 11.2 is a circuit of a class A push-pull amplifier. By class A, we mean that current flows in the output of the active device (each transistor) for the whole of the input cycle.

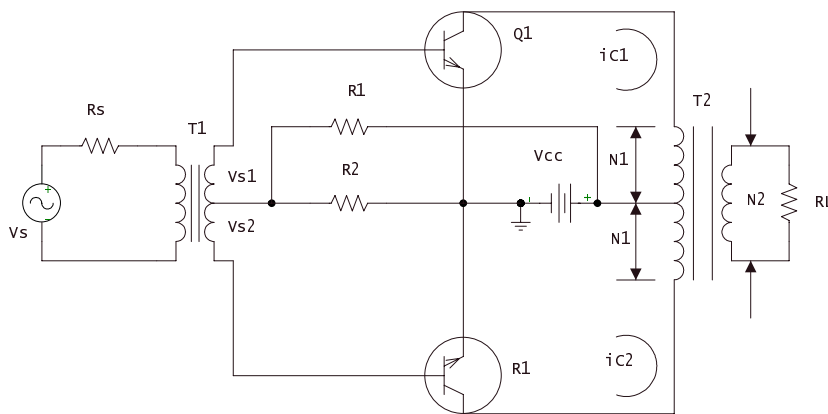


Fig. 11.2 Class A push-pull amplifier

CLASS B : In Class B amplifier each transistor “looks after” one-half of the signal. Both transistors are biased at cutoff. The output voltage is again dependent upon the difference of the collector currents, so that even harmonics will still cancel.

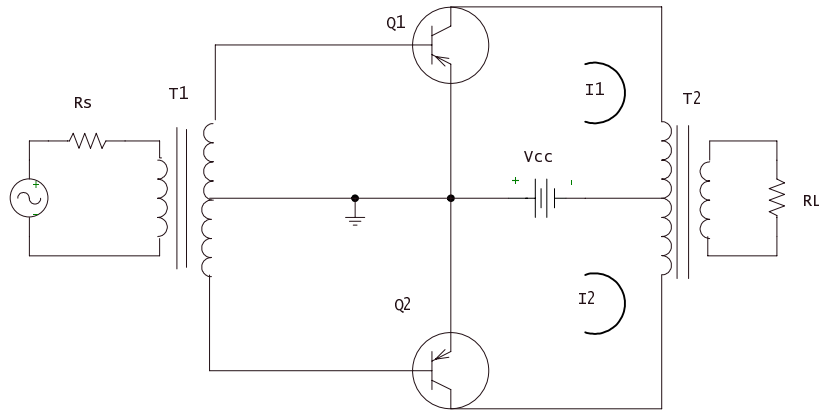


Fig. 11.3 Class B push-pull amplifier

Refer fig. 11.3

$$\text{Conversion efficiency } \eta = \frac{P_L'}{P_B}$$

The ac power delivered to the reflected resistance R_L' is given by $P_L' = V_{cI_c}$. The dc power supplied by the battery is given by $P_B = V_{CC}I_c$, where I_c is the average value of $i_{c1} + i_{c2}$. The peak value of the current delivered by the battery is $\sqrt{2}I_c$ (see Fig.)

$$I_{\text{avg}} = \frac{2I_m'}{\pi}$$

The average current delivered by V_{CC} is

$$I_c = I_{\text{avg}} = \frac{2\sqrt{2}I_c'}{\pi}$$

$$P_B = V_{CC}I_c = \sqrt{2}V_c \times \frac{2\sqrt{2}I_c'}{\pi} = \frac{4V_c I_c'}{\pi}$$

But $V_c I_c' = P_L'$.

$$\therefore P_B = \frac{4}{\pi} P_L'$$

$$\text{Conversion efficiency, } \eta = \frac{P_L'}{P_B} \times 100\%$$

$$= \frac{\pi}{4} \times 100\% = 78.5\%$$

Difference between Voltage Amplifier and Power Amplifier

The primary function of the voltage amplifier is to raise the voltage level of the signal. It is designed to achieve the largest possible voltage gain. Only very little power can be drawn from its output. On the other hand, a power amplifier is meant to boost the power level of the input signal. This amplifier can feed a large amount of power to the load. To obtain large power at the output of the power amplifier, its input signal voltage must be large. That is why, in an electronic system, a voltage amplifier invariably precede the power amplifier. Also that is why the power amplifiers are called large signal amplifiers.

The transistor single ended power amplifier is different from push-pull amplifier. The power amplifier makes the final stage and it drives the output. We already know that maximum power will be transferred only if its output impedance is the same as the impedance of the load. If it is not so, the load gets less power, though the amplifier is capable of delivering more power. To have maximum possible power output, the load impedance must match the output impedance of the amplifier.

Review Questions

1. What is the difference between voltage amplifier & power amplifier ?
2. How push pull Class A amplifier improves the conversion efficiency
3. In which part of the circuit the power amplifier is used?

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CHAPTER TWELVE

LINEAR ICs

Features:

- 12.1 Introduction
- 12.2 OP-AMP & Its Configuration
- 12.3 Characteristics
- 12.4 Applications

12.1 INTRODUCTION

Linear integrated circuits are characterized by an output that is proportional to its input. The categories of linear integrated circuit is listed below.

1. Voltage regulators
2. Voltage references
3. Operational Amplifiers
4. Instrumentation Amplifiers
5. Voltage comparators
6. Analogue switches
7. Sample and hold circuit
8. Analog -to-digital and digital-to-analog converters
9. Industrial,automotive,functional blocks and telecommunications
10. Audio,radio, and TV circuits
11. Transistor/diode array

These type of linear circuits are enclosed in flat pack, dual inline, or metal can packages. Many linear ICs are monolithic integrations, while a few are hybrid circuits. Although most are bipolar, some use MOS technology. Some linear ICs combine bipolar and field effect devices on the same substrate.

An important class of linear integrated circuits is operational amplifiers(op-amps).These amplifiers were originally utilised in analog computers to perform various mathematical operations.

12.2 Operational Amplifier & Its Configuration

One of the most prominent application for the integrated circuit is when it is used as an operational amplifier. This device if found in a great many different application. The operational amplifier, or OPAMP as it is usually called, is often used as the sole active device filter circuit. It is also utilized as a differential amplifier instrumentation amplifier, voltage amplifier, and impedance-matching device as well in many other applications.

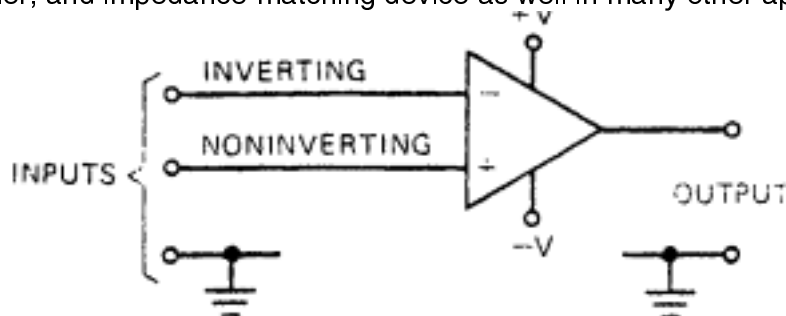


Fig 12.1 Block Diagram of OPAMP

The basic circuit configuration consists of two power sources, two inputs, and single output connections. All operational amplifiers have this type of circuit configuration.

The OP-AMP may be defined as a direct coupled semiconductor device having a very high gain factor. It is a voltage amplifier and is fabricated on a single piece of silicon material.

Power supply requirements for operational amplifier devices demand a dual polarity voltage source. The typical power supply connections for an OP-AMP is shown in figure 12.2. One must use either a dual voltage or as an alternative, design a voltage divider network with circuit common at the midpoint of the voltage-divider circuit.

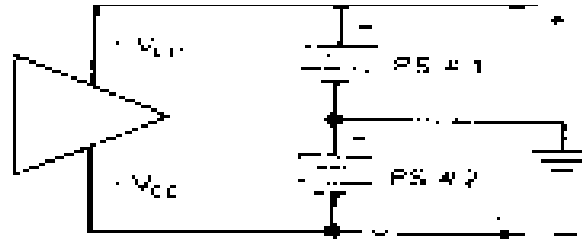


Fig 12.2

Input and output connections for the OP-AMP are shown below. The OP-AMP requires two input connections and has but one output connection. One of the input terminals is designated as a non-inverting input and the other is identified as an inverting input. The non-inverting input terminal is also shown as the positive (+) terminal while the inverting terminal is shown as the (-) connections. A circuit common, or ground, is also required. The OP-AMP has a single output terminal in additions to circuit common.

