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P.B. SIDDHARTHA COLLEGE OF ARTS & SCIENCE

(Autonomous)

SIDDHARTHA NAGAR, VIJAYAWADA – 520 010

A COLLEGE WITH POTENTIAL EXCELLENCE

ISO 9001:2015 NAAC Accredited

DEPARTMENT OF PHYSICS

APPLICATIONS OF ELECTRICITY & ELECTRONICS

PHYSET01

FOR B.Sc. SEMESTER-V

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P.B. SIDDHARTHA COLLEGE OF ARTS & SCIENCE

Siddhartha Nagar, Vijayawada – 520 010

Autonomous - ISO 9001 – 2015 Certified

III B.Sc.-PHYSICS: V SEMESTER: PAPER–VI

Domain Subject: **PHYSICS**

Title of the Paper: Course 6C: APPLICATIONS OF ELECTRICITY & ELECTRONICS

(Skill Enhancement Course (Elective), Credits: 05)

Offered to: B.Sc. (MPC & MPCs)

Course Type: Core (TH)

Year of Introduction: 2022-23

Hours Taught: 45 hrs. per Semester

Course Objectives:

- To help students to understand the principles and laws of electricity which is essential to constantly emerging newest technologies
- To create interest among the students about the communication systems by studying electricity and electronics
- Students will be able to understand applications of passive elements, AC, DC circuits and power supplies

Course Outcomes: 1

At the end of this course, students should be able to:

CO1 Understand the types of resistors, Inductors and capacitors and its applications

CO2 Distinguish between AC and DC sources and understand about the batteries and Network theorems for DC circuits

CO3 Explain the working principle and construction of Generators and transformers

CO4 Learn the applications of EM induction and power supplies

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SYLLABUS

UNIT-I: INTRODUCTION TO PASSIVE ELEMENTS (9 hrs)

a) **Passive elements**

Resistor - Types of Resistors, Colour coding, Combination of Resistors – Series combination (Voltage division), Parallel combination (Current division), Ohms Law and its limitation.

Inductor - Principle, Types of Inductors. Capacitor - Principle, Charging and discharging of a Capacitor, Types of Capacitors.

b) **Applications of Passive elements:**

Applications of a Resistor as a heating element in heaters and as a fuse element. Applications of Inductors, Application of choke in a fan and in a radio tuning circuit, Series resonance circuit as a Radio tuning circuit. Applications of Capacitor in power supplies, motors (Fans).

UNIT-II: POWER SOURCES (BATTERIES) (9 hrs)

a) **Power sources:**

Types of power sources-DC & AC sources, Different types of batteries, Rechargeable batteries - Lead acid batteries, Li-ion batteries, Series, Parallel & Series-Parallel configuration of batteries

b) **Network Theorems for DC circuits**

Thevenin's theorem, Norton's theorem, Maximum Power transfer theorem, Constant Voltage source - Constant Current Source-Applications of Current sources & Voltage sources.

UNIT-III: ALTERNATING & DIRECT CURRENTS (9 hrs)

a) A.C Generator, Construction and its working principle, DC Generator, Construction and its working principle, advantages and disadvantages, Differences between DC and AC generators

b) Transformers- Construction and its working principle, Open circuit and short circuit tests, Types of Transformers - Step-down and Step-up Transformers, Relation between primary and secondary turns of the transformer with emf, Use of Transformer in a regulated Power supply

UNIT-IV: MODULATION CIRCUITS (Skill Based) (9 hrs)

a) **Amplitude modulation:**

Amplitude modulation, modulation index, Waveforms, Power relations, AM transmitter, AM Receiver, Demodulation, Diode detector

b) **Frequency modulation:**

Frequency modulation, modulation index, Waveforms, FM Transmitter, FM Receiver

Unit-V: Applications of EM Induction & Power Supplies (Skill Based) (9 hrs)

a) DC motor – Construction and operating principle, Calculation of power, voltage and current in a DC motor, Design of a simple Motor (Fan) with suitable turns of coil

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b) Working of a DC regulated power supply, Construction of 5 volts regulated power supply, Design of a step-down (ex:220-12V) and step-up (ex:120-240V) transformers-Simple Design of FM Radio circuit using LCR series resonance (tuning) circuit, Design of a simple 5 volts DC charger

References:

1. Grob's Basic Electronics by Mitchel Schultz , TMH or McGraw Hill
2. Electronic and Electrical Servicing by Ian Robertson Sinclair, John Dunton, Elsevier Publications
3. Troubleshooting Electronic Equipment by R.S. Khandapur, TMH
4. Web sources suggested by the teacher concerned and the college librarian including reading material.

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Course 6C: Applications of Electricity & Electronics–

PRACTICAL (Laboratory) SYLLABUS *(Max Marks:50)*

EXPERIMENTS LIST

Minimum SIX experiments are to be done and recorded

1. Measurement of R using Color coding of Resistors and measurement of R using multimeter **- Resistors of different values, Multimeters**
2. Connect two or three resistors or capacitors or inductors and measure the Series, Parallel Combination values using a Multimeter and compare the values with the calculated values **- Capacitors of different values**
3. Use the Digital Multimeter and Analog Multimeter to measure the output voltage of an AC & DC power supply - **Digital Multimeters, Analog Multimeters**
4. Use the Multimeter to check the functionality of a Diode and Transistor. Also test whether the given transistor is PNP or NPN - **Different types of Transistors and Diodes**
5. Construct a series electric circuit with R, L and C having an AC source and study the frequency response of this circuit. Find the Resonance Frequency. – **Series Resonance Experiment (Function generators)**
6. Construct a Parallel electric circuit with R, L & C having an AC source and study the frequency response of this circuit .Find the resonant frequency. – **Parallel Resonance Experiment (Function generators)**
7. Test whether a circuit is a Open circuit or Short Circuit by measuring continuity with Multimeter and record your readings. – **Experimental Kit to do the tests**
8. AM Generation Kit
9. FM generation Kit

Project Work:

1. Acquainting with the soldering techniques
2. Design and Construction of a 5 Volts DC unregulated power supply
3. Construction of a Step down Transformer and measurement of its output voltage. And to compare it with the calculated value.

Lab References:

1. Laboratory Manual for Introductory Electronics Experiments by Maheshwari, L.K. Anand, M.M.S., New Age International (P) Ltd.
2. Electricity-Electronics Fundamentals: A Text-lab Manual by Paul B. Zbar, Joseph Sloop, & Joseph G. Sloop , McGraw-Hill Education
3. Laboratory Manual Basic Electrical Engineering by Umesh Agarwal, Notion Press

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4. **Basic Electrical and Electronics Engineering by** S.K. Bhattacharya, **Pearson Publishers.**
5. Web sources suggested by the teacher concerned.

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Model Question Paper

APPLICATIONS OF ELECTRICITY & ELECTRONICS

Section A

Answer ALL questions **5X10=50M**

1. A) Briefly explain the different types of resistors and capacitors. (CO1, L1)

(OR)

B) Write a note on applications of passive elements. (CO1, L1)

2 A) Describe Li ion batteries. (CO2, L2)

(OR)

B) Briefly explain the Thevenin's theorem. (CO2, L2)

3 A) Explain the construction and working principle of AC generator. (CO3, L1)

(OR)

B) Explain the construction and working principle of Transformers. (CO3, L1)

4 A) What is amplitude modulation? Explain. (CO4, L2)

(OR)

B) What is frequency modulation? Explain. (CO4, L2)

5 A) Explain the construction and operating principle of DC motor. (CO5, L1)

(OR)

B) Explain the working of DC regulated power supply. (CO5, L1)

Section B

Answer ANY FIVE of the following **5X5=25M**

6. What is Ohm's law? Explain. (CO1, L1)
7. Explain the Series resonance circuit as a Radio tuning circuit. (CO1, L1)
8. Explain series-parallel configuration of batteries. (CO2, L1)
9. Write the applications of current and voltage sources. (CO2, L1)
10. Write the Differences between DC and AC generators. (CO3, L2)
11. Explain the use of a Transformer in a regulated Power supply. (CO3, L1)
12. Briefly explain the concept of demodulation. (CO4, L1)
13. Write a note on transmitters and receivers. (CO4, L1)
14. Explain the measurement of power, current and voltage in DC motor. (CO5, L2)
15. Write a short note on step-down and step-up transformers. (CO5, L1)

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UNIT-I

INTRODUCTION TO PASSIVE AND ACTIVE ELEMENTS

Electronic Components:

An Electric circuit contains many small and large components. All electronic components may be broadly classified into two major classes.

1.Passive Components 2. Active Components

Passive Elements:

The three main passive components used in any circuit are the **Resistor, the Capacitor and the Inductor**. All the three passive components **limit the flow of electrical current** through a circuit but in different ways. Passive element **stores energy** in the form of voltage or current.

Examples: Resistor, Capacitor, Inductor and normal PN junction diode.

Active Element:

An active element is **an element capable of generating electrical energy**. The essential role of the active element is to magnify an input signal to yield a significantly larger output signal. Active element **produces energy** in the form of voltage or current.

Examples: Transistors, Op amps, Logic gates, Tunnel diode and Zener diode.

Resistors:

A resistor is a passive two-terminal electrical component that implements electrical resistance as a circuit element. In electronic circuits, resistors are used to reduce current flow, adjust signal levels, to divide voltages, bias active elements. High-power resistors that can dissipate many watts of electrical power as heat may be used as part of motor controls, in power distribution systems or as test loads for generators.

Types of Resistors:

There are numerous types of resistors that are available and used in electronic circuits. These different types of resistors have different properties depending upon their manufacture and construction. There are different types of resistors available for various applications. The resistors are available in different shapes, size, and materials. Normally, resistors are classified into two types namely linear resistor and non-linear resistor.

Linear Resistors:

The resistors whose value changes with the applied temperature and voltage are called linear resistors. Most types of resistors are linear devices that produce a voltage drop across themselves when a current flow through them. There are two basic types of resistors with linear properties namely fixed resistors and variable resistors.

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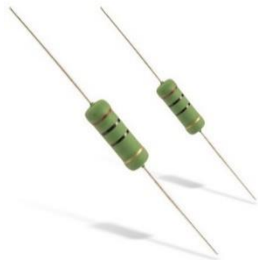
FIXED RESISTORS:

Fixed resistors are resistors with a specific value. Fixed resistors are used in electronic circuits to set the correct conditions in a circuit.

Types of Fixed Resistors

Wire Wound Resistors:



A resistor that is designed using a conductive wire to limit or restrict the flow of current within a circuit. The designing of the resistor can be done using a conductive wire by wounding around a non-conductive core. Generally, the material of the wire is made with Nichrome (Nickel-chromium alloy) or Manganin (copper-nickel-manganese alloy). These resistors generate very accurately, excellent properties for high power ratings & low resistance values. These resistors are used in industrial and high-power applications like fuses, circuit breakers.

Advantages of Wire Wound Resistor

The advantages are,

1.This resistor is employed in high power circuits
2.It will not affect by the noise
3.It is thermally constant.

Disadvantages of Wire Wound Resistor

The disadvantages are

1.These resistors are used for only low frequencies because it works as an inductor at high frequencies
2.It is expensive as compared with carbon resistor.
3.It is larger in size

Applications

The **applications of the wire-wound** resistors are,

1.Space and Defence
2.Transducer devices. (A ***transducer*** is a ***device*** that converts energy from one form to another).
3.Medical devices
4.Computers
5.Telecommunication
6.Current sensing
7.Telephone switching systems`

Thin Film Resistors

Definition:

The resistor which uses a thin film resistive layer is known as the thin-film resistor. This layer is arranged on top of a ceramic base. As compared to the thick film resistor, the thickness of the resistor is very thin

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approximately 0.1 microns. Generally, these resistors are stable, more accurate and have a better temperature coefficient so they are used in higher precision technologies. Both the thick film and thin film resistors look like same but their manufacturing processing is different.

Advantages:

The **advantages of a thin-film resistor** are,
1.The electrical performance of these resistors is high.
2.High-frequency response.
3.It provides a high-power rating.
4.It has less noise.

Disadvantages:

The **disadvantages of thin-film resistors** are,
1.These components are delicate.
2.High cost.
3.Need to handle very carefully.

Applications:

The **applications of thin-film resistors** are,
1.The function of a thin-film resistor is to use in applications where high accuracy, low noise, and high stability are required. These applications include different equipment like measurement, test, medical, monitoring, instrumentation, precision, and audio applications.
2.These resistors are used in precision applications.
3.These resistors are used to control the op-amps gain, stable voltage division, ADC or DAC.
4.Thin-film resistors are used where higher precision is necessary like equipment monitoring & measuring in the aerospace & medical fields, audio computer chips, RF applications, telecommunications, power supply converters, etc.

CARBON COMPOSITION RESISTORS:

Definition:

Carbon composition resistor is also known as carbon composite This is an old type of resistor but used as a main resistor in many tubes or valve-based devices such as radios, TVs, electronic devices, etc. The Carbon composition resistor is one kind of fixed resistor, used to restrict or reduce the flow of current to a certain stage.

Carbon Composition Resistor

Construction

The carbon composition resistors are made from a solid cylindrical resistive element with embedded wire leads or metal end caps. The cylindrical resistive element of the carbon composition resistor is made from the mixture of carbon or graphite powder and ceramic (made of clay). The carbon powder acts as the good conductor of electric current.

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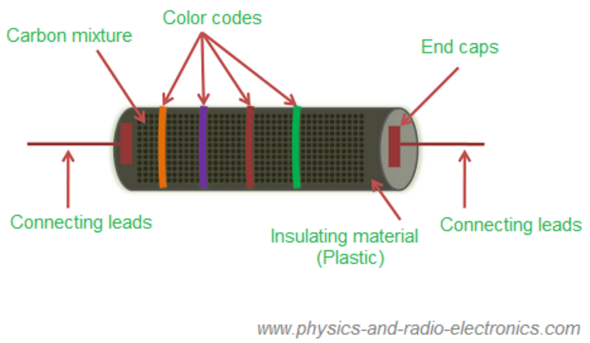
The solid cylindrical resistive element is covered with plastic to protect the resistor from outside heat. The leads made of copper are joined at two ends of the resistive element. The carbon composition resistors are available with different resistance values ranging from one ohm (1Ω) to 22-mega ohms (22 MΩ).



Amount of Carbon Added

The resistance of the carbon composition resistor is inversely proportional to the amount of carbon added.

We know that carbon is the good conductor of electricity. Hence, if more amount of carbon is added, more amount of electric current flows and only a small amount of electric current is blocked. Thus, the carbon composition resistor with more carbon has low resistance. If less amount of carbon is added, only a small amount of electric current flows and more amount of electric current is blocked. Thus, the carbon composition resistor with less carbon has more resistance.

Advantages

The **advantages of a carbon composition resisto**r are,

1.It can endure high energy pulses.
2.Less cost
3.These are available in small size.

Disadvantages:

The disadvantages of a carbon composition resistor are,
1.The stability of the carbon composition resistor is poor
2.Generates huge noise
3.Accuracy is less
4.It absorbs the water so it can lead to an increase/decrease in the resistance.

Applications of Carbon Composition Resistor:

The applications of the carbon composition resistor include the following.
1.Used in high-frequency applications
2.It is used to limit the current in the circuits
3.Used in the DC power supplies with high voltage
4.Used in the devices like X-ray, laser, radar & welding technology also.
5.Used in electronic, test equipment, and computers.

VARIABLE RESISTORS:

Variable Resistors consist of a slider which taps onto the main resistor element and a fixed resistor element. Simply we can say that a variable resistor is a potentiometer with only 2 connecting wires instead of 3.

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Types of Variable Resistors:

Potentiometer

The potentiometer is an instrument designed for measuring the unknown voltage by comparing it with the known voltage. In other words, it is the three-terminal device used for measuring the potential differences by manually varying the resistances. The known voltage is drawn by the cell or any other supply source.

The name "potentiometer" is a combination of Potential ifference and Metering.

Definition of Potentiometer:

Potentiometer

A potentiometer is a device used to measure the potential difference in a circuit. The potential difference between two points in a circuit is the amount of work done to bring a charge from the first point to the second.

When there is a potential difference in a circuit, the current flows through the circuit. It is a three-terminal resistor that acts as a voltage divider and when two terminals are used, it functions like a variable resistor or a rheostat.

Applications of Potentiometer

The instrument designed to measure the unknown voltage by comparing it with the known voltage is the potentiometer. There are various potentiometer applications. The following are the most uses:

1. **Audio control:** Low-power potentiometers, both slide and rotary are used to control audio equipment, changing loudness, frequency attenuation and other characteristics of audio signals.
2. **Television:** Potentiometers were formerly used to control picture brightness, contrast, and colour response.
3. **Transducers:** Potentiometers are also very widely used as a part of displacement transducers because of the simplicity of construction and because they can give a significant output signal.
4. **Potentiometers as tuners and calibrators:** Pots can be used in a circuit to tune them to get the desired output. Also, during the calibrations of a device, a preset pot is often mounted on the circuit board.
5. **Potentiometers as measuring devices:** The most typical application of a potentiometer is as a voltage measuring device. The name itself has that implication. It was first manufactured to measure and control the voltage.

Rheostat:

Rheostat is a variable resistor, which is used to control the flow of electric current by manually increasing or decreasing the resistance. The English scientist Sir Charles Wheatstone coined the word rheostat, it is derived from the Greek word "rheos" and "-statis" which means a stream controlling device or a current controlling device.

The electric current flowing through an electrical circuit is determined by two factors: the amount of voltage applied and the total resistance of the electrical circuit. If we reduce the circuit resistance, the flow of electric current through the circuit will be increased. On the other hand, if we increase the circuit resistance, the flow of electric current through the circuit will be decreased.

By placing the rheostat in the electrical circuit, the flow of electric current in the circuit is controlled (increase or decrease). Rheostat reduces the electric current flow to certain level. However, it does not completely block the electric current flow. To block the electric current flow, infinite resistance is needed. So, practically it is not possible to block the electric current.

Applications of Rheostat:

1. Rheostat is generally used in the applications where high voltage or current is required.

2. Rheostats are used in dim lights to change the intensity of light. If we increase the resistance of the rheostat, the flow of electric current through the light bulb decreases. As a result, the light brightness decreases. In the similar way, if we decrease the resistance of the rheostat, the flow of electric current through the light bulb increases. As a result, the light brightness increases.

3. Rheostats are used to increase or decrease the volume of a radio and to increase or decrease the speed of an electric motor.

Non-Linear Resistor:

Non-linear resistors are those type of resistors where the electric current flowing through it changes with the exchange in applied voltage or temperature and does not change according to Ohm’s law. There are several types of non-linear resistors, but the most commonly used are mentioned below.

Thermistors:

The term thermistor comes from “thermal” and “resistor”. Thermistors are a type of variable resistor that notices the change in temperature. In other words, it is a 2-terminal device that is very sensitive to temperature. The Resistance of a Thermistor is inversely proportional to the temperature.

The Thermistor or simply **Therm**ally Sensitive Res**istor** is a temperature sensor that works on the principle of varying resistance with temperature. They are made of semiconducting materials. The circuit symbol of the thermistor is shown in the figure.

Circuit Symbols

Thermistor

Thermistors are used to monitor the temperature surrounding a device and temperature changes in a device.

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Principle of Thermistor:

The thermistor works on the simple principle of change in resistance due to a change in temperature. When the ambient temperature changes the thermistor starts self-heating its elements. its resistance value is changed with respect to this change in temperature. This change depends on the type of thermistor used.

Advantages of Thermistors:

1.Less expensive.
2.More sensitive than other sensors.
3.Fast response.
4.Small in size.

Disadvantages of thermistors:

1.Limited Temperature range.
2.Resistance to temperature ratio correlation is non-linear.
3.An inaccurate measurement may be obtained due to the self-heating effect.

Applications of Thermistors:

1.Digital Thermostats.
2.Thermometers.
3.Battery pack temperature monitors.
4.In-rush-current limiting devices

Varistor Resistors:

A varistor is a non-linear resistor made of semiconductor and current through which depends non-linearly on the applied voltage across it. Metal Oxide Varistor (MOV) is the most commonly used form of Varistor Resistors.

A varistor is a type of resistor in which we can alter the resistance by altering the applied voltage. It is also called a voltage-dependent resistor. These are generally used as safety devices to prevent excess transient voltage in the circuit so that the components of the circuits remain protected. It even controls the operating conditions of the circuit.

Being a form of a resistor, varistors are two- terminal semiconductor components that protect the electrical and electronic devices from overvoltage transients. **When the voltage increases, their resistance reduces and in case of excessive voltage increases, their resistance drops drastically.**

So, varistor can be defined as nonlinear two-element semiconductors that drop-in resistance as voltage increases. They are often used as surge suppressors for sensitive circuits. Surges are often caused by lightning strikes and electrostatic discharges.

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Principle of Varistor:

A varistor does not obey Ohm's law and hence it is a non-ohmic resistor. The basic difference between a normal resistor and a voltage-dependent resistor is that would the resistance of a resistor can be altered only by manual action but we can alter the resistance by altering the voltage.

Advantages:

The advantages of Varistors are

1.It can be used to protect the electrical components of an electric circuit.
2.It provides surge protection (**voltage spikes)** to the AC and DC motors.

Disadvantages:

The disadvantages of Varistors are

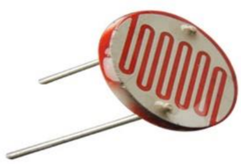
1.It cannot provide protection from current during a short circuit.
2.It cannot provide protection from current surges (current spikes) during the start-up of the device.
3.It cannot provide protection from voltage sags. **(decrease in the rms voltage magnitude)**

Applications of a Varistor

The applications are

1.It can also be used to provide surge protection in AC and DC motors.
2.Radio communication equipment transient suppression.
3.Telephone and other communication lines protection.
4.Microprocessor protection.
5.Electronics equipment protection.

Photo Resistor or LDR (Light Dependent Resistors):



LDR

Photo Resistor or LDR (Light Dependent Resistors) or Photo Conductive Cell is a light-controlled variable resistor. The photo resistor resistance decreases with increase in incident light intensity**.**

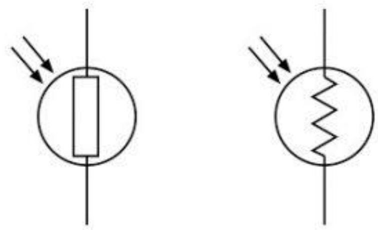
An electronic component LDR or light-dependent resistor is responsive to light. Once light rays drop on it, then immediately the resistance will be changed. The resistance values of an LDR may change over several orders of magnitude. The resistance value will be dropped when the light level increases.

The resistance values of LDR in darkness are several megaohms whereas in bright light it will be dropped to hundred ohms. So due to this change in resistance, these resistors are extremely used in different applications. The LDR sensitivity also changes through the incident light's wavelength.

The designing of LDRs can be done by using semiconductor materials to allow their light-sensitive properties. The material used in the resistor are cadmium sulphide, cadmium selenide lead sulphide and indium antimonide.

LDR Symbol:

In electronic circuits, the LDR symbol is used mainly depends on the resistor symbol, however, it illustrates the light rays in the arrows form. The LDR circuit symbols are



LDR Symbols

Principle of Light Dependent Resistor

The working principle of an LDR is photoconductivity, which is an optical phenomenon. When the light is absorbed by the material then the conductivity of the material enhances. When the light falls on the LDR, then the electrons in the valence band of the material are eager to the conduction band. But, the photons in the incident light must have energy superior to the bandgap of the material to make the electrons jump from one band to another band (valance to conduction).

Hence, when light having ample energy, more electrons are excited to the conduction band which grades in a large number of charge carriers. When the effect of this process and the flow of the current starts flowing more, the resistance of the device decreases.

LDR Advantages:

The **advantages of LDR** are,
1.Sensitivity is High
2.Simple & Small devices
3.Easily used
4.Inexpensive

LDR Disadvantages:

The **disadvantages of LDR** are,
1.Temperature stability is low for the best materials
2.In stable materials, it responses very slowly
3.The use of LDR is limited where the light signal changes very quickly

Applications of LDR:

Light-dependent resistors are simple and low-cost devices. These devices are used where there is a need to sense the presence and absence of light is necessary. These resistors are used as light sensors and the applications of LDR mainly include alarm clocks, street lights, light intensity meters, burglar alarm circuits.

Surface Mount Resistors:

Surface Mount Resistors also called SMD resistor are rectangular in shape. A Surface Mount Device (SMD) is an electronic component that is made to use with Surface Mount Technology (SMT).

Surface-mount resistors, also called chip resistors, are constructed by depositing a thick carbon film on a ceramic base. The exact resistance value is determined by the composition of the carbon itself, as well as by the amount of trimming done to the carbon deposit. The resistance can vary from a fraction of an ohm to million ohms. Power dissipation ratings are typically 1⁄8 to ¼ W. Electrical connection to the resistive element is made via two leadless solder end electrodes (terminals). The end electrodes are C-shaped. The physical dimensions of a 1⁄8-W chip resistor is 0.125-inch-long by 0.063-inch-wide and approximately 0.028 inch thick. This is many times smaller than a conventional resistor having axial leads. Chip resistors are very temperature-stable and also very rugged. The end electrodes are soldered directly to the copper traces of a circuit board, hence the name surface-mount.

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Types of Resistors

Applications of Resistors.

Resistors have many uses in circuits. Some of the uses of resistors include:

1. **Potential dividers:** Two or more resistors in series will give a voltage at their junction point proportional to the ratio of their values. This functionality is widely used in circuits for generating intermediate voltages
2. **Biasing resistors:** Transistors and many other devices need to have their AC and DC operating characteristics and gain values set up for correct operation. This is done with multiple resistors and is often called biasing
3. **Op-amp gain and feedback:** Most op-amp circuits need to have their gain and feedback functionality set by resistors external to the amplifier chip; resistors are the primary means of doing.
4. **Current limiting:** Resistors can be used to limit the amount of current that flows in a circuit element. This is a useful safety function in many circuits e.g. limiting the current that can flow into an LED to manage its brightness.

5. **Impedance matching:** To maximize power transmission at high frequencies the impedance of the receive and transmit ends of a circuit need to be the same. Resistors can perform at least part of this requirement.
6. **Current measuring:** Many circuits need to know how much current is flowing, however, it is much easier to measure voltage, so inserting a resistor into the circuit to 'develop' a voltage – remember Ohm's law- is a common technique for measuring current

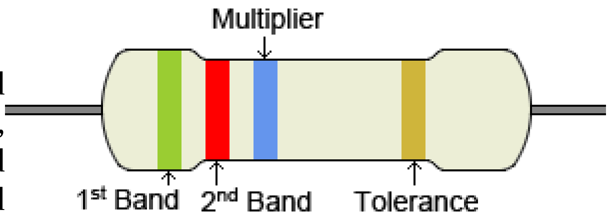
Resistor Colour Code:

An electronic colour code is a code that is used to specify the ratings of certain electrical components, such as the resistance in Ohms of a resistor.

Working:

The resistor colour code shown in the table involves various colour that represent significant figures, multiplier, tolerance, reliability, and temperature coefficient. In a typical four-band resistor, there is a spacing between the third and the fourth band to indicate how the resistor should be read (from left to right, with the lone band after the spacing being the right-most band).

Significant figure component:



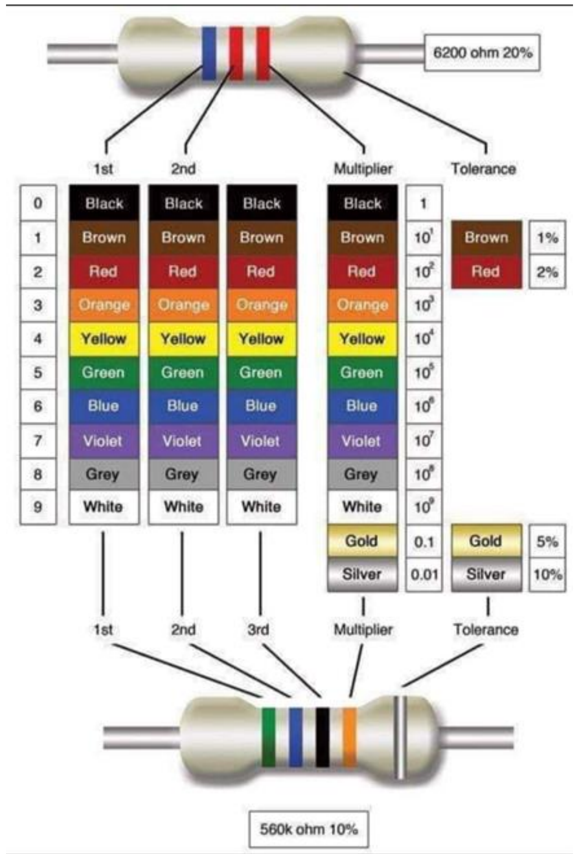
In a typical four-band resistor, the first and second bands represent significant figures. For this example, refer to the figure above with a green, red, blue, and gold band. Using the table provided below, the green band represents the number 5 and the red band is 2.

Multiplier:

The third, blue band, is the multiplier. Using the table, the multiplier is thus 1,000,000. This multiplier is multiplied by the significant figures determined from the previous bands, in this case 52, resulting in a value of 52,000,000 Ω, or 52 MΩ.

Tolerance:

The fourth band is not always present, but when it is, represents tolerance. This is a percentage by which the resistor value can vary. The gold band in this example indicates a tolerance of ±5%, which can be represented by the letter J. This means that the value 52 MΩ can vary by up to 5% in either direction, so the value of the resistor is 49.4 MΩ - 54.6 MΩ.



Reliability, temperature coefficient, and other variations:

Coded components have at least three bands: two significant figure bands and a multiplier, but there are other possible variations. For example, components that are typically four-band resistors have a fifth band that indicates the reliability of the resistor that is the temperature coefficient, which indicates the change in resistance of the component as a function of ambient temperature in terms of **Parts per Million per Kelvin (ppm**/K).

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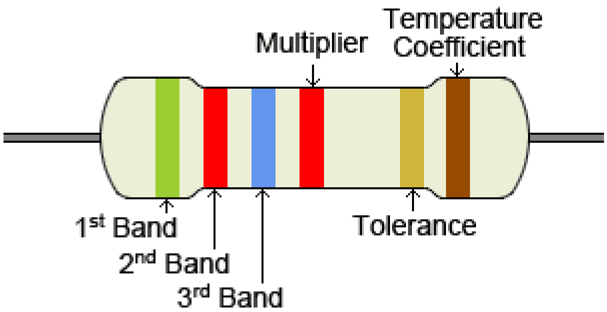
Colour	1st, 2nd, 3rd Band Significant Figures	Multiplier	Tolerance	Temperature Coefficient (Parts per Million per Kelvin)
Black	0	× 1		250 ppm/K (U)
Brown	1	× 10	±1% (F)	100 ppm/K (S)
Red	2	× 100	±2% (G)	50 ppm/K (R)
Orange	3	× 1K	±0.05% (W)	15 ppm/K (P)
Yellow	4	× 10K	±0.02% (P)	25 ppm/K (Q)
Green	5	× 100K	±0.5% (D)	20 ppm/K (Z)
Blue	6	× 1M	±0.25% (C)	10 ppm/K (Z)
Violet	7	× 10M	±0.1% (B)	5 ppm/K (M)
Grey	8	× 100M	±0.01% (L)	1 ppm/K (K)
White	9	× 1G		
Gold		× 0.1	±5% (J)	

Silver		× 0.01	±10% (K)	
None			±20% (K)	

On the most precise of resistors, a 6th band may be present. The first three bands would be the significant figure bands, the 4th the multiplier, the 5th the tolerance, and the 6th could be either reliability or temperature coefficient. There are also other possible variations, but these are some of the more common configurations.

Mnemonics were created to easily memorize the sequence as "B B ROY of Great Britain had a Very Good Wife" where the first letter of each word corresponds to the first letter of the colour.



VOLTAGE CURRENT RELATION IN A RESISTOR -THE OHM'S LAW:

The current that flows through a conductor depends upon the potential difference between the ends of the conductor.

According to Ohm's law, if the physical state of the conductor (temperature) remains the same, the potential difference across the ends of a conductor varies directly as the current I flowing through it.

Thus, $V \propto I$ or $V = RI$.

The constant of proportionality R is known as the resistances of the conductor and depends upon the size, temperature and material of the conductor.

Thus, Resistance **(R)** = $\dfrac{\text{Potential Difference (V)}}{\text{Current (I)}}$.

Limitations of Ohm's Law:

1. Ohm's Law is true for metallic conductors only.
2. Ohm's Law does not hold for all the electrical circuits
3. Ohm's law is not applicable for unilateral electrical networks. Unilateral networks allow the current to flow in one direction. Such types of network consist of elements like diode, transistor and etc.
4. For non-linear electrical elements with parameters like capacitance, resistance, etc. the voltage and the current won't be constant with respect to time making it difficult to use Ohm's law. Non-linear elements are those which do not have current exactly proportional to the applied voltage, which means the resistance value of those elements' changes for different value of voltage and current. Examples of non – linear elements are thyristor, electric arc, etc.

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5. The relation between V and I depends on the sign of V(+ or -). In other words, if I is the current for a certain V, then reversing the direction of V keeping its magnitude fixed, does not produce a current of the same magnitude as I in the opposite direction. This happens for example in the case of a diode.

Applications of Ohm's law:

Ohm's law can determine the voltage applied in a circuit, the value of resistance, and the current flowing through the circuit. With the help of the above three values, the value of other factors like resistivity and many more can be found.

Some the applications of Ohm's law:

- **In fuses:** In order to protect a circuit, fuses and circuit breakers are used. These are connected in series with the electrical appliances. Ohm's law allows us to find the value of the current which could flow through the fuses. If the current value is too large, then it could damage the circuit and even lead to the explosion of the electronic device.

- **To know power consumption:** The electrical heaters have a high-resistance metal coil that allows a certain amount of current to pass across them to provide the heat needed. Using this law, the power to be given to the heaters is determined.

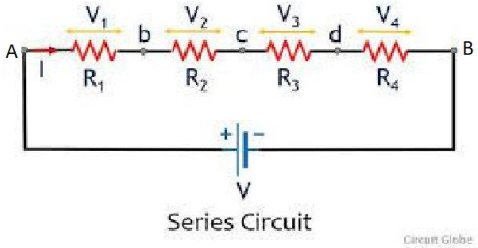
- **To control the speed of fans:** By shifting the regulator to the end from start, we can regulate the speed of the fans in our houses. By controlling the resistance via the regulator, the current flowing through the fan is managed here. We can measure the resistance, current, and thus power flowing via Ohm's Law for any particular value of the input.

- **For deciding the size of resistors:** Electric appliances like electric kettles and irons have a lot of resistors inside them. In order to provide the necessary amount of heat, the resistors restrict the amount of current that can flow through them. By using Ohm's law, the size of resistors included in them is defined.

COMBINATION OF RESISTANCES:

Reistors in Series:

When a number of resistances are connected end to end in succession is called **Series Combination** of Resistors and all the circuit current passes through each resistor.



Let R_1, R_2, R_3, & R_4 the resistances connected in series. Let I be the currents passing through the resistances. Let V_1, V_2, V_3 & V_4 be the voltages across the resistances R_1, R_2, R_3 & R_4 respectively.

$$\therefore V_1 = I R_1,\ V_2 = I R_2,\ V_3 = I R_3.\ \&\ V_4 = I R_4$$

If R is the equivalent resistance between A and B then V = IR.

`

∴ Total Voltage $V = V_1 + V_2 + V_{3.} + V_{4.}$

$$IR = I R_1 + I R_2, + I R_3 + I R_4$$

$$I R = I (R_1 + R_2 + R_{3+} R_4)$$

$$\therefore \; \boldsymbol{R_1 + R_2 + R_3 + R_{4.}}$$

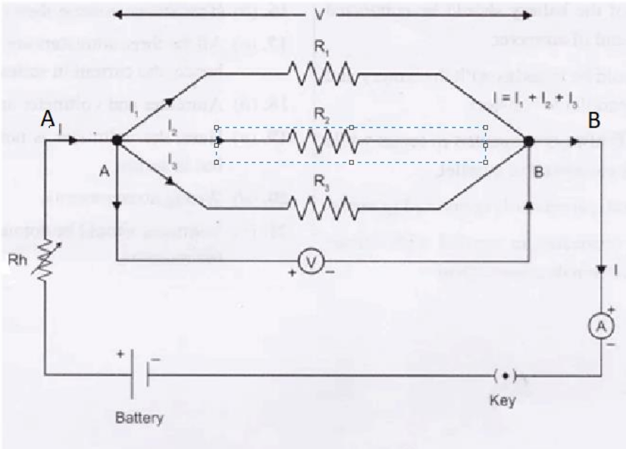
Thus, the equivalent resistance (R) of the combination is equal to the sum of individual resistors are connected.

<u>RESISTORS IN PARALLEL:</u>

When two or more resistors are connected side by side across a single voltage source is called Parallel combination of resistance.

In Parallel combination,

(a) Voltage (V) across each branch is the same.
(b) Current is different in different branches.



Parallel combination of resistors R1, R2 and R3

Let R_1, R_2, and R_3 be the resistances connected Parallel between A & B.

Let I_1, I_2, I_3 be the currents in the resistances R_1, R_2 and R_3 respectively and is equal to the total current I.

Let V be the voltage across the resistances.

Let $I = I_1 + I_2 + I_3$.

In each branch, the current is,

$$I_1 = \frac{V}{R_1}, \quad I_2 = \frac{V}{R_2}, \quad I_3 = \frac{V}{R_3}.$$

If R is the equivalent resistance of the parallel combination, then current

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

Therefore, $\frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}.$

$$\frac{V}{R} = V\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}.\right)$$

$$\frac{1}{R} = \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)$$

Thus, the reciprocal of the effective resistance in parallel combination is equal to the sum of the reciprocals of the individual resistance.

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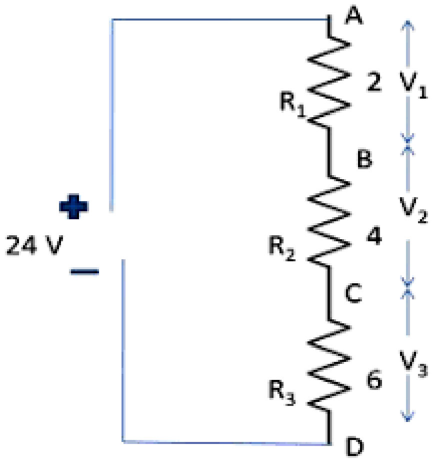
SERIES COMBINATION (VOLTAGE DIVIDER):

In an electronic equipment it is necessary to supply different voltages to different components from a simple power supply. This can be accomplished by using a voltage divider.

A simple voltage divider consists of two or more resistors connected in series with power supply. Then the current is same through all the resistors. Hence the voltage across each resistor will be proportional to its resistance. If the supply voltage be V and the total series resistance is R then the voltage across a resistance of resistance R is given by



$$V1=\frac{V}{R} \text{ x } R1 = \frac{V}{\varepsilon R}R1$$

This equation is known as the voltage divider rule.

Thus, the voltage divider rule states that the voltage across any resistor in a series circuit is equal to the resistance of that resistor times the ratio of the total resistance of all the series resistors.

It is observed that, the series element which has the highest resistance has the largest voltage drop across it.

Advantages:

1.The voltage divider method is that without knowing the value of the current in the circuit, the voltage drop across serval elements can be known.

Parallel Combination (Current Division):

A parallel circuit is often called current divider in which **terminals of all the components are connected in such a way that they share the same two end nodes**. These result in different parallel paths and branches for the current to flow through it

Current Divider circuits have two or more parallel branches for currents to flow through but the voltage is the same for all components in the parallel circuit.

Current Dividers are parallel circuits in which the source or supply current divides into a number of parallel paths. In a parallel connected circuit, all the components have their terminals connected together sharing the same two end nodes. This results in different paths and branches for the current to flow or pass along. However, the currents can have different values through each component.

The main characteristic of parallel circuits is that while they may produce different currents flowing through different branches, the voltage is common to all the connected paths. That is V_{R1} = V_{R2} = V_{R3} … etc. Therefore, the need to find the individual resistor voltages is eliminated allowing branch currents to be easily found with Kirchhoff's Current Law, (KCL) and of course Ohm's Law.

The basic current divider circuit consists of two resistors: R_1, and R_2 in parallel which splits the supply or source current I_S between them into two separate currents I_{R1} and I_{R2} before joining together again and returning back to the source.

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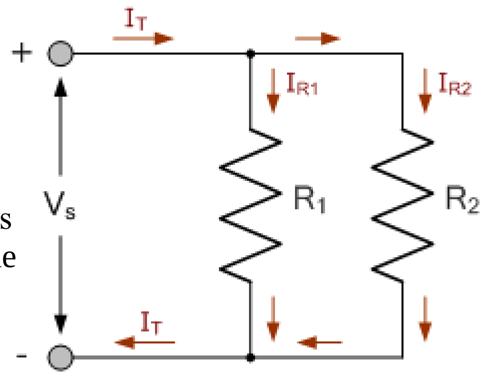
As the source or total current equals the sum of the individual branch currents, then the total current, I_T flowing in the circuit is given by Kirchhoff's current law KCL as being:

$$I_T = I_{R1} + I_{R2}$$

As the two resistors are connected in parallel, from Kirchhoff's Current Law, (KCL) to hold true it must therefore follow that the current flowing through resistor R_1 will be equal to:

$$I_{R1} = I_T - I_{R2}$$



and the current flowing through resistor R_2 will be equal to:

$$I_{R2} = I_T - I_{R1}$$

As the same voltage, (V) is present across each resistive element, we can find the current flowing through each resistor in terms of this common voltage as it is simply V = I*R following Ohm's Law. So, solving for the voltage (V) across the parallel combination gives us:

$$I_T = I_{R_1} + I_{R_2}$$

$$I_{R_1} = \frac{V}{R_1} \quad \text{and} \quad I_{R_2} = \frac{V}{R_2}$$

$$I_T = \frac{V}{R_1} + \frac{V}{R_2} = V\left[\frac{1}{R_1} + \frac{1}{R_2}\right]$$

$$\therefore V = I_T\left[\frac{1}{R_1} + \frac{1}{R_2}\right]^{-1} = I_T\left[\frac{R_1 R_2}{R_1 + R_2}\right]$$

Solving for I_{R1} gives: $I_{R_1} = \frac{V}{R_1} = I_T\left[\frac{\frac{1}{R_1}}{\frac{1}{R_1} + \frac{1}{R_2}}\right]$

$$\therefore I_{R_1} = I_T\left[\frac{R_2}{R_1 + R_2}\right]$$

Likewise, solving for I_{R2} gives: $IR_2 = \frac{V}{R_2} = I_T\left[\frac{\frac{1}{R_2}}{\frac{1}{R_1} + \frac{1}{R_2}}\right]$

$$\therefore I_{R_2} = I_T\left[\frac{R_1}{R_1 + R_2}\right]$$

Thus, above equations for each branch current has the opposite resistor in its numerator. That is to solve for I_1 we use R_2, and to solve for I_2 we use R_1. This is because each branch current is inversely proportional to its resistance resulting in the smaller resistance having the larger current.

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INDUCTORS:

An inductor (also known as an electrical inductor) is defined as a two-terminal passive electrical element that stores energy in the form of a magnetic field when electric current flows through it. It is also called a coil or chokes.

An inductor is simply a coil of wire. It usually consists of a coil of conducting material, typically insulated copper, wrapped into an iron core either of plastic or ferromagnetic material. Inductors are typically available in the range from 1 μH (10^{-6} H) to 20μH. Many inductors have a magnetic core made of ferrite or iron inside the coil, which is used to increase the magnetic field and thus the inductor's inductance.

According's to Faraday's law of electromagnetic induction, when an electric current flowing through an inductor or coil changes, the time-varying magnetic field produces an e.m.f. (electromotive force) or voltage in it. The induced voltage or e.m.f. across an inductor is directly proportional to the rate of change of the electric current flowing through the inductor.

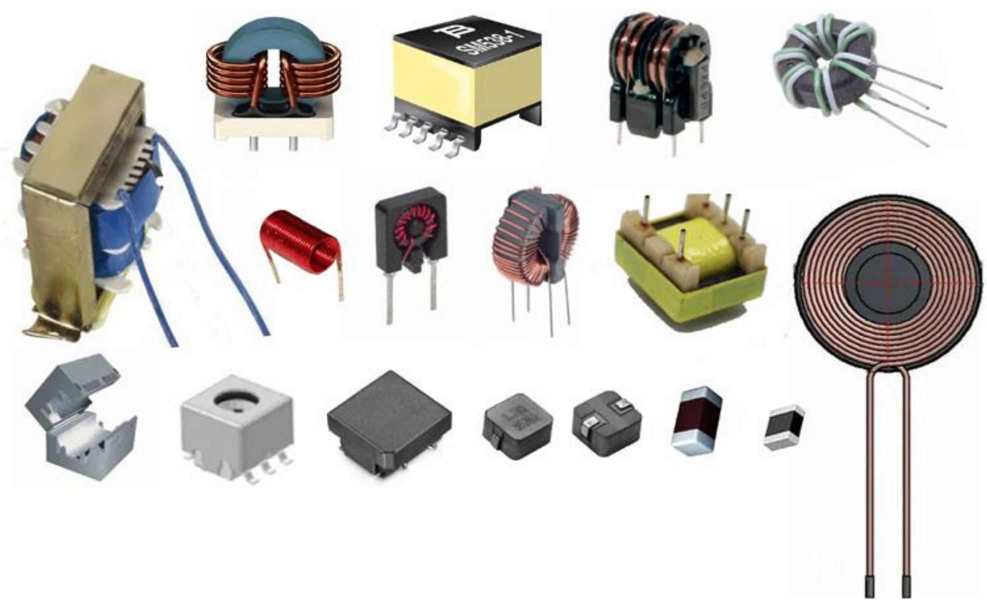
Inductance (L) is a property of an inductor that opposes any change in magnitude or direction of current flowing through it. The larger an inductor's inductance, the greater the capacity to store electrical energy in the form of the magnetic field.

The induced e.m.f. (e) in an inductor is e = $-L\left[\frac{dI}{dt}\right]$

Where, L= inductance in henry

$\left[\frac{dI}{dt}\right]$ = rate of change of current.

Different Types of Inductors and Their Applications:



Types of Different Inductors

INDUCTORS:

Inductors are often referred to as **"AC resistance".** The main characteristic of an inductor is its ability to resist changes in current and store energy in the form of a magnetic field. The standard unit of inductance is the **Henry.**

Types of Inductors:

Depending on the application there are many types of inductors, they come in various form factors, there are high-frequency inductors, low-frequency power line inductors, and some specially designed inductors for decoupling and filter applications.

Laminated Core Inductor:

The elements of a laminated core inductor consist of a bobbin, a laminated core and a coil which is wrapped around the bobbin.

To make a laminated core inductor, a wire is wrapped around the bobbin of the inductor, then the E and I plates are placed inside the bobbin one by one to form the core, this E and I sheets are made out of steel with high silicon content and its heat-treated to produce high permeability and to lower the hysteresis and eddy current losses.

Applications

1.Onboard charger for Electric Vehicles

2.Line and Noise Filter.

Air Core Inductor:

Construction:

By taking a cylindrical material of specific diameter (like a drill bit) as a template, we can wrap around a length of wire to make an air-core inductor, further the inductance can be stabilized by dipping the inductor in varnish or securing it by wax.

The core material is air, so it has low permeability hence lower inductance so, it can be used for high-frequency applications.

Applications:

1.It is used for constructing RF tuning coils.

2.The air core inductor is used in filter circuits.

3.Snubber Circuit. (*Snubber circuits* are essential for diodes used in switching circuits. It can save a diode from overvoltage spikes).

4.It is used to ensure a lower peak inductance,

5.It is used in high-frequency applications including TV and radio receivers

Ferrite Core Inductor:

By winding a length of wire around a ferrite core will result in a ferrite core inductor.

Mixing Iron oxide (Fe_2O_3) in combination with other metal oxides like (Mn), zinc (Zn) or magnesium (Mg) at a temperature of 1000° C - 1300° C will result in a material called ferrite.

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Ferrite core inductors have high permeability, high electrical resistivity and low eddy current losses these characteristics make them suitable for many high-frequency applications.

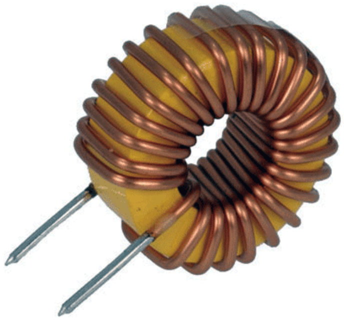
Applications:

1.It can be used at high and medium frequencies

2.It is used in switching circuit

3.Pi Filters

Bobbin Inductor



Construction:

Winding a length of wire in a specially made cylindrical bobbin and securing it with a shrink tube forms a bobbin inductor.

The core material is ferrite so, the properties are also similar to a ferrite core inductor. The small size makes them suitable for power adapter like applications.

Applications:

1.SMPS circuit

2.Input and output filter

3.Pi Filter

Toroidal Core Inductor:

Construction:

A length of wire is wrapped around a donut-shaped core is commonly known as a toroid core inductor. The core material is ferrite so, the material properties resemble a ferrite core inductor.

This type of core contains a magnetic field very well because of its closed-loop nature, thus improving the size and inductance.

Due to the high magnetic field and high inductance value with fewer windings, the impedance is very less which helps to improve the efficiency of the inductor.

Applications:

1.Medical Devices

2.Switching Regulators

3.Industrial Controllers

4.Output Filter (SMPS)

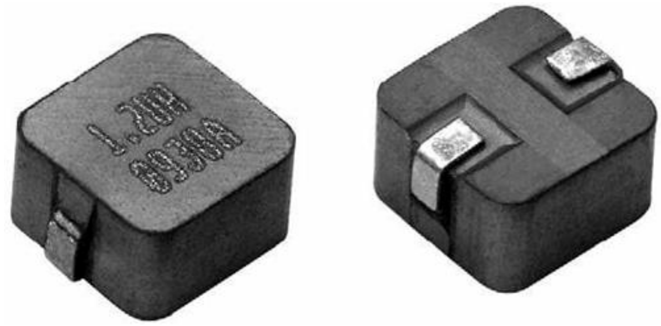
Axial Inductors / Colour Ring Inductor:

Construction:

To construct Axial inductor, a very thin copper wire is wrapped around a dumbbell-shaped ferrite core and two lids are connected at the top and the bottom of the dumbbell core. After that it goes through a moulding process (the green material surrounding the inductor) where the values are printed as coloured bands, therefore we can determine the value of the inductor just by reading the colour bands and comparing them with the colour code chart just like a resistor.

Applications:
1.As Line filter 2.In Filter Design 3.In Boost Converter

SHIELDED SURFACE MOUNT INDUCTOR:



Construction:

It is built by winding a length of wire in a cylindrical bobbin and securing it in a specially made ferrite housing forms.

These inductors are specially designed for PCB mounted applications and the shielding is there to reduce EMI **(Electromagnetic interference (EMI) is unwanted noise or interference in an electrical path or circuit caused by an outside source)** and noise from the inductor and to use in a high-density design.

Applications:

1.High current POL converters (Point of load converters)

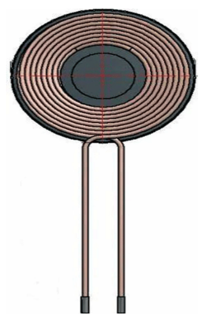
2.Low profile, high current power supplies

3.Battery-powered devices

4.DC/DC converters in distributed power systems.

WIRELESS CHARGING COILS:

Construction:



Coiling up a multi-stranded wire then putting it in a ferrite will result in a wireless charging coil.

A length of multi-stranded wire is used to reduce the skin effect, which describes a high-frequency magnetic field that can penetrate a certain depth, means if a solid wire is used in this case the most of the current will flow through the outer part of the conductor which therefore increase the resistance.

By placing a ferrite plate under a coil, it can improve the inductance and can also focus the magnetic field and reduces emissions.

Applications:

1.Wireless Charging

2.Information and communication products

3.Industrial, medical and other products

COUPLED INDUCTOR:

Construction:

Winding two wires in a common core form a coupled inductor. The windings can be connected in series, parallel or as a transformer, as per application requirements, they work by transferring energy from one winding to another by mutual inductance, the most common coupled inductors have one-to-one turns ratio used in manly DC-DC converters.

Applications:

1.Fly back Converter (Fly back converters are **a type of isolated buck-boost DC-DC converter that use a coupled inductor instead of an isolation AC transformer)**

2.SEPIC Converter (The single-ended primary-inductor converter (SEPIC) is **a DC/DC converter topology that allows the electrical potential (voltage) at its output to be greater than, less than, or equal to that at its input**. The output of the SEPIC is controlled by the duty cycle of the control switch.)

3.Cuka Converter (Cuk converter is used for **the voltage regulation for the Dc application systems**. ➢ Cuk converter is used in hybrid solar-wind energy system as a regulator where input voltage depends on speed of wind and sun, in order to make the output voltage as a constant source Cuk converter is used).

MULTILAYER CHIP INDUCTORS:

Construction:

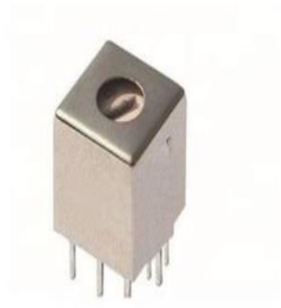
The name itself indicates that it consists of multilayers. It is built by using thin plates made out of ferrite. The coil pattern is printed on it, with special metallic paste (recipe confidential to manufacturer), proper placement of these sheets a layer after another forms a coil.

Applications:

1.Small Wearable Application
2.Wireless LANs
3.Bluetooth
4.Motherboard

SHIELDED VARIABLE INDUCTOR:

Construction:



By wrapping a length of wire around a hollow cylinder bobbin, and by placing and moving the core made out of ferromagnetic material or brass we can change the value of the inductor. If the core material is ferrite, then moving the core material in the centre of the winding will increase the inductance.

If the core material is brass, then moving it to the centre of the winding will decrease the inductance.

Applications:

1.High reliability conforms to automotive applications.

CAPACITORS:

The capacitor is a component which has the ability or "capacity" to store energy in the form of an electrical charge producing a potential difference (*Static Voltage*) across its plates.

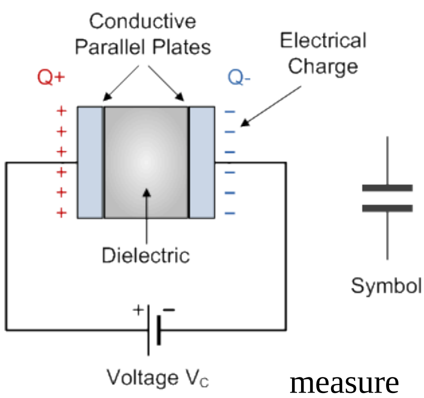
A capacitor consists of two or more parallel conductive (metal) plates which are not connected or touching each other, but are electrically separated either by air or by some form of a good insulating material such as waxed paper, mica, ceramic, plastic or some form of a liquid gel. The insulating layer between a capacitors plates is commonly called the **Dielectric**. Due to this insulating layer, DC current cannot flow through the capacitor.

The conductive metal plates of a capacitor can be either square, circular or rectangular or a cylindrical or spherical shape with the general shape, size and construction of a parallel plate capacitor depends on its application and voltage rating.

The flow of electrons onto the plates is known as the capacitors **Charging Current** which continues to flow until the voltage across both plates (and hence the capacitor) is equal to the applied voltage V_c. At this point the capacitor is said to be "fully charged" with electrons.

The amount of potential difference present across the capacitor depends upon how much charge was deposited onto the plates by the work being done by the source voltage and also by how much capacitance the capacitor has.

By applying a voltage to a capacitor and measuring the charge on the plates, the ratio of the charge Q to the voltage V is its capacitance value of the capacitor and is therefore given as C = Q/V this equation can also be re-arranged to give the familiar formula for the quantity of charge on the plates as Q = C x V



The Capacitance of a Capacitor:

Capacitance is the electrical property of a capacitor and is the measure of a capacitors ability to store an electrical charge onto its two plates with the unit of capacitance being the **Farad** (abbreviated to F) named after the British Physicist Michael Faraday.

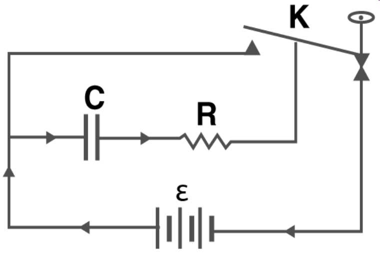
Capacitance is defined as the capacitance of **One Farad** when a charge of **One Coulomb** is stored on the plates by a voltage of **One volt**. Note that capacitance, C is always positive quantity. However, the Farad is a very large unit of measurement to use on its own so sub-multiples of the Farad are generally used such as micro-farads, nano-farads and pico-farads, for example.

Standard Units of Capacitance

- Microfarad (μF) 1μF = 1/1,000,000 = 0.000001 = 10^{-6} F
- Nanofarad (nF) 1nF = 1/1,000,000,000 = 0.000000001 = 10^{-9} F
- Picofarad (pF) 1pF = 1/1,000,000,000,000 = 0.000000000001 = 10^{-12} F.

CHARGING AND DISCHARGING OF A CAPACITOR THROUGH A RESISTOR:

Consider a circuit having a capacitance C and a resistance R which are joined in series with a battery of emf E through a key K.



Charging of a Capacitor

When the key is pressed, the capacitor begins to store charge. If at any time during charging, I is the current through the circuit and Q is the charge on the capacitor, then

Potential difference across resistor = IR, and

Potential difference between the plates of the capacitor = $\frac{Q}{C}$

Since the sum of both these potentials is equal to E,

$$RI + \frac{Q}{C} = E \ldots (1)$$

As the current stops flowing when the capacitor is fully charged,

When Q = Q_0 (the maximum value of the charge on the capacitor), I = 0

From equation. (1),

$$\frac{Q_o}{C} = E \ldots (2)$$

From equations. (1) and (2),

$$RI + \frac{Q}{C} = \frac{Q_o}{C}$$

or $$\frac{Q_o}{C} - \frac{Q}{C} = RI$$

or $$\frac{Q_o - Q}{C} = RI$$

or $$\frac{Q_o - Q}{CR} = I \text{------}(3)$$

Since I = $\frac{dQ}{dt}$, from equation … (3),

$$\frac{Q_0 - Q}{CR} = \frac{dQ}{dt} \text{ or } = \frac{dQ}{Q_0 - Q} = \frac{dt}{CR}$$

`

When t = 0, Q = 0 and when t = t, Q = Q,

Integrating both sides within proper limits, we get

$$\int_0^Q \frac{dQ}{Qo-Q} = \int_0^t \frac{dt}{CR} = \frac{1}{CR}\int_0^t dt$$

$$or \qquad |-\ln(Q_0 - Q)|_0^Q = \frac{1}{CR}|t|_0^t$$

$$or \qquad -\ln(Q_0 - Q) + \ln Q_0 = \frac{t}{CR}$$

$$\text{or } \ln(Q_0 - Q) - \ln Q_0 = -\frac{t}{CR}$$

$$\text{or } \ln\frac{(Q_0-Q)}{Q_0} = -\frac{t}{CR}$$

$$\text{or } \quad \frac{(Q_0-Q)}{Q_0} = e^{-t/CR}$$

$$\text{or } \ Q_0 - Q = Q_0 e^{-t/CR}$$

$$\text{or } Q = Q_0(1 - e^{-t/CR})$$

$$\text{or } Q = Q_0(1 - e^{-t/\tau})\text{-------}(4)$$

Where, $\tau = CR$,

Eqn. (4) gives us the value of charge on the capacitor at any time during charging.

Time Constant

The dimensions of CR are those of time. Further, if CR < < 1, Q will attain its final value rapidly and if CR > > 1, it will do so slowly. Thus, CR determines the rate at which the capacitor charges (or discharges) itself through a resistance. It is for this reason that the quantity CR is called the time constant or more appropriately, the capacitive time constant of the circuit.

If t = τ, then from eqn. (4),

$$Q = Q_0(1 - e^{-1})$$

$$\text{or } Q = Q_0(1 - \frac{1}{e})$$

$$\text{or } Q = Q_0(1 - \frac{1}{2.718})$$

$$\text{or } Q = Q_0(1 - 0.368) = 0.632Q_0$$

$$\text{or } Q = 63.2\% \text{ of} Q_0$$

Time constant of a CR circuit is thus the time during which the charge on the capacitor becomes 0.632 (approx., 2/3) of its maximum value.

For the charge on the capacitor to attain its maximum value (Q_0), i.e., for Q = Q_0,

$$e^{-t/CR} = 0 \text{ or } t = \infty$$

`

Thus, theoretically, the charge on the capacitor will attain its maximum value only after infinite time.

Discharging of a Capacitor:

When the key K is released [Figure], the circuit is broken without introducing any additional resistance. The battery is now out of the circuit and the capacitor will discharge itself through R. If I is the current at any time during discharge, then putting E= 0 in

$$RI + \frac{Q}{C} = E,$$

we get,

$$RI + \frac{Q}{C} = 0$$

$$\text{or } R\frac{dQ}{dt} + \frac{Q}{C} = 0$$

$$\text{or } R\frac{dQ}{dt} = -\frac{Q}{C}$$

$$\text{or } \frac{dQ}{dt} = -\frac{Q}{CR}$$

$$\frac{dQ}{Q} = -\frac{dt}{CR}$$

When t = 0, Q = Q_0 and when t = t, Q = Q

Integrating within proper limits we get,

$$\int_{Q0}^{Q} \frac{dQ}{Q} = -\int_0^t \frac{dt}{CR} = -\frac{1}{CR}\int_0^t dt$$

$$or\ |\ln Q|_{Q_0}^{Q} - \frac{1}{CR}|t|_0^t$$

$$\text{or } \ln Q - InQ_0 = -\frac{t}{CR}$$

$$\text{or } \ln\frac{Q}{Q0} = -\frac{t}{CR}$$

or Q= $Q_0 e^{-t/CR}$ = $Q_0 e^{-t/\tau}$--------(5)

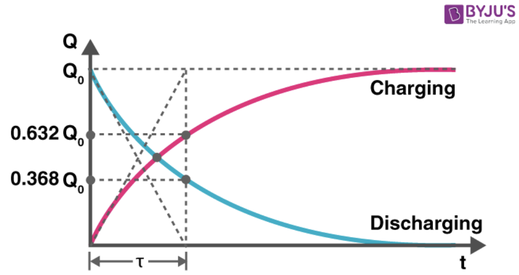
where, $\tau = CR,$

Eq. (5) gives the value of the charge on the capacitor at any time during discharging.