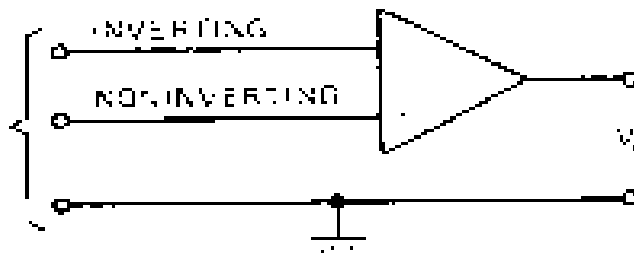


Fig. 12.3

The use of the (+) and (-) signs for the two inputs has a direct relation to the polarity of the output signal. The voltage, or signal, applied to the positive, as the input signal. A signal or voltage applied to the negative, or inverting, input terminal will appear at the output in an inverted, or 180° phase shifted signal operation characteristics.

12.3 Characteristics

An ideal OPAMP has the following characteristics :

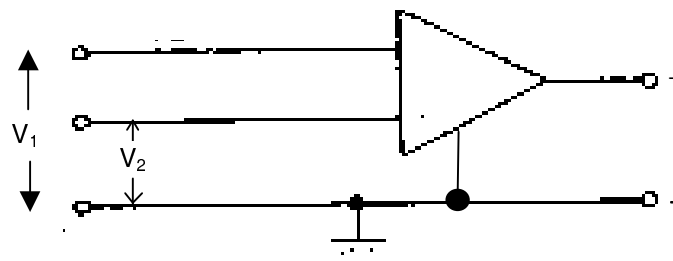


Fig. 12.4

- 1) Infinite gain $A \rightarrow \infty$
- 2) Infinite input impedance $Z_i = \infty$
- 3) Zero output impedance $Z_o = 0$
- 4) Zero output voltage $Z_o = 0$ i.e. zero offset.
- 5) Infinite bandwidth.

The op-amp is a high gain direct-coupled amplifier. It is basically a differential amplifier and hence is also called the 'difference amplifier'. It is mostly operated with feedback provided from output to input. Otherwise the op-amp will go into saturation for the slightest voltage at the input. The gain of the circuit is determined by the nature of feedback.

OP-AMP Generations : Almost 30% of linear ICs are op-amps. An op-amp is a high gain dc amplifier usable from 0 to over several MHz. By connecting external resistors to an op-amp, the gain and bandwidth can be adjusted according to the requirement.

First Generation of Opamps: The quality IC opamp came out in 1965 and was the famous Fairchild uA709. Similar opamps followed: National's LM709, Motorola's MC1709, TI's SN72709 and others. All these opamps have the same specifications and were referred to as the 709 series. 709 has versions like 709A, 709B and 709C. These have increasing tolerances and decreasing price i.e., 709 has best tolerance and costs more while 709C has worst tolerance and costs less.

709 typifies the first generation of opamps. The disadvantages of this are i) possible latch up ii) no short circuit protection and iii) need for external lag networks. Latch up means the output voltage can be latched or stuck at some value, regardless of the value of input voltage and occurs for large values of common mode input voltage. No short circuit protection means that accidentally shorting the output terminals may destroy the opamps; this can easily happen with 709 and other first generation opamps. Finally external lag networks mean extra work, ideally these should be integrated in the opamp.

Second Generation of Opamps: The 741 is typical of second generation opamps. It has no latch up problems, includes short circuit protection and has its own integrated lag network. The 741 has an integrated 30pF MOS capacitor for voltage gain roll-off. Other improvements are i) high Z_{in}

12.4 Applications

Most of the analog systems of today are constructed using opamp as the building block. These ICs augmented by a few external discrete components, either singly or in combination are used in a variety of applications, both linear and non-linear. Negative and positive feedback principles are applied too to derive a number of circuits. Volumes can be written on the applications of opamps. In the interest of brevity and keeping in view our objectives, select experiments are listed. However we have it to the user's imagination, the innumerable applications that are possible with opamps.

Inverting Amplifier : The input voltage drives the inverting terminal of the amplifier and the non-inverting terminal is grounded. The amplified and inverted output signal is then applied to the inverting input. Hence the feedback is negative. The circuit of an operational amplifier as an inverting amplifier is shown below in Fig 12.5

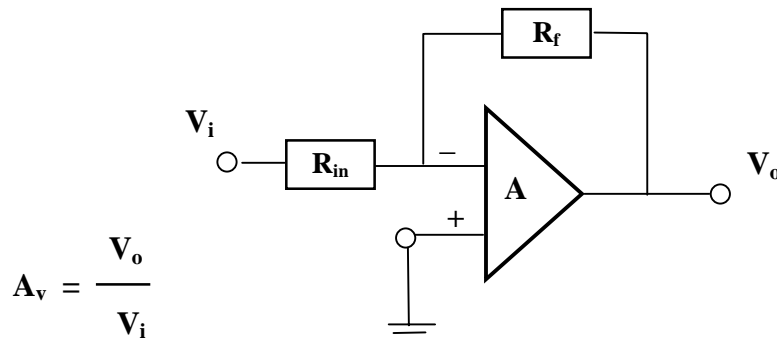


Fig 12.5 Operational amplifier as an inverting amplifier.

Non-Inverting Amplifier: The input voltage drives the non-inverting terminal. Feedback is applied to the inverting terminal. A portion of the output signal is fed back. The feedback network determines the overall closed-loop transfer function. The feedback network can be a voltage divider and with precision resistors, it can be accurate and stable. Therefore the closed loop gain will be highly stable.

Mathematical Operations using Opamps : We can use Opamps to realize the basic mathematical operations of addition, subtraction multiplication and division. Also integration and differentiation can be performed. These form the basis for 'Analog Computation' - a technique by which physical entities can be realized using a mathematical model. As the name implies analog computers operate on a continuously varying signal, unlike digital computer which operates on discrete steps.

Opamp as Adder: Also call as the 'Summing Amplifier', it is the same as the inverting amplifier, but with more than one input. Many inputs can be handled on account of the virtual ground existing at the inverting terminal.

Opamp as Subtractor : Subtraction can be readily performed if it is considered as addition of negative values. Hence use negative voltages for those quantities to be subtracted.

Opamp for Multiplication : From equation $V_o = -(R_f/R_s) V_i$. This can be rewritten as $V_o = -KV_i$ where $K=R_f/R_s$ i.e. the output voltage is k times the input voltage. So by properly choosing R_f and R_s any value of multiplication factor can be obtained.

Opamp for Division : Since division is equal to multiplying with the reciprocal of the divisor, it can be readily achieved by properly choosing R_f and R_s . Suppose it is required to divide by 0.1, then this is equal to multiplying by 10. Hence choose a multiplication factor of 10 with say $R_f = 10 R_s$. On the contrary if it is required to divide by 10, then choose a multiplication factor of 0.1 or $R_s = 10R_f$.

Division can also be performed by adding a potentiometer in the output. This is best suited when it is required to divide by a fraction.

Opamp as Integrator : The analog integrator is used in many applications which require the computing or processing or generation of analog signals. It uses an opamp in the inverting mode. The feedback resistance is replaced by capacitance.

Opamp as Differentiator : By interchanging the resistor and capacitor of the integrator circuit, the inverse function viz differentiation can be performed. It also uses the opamp in the inverting mode.

Opamp Filters : Noise plays an important part in electronic systems. At times it might overshadow the wanted signal. Signals are characterised by their frequency. It might hence be mandatory to extract the wanted signal from noise using, some form of a frequency selective circuit or 'filter'. Filters can be made using passive components or active components. Active filters use the opamp in conjunction with an RC network. The advantages arising out of using active filters are elimination of inductors which are large, excellent gain and isolation properties, good range of Q's (to a few hundreds) and inputs and outputs do not float w.r.t. power supply.

Low Pass Filter : It uses the opamp in the inverting mode.

At low frequencies, the capacitive reactance is very high and so it appears as open. The circuit behaves like an inverting amplifier. As the frequency increases, the reactance decreases and gain drops. At high frequencies, the capacitor acts as a short. At the cut off frequency f_c , the gain is down. Low Pass Filter' allows only low frequencies to pass to the output while simultaneously attenuating the high frequencies. The cut off frequency f_c can be shown to be $f_c = 1/2 R2C$.

High Pass Filter : It also uses the opamp in the inverting mode. At low frequencies, the capacitor appears open and the voltage gain approaches zero. At high frequencies, the capacitor appears shorted and the circuit behaves as an inverting amplifier with gain equal to $-R2/R1$. Thus the circuit allows only high frequencies to appear at its output. The cut off frequency f_c can be shown to be $f_c = 1/2 R1C$.