If $t = CR$, then from eq. (5),

Q= $Q_0 e^{-1}$ = $\frac{Q_0}{e}$ =0.368Q = 36.8% of Q_0

Time constant of a CR circuit is thus also the time during which the charge on the capacitor falls from its maximum value to 0.368 (approx.… 1/3) of its maximum value.
Thus, the charge on the capacitor will become zero only after infinite time.
The discharging of a capacitor has been shown in the figure.



Types of Capacitors:

Some of the important types of the capacitors are,

- Ceramic Capacitors.
- Film Capacitors.
- Power Film Capacitors.
- Electrolytic Capacitors.
- Paper capacitors.

CERAMIC CAPACITOR:

A ceramic capacitor is a fixed-value capacitor where the ceramic material acts as the dielectric. It is constructed of two or more alternating layers of ceramic and a metal layer acting as the electrodes. The composition of the ceramic material defines the electrical behavior and therefore applications.

Ceramics were one of the first materials to be used in the production of capacitors, as it was a known insulator. Different types of ceramic capacitors most often used in modern electronics are the multi-layer ceramic capacitor, otherwise named ceramic multi-layer chip capacitor (MLCC) and the ceramic disc capacitor. **MLCCs are the most produced capacitors with a quantity of approximately 1000 billion devices per year. They are made in SMD (surface-mounted Device) technology and are widely used due to their small size**. Ceramic capacitors are usually made with very small capacitance values, typically between 1nF and 1µF, although values up to 100µF are possible.

Advantages of Ceramic Capacitor:

The advantages of ceramic capacitors are:

1.Any size or shape is available.
2.Ceramic capacitors are inexpensive.
3.They are light in weight.
4.They can be designed to withstand up to sufficient high voltage (up to 100V).

Disadvantages of Ceramic Capacitor:

The disadvantages of ceramic capacitors are:

1.Very high-voltage ceramic capacitors are not available.
2.High capacitance values are not possible.
3.The tolerance values of ceramic capacitors are higher.

Applications of Ceramic Capacitors:

Ceramic capacitors have numerous applications are:

1.In transmitter stations in the resonant circuit
2.In High voltage laser power supplies
3.Induction furnaces

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FILM CAPACITORS:

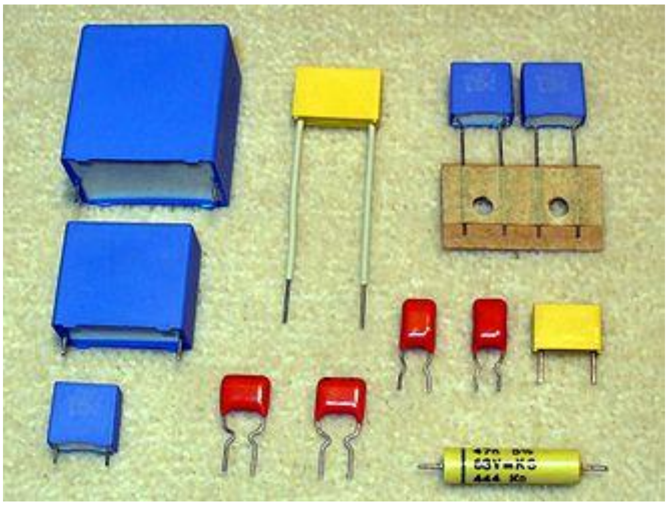
Film capacitors are capacitors which uses a thin plastic film as the dielectric. This film is made extremely thin using a sophisticated film drawing process. Once the film is manufactured, it is metallized or left untreated, depending on the properties of the capacitor. Electrodes are then added and the assembly is mounted into a case which protects it from environmental factors. They are used in many applications because of their stability, low inductance and low cost. There are many types of film capacitors, including polyester film, metallized film, polypropylene film, polytetrafluoroethylene (PTFE) film and polystyrene film. The core difference between these capacitor types is the material used as the dielectric and the proper dielectric must be chosen according to the application.

Example: Polytetrafluoroethylene (PTFE) film capacitors are heat-resistant and used in aerospace and military technology, while metallized polyester film capacitors are used in applications that require long term stability at a relatively low.

Applications for film capacitors:

1. Film capacitors are used in power electronics devices, phase shifters, X-ray flashes and pulsed lasers, while the low power variants are used as decoupling capacitors, filters and in A/D convertors.
2. Film capacitors can also be used in a more conventional way as voltage smoothing capacitors, in filters, audio crossovers.
3. They can be used to store energy and release it in a high-current pulse.

Power Film Capacitors:



Film capacitors, plastic film capacitors, film dielectric capacitors or polymer film capacitors, generally called film caps as well as power film capacitors, are electrical capacitors with an insulating plastic film as the dielectric, sometimes combined with paper as carrier of the electrodes.

The dielectric films, depending on the desired dielectric strength are drawn in a special process to an extremely thin thickness and are then provided with electrodes. The electrodes of film capacitors may be metallized aluminium or zinc applied directly to the surface of the plastic film or a separate metallic foil. Two of these conductive layers are wound into a cylinder-shaped winding, usually flattened to reduce mounting space requirements on a printed circuit board or layered as multiple single layers stacked together, to form a capacitor body.

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Advantages:

1.Very low dissipation factors, high quality factors (Q) and low inductance values (ESL).
2.No microphonics compared with ceramic capacitors.
3.Metallized construction has self-healing properties.

Disadvantages:

1.Larger physical size compared to electrolytic capacitors.
2.Limited number of types in surface-mount technology (SMT) packaging.

Applications of Power Film Capacitors:

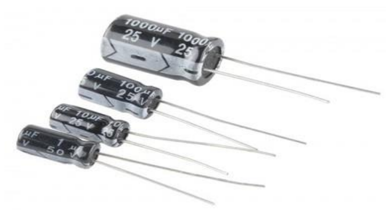
Power film capacitors are used in power electronics devices, phase shifters, X-ray flashes and pulsed lasers, while the low power variants are used as decoupling capacitors, filters and in A/D convertors.

Electrolytic Capacitors:

An electrolytic capacitor is popularly known as a polarized capacitor, wherein the anode has more positive voltage than the cathode. They are used in filtering applications, low-pass filters, audio amplifier circuits, and many more. Metals like aluminium, tantalum, niobium, manganese, etc. form an oxide layer in the electrochemical process, which blocks the electric current flowing in one direction but permits the flow of current in the opposite direction.

Electrolytic Capacitors uses an electrolyte to operate with a higher or more positive voltage on the anode than on the cathode. Therefore, the anode terminal is denoted with a positive sign, while the cathode with a negative sign. Applying a reverse polarity voltage of 1 to 1.5 volts may destroy the capacitor and dielectric and the result is hazardous, leading to an explosion or fire.

An electrolytic capacitor uses an electrolyte, in the form of solid, liquid or gel – serves as cathode or negative plate to achieve much higher capacitance per unit volume. On the other hand, a positive plate or anode made of metal acts as an insulating oxide layer formed through anodization. This allows an oxide layer to work as the dielectric of the capacitor.



Electrolytic Capacitor

Advantages:

The advantages of the **electrolytic capacitor** are
1.Used to achieve high capacitance value
2.Used in low-frequency applications
3.Tantalum capacitors are preferred over other types because of the high stability.

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Disadvantages:

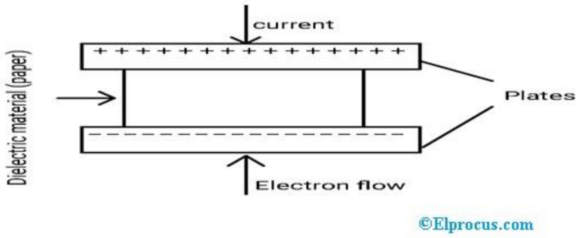
1.Must be attentive to ensure that the capacitors are corrected with right terminals
2.Reverse voltage may damage the capacitor
3.Easily gets affected due to temperature change

Applications of Electrolytic Capacitor:

1.Used in filtering applications to reduce the ripple in the power supplies.
2.Used as a low pass filter to smoothen the input and output signals.
3.Used in audio amplification circuits as filters to reduce hum.

PAPER CAPACITORS:

Definition: Paper capacitor is also known as a Fixed capacitor, in which paper is used as a dielectric medium, that stores energy in the form of the electrical field. These capacitors are used at power line frequency with a capacitance value of 1nf to $1\mu f$. It stores a fixed amount of electric charge.



Working:

A **Paper Capacitor** is made up of two metallic plates with a dielectric material paper between them. It has positive and negative plates. When a small amount of electric charge is applied over the plates, the positive charge is attracted to one plate and a negative charge is attracted to another plate. This electrical energy is stored in the form of the electrical field. This stored electrical energy is used by the discharging of a capacitor. These are available in the range of 500pF to 50nF.

Advantages:

The advantage of using a paper capacitor is that provides a fixed value of capacitance. The value of the capacitance is fixed during manufacturing.

Disadvantages:

The main disadvantage is, it absorbs moisture in the air and decreases the insulation resistance of the dielectric. As it absorbs moisture in the air, the dielectric medium is affected.

Applications:

Paper capacitors are widely used in various applications such as,
1.High voltage and high current applications.
2.Used in electrical and electronic applications.
3.Power conditioning systems to block DC signals and allow AC signals.

Energy Stored in A Capacitor:

The energy stored in a capacitor is nothing but the electric potential energy and is related to the voltage and charge on the capacitor. If the capacitance of a conductor is C, then it is initially uncharged and it acquires a potential difference V when connected to a battery. If q is the charge on the plate at that time, then

$$q=CV$$

`

The work done is equal to the product of the potential and charge. Hence, $W = Vq$

If the battery delivers a small amount of charge dQ at a constant potential V, then the work done is

$$dW = V\,dq = \frac{q}{c}\,dq$$

Now, the total work done in delivering a charge of an amount q to the capacitor is given by

$$W = \int_0^q \frac{q}{c}dq = \frac{1}{C}\frac{q^2}{2} = \frac{1}{2}\frac{q^2}{C}$$

Therefore, the energy stored in a capacitor is given by $U = \frac{1}{2}\frac{q^2}{C}$

Substituting $q=CV$

in the equation above, we get, $\mathbf{U = \frac{1}{2}\ CV^2}$

The energy stored in a capacitor is given by the equation $\mathbf{U = \frac{1}{2}\ CV^2}$

APPLICATIONS OF PASSIVE ELEMENTS:

RESISTOR AS A HEATING ELEMENT IN HEATERS:

A heating element is a material or device that directly converts electrical energy into heat or thermal energy through a principle known as Joule heating. Joule heating is the phenomenon where a conductor generates heat due to the flow of electric current. As the electric current flows through the material, electrons or other charge carriers collide with the ions or atoms of the conductor creating friction at an atomic scale. This friction then manifests as heat. Joule's first law (Joule-Lenz law) is used to describe the amount of heat produced from the flow of electricity in a conductor. This is expressed as,

$$P = IV \text{ or } P = I^2R \qquad (\because V=IR)$$

The Joule–Lenz law, also known as Joule's first law, states that Joule heating is proportional to the product of a conductor's electrical resistance and the square of the electrical current flowing through the conductor.

$$P \propto I^2 .\ R$$

Calculating Resistive Heating:

There are two simple formulas for calculating the amount of heat dissipated in a resistor (i.e., any object with some resistance). The heat is measured in terms of ***power***, which corresponds to energy per unit time. Thus, rate at which energy is being converted into heat inside a conductor is:

$$\mathbf{P = I \times V}$$

where P is the power, I is the current through the resistor and V is the voltage drop across the resistor.

Power is measured in units of watts (W), which correspond to amperes x volts. Thus, a current of one ampere flowing through a resistor across a voltage drop of one volt produces one watt of heat. The Unit of watts is also expressed as joules per second.

The relationship P = I x V makes sense if the voltage is a measure of energy per unit charge, while the current is the rate of flow of charge. The product of current and voltage therefore tells us how many electrons are "passing through," multiplied by the amount of energy each electron loses in the form of heat as it goes, giving an overall rate of heat production, i.e.,

$$P = I \times V$$

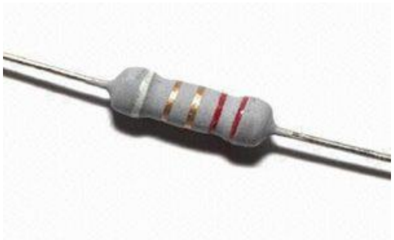
$$\frac{Charge}{Time} \cdot \frac{Energy}{Charge} = \frac{Energy}{Time}$$

and see that, with the charge cancelling out, units of current multiplied by units of voltage indeed give us unit of power.)

RESISTOR AS A FUSE ELEMENT:

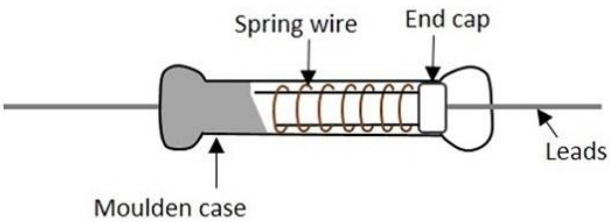
A **Fusible Resistor** known by the name current-limiting resistors, fuse resistor, meltdown resistor is a type of resistor that has a low power rating and is designed to melt when a certain amount of current flows through it, thus breaking an electrical circuit. It is the only type of resistor designed to burn quickly (and isolate itself) when overloaded with the current. Fusible resistors are used as safety devices to prevent electrical fires and other damage caused by excessive current being applied at once. They can be found in household appliances like washing machines and microwaves, as well as electronic devices like stereos.

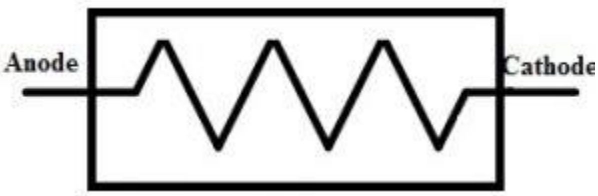
Definition of Fusible Resistor:



Fusible Resistors are power resistors that are designed to fail in a controlled manner. These resistors start as high-power resistors and have lead ends welded together and placed in a ceramic enclosure. If the resistor has too much current applied to it, it will short out and the resulting heat will cause the fusible resistor to melt, encapsulating the melted material.

The fusible resistor symbol is shown below. This is the combination of a resistor and a fuse.





Fusible Resistor Construction

Fusible resistors are constructed such that their resistance increases as the temperature rises. This characteristic allows the resistor to function as both a current limiting device and as an over-current fuse, protecting circuits from transient over-current surges and fault conditions.

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There are two most commonly used ways to construct a Fusible Resistor which are as follows

The first is a series of high resistance metal films sandwiched between two end caps, which are connected to the ends of the films.

The second consists of a non-metallic element wound into a coil and then coated with a thin layer of metal.

Advantages:

The **advantages of a fusible resistor** are discussed below.

1. One of the key advantages of a fusible resistor is that it allows current to flow through it until a certain maximum value is exceeded, at which point the resistor burns out, preventing damage to other components as a result of an overload.
2. They can be used in both AC and DC circuits. This is particularly beneficial in applications where the power source may vary from AC to DC.
3. A wide range of resistance values is available, ranging from 0.1 ohms to two megohms.

Disadvantages:

The **disadvantages of fusible resistors** are,

1. Fusible resistors have a limited lifespan and will eventually burn out under normal operating conditions, requiring replacement.
2. Fusible resistors’ power ratings are low, which means they can’t take on high-voltage applications.

Applications:

The applications of fusible resistors are

1. Fusible resistors are used in electrical circuits that may occasionally be exposed to short circuit conditions for a short period of time. They will blow out like a fuse in the event of a short circuit, protecting the circuit from damage and fire.
2. Fusible resistors are used in motor controller systems, automobiles, power supplies, rectifiers and inverters, home appliances, power tools, and other equipment.
3. The main benefit of using this resistor is that its resistance function controls inrush current.

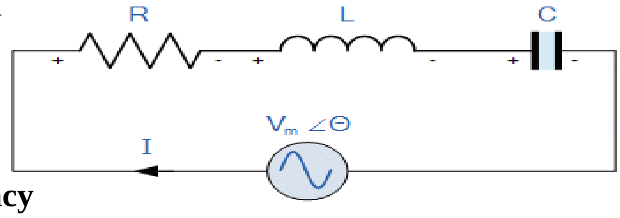
APPLICATION OF CHOKE IN A FAN:

A choke, also known as an inductor, is used to block higher-frequency while passing direct current (DC) and lower-frequencies of alternating current (AC) in an electrical circuit. The name comes from blocking, or "choking", high frequencies while passing low frequencies.

Radio frequency chokes (RFC) often have iron powder or ferrite cores which increases inductance and overall operation. They are often wound in complex patterns (basket winding) to reduce self-capacitance and proximity effect losses. Chokes for even higher frequencies have non-magnetic cores and low inductance. A modern form of choke used for eliminating digital RF noise from lines is the ferrite bead, a cylindrical or torus-shaped core of ferrite slipped over a wire. These are often seen on computer cables. A typical RF choke value could be 2 millihenries.

SERIES RESONANCE CIRCUIT AS A RADIO TUNING CIRCUIT:

Resonance occurs in a series circuit when the supply frequency causes the voltages across L and C to be equal and opposite in phase



In a series RLC circuit there becomes a frequency point were the inductive reactance of the inductor becomes equal in value to the capacitive reactance of the capacitor. In other words, $X_L = X_C$. The point at which this occurs is called the **Resonant Frequency** point, (f_r) of the circuit, and as we are analysing a series RLC circuit this resonance frequency produces a **Series Resonance**.

Series Resonance circuits are one of the most important circuits used electrical and electronic circuits. They can be found in various forms such as in AC mains filters, noise filters and also in radio and television tuning circuits producing a very selective tuning circuit for the receiving of the different frequency channels. Consider the simple series RLC circuit below.

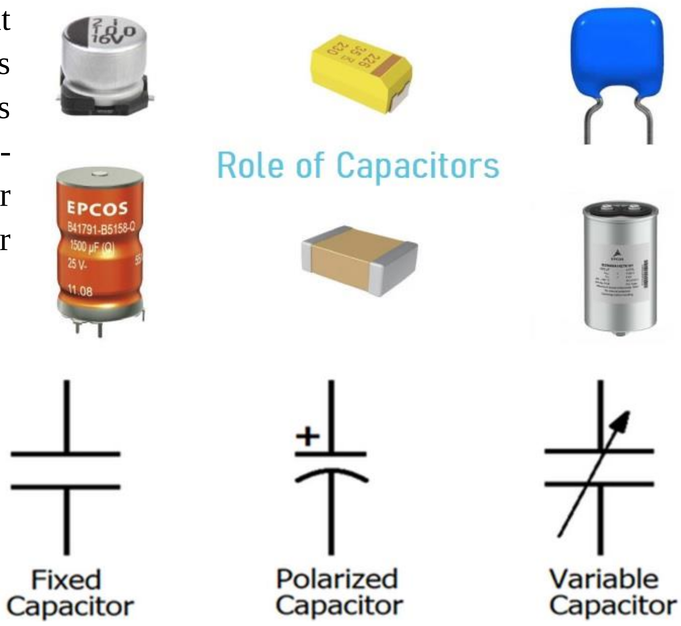
- Inductive reactance : $X_L = 2\pi f L = \omega L$
- Capacitive reactance : $X_C = \dfrac{1}{2\pi f C} = \dfrac{1}{\omega C}$
- When $X_L > X_C$ the circuit is Inductive
- When $X_C > X_L$ the circuit is Capacitive
- Total circuit reactance = $X_T = X_L - X_C$ or $X_C - X_L$
- Total circuit impedance = $Z = \sqrt{R^2 + X_T^2} = R + jX$

From the above equation for inductive reactance, if either the **Frequency** or the **Inductance** is increased the overall inductive reactance value of the inductor would also increase. As the frequency approaches infinity, the inductors reactance would also increase towards infinity with the circuit element acting like an open circuit.

However, as the frequency approaches zero or DC, the inductors reactance would decrease to zero, causing the opposite effect acting like a short circuit. This means then that inductive reactance is "**Proportional**" to frequency and is small at low frequencies and high at higher frequencies.

APPLICATIONS of CAPACITOR IN POWER SUPPLIES:

A capacitor is an electrical device that store charges that can be retained for a certain amount of time even when the applied power source is removed. Capacitors are used in every circuits with different versions, polarized or non-polarized, electrolytic or ceramic, thin film or tantalum, SMD (Surface Mount Device) or through hole, cylindrical or square, etc.



1. When a capacitor is used in power supply circuits, its major function is to carry out the role of bypass, decoupling, filtering and energy storage.

1) Filter:

Filtering is an important part of the role of capacitors. It is used in almost all power circuits. In theory, it is that the larger the capacitance, the smaller the impedance and the higher the frequency to be allowed to pass. The function of the capacitor is to pass the high frequency components of the signal and block low frequency part. The larger the capacitance, the easier the low frequency signal passes, and the smaller the capacitance, the easier the high frequency passes. Specifically used in filtering, a large capacitor (e.g. $470\mu f$) filters low frequencies, and a small capacitor (e.g. 120pF) filters high frequencies.

2) Bypass

The bypass capacitor is an energy storage device that provides energy for local devices. It can make the output of the voltage regulator smooth and reduce the load effect. To minimize the impedance, the bypass capacitor should be placed as close as possible to the power supply pin and ground pin of the load device. This can prevent ground potential rise and noise caused by excessive input value.

3) Decoupling Capacitors

Decoupling capacitor acts as a local electrical energy reservoir. Capacitors, like batteries, need time to charge and discharge. When used as decoupling capacitors, they oppose quick changes of voltage. If the input voltage suddenly drops, the capacitor provides the energy to keep the voltage

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stable. Similarly, if there is a voltage spike, the capacitor absorbs the excess energy. Decoupling capacitors are used to filter out voltage spikes and pass through only the DC component of the signal.

4) <u>Energy storage:</u>

The energy storage capacitor collects charge through the rectifier and transfers the stored energy to the output end of the power supply through the converter lead. Aluminium electrolytic capacitors with a voltage rating of 40 to 450 VDC and a capacitance between 220 and 150μF are more commonly used. According to different power requirements, devices are sometimes used in series, parallel or a combination of them. The energy stored in a capacitor is related to the voltage applied and the amount of charges residing on the plates. Therefore, in static state, the energy in the capacitor is in the form of electric field between its two conducting plates.

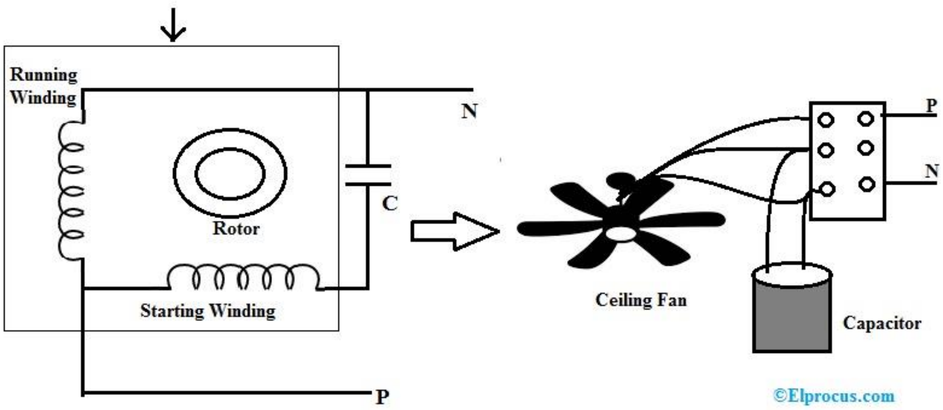
APPLICATIONS OF CAPACITOR IN MOTORS:

In Celling Fans:

A capacitor that is used to operate a ceiling fan is known as a fan capacitor. The capacitor used in a ceiling fan is a non-polarized electrolytic AC capacitor. The electrical parts of the ceiling fan include a stator, rotor, and regulator where a capacitor plays a key role to make the fan work properly. The main function of a capacitor in a fan is not only to operate but also it makes to rotate.

When we turn on a ceiling fan, an electric current will flow through the circuit, causing it to rotate. However, if we want the fan to operate at different speeds, we need to regulate its energy output. A capacitor allows to vary the amount of energy flowing into the motor, which in turn determines its rotational speed.

The **circuit diagram of the ceiling fan with a capacitor** is shown below. This circuit provides the proper connection of the ceiling fan with a switch, capacitor and regulator.



Fan Capacitor Connection Diagram

Generally, in a ceiling fan, there are two windings running winding & starting winding. A capacitor must be connected to the starting winding in series after that it must be connected across the power supply. Alternatively, the running winding is directly connected to the power supply.

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UNIT-II

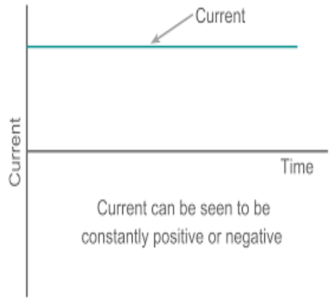
POWER SOURCES (Batteries)

TYPES OF POWER SOURCES:

A **power source** is a source of power.

Primary energy sources take many forms, including **nuclear energy**, **fossil energy** - like **oil**, **coal** and **natural gas** and **renewable** sources like **wind**, **solar**, **geothermal** and **hydropower**. These primary sources are converted to **electricity**, a secondary energy source, which flows through power lines and other transmission infrastructure to your home and business.

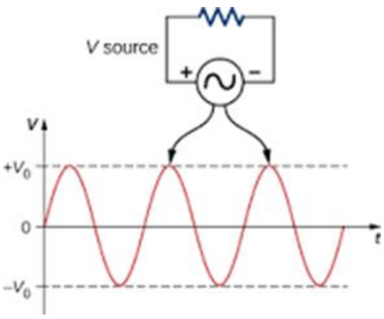
DC SOURCES:



DC sources refer to **sources of electrical energy which are associated with constant voltages and currents**. A DC power supply can be constructed as an electronic circuit operating from the ac mains electricity supply and designed for purpose.

Examples:

Some sources of direct current are **cells, DC generator**, etc. Dry cell, Dry cell battery, car battery, radio and television works only with D.C as they have a device in them which convert A.C supplied to them into D.C. The DC current is the current which does not change the direction with time.



AC POWER SUPPLIES:

An AC is produced by an alternating emf, which is generated in a power plant. If the AC source varies periodically, particularly sinusoidally, the circuit is known as an ac circuit. Examples include the **commercial and residential power** that serves so many of our needs.

The sources are **hydroelectric power plants, thermal power generators, nuclear power generators**, AC generators produce alternating current.

TYPES OF BATTERIES:

A Battery is a device consisting of one or more electrical cells that convert chemical energy into electrical energy. Every battery is basically a galvanic cell where redox reactions take place between two electrodes which act as the source of the chemical energy.

The electrochemical reaction in a battery is carried out by moving electrons from one material to another (called electrodes) using an electric current.

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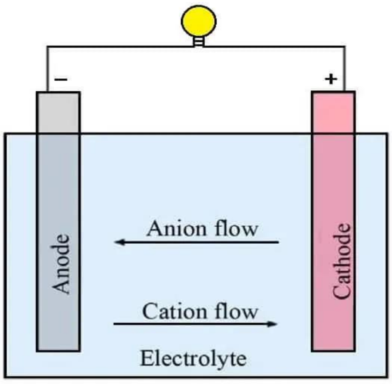
Working of A Battery:



The battery produces electrical energy on demand by using the terminals or electrodes of the battery. The positive terminal is located on the top of the battery which is used for flashlights and electronics.

The outer case or bottom of the battery is commonly referred to as the negative terminals. Both terminals are very common in all types of batteries. The chemicals that surround these terminals and the battery together form the power cell.

The power cell generates energy whenever the positive and negative terminals are connected to an electrical circuit.

Classification of Batteries:

1.Primary battery
2.Secondary battery

1 Primary Battery:

A primary battery is a simple and convenient source of electricity for many portable electronic devices such as lights, cameras, watches, toys, radios, etc. These types of batteries cannot be recharged once they are exhausted. They are composed of electrochemical cells whose electrochemical reactions cannot be reversed.

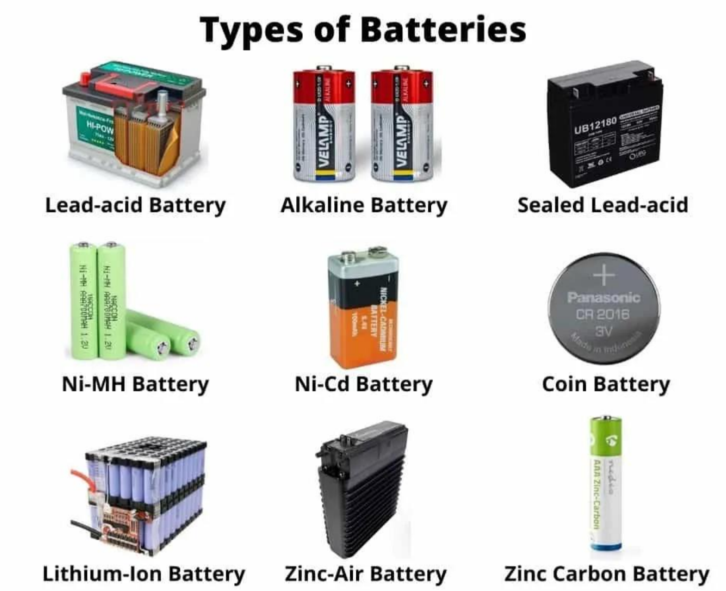
2. Secondary Battery:

They are also used where it would be too expensive or impractical to use a single charged battery. Small-capacity secondary batteries are used in portable devices such as mobile phones, while heavy-duty batteries are found in electric vehicles and other high-drain applications.

TYPES OF BATTERIES:

The following are different types of batteries.

1. Lead-acid batteries
2.Nickel-cadmium batteries (Ni-Cd)
3.Nickel-metal hybrid batteries (Ni-MH)
4.Lithium-ion batteries (Li-ion)
5.Alkaline batteries
6.Zinc-carbon batteries
7.Coin cell batteries
8.Zinc-air cells
9.Sealed lead-acid batteries



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RECHARGEABLE BATTERY:

A rechargeable battery is an energy storage device that can be charged again after being discharged by applying DC current to its terminals.

A rechargeable battery is generally a more sensible and sustainable replacement to one-time use batteries, which generate current through a chemical reaction in which a reactive anode is consumed. The anode in a rechargeable battery gets consumed as well but at a slower rate, allowing for many charges and discharges.

In use, rechargeable batteries are the same as conventional ones. However, after discharge the batteries are placed in a charger or in the case of built-in batteries, an AC/DC adapter is connected.

Rechargeable batteries are used in many applications such as cars, all manner of consumer electronics and even off-grid and supplemental facility power storage.

LEAD ACID BATTERY:

Definition:

The battery which uses sponge lead and lead peroxide for the conversion of the chemical energy into electrical power, such type of battery is called a lead acid battery. The lead acid battery is most commonly used in the power stations and substations because it has higher cell voltage and low cost.

Construction of Lead Acid Battery:

The various parts of the lead acid battery are the container and the plates. The container stores chemical energy which is converted into electrical energy by the help of the plates.

1. Container – The container of the lead acid battery is made of glass, lead lined wood, ebonite, the hard rubber of bituminous compound **(Bituminous means a material, consisting mainly of hydrocarbons and soluble in carbon disulphide),** ceramic materials or moulded plastics and are seated at the top to avoid the discharge of electrolyte. At the bottom of the container, there are four ribs, two of them rest the positive plate and the others support the negative plates.

The prism serves as the support for the plates and at the same time protect them from a short-circuit. The material of which the battery containers are made should be resistant to sulfuric acid, should not deform or porous, or contain impurities which damage the electrolyte.

2. Plate – The plate of the lead-acid cell is of diverse design and they all consist some form of a grid which is made up of lead and the active material. The grid is essential for conducting the electric current and for distributing the current equally on the active material. If the current is not uniformly distributed, then the active material will loosen and fall out.

3**.Grid:** The grids are made up of an alloy of lead and antimony. These are usually made with the transverse rib that crosses the places at a right angle or diagonally. The grid for the positive and negative plates is of the same design, but the grids for the negative plates are made lighter because they are not as essential for the uniform conduction of the current.

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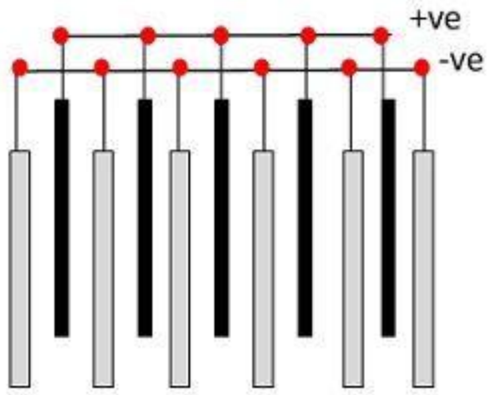
The plates of the battery are of two types. They are formed plates or plante plates and pasted or faure plates.

Plante's plates are used largely for stationary batteries as these are heavier in weight and more costly than the pasted plates. But the plates are more durable and less liable to lose active material by rapid charging and discharging. The plante plate has low capacity weight-ratio.



Arrangements of Plates in a Lead-acid-Battery

Faure process is much suitable for manufacturing of negative plates rather than positive plates. The negative active material is quite tough and it undergoes a comparatively low change from charging and discharging.

a. Active Material – The material in a cell which takes active participation in a chemical reaction (absorption or evolution of electrical energy) during charging or discharging is called the active material of the cell. The active elements of the lead acid are

b. Lead peroxide (PbO_2) – It forms the positive active material. The PbO_2 are dark chocolate broom in colour.

c. Sponge lead – Its form the negative active material. It is grey in colour.

d. Dilute Sulfuric Acid (H_2SO_4) – It is used as an electrolyte. It contains 31% of sulfuric acid.

The lead peroxide and sponge lead, which form the negative and positive active materials have the little mechanical strength and therefore can be used alone.

4. Separators – The separators are thin sheets of non-conducting material made up of chemically treated leadwood, porous rubbers, or mats of glass fibre and are placed between the positive and negative to insulate them from each other. Separators are grooved vertically on one side and are smooth on the other side.

5. Battery Terminals – A battery has two terminals the positive and the negative. The positive terminal with a diameter of 17.5 mm at the top is slightly larger than the negative terminal which is 16 mm in diameter.

Working Principle of Lead Acid Battery:

When the sulfuric acid dissolves, its molecules break up into positive hydrogen ions ($2H^+$) and sulphate negative ions (SO_4^{--}) and move freely. If the two electrodes are immersed in solutions and connected to DC supply then the hydrogen ions being positively charged and moved towards the electrodes and connected to the negative terminal of the supply. The SO_4^{--} ions being negatively charged moved towards the electrodes connected to the positive terminal of the supply main (i.e., anode).

Each hydrogen ion takes one electron from the cathode, and each sulphates ion takes the two negative ions from the anodes and react with water and form sulfuric and hydrogen acid.

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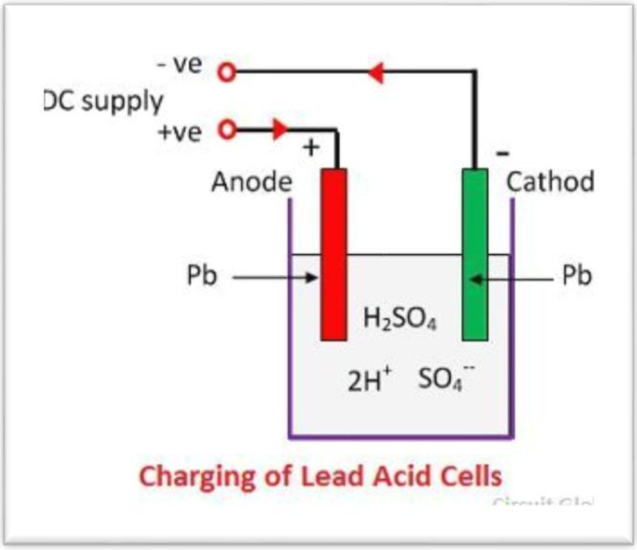
The oxygen, which produced from the above equation react with lead oxide and form lead peroxide (PbO_2.) Thus, during charging the lead cathode remain as lead, but lead anode gets converted into lead peroxide, chocolate in colour.

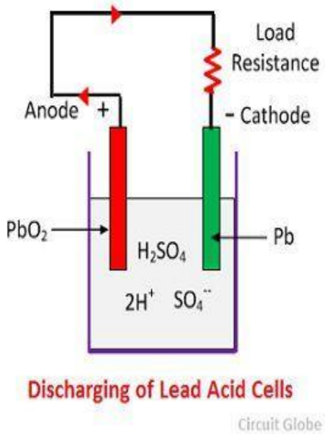


Charging of Lead Acid Cells

If the DC source of supply is disconnected and if the voltmeter connects between the electrodes, it shows the potential difference between them. If a wire is connected to the electrodes, then current will flow from the positive plate to the negative plate through external circuit i.e. the cell is capable of supplying electrical energy.

Chemical Action During Discharging

When the cell is fully discharge, then the anode is of lead peroxide (PbO_2) and a cathode is of metallic sponge lead (Pb). When the electrodes are connected through a resistance, the cell discharges and electrons flow in a direction opposite to that during charging.



Discharging of Lead Acid Cells

The hydrogen ions move to the anode and reaching the anode receives one electron from the anode and become hydrogen atom. The hydrogen atom comes in contacts with a PbO_2, so it attacks and forms lead sulphate ($PbSO_4$), whitish (tending to white) in colour and water according to the chemical equation.

$$PbSO_4 + 2H = PbO + H_2O$$

$$PbO + H_2SO_4 = PbSO_4 + 2H_2O$$

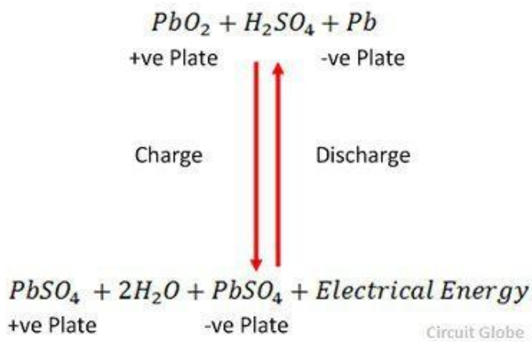
$$\overline{PbO_2 + H_2SO_4 + 2H = PbSO_4 + 2H_2O}$$

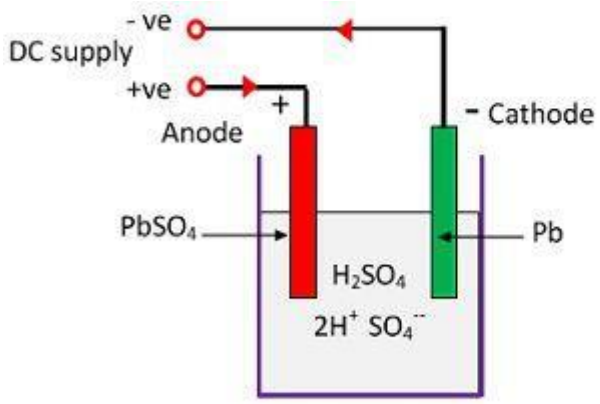
Each sulphate ion (SO_4^{--}) moves towards the cathode and reaching there gives up two electrons becomes radical SO_4, attack the metallic lead cathode and form lead sulphate whitish (tending to white) in colour according to the chemical equation.

Chemical Action During Recharging

For recharging, the anode and cathode are connected to the positive and the negative terminal of the DC supply mains. The molecules of the sulfuric acid break up into ions of $2H^+$ and SO_4^{--}. The hydrogen ions being positively charged moved towards the cathodes and receive two electrons from there and form a hydrogen atom. The hydrogen atom reacts with lead sulphate cathode forming lead and sulfuric acid according to the chemical equation.

$$PbSO_4 + 2H_2O + 2H = PbSO_4 + 2H_2SO_4$$





Recharging of Lead Acid Cell

Circuit Globe

SO_4^{--} ion moves to the anode, gives up its two additional electrons becomes radical SO_4, react with the lead sulphate anode and form leads peroxide and lead sulphuric acid according to the chemical equation.

$$PbSO_4 + 2H = H_2SO_4 + Pb$$

The charging and discharging are represented by a single reversible equation given below.

The equation should read downward for discharge and upward for recharge.

Lead Acid Battery Applications:

1.These are employed in emergency lightening to provide power for sump pumps.
2.Used in electric motors
3.Submarines
4.Nuclear submarines

Lead Acid Battery Advantages:

1.Mature technology

2.Large current capability

3.Can be made for a variety of applications

4.Tolerant of overcharging

5.Wide range of sizes and specifications available

Lead Acid Battery Disadvantages:

1.Fails after a few years use lifespan typically 300 - 500 cycles

2.Lead is not environmentally friendly

3.Acid needs disposing of with care

4.Not suitable for fast charging

5.Must be stored in charged state once electrolyte introduced

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LITHIUM-ION BATTERY (Li-ion Battery):

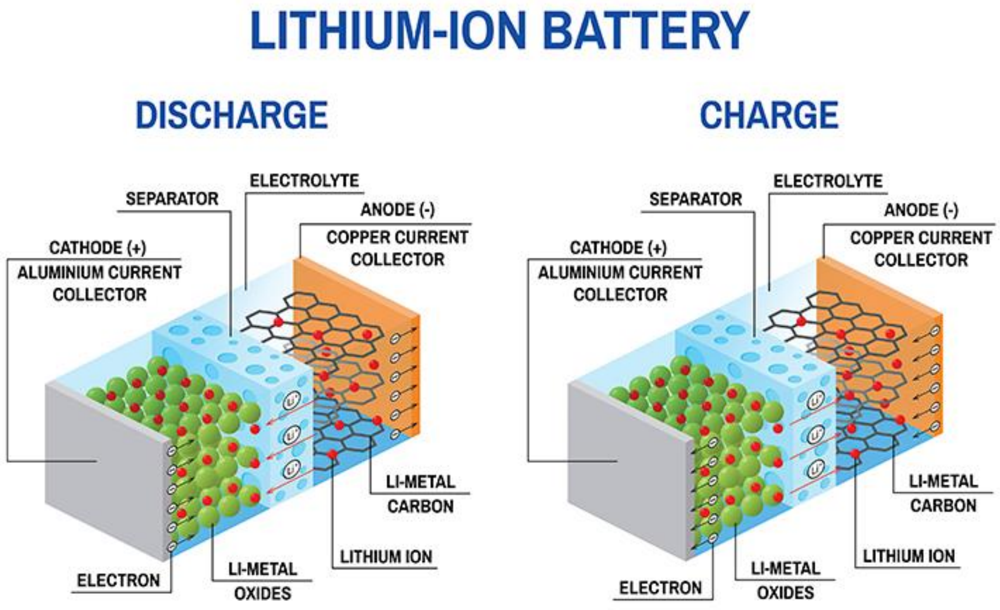
A lithium-ion battery is a type of rechargeable battery that makes use of charged particles of lithium to convert chemical energy into electrical energy. On the basis of the ability of recharging, lithium-ion batteries are classified into two broad categories, namely, primary and secondary. Primary lithium-ion batteries are non-rechargeable, while secondary lithium-ion batteries are rechargeable.

Working Principle of Lithium-ion Battery:

Lithium-ion batteries work on the **rocking chair principle**. Here, the conversion of chemical energy into electrical energy takes place with the help of redox reactions (**A chemical reaction in which electrons are transferred between two reactants participating in it**). Typically, a lithium-ion battery consists of two or more electrically connected electrochemical cells. When the battery is charged, the ions tend to move towards the negative electrode or the anode. When the battery gets completely discharged, the lithium ions return back to the positive electrode i.e., the cathode. This means that during the charging and discharging process. Thus, the lithium ions move back and forth between the two electrodes of the battery, so, the working principle of a lithium-ion battery is called the **rocking chair principle.**

Working of Lithium-ion Battery:

A typically battery consists of two electrodes, namely, anode and cathode. Cathode forms the positive terminal of the battery and anode is the negative terminal. The cathode of a lithium-ion battery is mainly composed of a lithium compound, while the prime element of the anode is graphite. When the battery is plugged in with an electric supply, the lithium ions tend to move from the cathode to the anode, i.e., from the positive electrode to the negative electrode. This is known as charging the battery. During the discharge phase of the battery, the movement of the lithium ions gets reversed from anode to cathode, i.e., from negative electrode to positive electrode, and the electrical energy gets transmitted to the attached load.



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Uses of Lithium-ion Battery:

1.Cellular Devices:
2.Power Banks:
3.Electric Vehicles:
4.Medical Devices:
5.Cameras:
6.Uninterrupted Power Supply System (UPS):
7.Robots:

Various Applications of Li-Ion Batteries

Advantages of Lithium-ion Battery:

1. Lithium-ion batteries have a significantly low self-discharge rate as compared to the other type of batteries.
2.They have a high energy density.
3.They require low maintenance.

Disadvantages of Lithium-ion Battery:

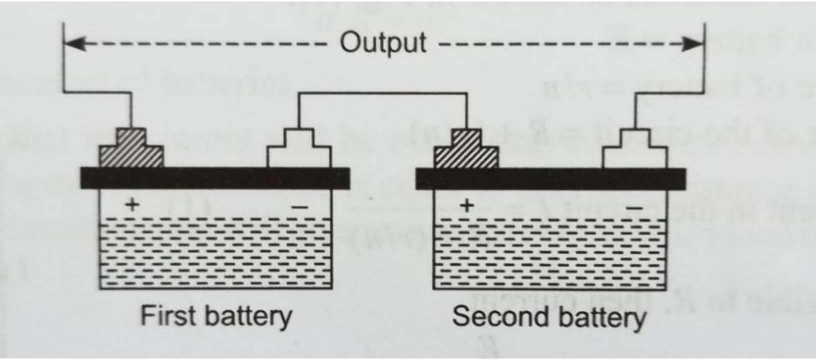
1. If the separator of the lithium-ion batteries gets damaged, they are susceptible to fire hazards.
2.. They are relatively expensive.
3. If the battery runs out of lithium ions, it cannot be replaced. Thus, the battery cannot be used after the tentative life span

COMBINATION OF TWO BATTERIES

Series Configuration of Batteries:

In a series configuration, the negative electrode of first battery is connected to the positive electrode of the second battery. The output is taken from the positive electrode of first battery and negative electrode of second battery. A combination of two batteries in series is

If number of batteries are available, the negative electrode of first battery is connected to the positive electrode of second battery and negative electrode second battery is connected to the positive electrode of third battery and so on is shown,



Series Combination of Batteries

Let, n = number of batteries connected in series

r = internal resistance of a battery

R = external load connected

E = e.m.f. of each cell.

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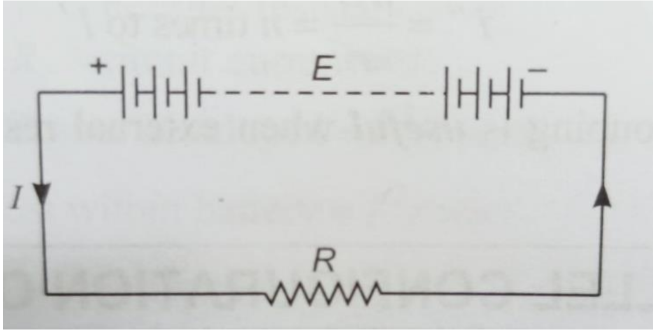
Total e.m.f. of n batteries = nE

Total internal resistance of the batteries = nr

Total circuit resistance = $R + nr$

Current in the circuit $I = \frac{nE}{R + nr}$ --------(1)



(i) If R is negligible as compared to nr, then
Series Combination of n Batteries

$$I' = \frac{nE}{nr} = \frac{E}{r}$$

Therefore, there is ***no increase in the current.***

(ii) If nr is negligible to the load resistance R, then

$$I'' = \frac{nE}{R} = n \times \frac{E}{R} = n I'$$

Thus, the ***current*** delivered by the battery has ***increased by n times.***

PARALLEL CONFIGURATION OF BATTERIES:

In parallel configuration, all the positive electrodes are connected to each other to give a positive electrode while all the negative electrodes are connected to each other to give a negative electrode.

Let e.m.f. of each battery = E

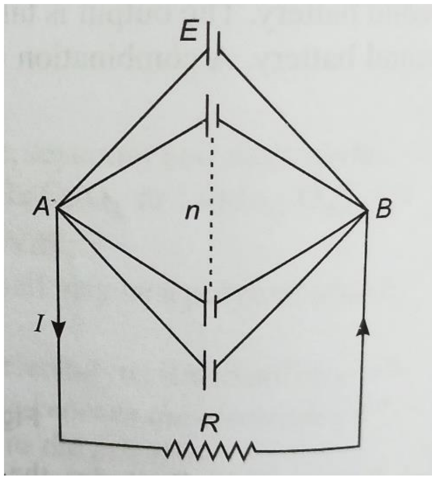
Internal resistance of the battery = $\frac{r}{n}$

Total resistance of the circuit = $R + \frac{r}{n}$

Current in the circuit $I = \frac{E}{R+\frac{r}{n}}$ ------------(1)

(i)If $\frac{r}{n}$ is negligible to R, then current $I' = \frac{E}{R}$ ----------(ii)

This shows that the group is not useful.



Parallel Combination of n Batteries

(ii) If R is negligible in comparison to $\frac{r}{n}$, then $I'' = \frac{nE}{R} = n$ times to **I**'

Thus, the grouping is useful when external resistance is small as compared to the internal resistance of the battery.

SERIES- PARALLEL COMBINATION OF BATTERIES:

In series-parallel grouping, some batteries are connected in series and then a combination of such series batteries (say m) is connected in parallel.

Let, number of batteries in series = n

Number of series batteries in parallel =m

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Resistance of series combination = *nr*

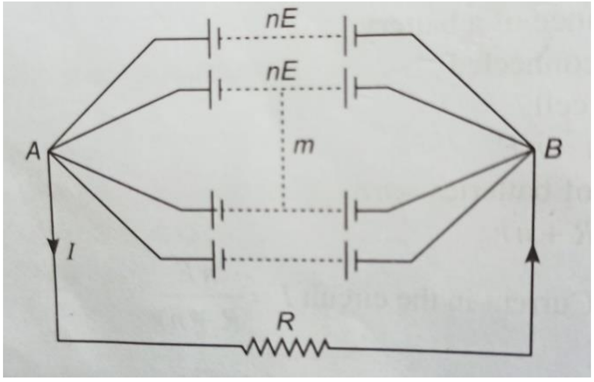
Let, number of batteries in series = *n*

Number of series batteries in parallel =m

Resistance of parallel combination = *nr*

Total resistance connected in the circuit =*R*
e.m.f. of batteries in one row =
Equivalent resistance of m rows connected in parallel

$= \frac{nr}{m}$



Series- Parallel Combination

∴ Total circuit resistance = R + $\left(\frac{nr}{m}\right)$

Therefore, current in the circuit I = $\frac{\text{nE}}{\text{R} + \left(\frac{nr}{m}\right)} = \frac{mnE}{mR+nR}$

∴ Current in the circuit I = $\frac{NE}{mR+nR}$ ----------(1)

where, N = m x n = total number of batteries.

It is clear from Eq. (1) that the current will be maximum when denominator is minimum, i.e., mR = nr or R = $\left(\frac{nr}{m}\right)$ or the external resistance is equal to internal resistance of battery.

Therefore, series- parallel configuration will give maximum current when load resistance R is equal to the internal resistance of the battery.

<u>EFFICIENCY OF BATTERY:</u>

The efficiency of a battery is defined as

$$\eta = \frac{output}{input} \; x\ 100\ \%$$

Let e.m.f. of battery = E, internal resistance = *r*,
external resistance = R, circuit current = *I*

∴ Power developed = I^2 R Watt

Power lost within battery = $I^2 r$ watt.

Total power development = $I^2 R + I^2 r = E\,I$ watt

Efficiency, $\eta = \frac{\text{I}^2\ \text{R}}{\text{I}^2\ \text{R} + \text{I}^2\ r} = \frac{\text{R}}{\text{R+r}}$

Or Efficiency $\eta = \frac{useful\ power}{total\ power\ produced}$

Thus, efficiency is higher when *R* is greater.

B) <u>NETWORK THEOREMS FOR DC CIRCUITS:</u>

THEVENIN'S THEOREM:

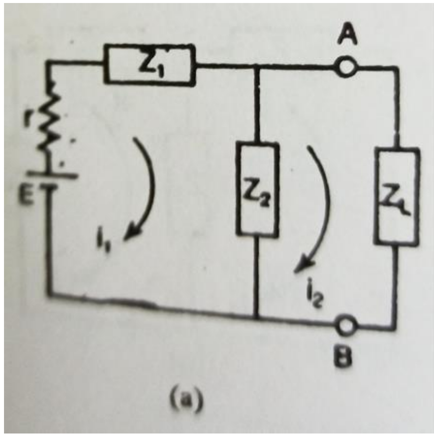
Statement:

Any two terminals of a network, containing sources of impedance and linear impedance, can be replaced by an equivalent circuit consisting of a voltage source E_{th} in series with impedance Z_{th}. The e.m.f. of the voltage source is equal to the potential difference between the two terminals in open circuit position (no external circuit is connected between them). The series impedance is equal to the impedance between the two terminals when all the sources being replaced by their internal impedance.

Procedure:

The procedure for drawing the Thevenin's equivalent circuit is as follows:

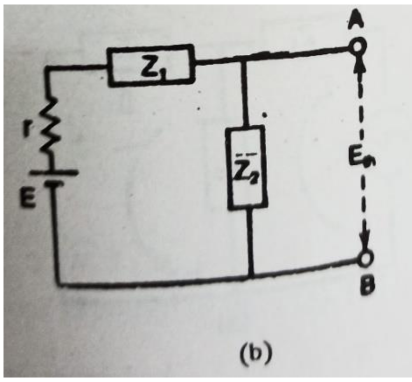
Consider a network as shown, fig(a),



(a)

It consists of a d.c. source of e.m.f. E of internal resistance ***r***. Z and Z_2 are the two impedances connected in series with the source. A and B are the two terminals of the network and Z_L is the external load.

Let the load terminals A and B open {see fig(b)], we calculate the open circuited e.m.f. of voltage source i.e., E_{th}. For this purpose, we calculate the current flowing in the circuit of fig(b). This is given by



(b)

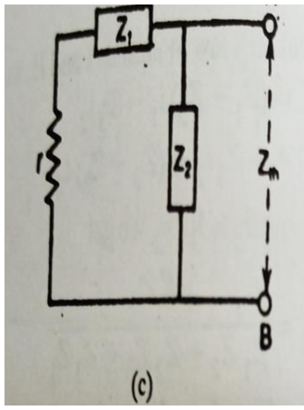
$$\mathbf{i} = \frac{E}{r+Z_1+Z_2}$$

Now the voltage across Z_2 is given by

$$\mathbf{E_{th} = current\ x\ impedance} = \left(\frac{E}{r+Z_1+Z_2}\right)\mathbf{Z_2} \text{ -----------}\mathbf{(1)}$$

To calculate the Z_{th} .

The circuit for calculating Z_{th} is shown in the fig. (c)



(c)

The battery is removed while its internal impedance ***r*** is considered. Corresponding to points **A and B, Z_1** and ***r*** are in series and equivalent impedance of the two is in parallel with Z_2.

The battery is removed while its internal impedance ***r*** is considered. Corresponding to points **A and B, Z_1** and ***r*** are in series and equivalent impedance of the two is in parallel with Z_2.

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Hence,

$$\mathbf{Z_{eq} = (Z_1 + r)}$$

Now, $\frac{1}{Z_{th}} = \frac{1}{Z_2} + \frac{1}{z_1+r}$ **or**

$$\mathbf{Z_{th}} = \frac{(Z_1 + r)Z_2}{r+Z_1+Z_2} \text{------------------} \mathbf{(2)}$$

The Thevenin's equivalent circuit is,

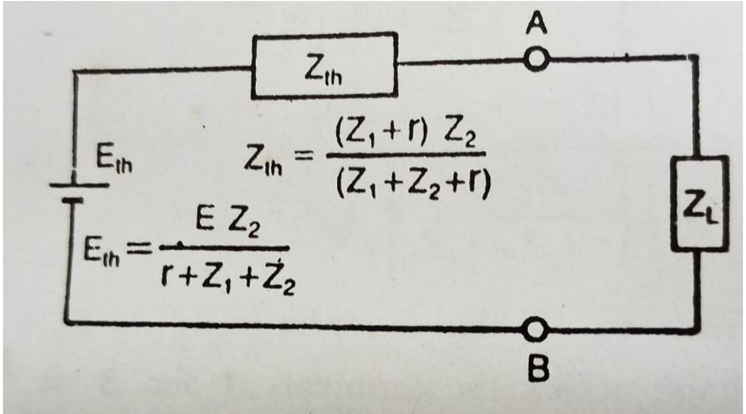


Fig. (16) Thevenin's equivalent circuit.

Proof:

Let i_1 **and** i_2 be the currents into meshes as shown. Applying Kirchhoff's law, we have

$$(r + Z_1 + Z_2)i_1 - Z_2 i_2 = E \text{------} (3)$$

$$(Z_2 + Z_L)\, i_2 - Z_2 i_1 = 0 \text{----------} (4)$$

From eq. (4) $i_1 = \left(\frac{(Z_2+Z_L)}{Z_2}\right) i_2$

Substituting the value of i_1 in eq. (3), we get,

$$(r + Z_1 + Z_2)\left[\frac{(Z_2+Z_L)}{Z_2}\right] i_2 - Z_2 i_2 = E$$

$$i_2 \left[\frac{(r+Z_1+Z_2)\,(Z_2+Z_L)}{Z_2} - Z_2\right] = E$$

$$i_2 = \frac{E}{\frac{(r+Z_1+Z_2)\,(Z_2+Z_L)}{Z_2} - Z_2} = \frac{E[Z_2/(r+Z_1+Z_2)]}{\left[(Z_2+Z_L) - \frac{Z_2^2}{(r+Z_1+Z_2)}\right]}$$

$$i_2 = \frac{E[Z_2/(r+Z_1+Z_2)]}{Z_2 - \frac{Z_2^2}{(r+Z_1+Z_2)} + Z_L} = \frac{E[Z_2/(r+Z_1+Z_2)]}{Z_2\left[1 - \frac{Z_2}{r+Z_1+Z_2}\right]}$$

$$i_2 = \frac{E[Z_2/(r+Z_1+Z_2)]}{z_2\left(\frac{Z_1+r}{r+Z_1+Z_2}\right) + Z_L} \text{-------------} (5)$$

From eq(5) that the term $E[Z_2/(r + Z_1 + Z_2)]$ is the open circuit voltage across the terminals A and B while the term $Z_2\,[Z_1 + r / (r + Z_1 + Z_2)$ is the impedance of the resulting network between the terminals A and B when e.m.f. source is short circuited. These are the same values as obtained in eq (1) & (2).

Hence the theorem is proved.

`

NORTON'S THEOREM:

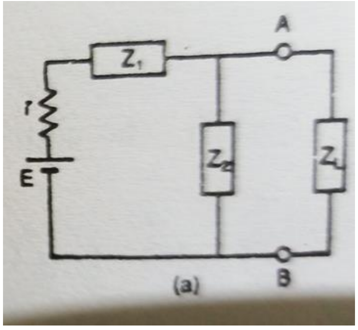
Statement:

Any two terminal linear network containing sources and impedances can be replaced by a constant current source in parallel with a single impedance. The current is the short-circuited current between the two terminals of the network while the impedance between the two terminals is the impedance when all the sources of e.m.f. are replaced by their internal impedance.

Procedure:

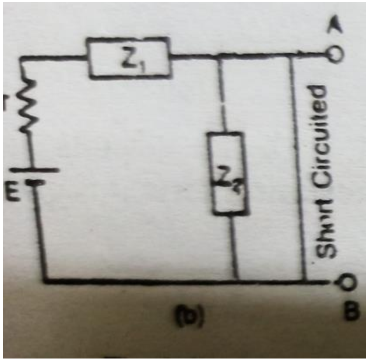
The Norton's equivalent circuit is drawn as

Consider a network shown in fig(a)



1.Let the terminals A and B are short circuited fig(b).

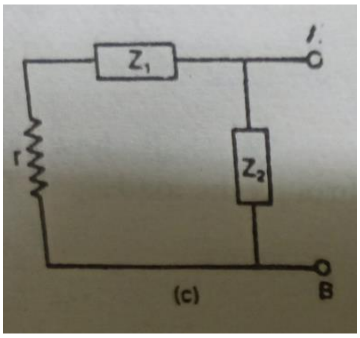
Now Z_2 becomes ineffective. The current flowing in the circuit is given by $\frac{E}{(r+Z_1)}$.



This is denoted by i_N.

Hence $i_N = \frac{E}{(r+Z_1)}$ ---------(1)

2. To open the terminals A and B, the battery E is removed and its internal impedance is considered as shown in the fig(c), t
   the impedance Z_N of the circuit from open terminals A and B is given by

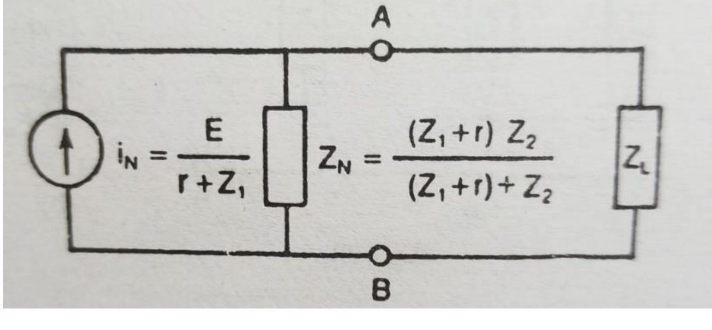


$$Z_N = \frac{(Z_1+r)Z_2}{(Z_1+r)+Z_2} \text{----------(2)}$$

because Z_1 and r are in series and then equivalent impedance

is in parallel with Z_2.