Opamp as Waveform Generators : The applications considered so far are all linear applications incorporating negative feedback. We shall now see certain non-linear applications of opamps employing positive feedback. The opamp can be used to generate a square wave, a pulse or a triangular waveform. Generation of non-linear Waveform generally requires as integrator, a comparator and a latching logic circuit.

Op-amp as Schmitt Trigger : The Schmitt Trigger or Regenerative Comparator uses the Op-amp in the positive feedback loop. With positive feedback, when the loop gain equals unity, then the overall gain approaches infinity. Such an ideal situation results in an abrupt transition between the extreme values of output voltage. If a loop gain in excess of unity is Chosen, then the circuit exhibits a phenomenon called 'Hysteresis' or 'Backlash'.

Review Questions

1. What are the various characteristics of an Opamp
2. Explain the configuration of an Opamp.
3. Explain the Opamp as the inverting amplifier.

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CHAPTER THIRTEEN

POWER SUPPLY

Features:

- 13.1 Introduction
- 13.2 Linear Power Supply
- 13.3 SMPS
- 13.4 Converter Topologies-Flyback, Pushpull, Half-Bridge, Full Bridge
- 13.5 Three Terminal Regulators

13.1 INTRODUCTION

The power supply is essential for every electronic product, yet often taken for granted. When we talk of Power supplies we rarely mean a battery or generating source. The basic power is from the AC mains supply. We are talking of altering, controlling or regulating a power source. Regulation involves a error correction process and involves circuits that can monitor the output and make necessary corrections to keep that output voltage within the specified limits.

Regulated power supplies are a vital part of all electronic circuitry. Unfortunately this is sometimes neglected by the design engineer who develops his circuits using high quality laboratory power supplies and leaves the design of the power supply till the last minute.

A badly designed power supply can cause problems in the functioning and efficiency of a circuit as shown in the figure where we compare the characteristics of an audio amplifier with and without a regulated power supply.

There are power supplies that are voltage regulated until a certain load current is demanded from them. Then they abruptly change to a constant current mode. Such a dual performance power supply automatically protects itself from overload. Often independent controls are provided for the regulated voltage level and the current level at which the supply becomes a current source. The task of power supply design is an enormous project in itself. Linear power supply has been used since the dawn of electronics. These supplies are bulky due to heavy isolation transformer, heat sinks and cooling fans. But with the advancement in technology, the demand is for smaller, higher efficient power supplies high frequency switching frequencies above the traditional 20 kHz & up to the Megahertz region.

13.2 The Linear Power Supply :

A linear power supply essentially, operates on line frequency and has the following blocks as shown in Fig. 13.1

- (a) Isolation and step down power transformer
- (b) Rectifier & filter
- (c) Series pass element
- (d) Feedback & control

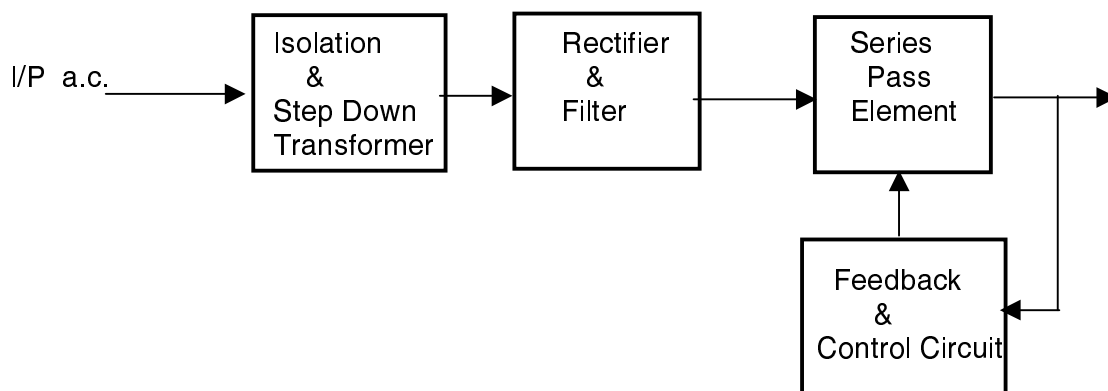


Fig 13.1

The isolation transformer provides the necessary isolation of power supply circuit from the input mains ac, and steps down the voltage to the required level. This secondary voltage is then rectified and filtered to give unregulated d.c. which is fed to the series pass element operating in the active region.

By sampling a portion of the output voltage and comprising it to a fixed reference voltage, the series pass element is used in the form of “variable resistor” to control and regulate the output voltage. Since the series-pass transistor operates in the active region, it dissipates lot of power as heat, necessitating use of heavy heat sinks & resulting in low efficiency between 30 to 50%. Linear power supplies have tight regulation band, low output noise & ripple. There are obvious disadvantages of low efficiency, bulky & heavy heat sinks, large power transformer, cooling fan. All this makes them almost unfit for today’s compact electronic systems.

13.3 SMPS

Introduction: Switch mode power supply (SMPS) has become the state of the art in power supply design. Small size, low cost and high efficiency are the three major features of SMPS. That has replaced the conventional linear power supply used earlier in electronic equipment.

Basic Principle of SMPS unit: Two different types of switching logic control are followed in SMPS designs. One approach is pulse width modulation (PWM) technique and the second approach is resonant mode approach. The PWM switch mode technique is commonly followed is SMPS used in PCs. In the PWM principle, a dc voltage is chopped at high frequency. The resultant square wave voltage is stepped up or stepped down by using a transformer. The transformer's secondary output is rectified and filtered. The regulation of the output voltage is achieved by varying the duty cycle of the square wave. Thus in an SMPS, the output voltage is compared to a reference and by controlling the duty factor of the signal applied to the switching circuit, the output voltage is maintained constant. The voltage control circuit can be incorporated either in the primary or secondary side of the transformer, as shown in figure 13.2 and 13.3.

The Bridge rectifier converts the a.c. input voltage in to d.c. voltage. The filter removes ripple at the output voltage. The switching transistor converts the d.c. voltage into square wave a.c. A full wave rectifier rectifies the a.c. square wave. The d.c. output voltage is compared with a reference voltage by the comparator. The error voltage at the comparator output is fed to the pulse width modulator. The opto-isolator provides isolation for the control loop against any pick up from the main path. The output of the opto-isolator is amplified by the drive stage. The driver output controls the switching transistor.

SMPS with primary side control

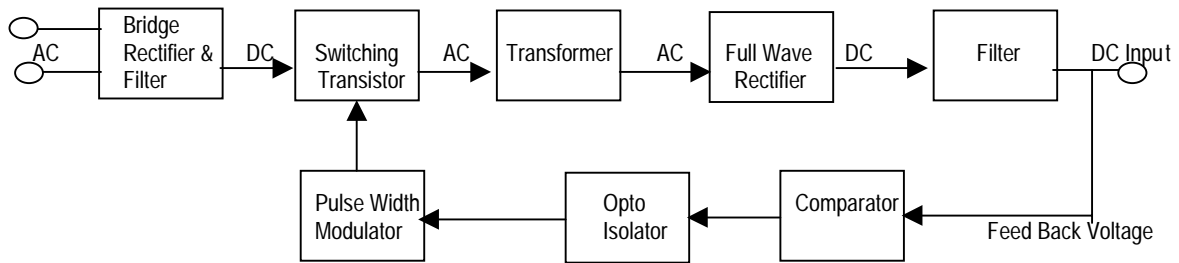


Fig. 13.2

SMPS with Secondary side control.

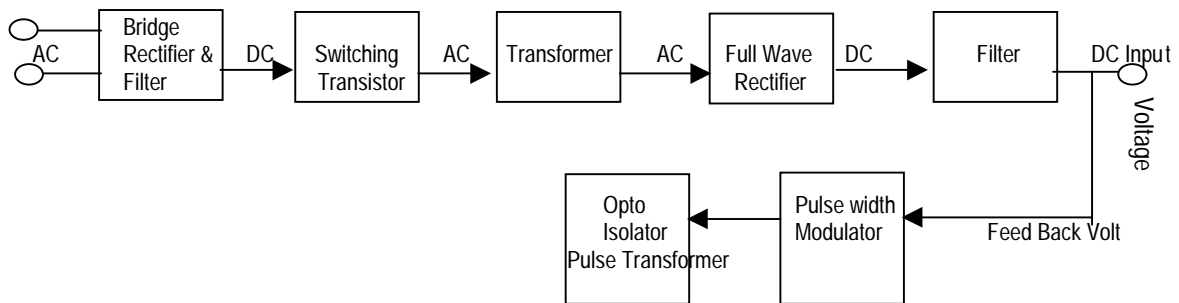


Fig. 13.3

Comparison Table of Linear Power Supply and SMPS

Parameter	Linear PS	SMPS
1. Efficiency	30-50%	70-80%
2. Size	0.3-0.5 Watts/inch ³	2 Watts/inch ³
3. Weight	10 Watts/lb	40Watts/lb
4. Line & Load Reg.	0.1%	0.1%
5. O/P Ripple	5 mV	50 mV
6. Noise (V _{p-p})	-	50-200 mV
7. Transient Response	20 μsec	1 ms
8. Hold-up time	1-2 ms	20-30 ms

All SMPS circuits in use today can be classified into one of the three major categories, namely flyback, forward and push-pull. The first two can be configured both in isolated and nonisolated circuits. The ;non-isolated versions are commonly referred to as Buck-Boost and Buck converters respectively. Push-pull circuits are almost invariably built with isolation between input & output.