Thus, the Norton's equivalent circuit is,



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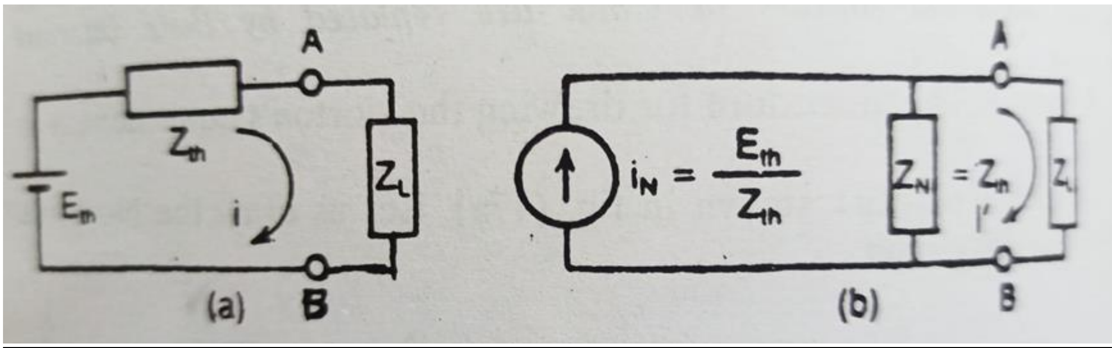
Proof:

The Norton's equivalent circuit is found from Thevenin equivalent circuit. Consider a Thevenin's circuit fig(a), its Norton's equivalent circuit is



To show that both the circuits are equivalent.

The current through the load Z_L in Thevenin's circuit is $I = \frac{E_{th}}{Z_{th}+Z_L}$--------(3)

The current flowing through load in Norton's circuit is given by

$$i' = \left(\frac{Z_{th}}{Z_{th}+Z_L}\right) i_N \text{ (by current division law)}$$

$$i' = \left(\frac{Z_{th}}{Z_{th}+Z_L}\right)\frac{E_{th}}{Z_{th}} = \frac{E_{th}}{Z_{th}+Z_L} \text{---------------(4)}$$

Eq (4) is same as eq (3).

This proves the Norton's theorem.

Maximum Power Transfer Theorem:

Statement:

Maximum Power Transfer Theorem states that maximum power is transferred from a source to the load, when the resistance (or impedance) of the load is equal to the resistance (or impedance) of the source.

(The rule is applicable to AC as well as DC sources)

Proof: Let us consider a voltage source E with internal resistance R_i which is delivering power to a load R_L.

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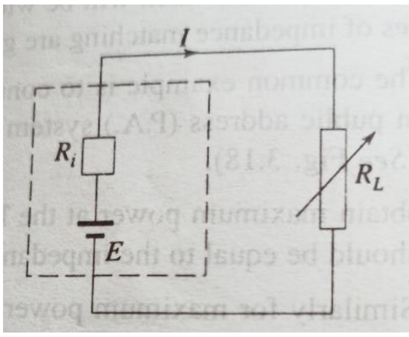
Current through the circuit, $I = \frac{E}{R_L + R_i}$



Power developed, $P = I^2 R_L$

$P = \left[\frac{E}{R_L + R_i}\right]^2 \times R_L$ Watts. --------------(1)

In the above expression, E and R_i are constant therefore power will depend only upon R_L which is variable.

For power to be maximum, the differentiation of eq (1) with respect to the variable quantity R_L should be zero.

$$\frac{d}{dR_L}(P) = E^2 \left[\frac{(R_L+R_i)^2 - 2R_L(R_L+R_i)}{(R_L+R_i)^4}\right] = 0$$

Solving, $(R_L + R_i)(R_L + R_i - 2R_L) = 0$

$(R_L + R_i)(R_i - R_L) = 0$

Now (i) either $(R_L + R_i) = 0$, which is not possible

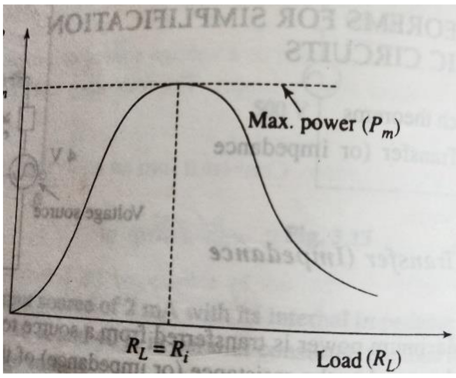
or (ii) $(R_i - R_L) = 0$

i.e., $R_i = R_L$

i.e., the internal resistance of the source should be equal to the internal resistance of the load.

This is shown graphically.

In case of impedance matching, maximum efficiency of power transfer transmission is only 50%. It is shown as,



Efficiency, $\eta = \frac{Outpout\ power\ at\ the\ load}{Input\ power\ to\ the\ source} = \frac{I^2 R_L}{I^2 (R_L + R_i)}$

Let, $R_i = R_L$ (Impedance matching)

Efficiency, $\eta = \frac{I^2 R_L}{I^2 (R_L + R_i)} = \frac{I^2 R_L}{I^2 . (2R_L)}$

Efficiency, $\eta = \frac{1}{2} = 50$ %.

`

DC regulated power supplies are broadly classified into "**DC constant voltage power supplies" whose output voltage is stable even when the load changes and "DC constant current power supplies" whose output current is stable**.

Constant Voltage:

A constant voltage driver is designed to maintain a constant voltage level during operation regardless of current variations.

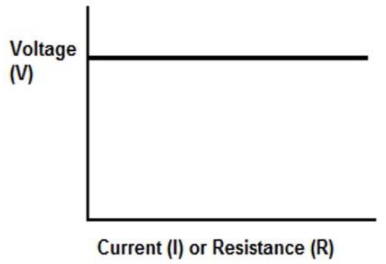
The constant voltage source provides a constant voltage to the load regardless of variations or changes in the load resistance. For this to happen, the source must have an internal resistance which is very low compared to the resistance of the load it is powering.

Some of the characteristics of an ideal constant voltage source is:

1.Zero internal resistance

2.Maintaining the same voltage regardless of variation in the amount of current drawn by load.

3.No current flows when the circuit is not loaded (open circuited).



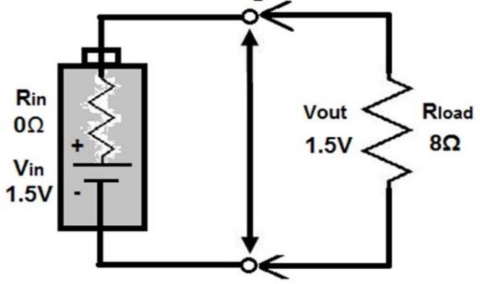
Ideal Constant Voltage Behaviour

Working of A constant voltage source:

For a voltage source to provide a constant voltage, it must have a very low internal resistance, preferably zero When the resistance is very low and using the voltage divider rule, most of the voltage will be dropped across the load, which has a higher resistance. When the internal resistance is much lower compared to the load resistance, the power source output approaches the ideal constant voltage.

In an ideal voltage source, the resistance should be zero and all the voltage is dropped across the load resistance. However, an ideal voltage source is usually practically impossible, and a typical voltage source will still have some form of internal resistance.

Ideal Voltage Source



Ideal voltage source with

zero impedance Image

The common constant voltage sources are the batteries and regulated power supplies. However, batteries cannot supply the constant voltage for a long time and must be recharged or replaced once exhausted.

There are various ways of getting a constant voltage in power supplies or when the input voltage is higher than the output. Some of the methods of obtaining the constant voltage include using a voltage divider, series transistor, Zener diode or a combination of Zener diode and switching device such as a transistor or thyristor. In addition, a voltage regulator IC may be used to provide a more stable output better than the discrete components.

A constant voltage is usually used in circuits that require a steady voltage supply for their efficient operation. For example, the constant voltage drivers are used for paralleled LED strip lighting due to the circuit design, which produces the most balanced current over the independent output channels.

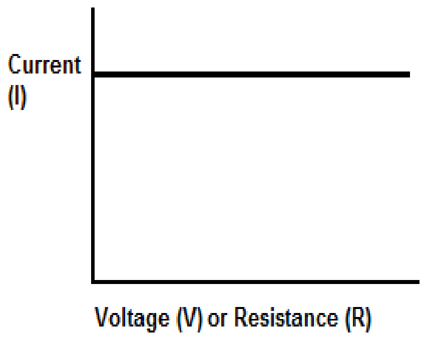
Applications of Voltage Sources:

The output voltage signal is a regulated DC signal. **Every power supply in the world uses a voltage regulator to provide the desired output voltage**. Computers, televisions, laptops and all sorts of devices are powered using this concept.

CONSTANT CURRENT SOURCES:

A constant current source is **a power source which provides a constant current to a load, even despite changes and variance in load resistance**. In other words, the current which a constant current source provides is steady, even if the resistance of the load varies. This comes in use when a circuit needs a steady current supply, without fluctuations.

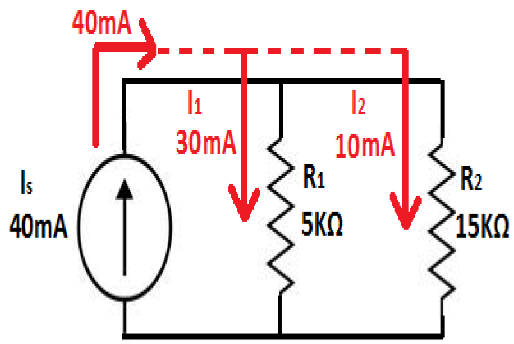
The graph below represents the current which comes from a constant current source.



Working of Constant Current Source:

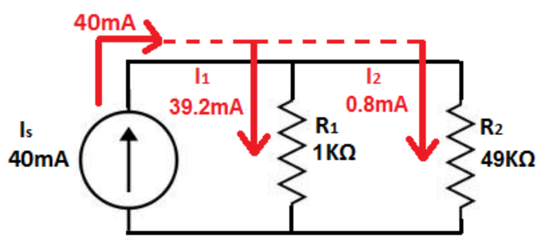
A constant current source is a power generator whose internal resistance is very high compared with the load resistance. As its internal resistance is so high, it can supply a constant current to a load whose resistance value varies, even over a wide range.

Thus, a constant current source follows the rules of current division. Being that it has very high internal resistance and the load resistance is much lower, current takes the path of least resistance, flowing out of the (high internal resistance) current source and into the load resistance, since it is of much lower resistance.



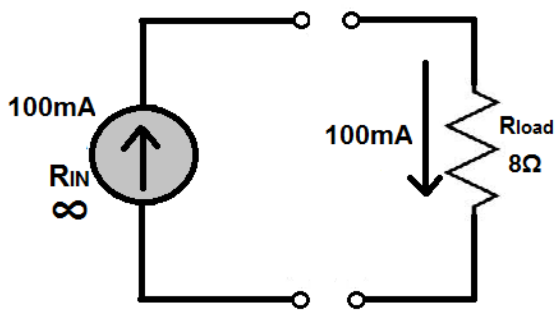
If a current source, supplies 40mA of total current, the majority of this 40mA of current takes the path of least resistance, i.e.,5KΩ resistor, and the other 10mA of current goes through the larger resistance, 15KΩ.

If a resistor of 1KΩ and the other resistor is 49KΩ, the vast majority of the current goes through the 1KΩ resistor. Very little current goes through the 49KΩ, as the resistance is of high value.



The current source represents a current source which has infinite internal resistance.

Ideal Current Source



As resistance is infinite and the load is only 8Ω, most of the current goes through the 8Ω resistor, which is the path of least resistance. If the current always take the path of least resistance, the load has infinite internal resistance, current will always seek to escape from it to a lower resistance path.

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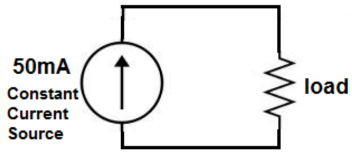
Constant Current Source Circuit:

A constant current source circuit is just a constant current source connected to the load which it powers. This load above will have a constant current of 50mA supplied to it regardless of whether the load resistance varies.



Applications of Current Sources:

Current sources **can be used to bias transistors and can also be used as active loads for high gain amplifier stages**. They may also be used as the emitter sources for differential amplifiers - for example they may be used in the transistor long tailed pair.

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UNIT-III

ALTERNATING & DIRECT CURRENTS

Alternating Current (AC) Generator:

AC generator is **a machine that converts mechanical energy into electrical energy**. The AC Generator's input supply is mechanical energy supplied by steam turbines, gas turbines and combustion engines. The output is alternating electrical power is in the form of alternating voltage and current.

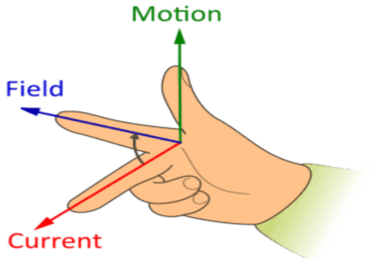
PRINCIPLE:

Alternating current generator is based on the of principle Electromagnetic induction.

According to the principle Electromagnetic induction, when a closed coil rotates in a strong magnetic field, the magnetic lines of force threading the coil changes continuously. Therefore, an e.m.f. is induced in the coil and a current flow in the coil. The direction of the current is given by Fleming's right hand rule. Thus, the mechanical energy given to the coil is converted into electrical energy in the coil.

Fleming's Right Hand Rule:

It states that "if the thumb, the forefinger and the middle finger are held in such a way that they are mutually perpendicular to each other (makes 90° of Angles), then the forefinger points the direction of the field, thumb points the direction of motion of the conductor and the middle finger points the direction of the current.

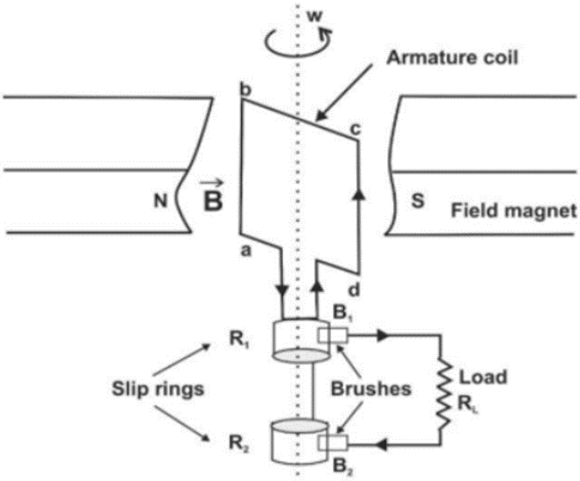


Fleming's Right-Hand Rule

CONSTRUCTION:

An alternating generator consists of the following parts:

(i) Armature
(ii) Field magnet
(iii) Slip rings
(iv) Brushes



(i) Armature:

Armature is a rectangular coil *ABCD* having large number of insulated copper wire over a soft iron core. The core increases the magnetic flux linked with the coil (armature).

(ii) Field Magnet:

Field magnet is a power fed permanent magnet having concave pole-piece N and S. The armature rotates between the two poles of magnets about an axis perpendicular to the magnetic field lines.

(iii) Slip Rings:

The leads from the armature coil are connected to two copper rings R_1 and R_2 separately. These rings help to provide movable contact and for this reason, they are called slip rings. These rings are concentric with the axis of the armature coil and rotate with it.

`

(iv)Brushes:

These are two carbon pieces B_1 and B_2, called brushes, which remains stationary, pressing against the slip-rings R_1 and R_2 respectively. The brushes are connected to external circuit (shown by the load) in which current is to be supplied by the generator.

Working Principle:

When the armature coil is made to rotate with uniform angular velocity ω and emf is set up in the coil due to increasing and decreasing flux through the coil.

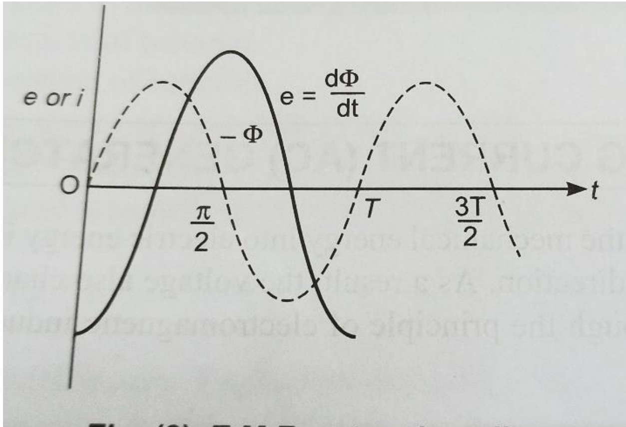


Fig. (2) E.M.F. set up in coil

When the circuit is closed through R, a current flow through R in the coil.

Let at an instant, the coil be oriented at an angle θ to the magnetic field B.

The flux $\emptyset$ through the coil $\emptyset$ = NAB Cos θ or

Or $\emptyset$ = NAB Cos ωt

Where, N = number of turns in the coil.

A = area of the coil

B = strength of magnetic field.

The current *i* through the coil is given by

$$i = \frac{e}{R} = -\frac{1}{R}\frac{d\emptyset}{dt} = -\frac{1}{R}\frac{d}{dt}\text{(NAB Cos } \omega t)$$

$$i = \frac{NAB\omega}{R} \sin \omega t$$

$$i = i_o \sin \omega t$$

Where, $i_o = \frac{NAB\omega}{R}$

Due to the nature of variation of current i with time *t*, the device is also called alternator.

If the alternator has more than one pair of poles, the frequency of rotation is equal to the product of the revolutions of armature per second (n) and the number of poles pairs (p).

Therefore, $f = \frac{np}{2}$.

Here, the factor $\left(\frac{1}{2}\right)$ is introduced due to the pairs of poles.

`

Advantages of AC Generators:

The main advantages of AC generators are:

1. The design of an AC generator is simpler than a DC generator, and hence it becomes easy to understand its working principle.
2. These generators operate silently, are low maintenance devices and have the lowest cost of ownership.
3. It does not require voltage matching.
4. It is possible to convert the current from AC generators to other voltage levels using AC transformers.
5. AC motors used in AC generators are easy to maintain and smell-free, unlike DC motors, which have a significant smell.

Disadvantages of AC Generators:

The main disadvantages of AC generators are:

1. It is not durable as a DC generator.
2. It requires additional insulation due to the generation of large currents.
3. It needs extra caution when working on high voltages.

DC GENERATOR-CONSTRUCTION OPERATING PRINCIPLE:

A DC generator is an electrical machine whose main function is to convert mechanical energy into electricity. When the conductor slashes magnetic flux, an emf will be generated based on the **Electromagnetic Induction Principle of Faraday's Laws**. This electromotive force can cause a flow of current when the conductor circuit is closed.

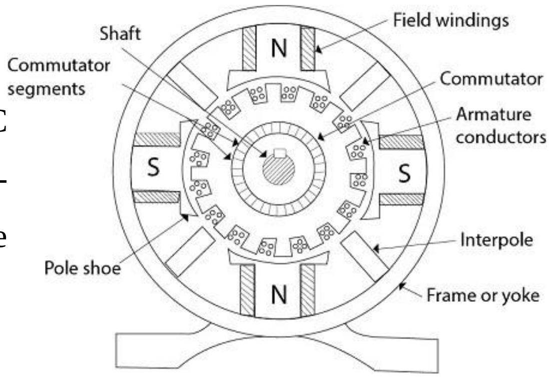
Electrical generators are standalone machines that provide electricity when power from the local grid is unavailable. These generators supply backup power to businesses and homes during power shortages. Generators do not create electrical energy, but they convert mechanical or chemical energy into electrical energy. Based on the output, generators are classified.

WORKING PRINCIPLE:

The working of the DC generator is based on Faraday's Law of Electromagnetic Induction. The movement of a conductor in a uniform magnetic field changes the magnetic flux linked with the coil, thus inducing an emf.

CONSTRUCTION OF DC GENERATOR:

The construction of a DC generator is similar to a DC motor. So, a DCgenerator can work as a DC motor and vice-versa. The basic constructional features of a DC generator are described.



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Yoke:

The yoke is the outer covering of the DC generator and is made of cast steel or castiron. It serves two purposes:

1) Provides a path for pole flux.
2) Provides mechanical support to the whole machine.

Field Poles:

It consists of pole core and pole shoes. The pole core supports the field winding while the pole shoe distributes the flux in the air gap uniformly.

Field Winding:

It is made of copper and wound around each pole core in such a way that adjacent North and South poles develop when the field winding is excited.

Armature Core:

The armature is the center of electromechanical conversion. It is the rotating part ofthe DC machine and consists of grooves or slots over the entire periphery. These slots carry the current-carrying armature conductors. The armature core is made up of thin laminations to reduce eddy current losses.

Armature Winding:

Armature winding is made of copper and placed inside the slots of the armature core. Each conductor in the winding is insulated from each other and also from the armature core. The armature winding is of two types: lap winding and wave winding.

Commutator:

A commutator is also known as a mechanical rectifier. It provides an electrical connection between the rotating armature coil and the stationary external circuit. It consists of hard-drawn copper segments insulated from each other forming a ring structure. In a dc generator, the commutator collects the current generated in the armature winding.

Brushes:

The brushes are either made of carbon, electro graphite, or copper graphite. They always slide over the commutator, thus ensuring a proper electrical connection. Their main function is to collect current from the commutator and supply it to the electrical load or external circuit.

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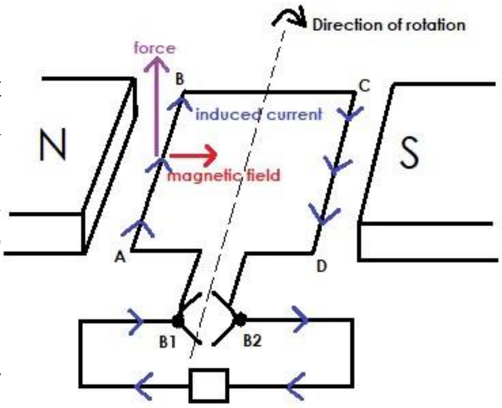
WORKING OF DC GENERATOR:

The working of DC Generator is based on Faraday's law. It states that whenever a conductor cuts magnetic flux, an EMF (Electromotive Force) is induced across the conductor. The magnitude of this induced EMF is directly proportional to the rate of change of flux linkage.

To understand how EMF gets induced in a conductor, let us consider a single-turn rectangular loop ABCD rotating in a clockwise direction between the poles.

CASE 1:

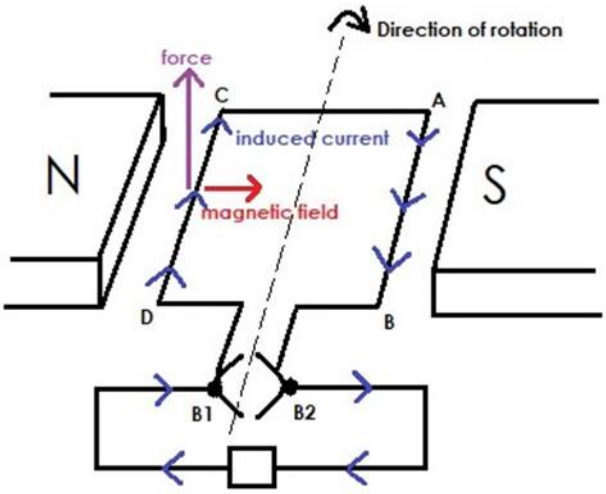
At any instant of time, the conductor AB is close to the North Pole and CD to the South Pole as shown in the figure below.



For conductor AB, the magnetic field is from left to right while the force on it is acting upwards. Now, to find the direction of the induced current, we will use Fleming's right-hand rule.

"If the thumb, forefinger, and middle finger of the right hand are stretched out and placed mutually perpendicular to each other in such a way that the thumb represents the direction of force, the forefinger represents the direction of the magnetic field, then the middle finger will give the direction of induced current." After applying the above rule to the conductor AB, the direction of the induced current is from A to B in the loop ABCD. This current flow externally from brush B_2 to B_1 powering the load on its way.

CASE 2:



After 180 degrees rotation of the coil, the conductor CD comes close to the North Pole while AB is near to the South Pole.

On applying Fleming's right-hand rule to conductor CD, the direction of the induced current is from D to C. Although the direction of the current in the loop ABCD is reversed now, the external current still flows from brush B2 to B1. Induced current direction from D to C

So, in both cases, the direction of the generated current is always from B2 to B1. Hence, a unidirectional current is obtained in the DC generator.

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Applications of DC Generators:

1. They are separately excited type DC generator, used for power and lighting purposes using the field regulators.
2. The series DC generator is used in arc lamps for stable current generator, lighting and booster.
3. Level compound DC generators are used to supply power to hostels, offices, lodges.
4. Compound DC generators are used for supplying power to DC welding machines.
5. A DC generator is used to compensate for the voltage drop in the feeders.

Advantages and Disadvantages of DC Generators:

ADVANTAGES:

1.They are used to operate big machines.

2.These generators are useful in supplying electricity to large motors.

3.Heavy electric devices are supplied electricity by using DC generators.

4.A DC generator significantly reduces the electric fluctuations in the armatureand gives a continuous supply.

DISADVANTAGES:

1. A major disadvantage of a DC generator is that it cannot be used with atransformer.
2. The efficiency of a DC generator is very low.

3.The current flowing in the generator experiences various losses such as Eddycurrent losses, copper losses, mechanical losses, and others.

4.DC generators placed at a long distance may experience major voltage drops.

Advantages of AC Generators over DC Generators:

Following are a few advantages of AC generators over DC generators:

1.AC generators can be easily stepped up and stepped down through transformers.

2.The transmission link size in AC Generators is thinner because of the step-up feature.

3.Losses in AC generators are relatively lesser than in DC machines

4.The size of an AC generator is smaller than a DC generator

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DIFFERENCES BETWEEN AC AND DC GENERATOR:

Sl. No.	Differentiating Property	AC Generator	DC Generator
1	**Definition**	AC generator is a mechanical device that converts mechanical energy into AC electrical power.	DC generator is a mechanical device that converts mechanical energy into DC electrical power.
2	**Direction of Current**	In an AC generator, the electrical current reverses direction periodically.	In a DC generator, the electrical current flows only in one direction.
3	**Basic Design**	In an AC generator, the coil through which the current flows is fixed while the magnet moves. The construction is simple and costs are less.	In a DC generator, the coil through which the current flows rotate in a fixed field. The overall design is very simple but construction is complex due to commutators and slip rings.
4	**Commutators**	AC generator does not have commutators.	DC generators have commutators to make the current flow in one direction only.
5	**Rings**	AC generators have slip-rings.	DC generators have commutators.
6	**Efficiency of Brushes**	Since slip-rings have a smooth and uninterrupted surface, they do not wear quickly and are highly efficient.	Both brushes and commutators of a DC generator wear out quickly and thus are less efficient.

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7	**Short Circuit Possibility**	As the brushes have high efficiency, a short circuit is very unlikely.	Since the brushes and commutators wear out quickly, sparking and short circuit possibility is high.
8	**Rotating Parts**	The rotating part in an AC Generator is a low current high resistivity rotor.	The rotating part in a DC generator is generally heavy.
9	**Current Induction**	In an AC generator, the output current can be either induced in the stator or in the rotor.	In a DC generator, the output current can only be induced in the rotor.
10	**Output Voltage**	AC generators produce a high voltage which varies in amplitude and time. The output frequency varies (mostly 50Hz to 60Hz).	DC generators produce a low voltage when compared to AC generator which is constant in amplitude and time i.e. output frequency is zero.
11	**Maintenance**	AC generators require very little maintenance and are highly reliable.	DC generators require frequent maintenance and are less reliable.
12	**Types**	AC generators can be of varying types like 3 phase generators, single-phase generators, synchronous generator, induction generator, etc.	DC generators are mainly two types which are Separately excited DC generator and self-excited DC generator. According to field and armature connection, they can be further classified as DC series, shunt, or compound generators, respectively.
13	**Cost**	The initial cost of an AC generator is high.	The initial cost of a DC generator is less when

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			compared to AC generators.
14	**Distribution and Transmission**	The output from AC generators is easy to distribute using a transformer.	The output from DC generators is difficult to distribute as transformers cannot be used.
15	**Efficiency**	AC generators are very efficient as the energy losses are less.	DC generators are less efficient due to sparking and other losses like copper, eddy current, mechanical, and hysteresis losses.
16	**Applications**	It is used to power smaller motors and electrical appliances at homes (mixers, vacuum cleaners, etc.)	DC generators power very large electric motors like those needed for subway systems.

TRANSFORMERS- CONSTRUCTION AND ITS WORKING PRINCIPLE:

The transformer works on the principle of **Faraday's law of Electromagnetic Induction and Mutual Induction**. There are usually two coils, primary coil and secondary coil on the transformer core. The core laminations are joined in the form of strips. The two coils have high mutual inductance.

Electrical transformer is a static electrical machine which transforms electrical power from one circuit to another circuit, without changing the frequency. Transformer can increase or decrease the voltage with corresponding decrease or increase in current.

Working Principle of a Transformer:

Transformer is a static device (and doesn't contain on rotating parts, hence no friction losses), which convert electrical power from one circuit to another without changing its frequency. It Step up (or Step down) the level of AC Voltage and Current.

Transformer works on the principle of mutual induction of two coils or Faraday Laws of Electromagnetic induction. When current in the primary coil is changed the flux linked to the secondary coil also changes. Consequently, an EMF is induced in the secondary coil due to Faraday law of electromagnetic induction.

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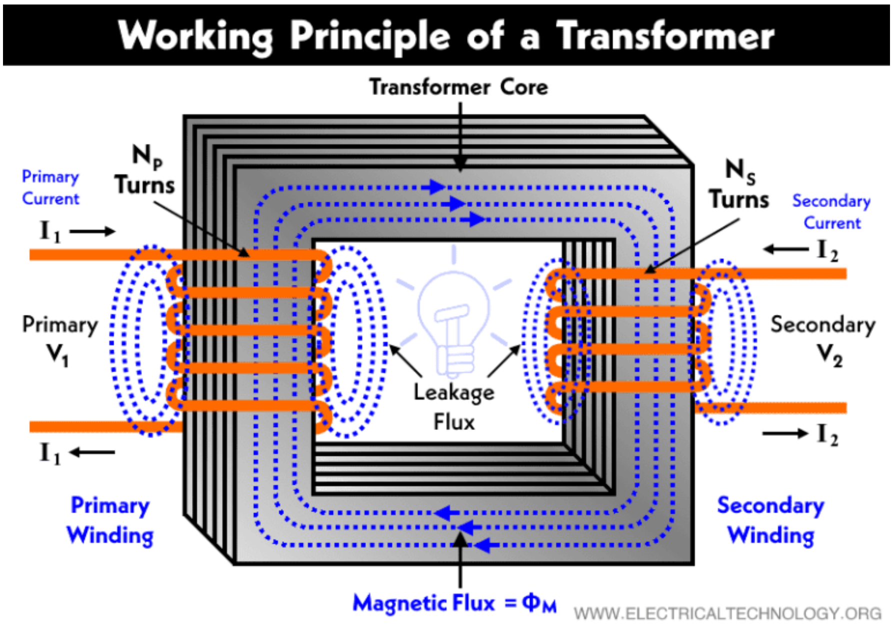
Construction:

A simple transformer has a soft iron or silicon steel core and windings placed on it (iron core). Both the core and the windings are insulated from each other. The winding connected to the main supply is called the primary and the winding connected to the load circuit is called the secondary.