13.4 BASIC CONVERTER TOPOLOGIES

All converters in use today are derived from three basic topologies namely the Buck, Boost and the Buck-boost. The basic arrangement for each of these topologies is shown

below. While the conceptual circuits are quite simple and use linear components, the switching of the switch makes these circuits non-linear.

The boost and Buck-boost converters store energy in the inductor when the switch is on and later transfer it to the reservoir capacitor when the switch is off. The Buck converter, in contrast transfers energy to the output during both states. Thus the output current is continuous for the converter which leads to lower ripple and reduced stress on output capacitor. In contrast, the boost converter drains continuous current for input and delivers pulsed to the output, thereby providing a better input current waveform. The Buck-boost converter has a pulsed input output current waveform. The Buck-boost converter has a pulsed input output current waveform. These basic characteristics can sometimes be important in selection a converter topology.

DERIVED TOPOLOGIES: All the popular ckts in use today are derived from the above three basic configurations and some of these are discussed below.

FLYBACK CONVERTER: The flyback converter acquires its name from its wide-spread use in TV deflection circuits. This circuit is derived from the buck boost converter by replacing the inductor with a transformer.

PUSH PULL CONVERTER :The next major derived converter is the push pull circuit which has been a workhorse circuit for many years, especially for equipment operating from low DC voltage. For off-line application its use is somewhat limited by the requirement of the transistor voltage rating of at least three times the input voltage.

This converter is easily capable of delivering power in the range of few watts to several kilowatts. It does require careful design, for high powers especially.

The push-pull converter has various advantages like nonisolated and simple base drive circuits for the two transistors, but has certain disadvantages which make it's use as an off-line converter very impractical.

(i) First limitation is the voltage rating of the transistor which should handle twice the input voltage to the converter plus any voltage to the converter plus any voltage spike which might result because of transformer leakage inductance

(ii) The second problem of core saturation is more severe.

THE HALF-BRIDGE CONVERTER : This circuit is an adaptation of the push-pull ckt that reduces the peak voltage applied to each power switch. The half-bridge ckt is the undisputed choice for off-line SMPS in the 100 to 500 watt range and is hence the most popular configuration in the industry today.

THE FULL-BRIDGE CONVERTER : The full-bridge is an extension of the half-bridge converter and in modern design should not be really considered for power levels below 500W. On the other hand, its very popular in UPS ckts because of excellent power handling capabilities.

FORWARD CONVERTER: This circuit is last of the buck-derived converters that are commonly used. In the 100 to 200 W range this configuration is a serious competitor to the half-bridge.

13.5 THREE-TERMINAL REGULATORS

For most non-critical applications the best choice for a voltage regulator is the simple 3-terminal type. It has only three connections (input, output and ground) and is factory-trimmed to provide a fixed output. Typical of this type is the 78xx.

The voltage is specified by the last two digits of the part number and can be any of the following 05, 06, 08, 10, 12, 15, 18, or 24. Figure 13.4 shows how easy it is to make a +5 volt regulator, for instance, with one of these regulates. The capacitor across the output improves transient response and keeps the impedance low at high frequencies (an input capacitor of at least 0.33 mF should be used in addition if the regulator is located a considerable distance from the filter capacitors).

The 7800 series is available in plastic or metal power packages (same as power transistors). A low-power version, the 79Lxx, comes in the same plastic and metal packages as small-signal transistors. The 7900 series can provide up to 1 amp load current and has on-chip circuitry to prevent damage in the event of overheating or excessive load current., the chip simply shuts down, rather than blowing out. In addition, on-chip circuitry prevents operation outside the transistor safe operating area by reducing available output current for large input-output voltage differential.

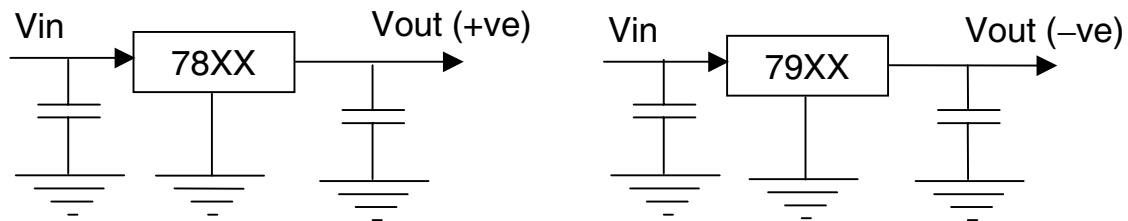


Fig. 13.4

Additional comments about 3-terminal regulators : The following specifications are typical for most 3 terminal regulators, both fixed and adjustable, and they may be useful as a rough guide to the performance you can expect,

Output Voltage Tolerance	1-2%
Dropout Voltage	0.5-2 Volts Maximum Input Voltage 35 Volts (except TL783 to 125 Volts)
Ripple Rejection	0.01-0.1%
Spike Rejection	0.01-0.3%
Load Regulation	0.1-0.5%, full load change
DC Input Rejection	0.2%
Temperature Stability	0.5%, over full temp range

Review Questions

1. Explain SMPS with the block diagram.
2. Make the block diagram for the linear power supply.
3. Which three terminal regulator will be used for +5V.
 - a) 7805
 - b) 7812
 - c) 7905

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CHAPTER FOURTEEN

TEST AND MEASURING EQUIPMENT, SOLDERING TECHNIQUES

Features:

- 14.1 Introduction
- 14.2 Soldering & De-Soldering Techniques
- 14.3 Types of Test & Measuring Equipment

14.1 INTRODUCTION

A soldered connection ensures metal continuity. The soldering process involves:

- (i) Melting of the flux which in turn removes the oxide film on the metal to be soldered.
- (ii) Melting the solder which removes the impurities.
- (iii) The solder partially dissolves some of the metal in the connection.
- (iv) The solder cools and fuses with the metal.

The soldering technique involves knowledge of:

- (i) Soldering iron.
- (ii) Soldering wire
- (iii) Soldering procedure
- (iv) Replacing components
- (v) Precautions when using C-MOS. devices.
- (vi) Knowledge of good and bad soldering joints.
- (vii) Desoldering techniques.

14.2 SOLDERING & DE-SOLDERING TECHNIQUES

(i) Soldering Iron: Soldering iron is an essential tool for soldering. A soldering iron should give sufficient heat to melt solder by heat transfer when the iron tip is applied to a connection to be soldered.

The selection of the soldering iron can be made as regard to its tip size, shape and wattage. Soldering iron temperature is selected and controlled according to the work to be performed. Generally two types of soldering irons are available: Soldering Pencil and Soldering Gun.

Soldering Pencils: These are light weight soldering iron which can generate around 12 watts to 50 watts of heat. Modular soldering irons use interchangeable heating elements and tips, which are in a main pencil body. A variety of tips are available to handle most soldering tasks. Very fine & rounded tips are used on PCBs with IC components and SMD's closely spaced.

Soldering Gun: This soldering iron is heavier and generates more heat than the pencil type of iron. Soldering of big capacitors or connectors is done through the use of this kind of gun. This gun can generate enough heat to quickly bring a heavy metal joint up to the proper soldering temperature. They are called soldering guns because they resembles a gun.

(ii) Soldering Alloy

Soldering Material: The soldering material is used to join together two or more metals at temperatures below their melting point. The solder alloy consists of Lead (37%) and Tin (63%). The continuous connection between two metal joints is made by solder material.

Most commonly used solder wire consists of 60% of Tin and 40% Lead. This is in the form of a hollow wire whose centre is filled with an organic paste like material called rosin. Its melting temperature is 190°C (190 degree centigrade).

Flux: Flux is a material used to aid soldering process. Flux is needed to scratch away the small film of oxides on the surfaces of metals to be soldered. This flux forms a protective film that prevents re-oxidation while the connection is heated to the point at which the solder melts. Flux is very helpful on a old, dusty, eroded joint.

Flux is normally available in the core of the soldering wire. It is also available packed independently.

(iii) Soldering Procedure

The soldering procedure involves selection of soldering iron, cleaning of component to be soldered and cleaning of the PCB to be soldered.

The soldering iron should be selected according to the job and should be powerful enough to provide heat. The tip of the soldering iron should be selected as per the space available for soldering.

The component that has to be soldered should be properly bent and its leads should be properly inserted in the PCB. Before insertion in the PCB, the lead should be properly cleaned. After component has been inserted it can be soldered.

The oxide on the PCB can be removed by using flux, sandpaper. The tip of the soldering iron should be clean and should have proper shape. The shape of the tip normally gets bad over a period of time. The shape can be made proper by filing.

During soldering excessive heat is generated at the soldering iron tip. If the soldering iron tip is in contact with component for a longer time then there is a possibility of damage of the component. The component can either be permanently damaged or may lose its characteristics. Such effects may not be noticed during assembly but may show up when the equipment is in use.

(iv) Zero Defect Soldering

A good soldering technique should ensure following:

- (i) The solder forms a strong joint and covers all the elements of the joint.
- (ii) The solder should appear convex, spherical shaped.
- (iii) The solder when becomes solid, appears as a bright solid without any cracks.

To bring about this result following procedure should be done:

- (i) Place iron tip at 45° to the PCB and component joint.
- (ii) Place the solder near the iron and let it flow.
- (iii) Smoothen the area of joint by the soldering iron tip. By doing this, the molten solder alloy flows into the PCB hole.
- (iv) Soldering should be done when the equipment is off.

(v) Replacement of Components

In case of single sided PCB, the component to be removed can be desoldered with the help of iron and flux. The only precaution that has to be taken is that the track should not break while removing.

In case of Through Hole PCB, care has to be taken so that the component while removing does not damage the Through Hole. In this case the component is soldered on one side and the lead flows through the hole to the other side, so Desoldering and removing becomes very difficult and requires practice. If one has already identified the faulty component, then one should not try to remove or desolder the component. The component should simply be cut and taken out.

(vi) Considerations for handling CMOS Devices

CMOS Devices are sensitive to static charges. So care has to be taken while handling these devices. Static charge is generated by rubbing cloth with human body or by any other friction of human body.

- (i) Before storing or handling CMOS Devices, static charge should be discharged by touching the ground or metallic chassis of the equipment.
- (ii) One can wear a metallic band in hand, which is connected to ground.
- (iii) The working table should be either of wood or should have rubber sheet.
- (iv) The soldering iron tip should be static charge free.

(vii) Desoldering Technique: Desoldering can be done by following two ways :

- (i) By using a desoldering wick.
- (ii) By using a desoldering pump.

Desoldering wick is made of fine copper wire mesh. When this is applied to the heated component, the molten solder gets attached to the wire mesh by capillary action.

Desoldering pump has a suction pump. The nozzle of the desoldering pump is kept close to the heated component. The molten solder is sucked by a spring action.

14.3 TYPES OF TEST & MEASURING EQUIPMENT

The task of troubleshooting is essentially carried out by using test instruments. A majority of the system faults can be located and rectified by using the following two instruments.

1. Multimeter
 - a) Analog
 - b) Digital
2. Oscilloscope

THE ANALOG MULTIMETER

The type of measurements usually carried out in electronic circuits is basically d.c. and a.c voltages, current and resistance measurements.

Besides, there are a variety of measurements in terms of amplitude, frequency, phase and a detailed waveform analysis that needs to be performed on complex circuit for troubleshooting.

A multimeter is the most common and most useful tool of the electronics trade. This instrument allows making measurement of d.c voltage, a.c voltage, d.c current and resistance values. The multimeter is particularly useful for the following tests.

- (i) Measurement of the in-circuit resistance i.e. checking for dry joints, taking resistance readings alongwith other discrete components e.g. transistors and diodes.
- (ii) Measurement of d.c voltages around doubtful transistor to determine whether the transistor is conducting or non-conducting.
- (iii) Measurement of d.c voltages around the doubtful transistors to find whether the transistor is conducting or not.
- (iv) Measurement of the ICs supply voltage.

The analog multimeter's accuracy (1%) is sufficient for majority of requirements specifically in which, the presence of a value near the one specified is required. Such requirements are generally met with an analog meter in comparison to a digital reading type instrument because approximate voltage level is more quickly observed on this instrument. A digital multimeter is preferred whenever high accuracy is required especially when any small change in a level needs to be measured.

The loading effect of digital multimeter is negligible in the circuit, since it has high input impedance (typically 10-M ohm). A digital multimeter with 0 to 500 V voltage range and 0 to 12-M ohm resistance range and an accuracy of 1% is adequate for most of the test applications. Test probes are usually insulated to prevent accidental shorting.

Analog multimeter is normally a moving coil meter, which by switching of the selection probe jacks, can be changed to a dc voltmeter, an ac voltmeter and dc milli-ammeter or an ohmmeter.

HOW TO USE MULTIMETER

MEASUREMENT OF CURRENT: For the measurement of current, the ammeter is placed in series in the applicable circuit. For doing this the circuit must be broken to connect the ammeter .The ammeter, thus becomes a part of the circuit. The ammeter has small internal resistance, its insertion into the circuit will decrease the current negligibly.

MEASUREMENT OF VOLTAGE : The potential difference between any two points in a circuit is measured by connecting the two voltmeter leads across these points. The voltmeter is connected across or in parallel with the circuit where voltage is to be measured.

To measure a.c voltage, the signal needs to be rectified first. As in the a.c current meters, an a.c voltmeter also responds to the average value of the rectified voltage but are calibrated in volt rms. for a sine-wave.

MEASUREMENT OF RESISTANCE : The Ohmmeter/ multimeter is usually used to measure the resistance, when the circuit is not powered on. The resistance of the component is measured by connecting the leads across the component. For more precise measurement of values , one can select the appropriate range for the resistance measurement.

Precautions in the use of Multimeter

1. The batteries in the multimeter should be checked frequently for low battery for correct operation especially in the resistance ranges.
2. The instrument should be stored away from the corrosive atmosphere for the sake of the switch contacts.
3. The function switch of the multimeter should always be kept on a high d.c volts scale to avoid
 - a) Draining of batteries by accidental short-circuiting of leads during storage.
 - b) Burning out the rectifier by accidentally connecting to the d.c voltage when on the a.c scale.

DIGITAL MULTIMETER

In comparison to Analogue Multimeter, Digital Multimeter has high input impedance, better accuracy and resolution. They usually have features auto ranging, auto polarity and auto zero facilities, which means the user need only adjust the function switch and take the reading.

The digital multimeter converts an analog signal into its digital equivalent and displays it. The analog signal input can be a d.c voltage, an a.c voltage, a resistance or an a.c or d.c current.

The heart of the DMM is the analog to digital (A/D) converter. There are different principles on which the A/D converters can be designed. However the most popular and widely used method is the dual slope technique.

The front end of the DMM contains circuit blocks, which govern its basic characteristics such as its number of digits, ranges, sensitivity etc. Since the input to the A/D converter must be d.c voltage, all other quantities should be reduced to d.c. Therefore, for measurement of a.c voltage, it is first rectified to derive a d.c voltage proportional to the average value of the a.c waveform calibrated to the rms value for a sine wave, and the resulting d.c voltage is applied to the integrator.

Resistance is normally measured by feeding 1-volt reference signal to the input amplifier through a range resistor and configuring the amplifier to place the unknown as the feed back resistor.

The amplifier output is proportional to the ratio of the unknown resistance of the range resistor.

OSCILLOSCOPES

INTRODUCTION

The cathode ray oscilloscope is the most versatile tool for the development of the electronic circuits and systems. The cathode ray oscilloscope is a device that allows the amplitude of electric signals, whether they be voltage, current, power etc to be displaced primarily as the function of time. The oscilloscope depends on the movement of an electron beam, which is then made visible by allowing the beam to impinge on a phosphor surface, which produces a visible spot. If the electron beam is deflected in either direction such as X or Y-axis, the luminous spot can be used to create a two dimensional displays. The x-axis of the oscilloscope is deflected at a constant rate relative to time and the vertical or y- axis is deflected in response to an input stimulus such as voltage.