Winding (coil) connected to higher voltage is known as high voltage winding while the winding connected to low voltage is known as low voltage winding. In case of a step-up transformer, the primary coil (winding) is the low voltage winding, the number of turns of the windings of the secondary is more than that of the primary, Vice versa for step down transformer.

According to the principle of mutual inductance, when an alternating voltage is applied to the primary winding of the transformer, an alternating flux ϕ_m which is called as the mutual flux is produced in the core. This alternating flux links both the windings magnetically and induces EMFs E_1 in the primary winding and E_2 in the secondary winding of the transformer according to Faraday's law of electromagnetic induction. The EMF (E_1) is called as primary EMF and the EMF (E_2) is known as secondary EMF

Open Circuit and Short Circuit Test on Transformer:



Open and short circuit tests are performed on a transformer to determine the:

1. Equivalent circuit of transformer
2. Voltage regulation of transformer
3. Efficiency of transformer

The power required for open circuit tests and short circuit tests on a transformer is equal to the power loss occurring in the transformer.

Open Circuit Test On Transformer:

The purpose of the open-circuit test is to determine the no-load current and losses of the transformer because of which their no-load parameters are determined. This test is performed on the primary winding of the transformer. The wattmeter, ammeter and the voltage are connected to their primary winding. The nominal rated voltage is supplied to their primary winding with the help of the ac source.

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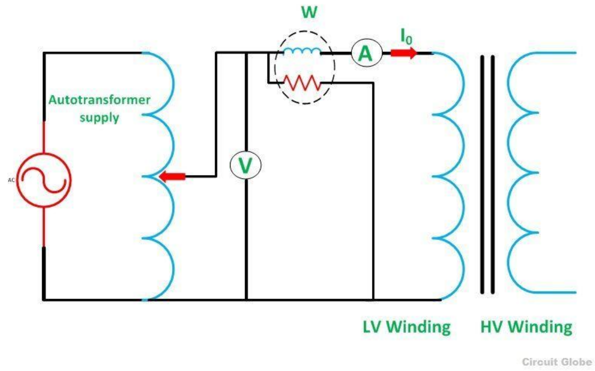
The secondary winding of the transformer is kept open, and the voltmeter is connected to their terminal. This voltmeter measures the **secondary induced voltage**. As the secondary of the transformer is open, thus no-load current flows through the primary winding.



The value of no-load current is very small as compared to the full rated current. The copper loss occurs only on the primary winding of the transformer because the secondary winding is open. The reading of the wattmeter only represents the core and iron losses. The core loss of the transformer is the same for all types of loads.

Calculation of open-circuit test

Let,

- W_0 – wattmeter reading
- V_1 – voltmeter reading
- I_0 – ammeter reading

Then the iron loss of the transformer $P_i = W_0$

and $W_0 = V_1 I_0 \text{ Cos } \varphi_0$ − − − − − − − − (1)

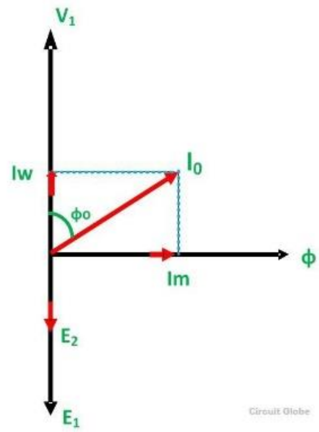
The no-load power factor is $\text{Cos } \varphi_0 = \frac{W_0}{V_1 I_0}$ ------------(2)

Working component I_w is, $I_W = \frac{W_0}{V_1} = \frac{Iron\ loss\ of\ Transformer}{Voltmeter\ reading}$

Substituting the value of W_0 from the equation (1) in equation (2)

we get the value of the working component as, $I_W = I_0 \text{ Cos } \varphi_0$

$$\left[I_w = \frac{V_1 I_0 cos\varphi}{V_1}\right]$$



Phasor diagram of Open Circuit Test

Magnetizing component is $I_m = \sqrt{I_0 - I_w^2}$

No-load parameters are given as,

Equivalent exciting resistance is, $R_0 = \frac{V_1}{I_W} = \frac{Voltmeter\ reading}{Working\ Component}$

Equivalent exciting reactance is, $X_0 = \frac{V_1}{I_m} = \frac{Voltmeter\ reading}{Magnetizing\ Component}$

The iron losses measured by the open efficiency of the transformer.

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Short Circuit Test on Transformers:

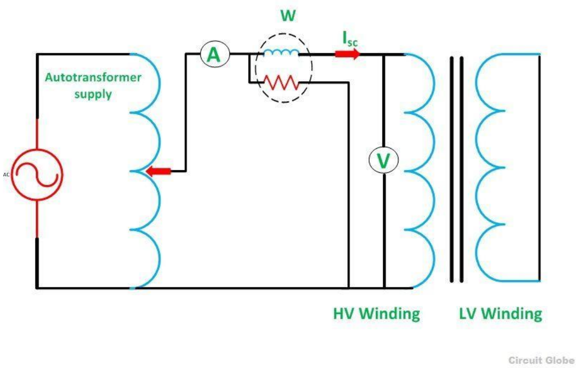
The short circuit test is performed for determining the below mention parameter of the transformer.

- It determines the copper loss occur on the full load. The copper loss is used for finding the efficiency of the transformer.
- The equivalent resistance, impedance, and leakage reactance are known by the short circuit test.

The short circuit test is performed on the secondary or high voltage winding of the transformer. The measuring instruments like wattmeter, voltmeter and ammeter are connected to the high voltage winding of the transformer. Their primary winding is short-circuited by the help of thick strip or ammeter which is connected to its terminal.

The low voltage source is connected across the secondary winding because of which the full load current flows from both the secondary and the primary winding of the transformer. The full load current is measured by the ammeter connected across their secondary

The circuit diagram of the short circuit test is shown:



The low voltage source is applied across the secondary winding, which is approximately **5 to 10%** of the normal rated voltage. The flux is set up in the core of the transformer. The magnitude of the flux is small as compared to the normal flux.

The iron loss of the transformer depends on the flux. It is less occurred in the short circuit test because of the low value of flux. The reading of the wattmeter only determines the copper loss occurred, in their windings. The voltmeter measures the voltage applied to their high voltage winding. The secondary current induces in the transformer because of the applied voltage.

Calculation of Short Circuit Test:

Let,

- W_c – Wattmeter reading
- V_{2sc} – voltmeter reading
- I_{2sc} – ammeter reading,
- R_{es} = Equivalent resistance in secondary

Then the full load copper loss of the transformer is given by

$P_C = \left(\frac{I_{2fl}}{I_{2sc}}\right)^2 W_C$ and $I_{2SC}^2 R_{es} = W_C$ (R_{es} = Equivalent resistance in secondary)

Equivalent resistance referred to the secondary side is, $R_{es} = \frac{W_C}{I_{2SC}^2}$.

`

The phasor diagram of the short circuit test of the transformer is shown.

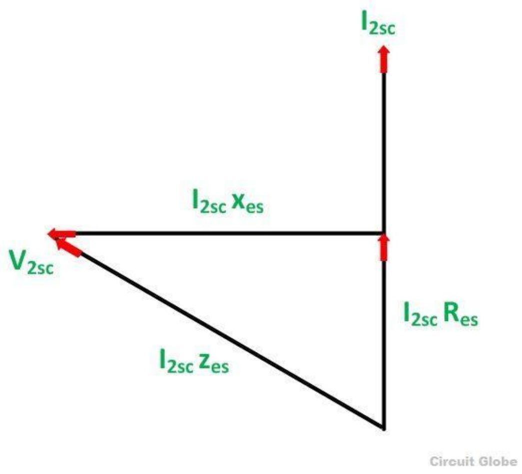
From the phasor diagram, $I_{2SC}Z_{es} = V_{2sc}$

Equivalent impedance referred to the secondary side is given by, $Z_{es} = \frac{V_{2sc}}{I_{2SC}}$

The equivalent reactance referred to the secondary side is given by

$$X_{es} = \sqrt{(z_{es})^2 - (R_{es})^2}$$

The voltage regulation of the transformer is determined at any load and power factor after knowing the values of **Z_{es}** and **R_{es}**.



Phasor Diagram of Short Circuit Test

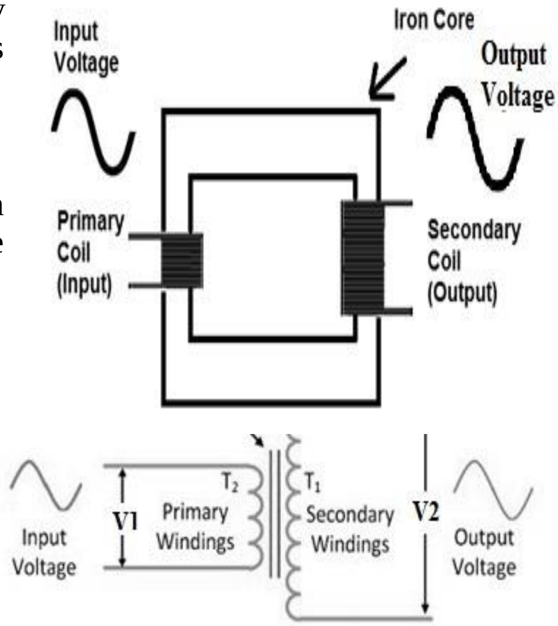
In the short circuit test the wattmeter record, the total losses, including core loss but the value of core loss are very small as compared to copper loss so the core loss can be neglected.

STEP UP TRANSFORMER:

A step-up transformer is **a transformer that increases the voltage from the primary coil to the secondary coil while managing the same power at the rated frequency in both coils**. It converts low voltage & high current from the primary side to the high voltage & low current on the secondary side of the transformer.

A transformer that is used to step up the output voltage by maintaining the flow of current stable without any variation is known as a step-up transformer.

This transformer includes two windings like primary and secondary. The primary winding has fewer turns as compared with the secondary winding.



Working of A Step-up Transformer:

Let the input & output voltages are represented with V_1 & V_2 respectively. The turns on the windings of the transformer are N_1 & N_2.

The output voltage is high as compared with input voltage because the turns of wire in the primary is less than secondary. Once the alternating current flows in a transformer then the current will flow in one direction, stops and changes the direction to flow in another direction

The current flow will create a **magnetic** field in the region of the winding. The directions of the magnetic poles will be changed once the flow of the current changes its direction.

`

The voltage is induced into the windings through the magnetic field. Likewise, the voltage will be induced within the secondary coil once it is located in a moving magnetic field is known as mutual induction. So, the AC in the primary winding generates a moving magnetic field so that voltage can be induced in the secondary winding.

The main relationship between the number of turns in every coil and the voltage are given by using the **step-up transformer formula**,

$$\frac{V_2}{v_1} = \frac{N_2}{N_1}$$

Where 'V_2' is the voltage in the secondary coil.
'V_1' is voltage is the primary coil.
'N_2' turns on the secondary coil.
'N_1' turns on the primary coil.

Different Factors:

There are different factors that need to check while selecting the step-up transformer. They are

1.Transformers Efficiency
2.Number of Phases
3.Transformers Rating
4.Cooling Medium
5.Material of Winding

Advantages:

The **advantages of Step-up transformer** are
1.These are used in residential and commercial places
2.Power Transmitter
3.Maintenance
4.Efficiency
5.Continuous Working
6.Quick Start

Disadvantages:

The **disadvantages of Step-up transformer are,**
1.It requires a cooling system
2.Works for Alternate Current
3.Size of these transformers is huge.

`

Applications of the Step-up Transformer:

The use of Step-up Transformers includes the following,

1.These transformers are used in electronic equipment such as Inverters & Voltage Stabilizers for low to high voltage stability.

2.It is used to distribute electrical energy.

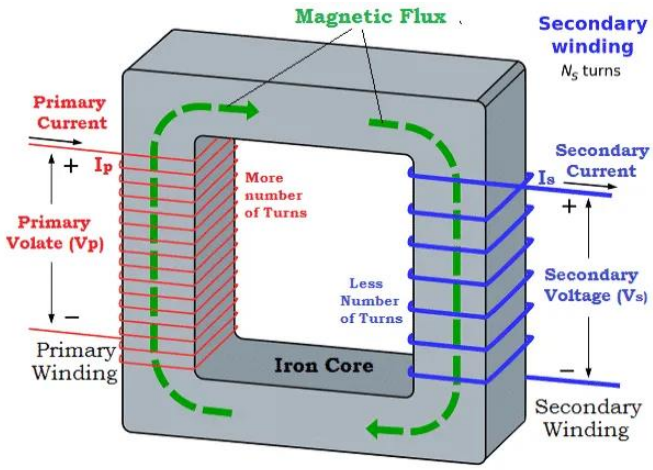
3.This transformer is used to change the high voltage in power transmission lines generated by generators.

4.This transformer is also used to make electric motors running, X-ray machines, microwave ovens, etc.

5.It is used to enhance electrical and electronic equipment.

STEP -DOWN TRANSFORMER:

A Step-Down Transformer is a device which converts high primary voltage to a low secondary voltage. In a Step-Down Transformer, the primary winding of a coil has more turns than the secondary winding.



Working Principle of Step-Down Transformer:

Transformer work on the principle of "Faraday's law of electromagnetic induction". Mutual induction between the windings is responsible for transmission action in a transformer.

Faraday's law states that "when the magnetic flux linking a circuit changes, an electromotive force is induced in the circuit proportional to the rate of change of the flux linkage".

The emf (Electro Motive Force) induced between the two windings is determined by the number of turns in primary and secondary winding respectively. This ratio is called as **Turns Ratio**.

The voltage reduction capability of step-down transformers depends on the turn ratio of the primary and secondary coil. As the number of windings in secondary coil is less as compared to the number of windings in primary coil, so the amount of flux linkage to the secondary coil of the transformer will also be less compared to the primary coil.

Accordingly, the emf induced will be less in the secondary coil. Due to this, the voltage reduces at the secondary winding compared to primary winding.

`

Step Down Transformer Equation:

The formula used to design a Step-Down Transformer is, $\frac{N_S}{N_P} = \frac{V_S}{V_P}$

Where,

- Ns = number of turns in secondary
- Np = number of turns in primary
- V_s = Voltage in secondary
- Vp = Voltage in primary

The number of turns in secondary winding should always be less than the number of turns in the primary winding of the transformer i.e. **Np**>**Ns** to work a transformer as "Step-Down Transformer".

As the number of turns will be less in secondary winding, so will be total induced emf and hence the output voltage in the secondary will also be less than the primary input voltage.

Applications of Step-Down Transformer:

The various applications of Step-Down Transformers are:

1.In main adapters and chargers for cell phones, stereos and CD players
2.To step down the voltage level in transmission line
3.In welding machines by reducing voltage and increasing current.
4.In televisions, voltage stabilizers, inverters, etc.

Advantages of Step-Down Transformer:

The advantages of Step-Down Transformers are as follows:

1.Useful in stepping down the voltage, thereby making transmission power easier and cheaper
2.More than 99% of efficiency
3.Provides varied voltage requirements
4.Low Cost
5.High Reliability
6.High Durability

Disadvantages of Step-Down Transformer:

The disadvantages of Step-Down Transformers are as follows:

1.Requires a lot of maintenance failing which can damage the transformer
2.Volatility in feedstock costs
3.Fault rectification takes more time

TRANSFORMER'S EMF EQUATION:

Magnitude of the **induced EMF** (or Voltage) in a transformer is found by **EMF equation of the transformer**. When a source of alternating current (AC) is applied to the primary winding of the transformer which is known as **magnetizing current**, it produces alternating flux in the core of a transformer.

The produced alternating flux in the primary of the transformer gets linked with the secondary winding of the transformer by **mutual induction** as it is alternating flux in nature, there must be a rate of change of flux according to **Faraday's law of electromagnetic induction** which states that if a conductor or coil links with any changing flux, there must be an induced emf in it.

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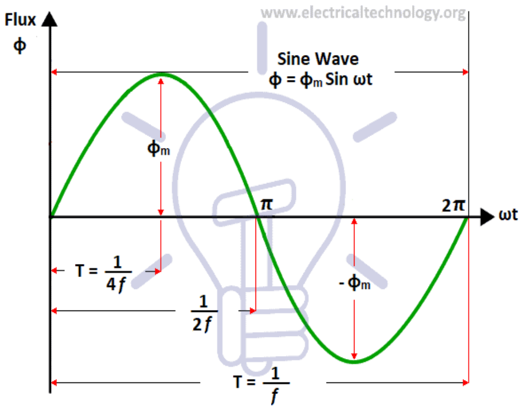
EMF Equation of Electrical Transformer



EMF Equation Of a Transformer

Lets,

- **N_1** = Number of turns in primary windings.
- **N_2** = Number of turns in second windings.
- **Φ_m** = Maximum flux in the core in Weber = (**Φ_m** = B_m. A)
- f = Frequency of A.C input in H_z.

As shown in fig, flux increases from its zero value to maximum value **Φ_m** in one quarter of the cycle i.e. in ¼ **second**.

Average rate of change of flux = [**Φ_m /(¼ f.)**]

= $4f\ \Phi_m$ Wb/s or volt

Now rate of change of flux per turn means induced EMF in volts.

Average EMF / per turn = **$4f\ \Phi_m$** volt.

If flux Φ_m varies sinusoidally, then RMS value of induced EMF is obtained by multiplying the average value with form factor.

Form Factor = *RMS value / Average value* = 1.11

RMS value of EMF / turn = Form factor x Avg. rate of change of flux

= **$1.11.\ 4f\ \Phi_m = 4.44f\ \Phi_m$** volt

Now, RMS value of the induced EMF in the whole primary winding.

= (induced **EMF / turn**) x **number of primary turns**

$$E_1 = 4.44 \times f \times N_1\ \Phi_m \text{ -------------------------(1)}$$

$$E_1 = 4.44 \times f\ N_1\ B_m\ A \ldots \ [as\ (\Phi_m = B_m\ A)]$$

Similarly, RMS value of the EMF induced in secondary is,

$$E_2 = 4.44 \times f\ N_2\ \Phi_m \text{ ------------------------(2)}$$

$$E_2 = 4.44 \times f\ N_2\ B_m\ A. \ \ldots \ [as\ (\Phi_m = B_m\ A)]$$

It's seen from eq *(1)* and *(2)* ,

EMF Equation of the Transformer = $E_1 / N_1 = E_2 / N_2 = 4.44 \times f\ \Phi_m$. ------------------------(3)

It means that **EMF / turn is the same in both the primary and secondary windings in the transformer** i.e. flux in Primary and Secondary Winding of the Transformer is same.

Moreover, from the power equation of the transformer, i.e., in an ideal Transformer (there are no losses in transformer) on no-load,

$$V_1 = E_1 \quad \text{and} \quad E_2 = V_2$$

Where,

- **V_1 =** supply voltage of primary winding
- **V_2 =** supply voltage of secondary winding
- **E_1** = terminal voltage induced in the primary winding of the transformer.
- **E_2** = terminal voltage induced in the secondary winding of the transformer.

`

Voltage Transformation Ratio (K):

From the EMF equation of the transformer *(3), the voltage transformation ratio is,*

$$E_1 / N_1 = E_2 / N_2 = K$$

Where, **K is a Constant.**

The constant **"K"** is known as **voltage transformation ratio**.

- If $N_2 > N_1$, i.e. $K > 1$, then the transformer is known as a step-up transformer.
- If $N_2 < N_1$, i.e. $K < 1$, then the transformer is called step-down transformer.

Where,

N_1 = Primary number of turns of the coil in a transformer.

N_2 = Secondary number of turns of the coil in a transformer.

USE OF TRANSFORMER IN A REGULATED POWER SUPPLY

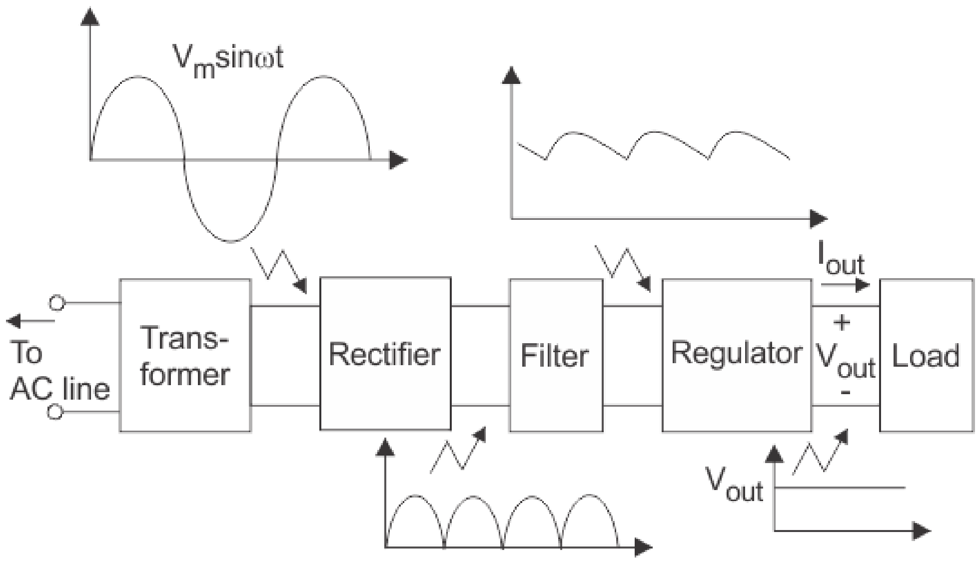
A regulated power supply converts unregulated AC (Alternating Current) to a constant DC (Direct Current). A regulated power supply is used to ensure that the output remains constant even if the input changes.

A regulated DC power supply is also known as a linear power supply, it is an embedded circuit and consists of various blocks.

The regulated power supply will accept an AC input and give a constant DC output. The figure below shows the block diagram of a typical regulated DC power supply.

The basic building blocks of a regulated DC power supply are:

1. A step-down transformer
2. A rectifier
3. A DC filters
4. A regulator



Components of typical linear power supply

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Operation of Regulated Power Supply

1. Step down Transformer

A step down transformer will step down the voltage from the ac mains to the required voltage level. The turn’s ratio of the transformer is so adjusted such as to obtain the required voltage value. The output of the transformer is given as an input tothe rectifier circuit.

2. Rectifier:

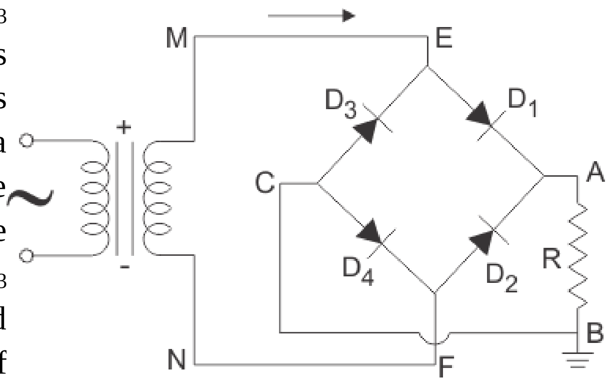
Rectifier is an electronic circuit consisting of diodes which carries out the rectification process. Rectification is the process of converting an alternating voltage or current into corresponding direct (DC) quantity. The input to a rectifier is AC whereas its output is unidirectional pulsating DC.

Although a half wave rectifier could technically be used, its power losses are significant compared to a full wave rectifier. As such, a full wave rectifier or a bridge rectifier is used to rectify both the half cycles of the ac supply (full wave rectification).The figure below shows a full wave bridge rectifier.

A bridge rectifier consists of four p-n junction diodes connected in the manner shown above. In the positive half cycle of the supply, the voltage induced across the secondary of the electrical transformer i.e. VMN is positive. Therefore, point E is positive with respect to F.

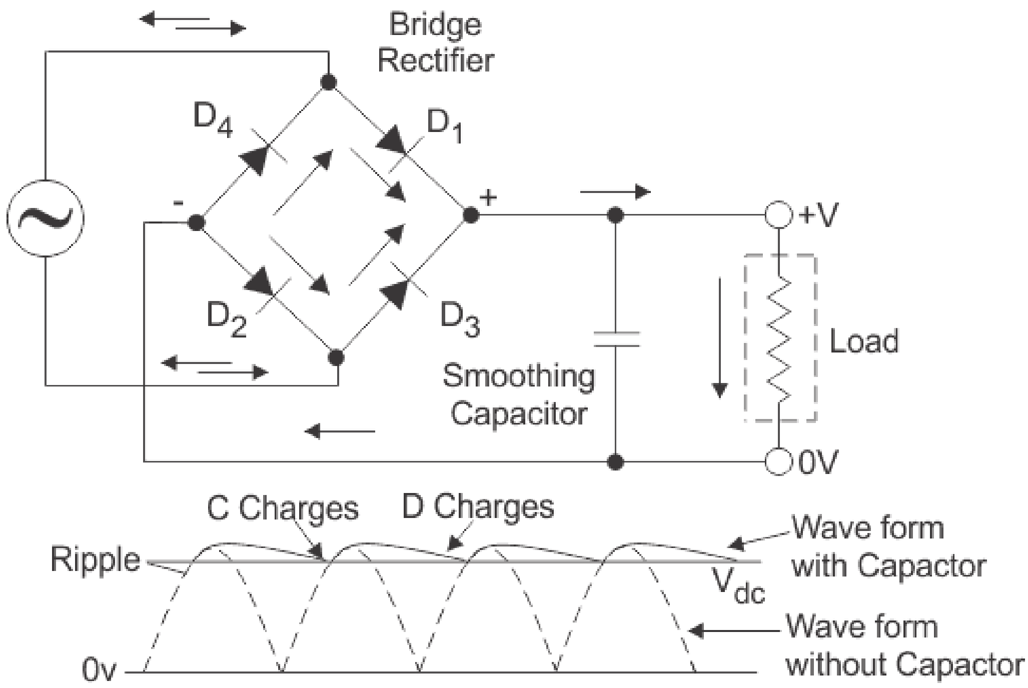
Hence, diodes D_3 and D_2 are reversed biased and diodes D_1 and D_4 are forward biased. The diode D_3 and D_2 will act as open switches (practically there is some voltage drop) and diodes D_1 and D_4 will act as closed switches and will start conducting. Hence a rectified waveform appears at the output of the rectifier as shown in the first figure. When voltage induced in secondary i.e. VMN is negative then D_3 and D_2 are forward biased with the other two reversed biased and a positive voltage appears at the input of the filter.

Full Wave Rectifier Bridge



3. DC Filtration:

The rectified voltage from the rectifier is a pulsating DC voltage having very high ripple content. But this is not we want, we want a pure ripple free DC waveform. Hence a filter is used. Different types of filters are used such as capacitor filter, LC filter, Choke input filter, π type filter. The figure below shows a capacitor filter connected along the output of the rectifier and the resultant output waveform.



Resultant Output Waveform

As the instantaneous voltage starts increasing, the capacitor charges, it charges until the waveform reaches its peak value. When the instantaneous value starts reducing the capacitor starts discharging exponentially and slowly through the load (input of the regulator in this case). Hence, an almost constant DC value having very less ripple content is obtained.

4.Regulation:

This is the last block in a regulated DC power supply. The output voltage or current will change or fluctuate when there is a change in the input from ac mains or due to change in load current at the output of the regulated power supply or due to other factors like temperature changes. This problem can be eliminated by using a regulator. A regulator will maintain the output constant even when changes at theinput or any other changes occur. Transistor series regulator, Fixed and variable IC regulators or a Zener diode operated in the Zener region can be used depending on their applications. IC's like IC 7805 are used to obtained fixed values of voltages atthe output.

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UNIT- IV

MODULATION CIRCUITS (SKILL BASED)

MODULATION:

Definition:

Modulation means to "change". It is the process of changing some characteristic (e.g. amplitude, frequency or phase) of a carrier wave in accordance with the intensity of the signal is known as modulation. In another word, it can be said that- "it is the process of combining an audio-frequency (AF) signal with a radio-frequency (RF) carrier wave". The audio-frequency (AF) signal is also called a modulating wave and the resultant wave produced is called modulated wave. During modulation, some characteristic of the carrier wave is varied with time with the modulating signal and accomplished by combining the two.

NEED FOR MODULATION:

Modulation is particularly essential in communication system due to the following reason:

Mutual Interference Reduction:

The main purpose of modulation is the reduction of mutual interference. When the signal is fed to the transmitter via modulator to the air, the signals overlap and then interference occurs. So, modulation needs to reduce the interference.

Practical Antenna Length:

The length of the transmitting antenna should be approximately equal to the wavelength of the wave. Now

$$\text{Wavelength } \lambda = \frac{Velocity\ (v)}{frequency(f)} = \frac{3\ x\ 10^8}{frequency(f)}$$

As the audio frequencies range from 20 Hz to 20 KHz, therefore if they are transmitted directly into space, the length of the transmitting antenna required would be extremely large. For instance, to radiate a frequency of 20 KHz directly into space, we would need an antenna length of t o o long to be constructed practically. For this reason, it is impracticable to radiate audio signal directly into space. On the other hand, if a carrier wave of 1000 KHz is used to carry the signal, we need an antenna length of 300 meters only and this size can be easily constructed.

Operating Range:

The energy of a wave depends upon its frequency. The greater the frequency of the wave, the greater the energy possessed by it. As the audio signal frequencies are small, therefore, these can't be transmitted over longer distances if radiated directly into space. The only practical solution is to modulate a high frequency carrier wave with audio signal and permits the transmission to occur at this high frequency.

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Wireless Communication:

One of the popular feature of radio transmission is that it should be carried without wires i.e. radiated into space. At audio frequencies, radiation is not practicable because the efficiency of radiation is poor. However, efficient radiation of electrical energy is possible at high frequencies (>20 Hz). for this reason, modulation is always done in communication

Types of modulation:

Accordingly, there are three basic types of modulation, which are given below:

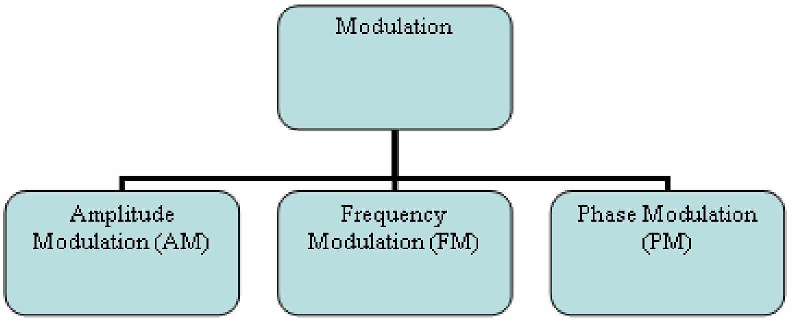

Fig: Basic types of modulation

AMPLITUDE MODULATION:

The modulation in which the amplitude of a high frequency carrier wave is varied in accordance with some characteristic of the modulating signal is called Amplitude Modulation. Here there is no changein frequency and phase of the carrier wave.

FREQUENCY MODULATION:

The modulation in which the frequency of a high frequency carrier wave is varied in accordance with some characteristic of the modulating signal is called Frequency Modulation. Here there is no changein Amplitude and phase of the carrier wave.

PHASE MODULATION:

The modulation in which the Phase of a high frequency carrier wave is varied in accordance with some characteristic of the modulating signal is called Phase Modulation. Here there is no change in Amplitude and frequency of the carrier wave.