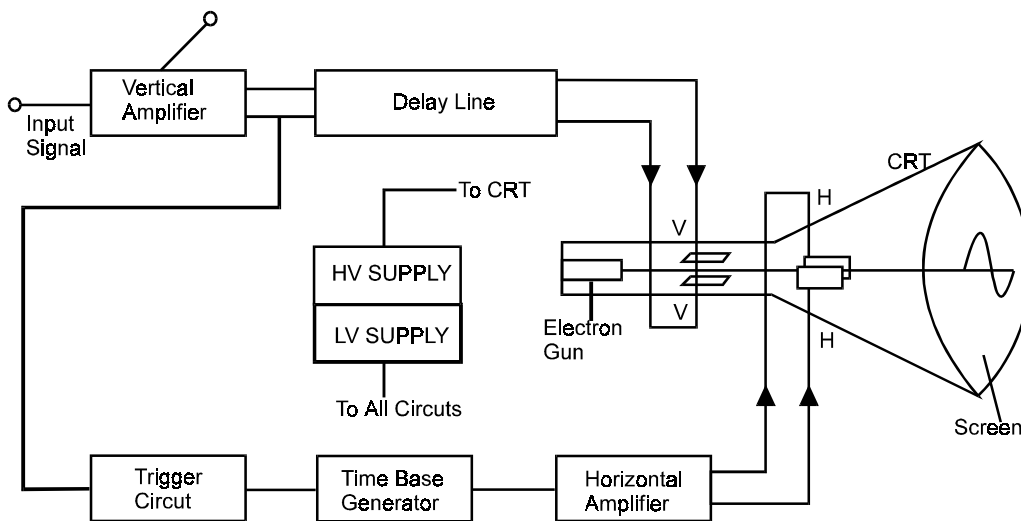


Fig. 14.1 Block Diagram of General Purpose Oscilloscope

The heart of the oscilloscope is the cathode ray tube which generates the electronic beam, accelerates the electron beam to a high velocity deflects the beam to create the image, and contains the phosphor screen where the electron beam eventually becomes visible. To accomplish these tasks various electric and voltages are required as shown in fig.14.1The power supply provides the voltage required by the cathode ray tube to generate and accelerate the electron beam as well as to supply the required operating voltages for the other circuits of the oscilloscope. Relatively high voltages are required by the cathode ray tubes, of the order of the few thousand volts, for acceleration as well as low voltage for the heater of the electron gun, which emits the electrons. The oscilloscope has a time base, which generates the correct voltage to supply the cathode ray tube to deflect the spot at a constant time dependent rate. The signal to be viewed is fed to a vertical amplifier, which increases the potential of the input signal to a level that will provide useable deflection of the electron beam. To synchronize the horizontal deflection with the vertical input a synchronizing or triggering circuit is used. This circuit is a link between the vertical input and horizontal time base.

CRT CIRCUITS

The cathode ray tube must be supplied with several dc potentials to provide the proper control, acceleration, and focussing action. Fig 14.2 shows a cathode ray tube and the associate circuits that provide the required potentials for operation. The first requirement is a low voltage for the cathode. This is usually supplied from a well-insulated and separate winding on the cathode to prevent breakdown between these two elements. The total accelerating voltage will be applied to the cathode ray tube in two halves. First, a high negative potential will be applied to the cathode grid and focussing electrodes. Second, a high positive potential will be applied to the post deflection acceleration electrode, resulting in the deflection plates being at approximately ground potential. This prevents the output of the deflection amplifier from being at a high potential and simplifies the design of the circuit.

Very few of the elements of the cathode ray tube require any significant power, and the required operating voltages are derived from simple voltage dividers, as shown in fig14.2. Three controls are associated with the operating voltages of the cathode ray tube: INTENSITY, FOCUS, and ASTIGMATISM. The intensity control varies the potential between the cathode and the control grid and simply adjusts the beam current in the tube. The increased beam current increases the number of electrons landing on the phosphor and thus adjusts the light output. The focus control adjusts the focal length of the electrostatic lens. The astigmatism control adjusts the potential between the deflection plates and the first accelerating electrode and is used to produce a round spot.

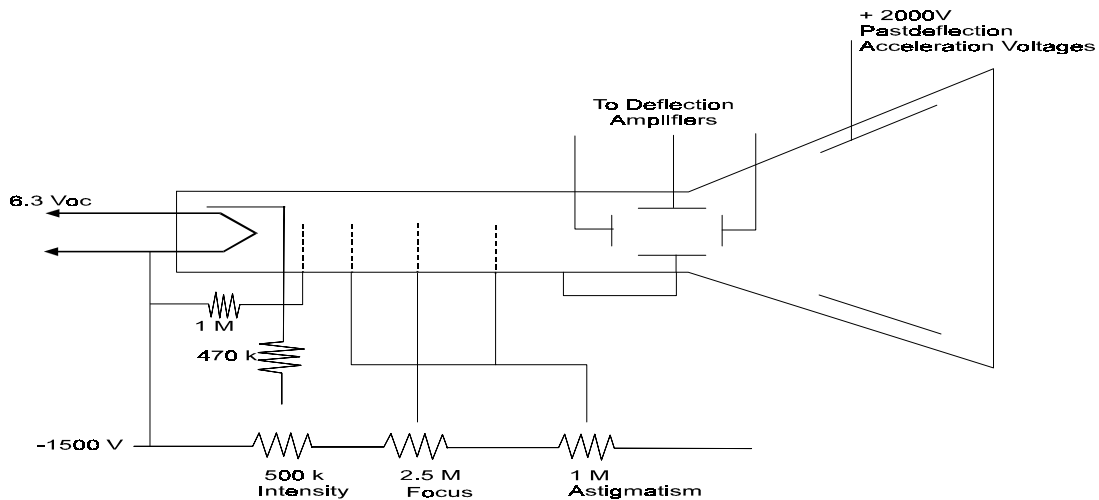


Fig 14.2. CRT Showing the Electrode Voltages & Adjustments

The deflection sensitivity and thus the accuracy of the oscilloscope is dependent on the value of the accelerating voltage before the deflection plate, and usually this voltage is regulated. Deflection sensitivity is not a function of the post deflection acceleration voltage, and this supply is not usually regulated.

Although not a part of the required tube voltages, a constant current, as adjusted by the trace rotation control, is supplied to the wire supplying the trace rotation magnetic field.

VERTICAL DEFLECTION SYSTEM

The function of the vertical deflection is rather straightforward, it must provide an amplified signal of the proper level to drive the vertical deflection plates without introducing any appreciable distortion into the system.

Although the oscilloscope can eventually be used to display practically any parameter, the input to the oscilloscope is voltage. The general laboratory oscilloscope can accept as low as a few milli volts per centimeter of deflection up to hundreds of volts using the built in attenuate or and external probes. Fig 14.3 shows the block diagram of a complete vertical deflection system. The input connector feeds input attenuate after which follows the vertical amplifier. The input impedance of an oscilloscope is rather high ,being of the order of 1Mohm,which is desirable for measuring voltages in high impedance circuits. The attenuator sets the sensitivity of the oscilloscope in the common 1-2-5 sequence. As an example, the input attenuator could provide for 10,20,50,100,200 mV, etc per centimeter. The input attenuator must provide the correct 1-2-5 sequence attenuation while maintaining a constant input impedance, as well as maintaining both the input impedance and attenuation over the frequency range for which the oscilloscope was designed.

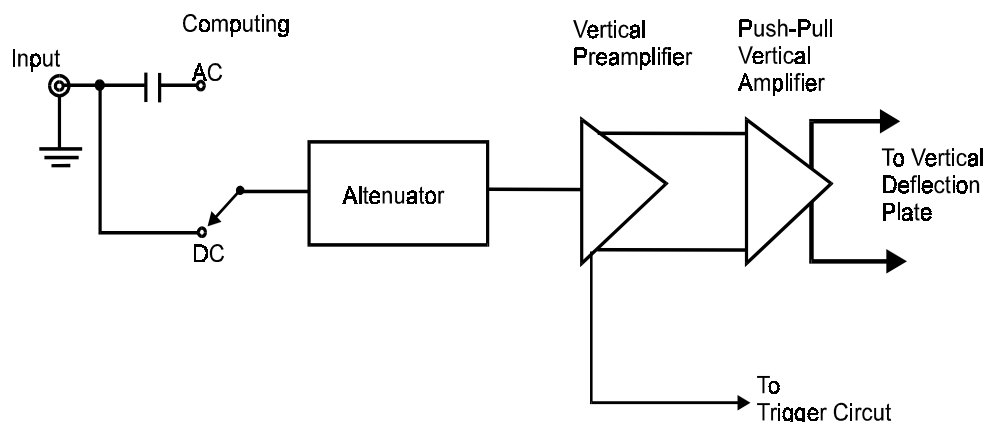


Fig 14.3 Block Diagram of the Vertical Section of an Oscilloscope

Practically all oscilloscopes provide a switchable input coupling capacitance. This is provided so that measurements of a.c signals may be viewed in the presence of high dc voltages by including the coupling capacitor. When d.c measurements are to be made, the capacitor may be removed. The value of the capacitor is chosen so that the frequency response of the oscilloscope is preserved down to a few hertz.

The input impedance of an oscilloscope is 1M ohm shunted with between 10 and 30 pF. If a probe were connected to the oscilloscope, the input impedance of the probe tip would have greater capacitance because of the added capacitance of the probe assembly and of the connecting shielded cable. It is desirable, especially for high frequency oscilloscope, to have input capacitance much less than 20 or 30 pF, and this is achieved by the use of an attenuator probe.

Because the input capacitance of an oscilloscope cannot be guaranteed from unit to unit, the 10 to 1 probe is provided with an easily adjustable compensating capacitor. If

the ratio of the series to shunt capacitance is not adjusted to be precisely 10 to 1, the frequency response of the oscilloscope will not be flat.

The effects of incorrect setting of an oscilloscope compensation can readily be seen by observing a fast rise time pulse. If the frequency response of the oscilloscope is not correct, the pulse will be distorted and the compensation can be adjusted to achieve the least amount of distortion.

MULTIPLE TRACE

In the analysis of electronic circuits and systems, it is very useful to be able to view the behaviour of two or more voltage simultaneously. This could be accomplished by using two oscilloscopes. Aside from the expense, it is difficult to trigger the sweep of each oscilloscope at precisely the same time to insure that the sweep generators operate precisely the same. Even if all this should be achieved, the two traces to be viewed will be on two different oscilloscope tubes, and not one atop the other where the comparison can be made easily.

There is an elegant solution to this problem, which requires a special cathode ray tube that has two separate electron guns generating two separate beams. Each electron beam has its own vertical deflection plates, but the two beams are deflected in the horizontal direction by a common set of deflection plates and deflection generator. This is called a dual-beam cathode ray tube and is only used in systems where absolute independence of the vertical channels is required.

A more common and less costly method is to use the dual trace, as opposed to dual beam, method. In this method, the same electron beam is used to generate two traces that can be deflected from two independent vertical sources. One method is to deflect the oscilloscope and display the first or A vertical input. Then the oscilloscope is triggered and the B vertical input is displayed at a different position on the oscilloscope screen. A block diagram of this system is shown in fig.14.4. An electronic switch is used to switch between the two vertical sources, which are processed in separate vertical amplifiers that include separate position controls. Each time the sweep generator is triggered, the electronic switch is changed to the other channel. The disadvantage of this system is that the display is not actually a representation of two simultaneous events; the events were at two different times. If the events are cyclical, this may not pose a problem. However, if the events are a single occurrence this alternate sweep method will not provide a true picture.

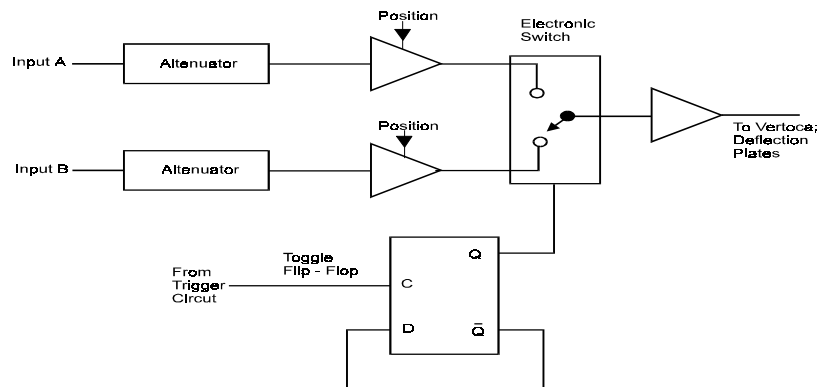


Fig. 14.4 Block Diagram of a Dual Trace Oscilloscope

A second method is to switch from one vertical channel to the other at such a rapid rate that the display is created from small segments of the actual waveform. This requires that the chopping frequency be much greater than the input waveform in order to prevent the display from being unrecognizable. The practical switching speed of an electronic switch will limit the frequency capability of this method, and chopping frequencies are usually less than 500 kHz. The electronic circuits required to generate the chop method of dual trace generation are precisely the same as those used to generate the alternate method, except the electronic switch is a high frequency clock rather than the trigger generator.

Because there are significant advantages and disadvantages with each system, most oscilloscopes have a switch that is capable of selecting either method.

HORIZONTAL DEFLECTION SYSTEM

It is the purpose of most laboratory oscilloscopes to deflect the horizontal portion of the trace at the constant rate relative to time, which is often referred to as linear sweep. The horizontal deflection system consists of a time base generator, a trigger circuit, and a horizontal amplifier as shown in fig14.1. The time base generator controls the rate at which the beam is scanned across the face of the cathode ray tube and is adjusted from the front panel. The trigger circuit as previously described, insures that the horizontal sweep starts at the same point of vertical input signal. The horizontal amplifier is similar to the vertical amplifier and is required to increase the amplitude of the signals generated in the sweep generator to the level required by the horizontal deflection plates of the cathode ray tube.

The sweep generator uses the charging characteristics of a capacitor to generate linear rise time voltage to feed to the horizontal amplifier. There are four basic types of sweeps.

- a) **FREE RUNNING OR RECURRENT SWEEP:** In the free running or recurrent sweep, the swatch waveform is repetitive. A new sweep is started immediately after the previous sweep is terminated and the circuit is not initiated by any external signal.
- b) **TRIGGERED SWEEP:** A waveform to be observed on CRO may not be periodic but may perhaps occur at irregular intervals. In this case it is desirable that the sweep circuit remain inoperative and the sweep be initiated by the waveform under examination. In some cases the waveform may be periodic, but it may be that the interesting part of the waveform is of very short duration compared to the period of the waveform. Under such cases a triggered sweep is used.

In the triggered sweep or single sweep, the spot swept once across the screen in response to a trigger signal. The triggered sweep is used for examination of transients or one time signal and the waveform is photographed for record. The trigger can be obtained from the signal under investigation or by an external source.

(a) DRIVEN SWEEP: In most cases, a driven sweep is used where the sweep is recurrent but triggered by the signal under test.

(b) NON SAW TOOTH SWEEP:

For some applications like comparison of two frequencies or for finding phase shift between two voltages, non-saw tooth sweep voltages are utilized for the sweep circuit. Sweep frequencies vary with the type of oscilloscope. A laboratory oscilloscope may have sweep frequency up to several MHz; a simple oscilloscope for audio work has an upper limit of 100 kHz. Most TV service require a sweep voltage frequency up to 1 MHz.

TRIGGERING

The sweep does not start until a triggering pulse is received from the triggering circuit. The relation between the sweep generator and the trigger pulses, which represent the same point of the input waveform, is shown in fig.14.5. The sweep does not usually trigger for each cycle of the vertical input waveform unless the sweep plus the hold off time is less than the period of the input. In some oscilloscopes the hold off time can be adjusted from the front panel to facilitate stable triggering from complex waveforms.

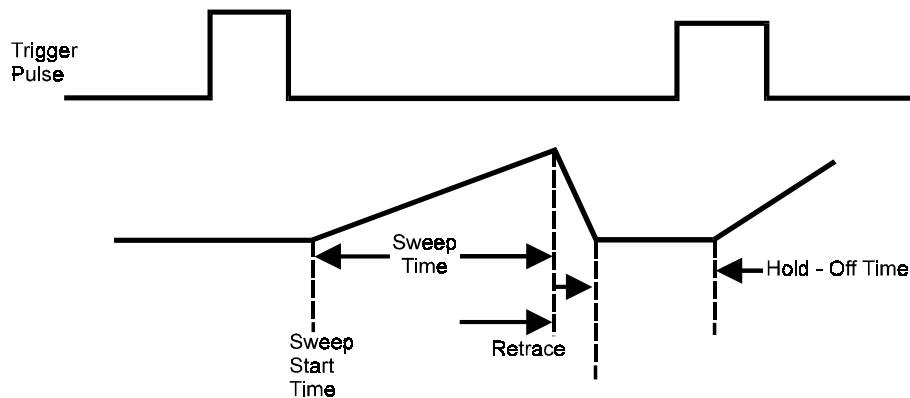


Fig. 14.5 Relation Between the Trigger Pulse & Sweep in an Oscilloscope

When the oscilloscope has not been triggered, the electron beam in the cathode ray tube is turned off or blanked. Otherwise, a bright spot will appear at the left side of the screen and will in a short period of time destroy the phosphor coating at that point. In addition, the electron beam is turned off or blanked during the retrace. The image painted by the retrace is reversed in time and of a different rate. It therefore provides no useful information and clutters the desired trace. Generally, in an oscilloscope the trace is blanked and signals are applied to unblank the trace. When the triggering circuit supplies a negative going pulse to allow the capacitor in the sweep circuit to charge and start the sweep, the same pulse is used to unblank the beam.