AMPLITUDE MODULATION:

Amplitude modulation is the process in which the peak amplitude of a high frequency sinusoidal carrier wave is varied in proportion to the instantaneous amplitude of the AF (Modulation) signal. In amplitude modulation only the amplitude of carrier wave is changed while its frequency and phase remain unchanged. Greater the amplitude of audio frequency modulating signal, greater is the fluctuations in the amplitude modulated carrier wave.

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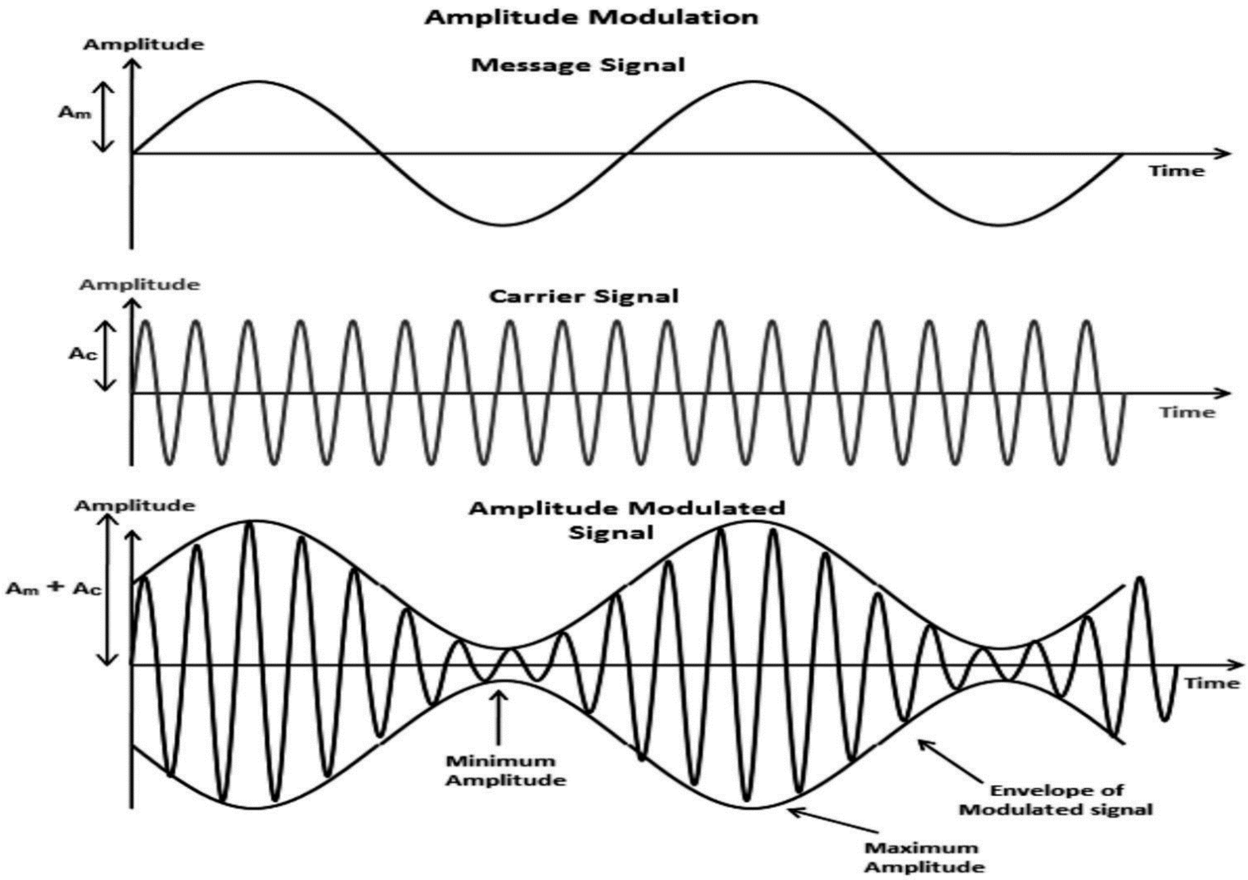

Graphically Representation Principle of Amplitude Modulation

In higher frequency carrier wave of constant amplitude, the audio frequency modulating signal which has been assumed sinusoidal and the resultant wave called amplitude modulated wave.

when signal increases in the positive sense, the amplitude of the amplitude modulated wave also increases but during negative half cycle of signal, the amplitude of modulated carrier wave decreases.

Thus, during amplitude modulation,

1.The amplitude of the modulated wave changes in accordance the AF signal amplitude.

2.The frequency of the amplitude modulated wave remains at its premodulation value i.e., equal to the carrier frequency f_c.

3.The rate at which fluctuations in the amplitude of modulated carrier wave takes place depends on the frequency f_s of the AF signal.

MODULATION INDEX (OR) DEPTH OF MODULATION:

The AM modulation index is the measure of the amplitude variation surrounding an unmodulated carrier. As with other modulation indices, in AM the quantity (also called "modulation depth") indicates how much the modulation varies around its "original" level. For AM, it relates to variations in carrier amplitude and is defined as the ratio of amplitude change of carrier wave to the amplitude of normal carrier wave.

`

$$\textit{Modulating Index(m)} = \frac{\textit{Amplitude change of carrier wave}}{\textit{Amplitude of normal carrier wave}}$$

Its value depends upon the amplitude of carrier and signal wave. It is also known as modulation index and is defined a

$$\textit{Modulating Index (m)} = \frac{\textit{Maximum value of signal wave}}{\textit{Maximum value of carrier wave}}$$

MODULATION INDEX IN AMPLITUDE MODULATION:

Definition:

In Amplitude Modulation, the modulation index(m) is defined as the ratio of amplitude of modulating signal to the carrier signal.

$$\textit{Modulating Index} = \frac{\textit{Modulating signal Amplitude}}{\textit{Carrier Signal Amplitude}} = \frac{E_m}{E_C}$$

If modulation index is expressed in percentage, it is called **Percentage Modulation.**

$$\textit{Percent Modulation (\%m)} = \frac{E_m}{E_C} \times 100$$

In terms of voltage, the modulation index is $m = \frac{V_{max} - V_{min}}{V_{max} + V_{min}}$

POWER IN AN AMPLITUDE MODULATED WAVE:

An amplitude modulated wave consists of a carrier and two side frequency components.

The amplitude modulated wave equation is

$$E = E_c \sin \omega_c t + \frac{mE_c}{2} \cos(\omega_c - \omega_s) - \frac{mE_c}{2} \cos(\omega_c + \omega_s)$$

Carrier Wave **Lower Side Band** **Upper Side Band**

The power carried by a signal is proportional to the square of its amplitude.

The amplitude modulated wave consists of three components of amplitude of rms value,

$$\text{i.e., } \frac{E_c}{\sqrt{2}}, \frac{mE_c}{2\sqrt{2}}, \frac{mE_c}{2\sqrt{2}}$$

Therefore, total power carried by the AM wave is

$$P_T \propto \left[\left(\frac{E_c}{\sqrt{2}}\right)^2 + \left(\frac{mE_c}{2\sqrt{2}}\right)^2 + \left(\frac{mE_c}{2\sqrt{2}}\right)^2\right]$$

$$P_T \propto \left[\frac{E_C^2}{2} + \frac{m^2E_C^2}{8} + \frac{m^2E_C^2}{8}\right]$$

$$P_T \propto \left[\frac{E_C^2}{2} + \frac{m^2E_C^2}{4}\right]$$

$$P_T \propto \frac{E_C^2}{2}\left[1 + \frac{m^2}{2}\right] \text{------------------------(1)}$$

`

In eq (1), $\frac{E_C^2}{2}$ represents the power of the carrier components i.e., $P_c \propto \frac{E_C^2}{2}$ -------(2)

$$P_T = P_c\left[1+\frac{m^2}{2}\right] \text{-----------------------(3)}$$

Power carried by the side bands is $P_{SB} \propto \left[(\frac{\boldsymbol{mE_C}}{\mathbf{2\sqrt{2}}})^{\mathbf{2}} + (\frac{\boldsymbol{mE_C}}{\mathbf{2\sqrt{2}}})^{\mathbf{2}}\right]$

$$\propto \frac{m^2E_C^2}{4} \propto \frac{E_C^2}{2}, \frac{m^2}{2} \text{---------(4)}$$

$$P_{SB} = P_c\left[\frac{m^2}{2}\right] \text{ ------------(5)}$$

Therefore, fraction of total power carried by side bands,

$$\frac{P_{SB}}{P_T} = \frac{Pc\left[\frac{m^2}{2}\right]}{Pc\left[1+\frac{m^2}{2}\right]} = \frac{\left[\frac{m^2}{2}\right]}{\left[1+\frac{m^2}{2}\right]} = \frac{m^2}{2+m^2}\text{--------(6)} \qquad [P_{SB} = P_T\left(\frac{m^2}{2+m^2}\right)]$$

But since, $P_{USB} = P_{LSB} = \frac{1}{2} P_{SB}.$

$$\therefore \quad P_{USB} = P_{LSB} = \frac{1}{2}\left(\frac{m^2}{2+m^2}\right)P_T \text{-----------(7)}$$

Therefore, useful power is in the side bands depends upon the value of modulation factor m, i.e., greater the value of m, greater is the useful power carried by the side bands.

Examples:

1. When m=0.5, Power carried by Side Bands,

$P_{SB} = \left(\frac{m^2}{2+m^2}\right)P_T = \left(\frac{(0.5)^2}{2+(0.5)^2}\right)P_T = 11.1\%$ of the total Power of AM Wave.

2.If the total Power of AM wave is 900 Watt and modulation is 100%, i.e., m=1

$$\therefore \quad P_{SB} = \frac{900}{3} = 300 \text{ Watts,}$$

and $P_C = P_T - P_{SB}$ = 900-300 = 600 Watts.

AMLITUDE MODULATOR TRANSMITTER (AM TRANSMITTER):

Transmitters that transmit AM signals are known as AM transmitters. These transmitters are used in medium wave (MW) and short wave (SW) frequency bands for AM broadcast. The Medium wave (MW) band has frequencies between 550 KHz and 1650 KHz and the Shortwave (SW) band has frequencies ranging from 3 MHz to 30 MHz.

`

The two types of AM transmitters that are used based on their transmitting powers are:

- High Level
- Low Level

High level transmitters use high level modulation and low-level transmitters use low level modulation. The choice between the two modulation schemes depends on the transmitting power of the AM transmitter. In broadcast transmitters, where the transmitting power may be of the order of kilowatts, high level modulation is employed. In low power transmitters, where only a few watts of transmitting power is required, low level modulation is used.

High-Level and Low-Level Transmitters:

The basic differencebetween the two transmitters is the power amplification of the carrier and modulating signals.

The block diagram of high-level AM transmitter is,

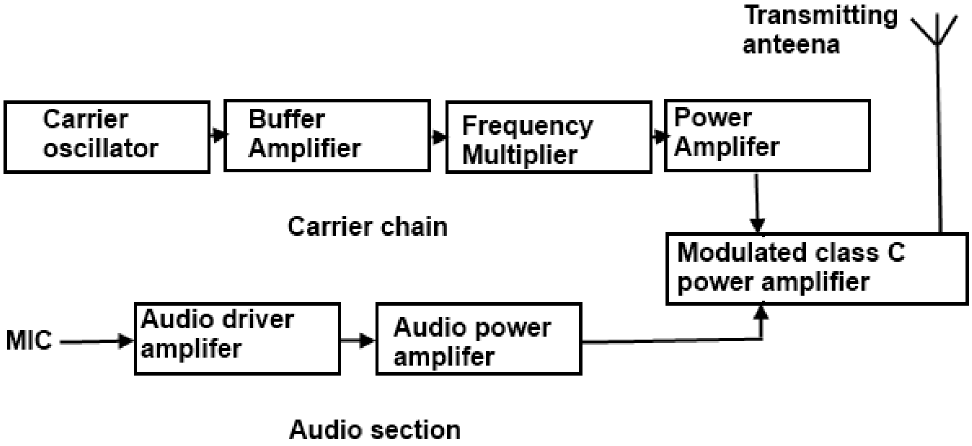

Figure (a) Block diagram of high level AM transmitter

In high-level transmission, the powers of the carrier and modulating signals are amplified before applying to the modulator stage. In low-level modulation, the powers of the two input signals of the modulator stage are not amplified. The required transmitting power is obtained from the last stage of the transmitter, the class C power amplifier.

The various sections of the AM transmitter are,

- Carrier oscillator
- Buffer amplifier
- Frequency multiplier
- Power amplifier
- Audio chain
- Modulated class C power amplifier

`

Carrier Oscillator:

The carrier oscillator generates the carrier signal, which lies in the Radio Frequency (RF) range. The frequency of the carrier is always very high. Because it is very difficult to generate high frequencies with good frequency stability, the carrier oscillator generates a sub multiple with the required carrier frequency. This sub multiple frequency is multiplied by the frequency multiplier stage to get the required carrier frequency. Further, a crystal oscillator can be used in this stage to generate a low frequency carrier with the best frequency stability. The frequency multiplier stage then increases the frequency of the carrier to its required value.

Buffer Amplifier:

The purpose of the buffer amplifier is twofold. It first matches the output impedance of the carrier oscillator with the input impedance of the frequency multiplier, the second stage of the carrier oscillator, isolates the carrier oscillator and frequency multiplier.

Buffer Amplifier is required so that the multiplier does not draw a large current from the carrier oscillator. If this occurs,the frequency of the carrier oscillator will not remain stable.

Frequency Multiplier:

The sub-multiple frequency of the carrier signal, generated by the carrier oscillator is applied to the frequency multiplier through the buffer amplifier. This stage is also known as harmonic generator. The frequency multiplier generates higher harmonics of carrier oscillator frequency. The frequency multiplier is a tuned circuit that can be tuned to the requisite carrier frequency that is to be transmitted.

Power Amplifier:

The power of the carrier signal is then amplified in the power amplifier stage. This is the basic requirement of a high-level transmitter. A class C power amplifier gives high power current pulses of the carrier signal at its output.

Audio Chain:

The audio signal to be transmitted is obtained from the microphone. The audio driver amplifier amplifies the voltage of the signal. The amplification is necessary to drive the audio power amplifier. Next, a class A or a class B power amplifier amplifies the power of the audio signal.

Modulated Class C Amplifier:

This is the output stage of the transmitter. The modulating audio signal and the carrier signal, after poweramplification, are applied to the modulating stage. The modulation takes place at this stage. The class C amplifier also amplifies the power of the AM signal to the reacquired transmitting power. The signal is finally passed to the antenna., which radiates the signal into space of transmission.

ANTENNA:

The output of the final amplifier is fed to an antenna matching network which includes the tank circuit (LC)in the collector of the final amplifier. It is fed to the transmitting antenna which radiates it in space. The function of generation of radio waves is performed by the radio transmitter and its associated transmitting antenna. The output of this section is fed to the antenna for transmission.

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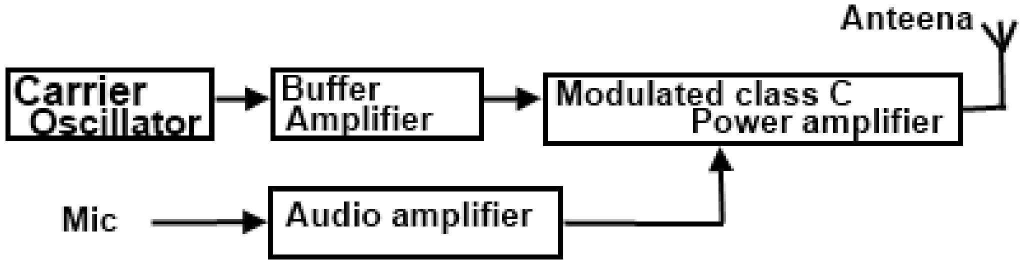

Figure (b) Block diagram of Low-level AM transmitter

The low-level AM transmitter is similar to a high-level transmitter, except that the powers of the carrier and audio signals are not amplified. These two signals are directly applied to the modulated class C power amplifier.

Modulation takes place at this stage and the power of the modulated signal is amplified to the required transmitting power level. The transmitting antenna then transmits the signal.

AMP LITUDE MODULATION RECEIVER (AM RECEIVER) – SUPERERHETERODYNE RECEIVERS:

A radio receiver is a device which picks up any desired radio frequency signal i.e., modulated carrier voltage, transmitted by the transmitter and converts it into an audible sound wave.

The term ***heterodyne*** is to mix while ***superheterodyne*** stands for ***'Supersonics heterodyne'*** i.e., the production of beat frequencies above the range of hearing. In ***superheterodyne receivers*** or ***superhet,*** all the incoming carrier frequencies are converted to a lower fixed value called the ***Intermediate frequency*** **(**I.F.).

PRINCIPLE:

In the process of superheterodyne reception, the signal voltage is combined with a local oscillator voltage and is converted into a new signal with the same modulation, but of lower carrier frequency called the intermediate frequency, which is then amplified and detected to produce the original modulation.

Antenna or Aerial:

The receiver antenna intercepts the electromagnetic wave, convert them into Radio frequency (R.F.) voltage and delivers into the receiver input by means of feeder wire, where a parallel turned circuit responds only to the voltages at the desired carrier frequency. The voltage so picked up is fed to the input of R.F. amplifier stage.

R. F. Amplifier Stage:

The voltage developed across the capacitor of the input tuned circuit should be amplified to detect the weak signals. It is done by using a R.F. It raises the level of signal voltage before it is fed to the mixer. It also improves the signal/noise ratio.

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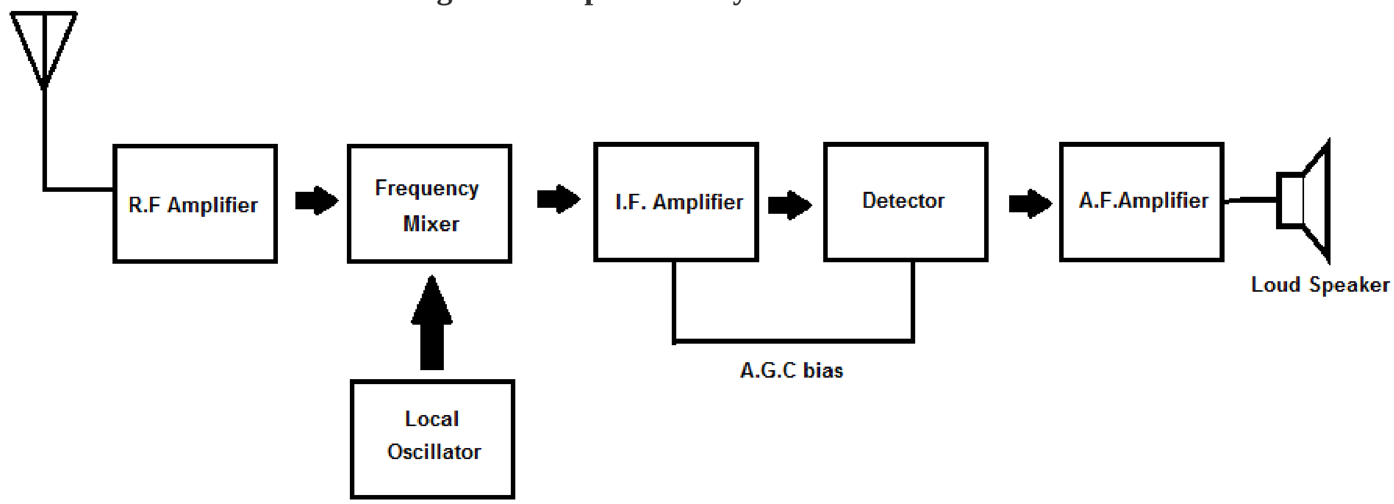
Block Diagram of Superheterodyne Receivers



Mixer or Frequency Converter Stage:

The frequency changing section of the receiver is required to convert the frequency of all incoming carriers to the intermediate frequency (I.F.) value which in most common cases is 455kHz. To obtain the I.F., the radio signal voltage of frequency f_s and a local oscillator voltage f_0 are heterodyned or mixed in the mixer stage. The output current has the frequency components, f_s, f_0, $f_0 + f_s$, $f_0 - f_s$.

If signal frequency f_s is 1500KHz, then the frequency of the local oscillator may be,

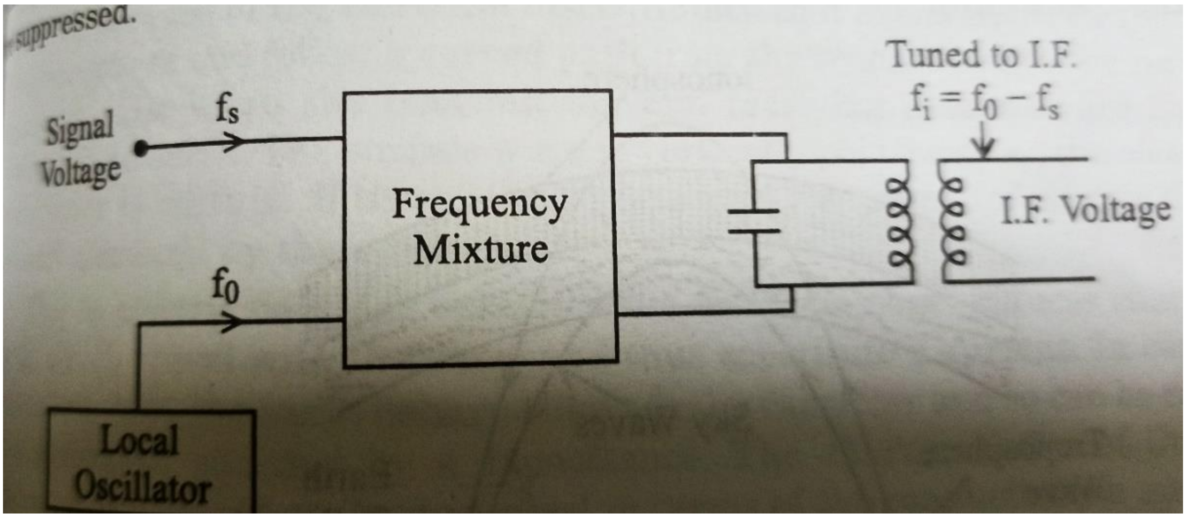
1500+455 = 1955 → The sum component

150 - 455 = 1045 → The difference component

But the local oscillator frequencies are always higher than the frequency of the incoming signal. Thus, the frequency of local oscillator is 1955 gives the beat frequency 1955-1500 = 455KHz. The output load for the frequency changer is a resonant circuit turned to the difference frequency $f_0 - f_s$. Thus, other undesired frequencies are suppressed.

I.F. Amplifier:

I.F. signals produced by mixer stage are amplified by I.F. amplifier which have one or more stages of amplification are designed to amplify only narrow band of frequencies around a fixed central frequency.



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Detector and A.G.C.:

Output of I.F. amplifier is fed to the detector to separate the modulating signal from the carrier from the carrier wave. In addition to convert I.F. signal into audio, the stage provides AGC bias to preceding stages. A linear diode detector is employed.

Audio Frequency Amplifier:

The audio frequency signal obtained at the output of detector is of insufficient amplitude. It is, therefore, fed to A.F. amplifier to provide additional amplification. Usually one stage of audio voltage amplifier is used which is followed by one or more stages of audio power amplifier.

Loudspeaker:

Through an impedance matching transformer, the amplified audio output voltage of audio power amplifier is fed to the loudspeaker. It is an electromagnetic device that is used to convert the audio currents into sound waves. Thus, the original programme is reproduced.

DEMODULATION:

The Process of separating the audio signal from a modulated carrier wave is known as demodulation or detection. It is the reverse process of modulation and is highly essential in all radio receivers.

NECESSITY OF DETECTION:

The Amplitude modulated wave radiated in space from transmitting antenna, consists of carrier wave and sideband frequencies. If these high frequency currents even after amplification, are fed directly to loud speaker, no sound will be heard because,

1.There are much above the audible limit,

2.Diaphragm of Loud speaker will not be able to respond to such high frequencies due tolarge inertia.

Therefore, it is essential that audio signal be separated from the carrier first and then fed to loud- speaker for conversion into sound after amplification.

DIODE DETECTOR:

Detection of AM signal essentially involves two operations:

1.Rectification of the modulated wave i.e. elimination of R.F component of the modulated wave.

2.Separation of audio signal from carrier i.e., elimination of R.F component of the modulated wave.

This can be done by the detecting circuit element called diode detector or envelope detector because it recovers the AF signal envelope from the composite signal. A diode detector is also called as Linear detector because its output is proportional to the voltage of the input signal.

Circuit Details:

The diode detector circuit is similar to a half wave rectifier with a capacitor filter. The input to the detector is an amplitude modulated carrier voltage. Tuned L_1, C_1 selects the modulated wave of desired frequency. Capacitor C offers a low impedance to the carrier while R is relatively high resistance. C_B is a blocking capacitor which can pass low frequency AF signals only, but

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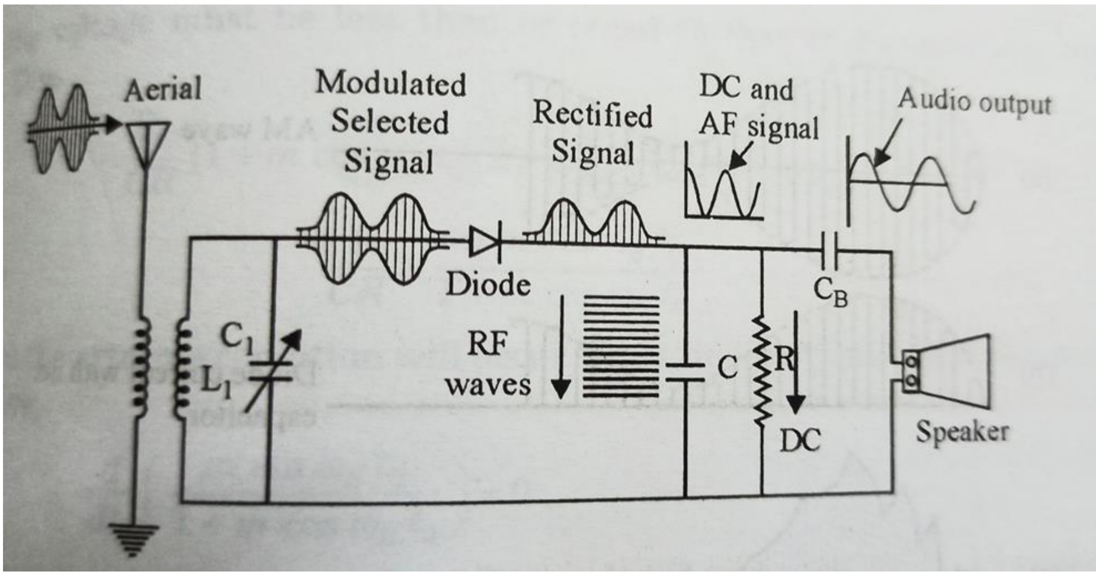
blocks DC from appearing in the output.



DIODE DETECTOR

Operation:

By varying the capacity C_1, the resonant frequency of tuned circuit L_1, C_1 is varied and RF signal of any desired frequency can be tuned in. Thus, the modulated wave of desired frequency is selected by the parallel tuned circuit L_1, C_1 and is applied to the P-N junction diode. During the positive half cycle of modulated wave, the diode conducts but not during negative half cycles. As a result of this rectifying action, we get only the positive half cycles of the modulated wave in the output of the diode.

The rectified modulated wave consists of radio frequency and the signal cannot be applied directly to the speaker for sound production. The RF carrier wave is filtered out by Capacitor C which presents a low reactance path to RF components but a relatively high reactance to the audio signals. The DC component of the remaining signal cannot easily pass through blocking capacitor C_B and is shunted out through R. The low frequency audio signal can easily pass through C_B. Thus, modulating signal is recovered at the detector output and passed on to the speaker for reproduction of sound.

Mathematical Analysis:

At each positive peak of the radio frequency cycle of the carrier voltage, capacitor C charges to a potential which is almost but not equal to the peak value of the applied voltage. It is slightly less than peak value, because of voltage drop across the diode. Between two consecutive peak voltage drops by a small amount. The amount of charge is replenished by an appropriate new charging of capacitor C at the peak of next radio frequency cycle. As a result, the output voltage developed across the load impedance RC becomes almost the same as the envelop of the modulated wave.

The time constant RC must be small enough so that the rate of decrease of voltage across C due to discharge will be the same as the rate of decrease of amplitude of the envelope the parts

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of the modulating cycle when the envelope voltage is decreasing in the amplitude.

The most favourable condition must prevail at the highest modulating frequency ω_s for which the detector is designed.

The equation of the envelope is

$$e = E_C\,[1 + m \cos \omega_s t]$$

At any particular time, t = t_0, the value of the modulated envelope is

$$e = E_C\,[1 + m \cos \omega_s t_0]$$

Corresponding slope,

$$\left(\frac{de}{dt}\right)_{t=t_0} = \omega_s m\, E_C \sin \omega_s t_0$$

If the voltage across the capacitor C is equal to the modulating voltage e_a at the instant t = t_0,

$$e_a = E_C\,[1 + m \cos \omega_s t]$$

and the voltage decreases according to the exponential expression as the capacitor discharges with time constant CR

$$e_a = e_{ao} e^{-(t-t_0)/CR}$$

The initial rate of change of the output voltage at t = t_0 is

$$\left(\frac{de}{dt}\right)_{t=t_0} = \frac{-e_a}{CR} = \frac{-E_C}{CR}\,(1 + m \cos \omega_s t_0)$$

To avoid clipping distortion, the capacitor voltage should be less than the value of the envelope for the time t = t_0.

Therefore, the slope of the capacitor voltage must be less than or equal to that of the envelope voltage at t = t_0.

Thus, $$\frac{-E_C}{CR}\,(1 + m \cos \omega_s t_0) \geq -\omega_s m\, E_C \sin \omega_s t_0$$

Or $$\frac{1}{CR} \geq \frac{\omega_s m\, EC \sin \omega_s t_0}{1 + m \cos \omega_s t_0}$$

But the extreme conditions will occur when the fraction of RHS is a maximum.

Therefore, $$\frac{d}{dt_0}\left(\frac{m \sin \omega_s t_0}{1 + m \cos \omega_s t_0}\right) = 0$$

Or $$m\, \omega_s \cos \cos^2 \omega_s t_0 + \omega_s m^2 (\cos^2 \omega_s t_0 + \sin^2 \omega_s t_0) = 0$$

Or $$\cos \omega_s t_0 = m$$

Or $$\sin \omega_s t_0 = \sqrt{1 - m^2}$$

Hence the required condition is $\frac{1}{CR} \geq \frac{\omega_s m}{\sqrt{1 - m^2}}$.

Limitations of Amplitude Modulation:

- Low Efficiency- Since the useful power that lies in the small bands is quite small, so the efficiency of AM system is low.
- Limited Operating Range – The range of operation is small due to low efficiency. Thus, transmission of signals is difficult.

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- Noise in Reception – As the radio receiver finds it difficult to distinguish between the amplitude variations that represent noise and those with the signals, heavy noise is prone to occur in its reception.

- Poor Audio Quality – To obtain high fidelity reception, all audio frequencies till 15 KHz must be reproduced and this necessitates the bandwidth of 10 KHz to minimize the interference from the adjacent broadcasting stations. Therefore, in AM broadcasting stations audio quality is known to be poor.