SYNCHRONIZATION

Whatever type of sweep is used it must be synchronized with the signal being measured. Synchronization has to be done to obtain a stationary pattern. This requires that the time base be operated at a sub-multiple frequency of the signal under measurement (applied to Y plates). If synchronization is not done, the pattern is not stationary, but appears to drift across the screen in a random fashion.

SOURCES OF SYNCHRONIZATION

There are three usual sources for synchronization, which can be selected. Synchronizing selectors:

- i) Internal: In this type of synchronization, the trigger is obtained from the signal being measured through the vertical amplifier.
- ii) External: In this method, an external trigger source is also used to trigger or initiate the signal being measured.

LINE

In this case ,the trigger is obtained from the power supply to the CRO.

BLANKING CIRCUIT

The sawtooth sweep voltage applied to the X plates moves the beam across the CRT tube in a straight horizontal line from left to right during the sweep or trace time T . A comparatively slow movement of the spot will appear as a solid line, provided the rate of the movement exceeds the threshold of persistence of vision. Below this threshold limit, a moving spot is perceived.

On the other hand, the comparatively rapid movement of spot will appear as a thin and dim line, or may be invisible. Thus if the retrace or flyback time is very small, the spot remains invisible. In an ideal case the flyback time T , is zero and hence the spot while moving from right to left remains invisible. However in actual practice the flyback time is not zero and therefore the retrace may cause confusion. Thus the retrace should be eliminated or blanked out. The retrace is blanked out by applying a high negative voltage to the grid during the flyback period T . The blanking voltage is usually developed by sweep generator.

INTENSITY MODULATION

Intensity modulation (z-axis modulation) is done by inserting a signal between the ground and the cathode (or control grid). Z-axis modulation is applied normally during visible portion of the trace.

The z-axis modulation can be used for brightening the display. Periodic positive pulses are applied to the grid alternately negative pulses are applied to the cathode to brighten the beam during its sweep period. These periodically brightened spots may be used as markers for time calibration of the trace.

POSITIONING CONTROLS

It is necessary to provide some means of positioning the trace on the screen. The positioning of the trace is done by applying small independent, internal d.c voltage to the deflecting plates and control can be exercised by varying the voltage with help of potentiometers.

FOCUS CONTROL

As mentioned earlier, the focussing electrode acts like a lens whose focal length can be changed. This change can be brought about by changing the potential of the focusing anode.

INTENSITY CONTROL

The intensity of the beam is varied by the intensity control potentiometer, which changes the grid potential with respect to cathode. The grid potential determines the amount of electrons leaving the cathode and thus controls the intensity of the beam.

CALIBRATION CIRCUIT

Laboratory oscilloscopes normally have an internally generated and stabilized voltage of known amplitude, which is used for calibration purposes. Usually the calibrating voltage has a square waveform.

ASTIGMATISM

In most modern oscilloscopes there is an additional focusing control marked astigmatism. This is used to correct an effect, which exactly is analogous to astigmatism in optical lenses. To focus the spot correctly, switching off the time base and adjusting the X and Y positioning controls. The spot is then made as sharp as possible by successive adjustment of focus and astigmatism controls.

Review Questions

1. Write a short note on soldering process.
2. What are the considerations for handling the CMOS devices?
3. Which parameters can be measured by Multimeter?
4. Write short note on CRO.
5. What are the various controls on CRO?

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CHAPTER FIFTEEN

TOOLS AND AIDS

Features:

- 15.1 Introduction
- 15.2 Types of Tools

15.1 INTRODUCTION

The type and variety of tools and test equipment that a professional technician possesses have a direct impact on his efficiency to do the job.

15.2 TYPES OF TOOLS

The tools which are generally used in electronic equipment servicing practice are :

- (a) Pliers, tweezers, wire strippers.
- (b) Cutter
- (c) Screw drivers - various sizes.
- (d) Brushes - soft and hard.
- (e) Soldering irons
- (f) Desoldering pump, desoldering wire.

All these tools are important in an electronic workshop.

Pliers: Pliers are frequently used to hold wires in place during soldering, acting as a heat sink to protect a delicate component, bending component leads to fit mounting holes on a circuit board and pulling wires through a PCB hole.

One single design in pliers cannot meet all the demands. Thus there are many types of pliers. Some pliers have cutting knives also. A long nose pliers is most useful and adequate for most of the jobs.

Pliers have different shapes of handles, the most common are with curved handles. Extended handles are provided on some long nose pliers for longer reach.

Cutters: Cutters are essential tools for component lead cutting and removing insulation prior to soldering. Cutters should be of side cutter (flush cutter/surface cutter). Preferably cutter should have insulated grips. They should be slim line and light weight for precision work.

The tips of the cutters should be tapered to allow the user to reach a particular wire in a crowded area. Cutter blades should be very well aligned so that cutting edges meet squarely and allow little or no light to pass through when held together. Cutter action should be smooth and clean. Cutter should normally be used to cut copper wire or leads of components.

Wire Stripper: It is difficult to strip the wire with the cutters. Thus Wire Strippers are used to remove insulation from the wires. The most commonly used strippers are of cutting type. In strippers there are two sets of jaws, one set of jaws holds the wire and another set of jaws hold the sleeve of wire and pull it apart. It has two handles. The set of jaws operate when the jaw's handle is pressed together.

Wrenches: The various types of wrenches are : combination, open-end and box wrenches, adjustable wrenches, socket wrenches, combination wrench set, torque wrenches and pipe wrench.

In case of electronic equipment, Allen Wrench and Bristol Wrenches are commonly used. The wrench is an excellent tool for applying torque to the task of turning bolts, nuts and shafts. Hexagonal keys (Allen keys) do the same job as wrench and are called Hexagonal Wrenches or Allen Wrenches. Allen Wrenches are most useful for opening many control knobs.

Screw Drivers: A variety of sizes and types of screwdrivers are required in the equipment servicing practice. The handle of the screwdriver is usually made of tough transparent plastic. Its smooth and semi rounded corners fit the palm comfortably for applying the power needed to open a screw. The blade of the screwdriver is made of steel, which is heat treated and tempered to apply torque to the screw head. Normally the blade is chrome plated.

Screwdriver types are:

- (a) Tip shape-like Philips (+)
- (b) Blade type regular.

Blade screwdrivers come in a number of sizes. Normally five sizes are provided in a screwdriver set.

Philips screws are those with star-shaped holes in their head as opposed to straight slots. For opening these screws star-shaped (+) screw driver is used, which is called a Philips Screw Driver.

Chemicals required for servicing: Chemical tools, which are generally employed, include:

- (a) Solvents
- (b) Adhesives
- (c) Lubricants

Solvents: Solvents are used for cleaning purposes. Solvents come either as aerosols (spray solvents) or as liquids. Various types of solvents that are available are Non-Lubricating Cleaners, Lubricating Cleaners, Foam-type Cleaners.

Non-Lubricating Cleaners are used to remove dust from circuit boards, mechanical assemblies and parts like magnetic tape heads.

Lubricating Cleaners should not be used for applications in which the lubricant is likely to attract dust after its application, as the dust creates friction in moving parts. Lubricating cleaners are preferred in potentiometers and switches.

Foam type Cleaners are specially made compounds, which are packed as spray. These compounds contain mild abrasives in a thick viscous (high-density) base.

Adhesives: Adhesives are used to fasten two pieces together reliably and quickly. They can be useful if the broken parts are unavailable or in cases like cabinets.

Epoxy: Epoxy is universal adhesives that have a variety of setting time & viscosity. Epoxy binds most materials, including metals, glass, ceramics, rubber, fiber and most

plastics (except nylon and similar compounds). Epoxy bond strength is generally same as the strength of bonded materials themselves.

Lubricants: Lubricants are required to lubricate moving parts of equipment. Parts that slide against each other require frequent lubrication. When, lubricating small mechanisms, the lesser quantity of lubricant should be used.

For gear trains, bearings a good grade of light-bodies greases should be used. This provides long lasting lubrication. The grease does not oxidize or becomes gummy for a long time.

Freeze Sprays: Freeze Sprays as the name goes, are sprays. These sprays are used to cool suspected components, which get heated during the operation of the equipment.

When any component gets heated beyond reasonable allowed limits, it starts behaving erratically. This leads to the total equipment behaving abnormally or totally shut down. To trouble shoot the problem, we normally cool the suspected component with freeze sprays, the equipment then starts behaving normally for sometime. After the passage of some time if again the equipment behaves erratically, then it is clear that it was because of the heated component.

Freeze sprays do not harm the PCB. However, their use should be avoided around clear plastic or cabinet plastic or any painted finish.

Another use of freeze sprays is to disassemble tight fitting metal parts, as cooling the inside piece will reduce its size temporarily.

Review Questions

1. What is the difference between a cutter and wire stripper?
2. What are the chemical tools?
3. What is the use of freeze sprays?

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