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FREQUENCY MODULATION:

Frequency Modulation:

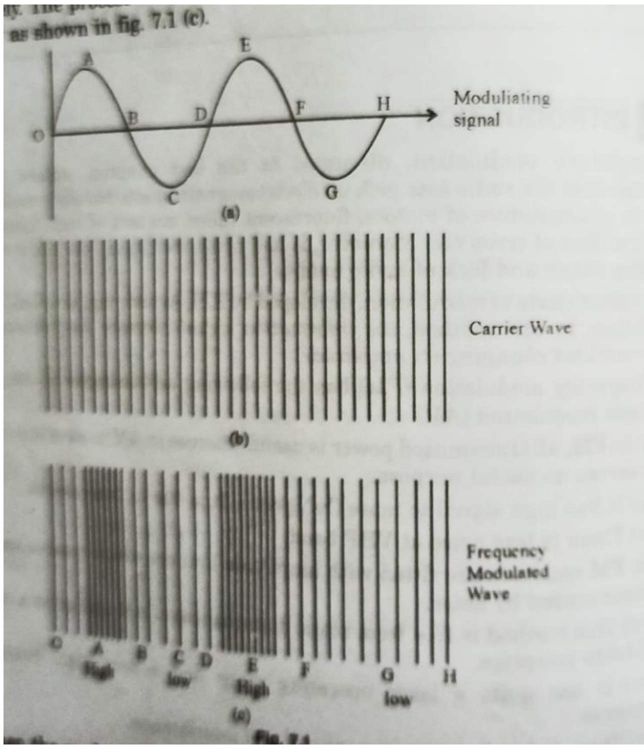
Frequency modulation is a technique or a process of encoding information on a particular signal by varying the carrier wave frequency in accordance with the frequency of the modulating signal. As we know, a modulating signal is nothing but information or message that has to be transmitted after being converted into an electronic signal.

Much like in amplitude modulation, frequency modulation also has a similar approach where a carrier signal is modulated by the input signal. However, in the case of FM, the amplitude of the modulated signal is kept or it remains constant.

Frequency Modulation:

The process in which the high frequency of a high frequency sinusoidal carrier wave is made to vary in proportion to the instantaneous amplitude of the modulating signal. The amplitude of carrier wave in this case is not disturbed and remains constant.

WORKING OF FREQUENCY MODUATION:



- ❖ Fig (a) and (b) represent the modulating signal and carrier wave respectively.
- ❖ It is the process of frequency modulation leads to changes in the carrier frequency as shown in fig(c).
- ❖ when the modulating signal voltage is zero at 0, B, D, F and H. the carrier frequency is unchanged.
- ❖ When the signal approaches its positive peaks as at A and E carrier frequency is increased to maximum (high) as shown by the closely spaced cycles.
- ❖ During negative peaks of signal, as at C and G, the carrier frequency decreases to minimum as shown by the widely spaced cycles in fig.
- ❖ Thus, the frequency of modulated carrier increases with increase in signal amplitude but decreases as the signal amplitude decreases.
- ❖ It is highest when the signal amplitude is at its maximum positive value and lowest when signal amplitude has maximum negative value. The carrier frequency, however, remains unchanged.
- ❖ When signal amplitude is zero, this carrier frequency remains unchanged, called resting frequency or centre frequency
- ❖ The amount of change in frequency, in frequency modulation, depends on the amplitude of the audio signal.
- ❖ Louder the sound, greater the frequency deviation or shift. But the rate of change of frequency (rate of frequency deviation) depends on the signal frequency.

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FREQUENCY DEVIATION AND CARRIER SWING:

Every radio station is allowed to broadcast at a fixed carrier frequency, called the resting frequency or centre frequency and is the carrier frequency. When modulating signal is applied, a positive change is produced in the carrier frequency when signal goes positive and a negative change when signal goes to negative. Thus, the Carrier frequency shifts up and down from its resting value f_o. This shift (or change), either, above or below the centre frequency, is termed as frequency deviation and it is denoted by Δf.

The total change in frequency from the lowest to the highest is called carrier swing (CS), Thus,

Carrier swing =2 x frequency deviation

CS =2xΔf.

In FM broadcasting system Δf, has a maximum permissible value of 75KHz.

Therefore. FM channel width = 2x 75 = 150 KHz.

In addition to it, for avoiding adjacent channel interference. a guard band of 25KHz has been allowed on either side.

Hence exact FM channel width = 2 (75 + 25) = 200 kHz.

Modulation Index:

The frequency Modulation Index m_f is defined as the ratio of the maximum frequency deviation to the modulating frequency.

$$m_f = \frac{Frequency\ deviation}{Modulating\ (or\ signal) frequency} = \frac{\Delta f}{f_s}$$

m_f can have values both greater than unity or less than unity.

The number of significant side bands and the band width of the FM signal is calculated by knowing the value of m_f.

Deviation Ratio:

Deviation ratio is defined as the ratio of maximum allowed frequency deviation

(Δ*fmax) to the* maximum allowed modulating (audio) frequency.

$$\text{Deviation ratio} = (\ \delta\ ) = \frac{Maximum\ frequency\ deviation}{Maximum\ modulating\ frequency} = \frac{(\Delta f)_{max}}{(f_S)_{max}}$$

FREQUENCY MODULATION (FM) TRANSMITTER:

The master oscillator generates the RF signal (carrier) required for modulation. Master oscillator is generally a well-defined LC oscillator. The buffer amplifier is used to make the oscillator frequency free from the loading to the next stages.

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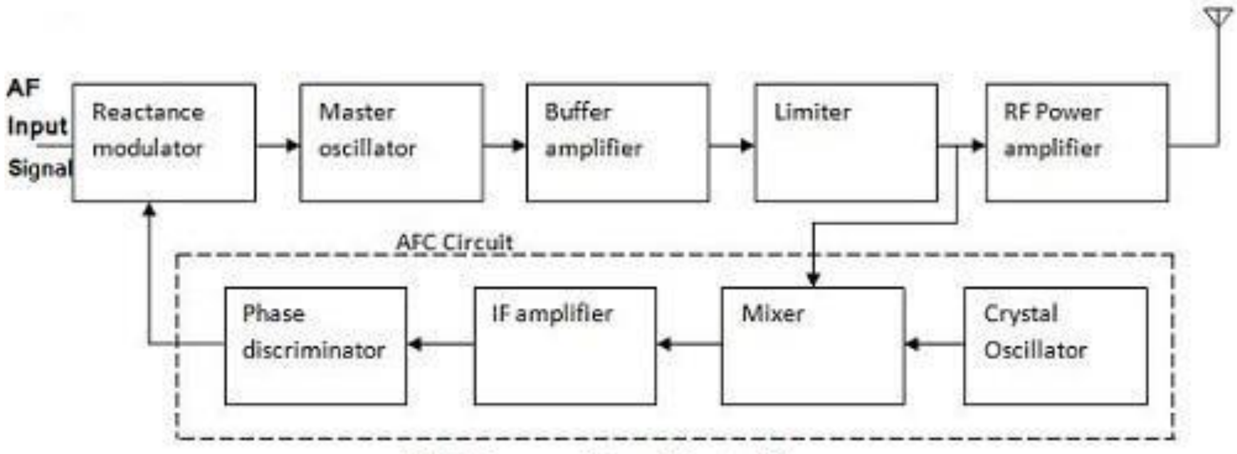
The frequency modulation is achieved by the reactance modulator. In reactance modulator, a voltage variable reactance is placed across the tank circuit of the master oscillator. It can be a varactor diode, FET, BJT or vacuum tube. The tank is tuned so that the oscillating frequency is equal to the desired carrier frequency. When we apply the modulating voltage, the reactance of the voltage variable reactance changes and hence the tank circuit reactance also varies. This changes the frequency of oscillation of the oscillator.



FM Transmitter Block Diagram

When the modulating voltage is increasing positively, the oscillator frequency also increases. When the modulatingvoltage is zero, there is no reactance oscillation and the frequency of oscillation remains unchanged. When the modulating voltage is increasing negatively, the oscillator frequency will decrease. Thus, the frequency modulation is obtained.

Since the reactance modulator operates on the tank circuit of an LC oscillator, the master oscillator cannot be crystal controlled. But it must have the stability of a crystal oscillator since it is the part of a commercial transmitter. If the frequency of the master oscillator shifts, the output frequency of the whole system must drift equally. Hence automaticfrequency control (AFC) must be employed.

In AFC circuit, the master oscillator frequency is mixed with the frequency obtained from a crystal oscillator. The crystal oscillator will be tuned such that the resulting difference frequency of the output of the mixer will have usually about 1/20th of the master oscillator frequency This intermediate frequency (IF) signal from the output of the mixer is amplified by the IF amplifier and fed to the input of a phase discriminator. The discriminator output will be zero when the master oscillator frequency is equal to the carrier frequency (Centre frequency).

When the master oscillator frequency increases the discriminator produces a positive DC voltage. This voltage is fed in series with the reactance modulator. Then the master oscillator frequency decreases correspondingly. If the master oscillator frequency decreases, the discriminator output will be a negative DC voltage and the master oscillator frequency increases correspondingly.

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The phase discriminator will not react to normal frequency changes due to frequency modulation, since they are very small frequency changes. Discriminator will react only to slow changes in the incoming frequency. The RF power amplifier raises the power of the frequency modulated signal to a required level for transmission through the antenna. It will be a class C amplifier. The transmitting antenna radiates the RF power into space.

For commercial FM radio broadcasting, the assigned carrier frequency is within the range 88- 108 MHz, with a transmission bandwidth of 200 kHz.

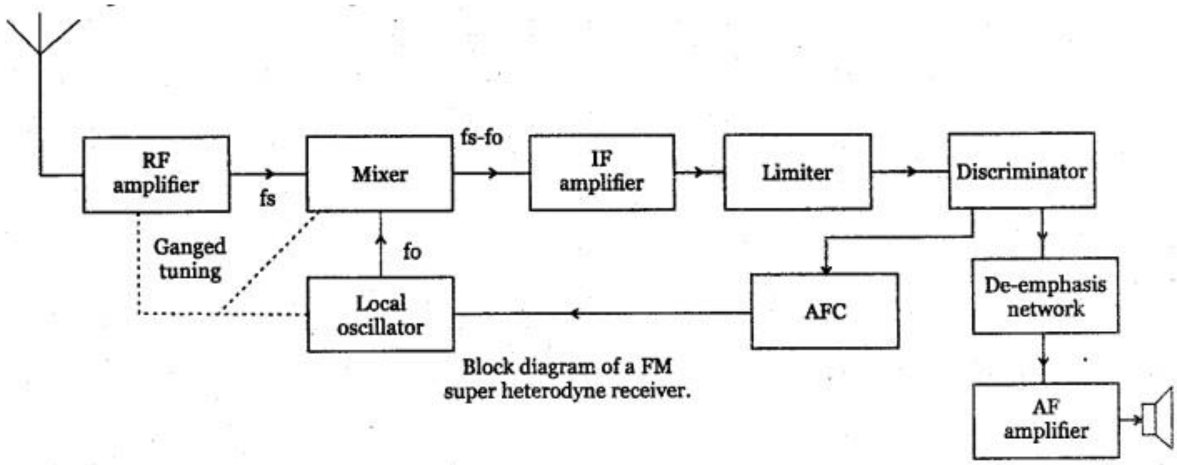
FREQUENCY MODULATION RECEIVER:

RF amplifier: The RF amplifier increases the signal strength before the signal is fed to tune to the desired frequency. The RF amplifier is designed to handle large bandwidth of 150 kHz.

Mixer: The incoming RF signal of frequency f_m is applied to a mixer which also receives the output from the local oscillator. A new frequency called intermediate frequency IF is produced whose value is difference of local oscillator signal and signal frequency.

Local oscillator: The receiver converts incoming carrier frequency to the IF by using local oscillator frequency higher than incoming tuned frequency. Colpitts oscillator is used as the local oscillator.

FREQUENCY MODULATION RECEIVER:



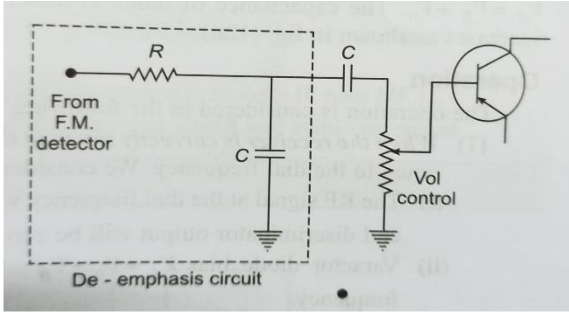
Block diagram of a FM super heterodyne receiver.

IF amplifier: IF signal is amplified by one or more number of amplifiers, which raises the strength of IF signal. It has multistage class A amplifier providing better selectivity and gain.

Limiter: It removes all the amplitude variation in FM signal caused by noise. Differential amplifiers are preferred for limiter.

Discriminator: It recovers the modulating signal from the IF signal. It converts frequency variation into corresponding voltage variation and produces the modulating signal.

De-emphasis network: It reduces the relative amplitude of high frequency signals that are boosted in the transmitter and brings them back to their original level.



De-emphasis consists of RC circuit connected across the output of FM detector and often proceeds the volume control. The higher the audio frequency, the lower is the reactance of capacitance. Therefore, signal amplitude applied to the audio amplifier will be relatively lower, removing the pre-emphasis.

AF amplifier: It amplifies the modulating signal recovered by the FM detector. The speaker converts the electrical signal into sound signal.

ADVANTAGES & DISADVANTAGES OF FREQUENCY MODULATION:

ADVANTAGES

1. It gives noiseless reception. Noise is a form of amplitude variation and a FM receiver will reject such noise signals.
2. The operating range is quite large.
3. The efficiency of transmission is very high.
4. Power Consumption is less as compared to AM.
5. Adjacent FM channels are separated by guard bands.

DISADVANTAGES:

1. Equipment cost is higher, Has a large bandwidth.
2. The receiving is of FM signal is small.
3. The antennas for FM systems should be kept close for better communication.
4. A much wider channel is required by FM.
5. FM transmitting and receiving equipment tends to be more complex.

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DIFFERENCE BETWEEN AMPLITUDE & FREQUENCY MODULATION

AMPLITUDE MODULATION	FREQUENCY MODULATION
1. In AM, a radio wave known as the "carrier" or "carrier wave" is modulated in amplitude by the signal that is to be transmitted.	1.In FM, a radio wave known as the "carrier" or "carrier wave" is modulated in frequency by the signal that is to be transmitted.
2. It is used in both analog and digital communication and telemetry.	2.It is used in both analog and digital communication and telemetry.
3. AM has poorer sound quality compared to FM, but is cheaper and can be transmitted over long distances. It has a smaller bandwidth so it can have more stations available in any frequency range.	3.FM is less prone to interference than AM. However, FM signals are impacted by physical barriers. FM has greater sound quality due to higher bandwidth.
4. AM radio ranges from 535 to 1705 kilohertz.	4. FM radio ranges in a higher spectrum from 88 to 108 megahertz.
5. Twice the highest modulating frequency. In AM radio broadcasting, the modulating signal has bandwidth of 15kHz, and hence the bandwidth of an amplitude-modulated signal is 30kHz.	5. Twice the sum of the modulating signal frequency and the frequency deviation. If the frequency deviation is 75kHz and the modulating signal frequency is 15kHz, the bandwidth required is 180kHz.

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UNIT-V

APPLICATIONS OF ELECTROMAGNETIC INDUCTION

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POWER SUPPLIES (SKILL BASED)

CONSTRUCTION AND OPERATING PRINCIPLE OF A DC MOTOR

An DC motor operates on the principle of electromagnetic induction i.e., when the magnetic flux linking a conductor changes, an EMF is induced in the conductor.

A DC motor is an electrical machine that converts Electrical energy into Mechanical energy.

In a DC motor, the input electrical energy is the direct current which is transformed into the mechanical rotation.

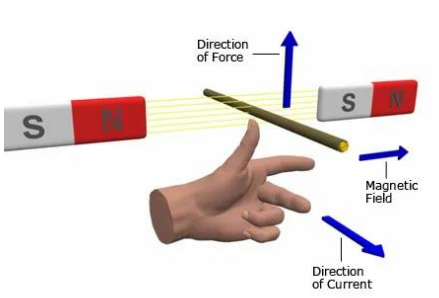
A DC motor converts electrical energy into mechanical energy. The input electrical energy is obtained from rechargeable batteries, solar cells, etc. The mechanical energy generated is further utilized to rotate pumps, fans, compressors, wheels, etc.

Working Principle:

The DC motor works on the principle that a current-carrying conductor experiences a mechanical force when placed in a magnetic field. This is known as the Lorentz force and the direction of this force is given by **Fleming Left-Hand Rule.**

FLEMING'S LEFT-HAND RULE.

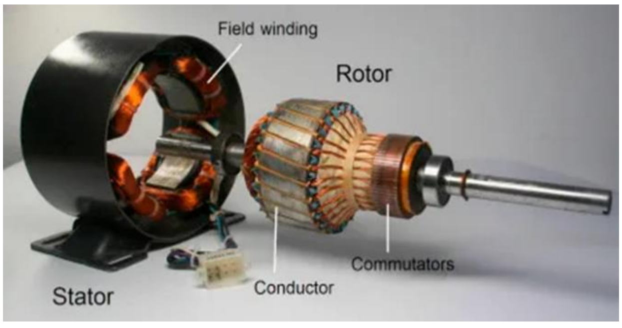
If you stretch the index finger, middle finger, and thumb of the left hand mutually perpendicular to each other, the index finger indicates the direction of the magnetic field, the middle finger indicates the direction of current through the conductor, then the thumb will indicate the direction of force acting on the conductor**.**



Fleming Left-Hand Rule

Construction of Dc Motor:

Structure of DC Motor:



All DC motors mainly consist of two parts. One is the **stator** and the other is **Rotor**. The stator is a stationary part that includes Yoke, Pole, Pole winding, and Interpoles. The stator produces the magnetic flux.

The rotor of the dc machine consists of a commutator, brushes, compensating winding and a shaft. It rotates in external magnetic flux (produced by the stator) when the current flows in it.

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PARTS OF THE STATOR

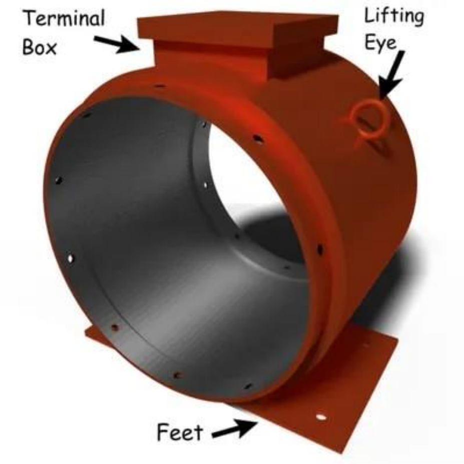
Yoke:

The yoke or outer frame provides coverage to a dc motor. It is made up of **cast steel** for large dc motors and of **cast iron** for small dc motors. The yoke is used in DC machines because:

A) It provides mechanical support to poles.

B) Acts as a protective cover against mechanical damage.

C) And provides a passage for the magnetic flux produced by the poles of the machine.

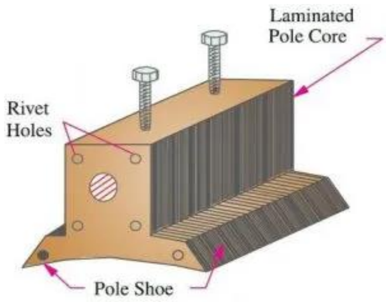


Yoke

Core and Pole Shoe:

Both pole core and pole shoes are made of cast steel. But pole shoes are laminated as they are close to the armature.

If the load changes during the operation of the DC motor, the armature current changes. As a result, the magnetic flux also changes. This flux links the pole shoe and causes **eddy current** to flow and to minimize these eddy currents, pole shoes are laminated.



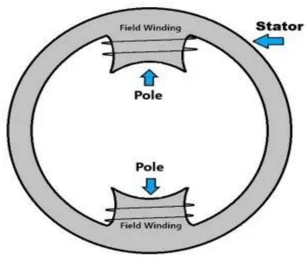
Pole core and pole

Shoe:

The main purpose of the pole shoe is to spread the flux and to reduce the reluctance of the magnetic path. ***(Magnetic reluctance also known as reluctance, magnetic resistance, or a magnetic insulator is defined as the opposition offered by a magnetic circuit to the production of magnetic flux. It is the property of the material that opposes the creation of magnetic flux in a magnetic circuit.).*** Whereas the pole core is excited with field winding and used to support them.

Pole Winding or Field Coils:

The pole winding and field coils consist of copper wire placed in position around the pole core. When current passes through these coils, they electro-magnetize the pole which produces the magnetic flux. This flux passes through the rotor and produces a rotating torque as soon as the current starts flowing in the armature of the rotor.



Pole Winding or Field Coils

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PARTS OF THE ROTOR:

Armature Core:

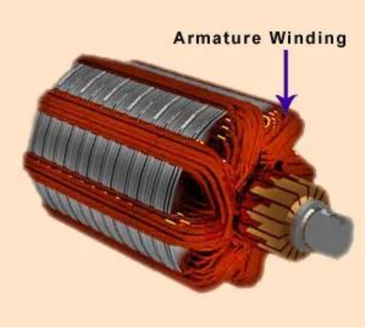
The armature core is the rotating part of a DC/AC motor. It is made up of **silicon steel**. The cylindrical structure is laminated to reduce the eddy current loss. Its main purpose is to offer a low reluctance path to the magnetic flux and to house the armature conductors.

Armature Core in a Rotor

Armature Winding:

Armature winding is composed of coils embedded in armature core slots. These coils are lined next to each other with tough insulating material. The insulating material prevents the two adjacent coils from a short circuit.

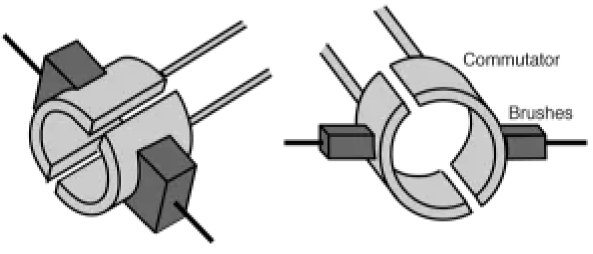
Whereas the slot insulation is folded over the armature conductor and is secured firmly by wood or Fibre wedges. In simple words, it is an arrangement of current-carrying conductors that produce EMF in the machine due to relative motion between the windings and the main field.



Armature Winding

Commutator:

The commutator contains wedge-shaped hard-drawn copper segments, forming a cylindrical structure. A thin sheet of **high-quality mica** insulates the segments from each other. A commutator periodically changes the direction of the current between the rotor and the external circuit**.**



Commutator Ring

Hence, it acts as a switch causing a unidirectional torque in the dc motor.

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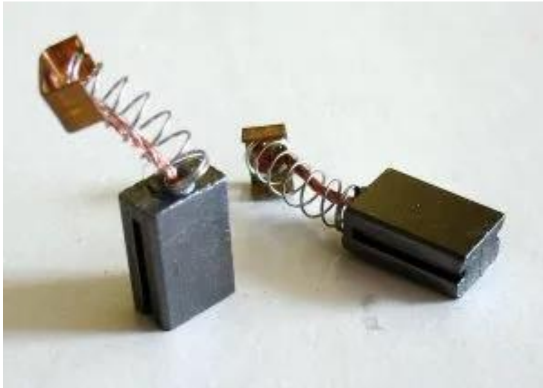
Brushes:

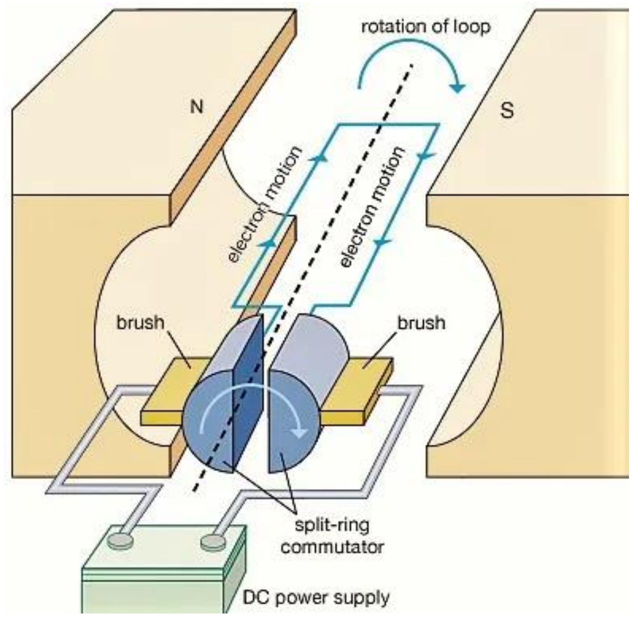


Brushes

Brushes are usually made of rectangular carbon blocks housed in brush holders. The function of brushes in DC motors is to supply the current to the commutator from an external dc source.

Whereas the function of the brushes in a **DC generator** is to collect the current from the commutator and supply it to the external load circuit.

WORKING OF DC MOTOR:

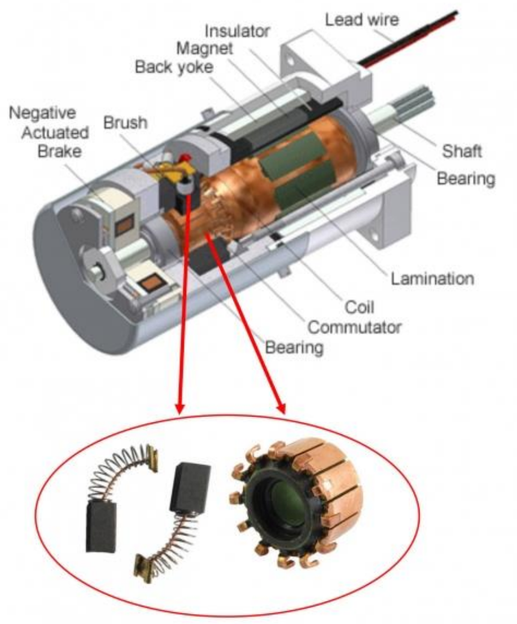


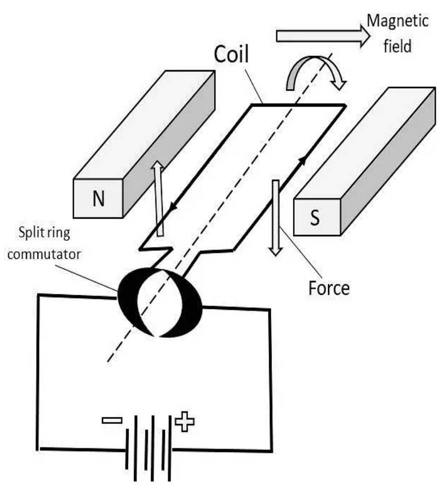
The working principle of a DC motor requires magnetic flux and a current-carrying conductor. Consider a coil carrying DC current through commutator and brushes. These commutator segments rotate freely about its axis.

The commutator segment which comes in contact with the left brush gets positive polarity while the right one gets negative polarity. This leads to the flow of current in the coil.

By applying Fleming's Left-Hand Rule, the conductor on the left side always experiences a force in an upward direction while the conductor on the right side experiences a downward force.

Hence, a unidirectional torque is achieved in dc motors.





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BACK EMF:

The interaction of the current-carrying conductor with the changing magnetic field produced by the field winding induces an EMF in the conductor. This EMF acts in the opposite direction to the applied voltage. This induced EMF in the motor is known as BACK EMF.

Calculation of Power, Voltage and Current in a DC Motor:

Voltage Equation for A DC Motor:

In case of a dc motor, supply voltage V has to overcome the back emf E_b which is opposing the voltage V and also various drops as armature resistance drop $I_a R_a$, brush drop (V_{Br})
Hence the voltage equation for a dc motor is,

$$\boxed{V = E_b + I_a R_a + V_{\mathrm{Br}}}$$

$V_{Br} \longrightarrow$ brush drop
Neglecting the brush drop, the **generalized voltage equation** is,

In the case of a dc motor $\Longrightarrow V = E_b + I_a R_a$

Current Equation for A Dc Motor:

In the case of a dc motor, the back emf is always less than the supply voltage. But R_a is very small hence under normal running conditions, the difference between the back emf and the supply voltage is very small. The net voltage across the armature is the difference between the supply voltage and back emf which decides the armature current. Hence from the current equation is,

$$\boxed{I_a = \left(\frac{V - E_b}{R_a}\right)}$$

Power Equation for A Dc Motor:

The voltage equation for a dc motor is given by the expression,

$$V = E_b + I_a R_a$$

Multiplying both sides of the above equation by I_a we get,

$$\boxed{V\ I_a = I_a\ E_b + I_a^2\ R_a}$$

The above equation is called as the power equation for a dc motor.

`

$VI_a =$Net electrical power input to the armature measured in watts.

$I_a^2 R_a =$Power loss due to the resistance of the armature called armature copper loss.

So, difference between VI_a and $I_a^2 R_a$ i.e. Input – losses given by the output power.

So, $E_b I_a$ is called **electrical equivalent of gross mechanical power** developed by the armature. This is denoted as P_m

Gross mechanical power developed in the armature=
power input to the armature – armature copper loss

Condition for Maximum Power:

For a motor from power equation it is known that

$$P_m = VI_a - I_a^2 R_a$$

For maximum gross mechanical power

$$\implies \left(\frac{dP_m}{dI_a}\right) = 0$$

$$V - 2I_a R_a = 0$$

$$I_a = \frac{V}{2R_a}$$

$$I_a R_a = \frac{V}{2}$$

$$V = E_b + I_a R_a = E_b + \frac{V}{2}$$

$$\boxed{E_b = \frac{V}{2}}$$

Design of a simple Motor (Fan) with suitable turns of coil:

Ceiling fan motors are essentially induction motors employing the principle of Electromagnetic induction in the performance of their operations. The optimal performance of a ceiling fan would, therefore, depend greatly on the health of the induction motor employed. Basically, single phase induction motors are employed in the design of ceiling fans. Ceiling fan motors present an exciting, yet challenging aspect of cooling this is due to their small weight, low cost and very high efficiency.

Single phase induction motor is very simple and robust in construction. A single-phase induction motor is similar to a 3-phase squirrel cage induction motor in physical appearance. The rotor is same as that employed in 3-phase squirrel cage induction motor. There is uniform air gap between stator and rotor but no electrical connection between them. The single-phase induction motor has two main parts one is stator (which is stationary) and other is rotor (which is rotating).

Stator:

It is the stationary part of the motor. It has three main parts

1. Outer frame
2. Stator core
3. Stator Winding

Outer Frame:

Outer body of the motor to support the stator core and the stator windings

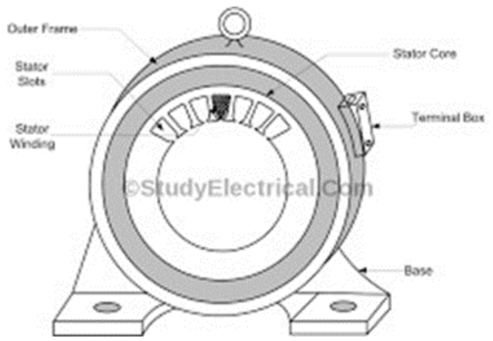
Stator Core:

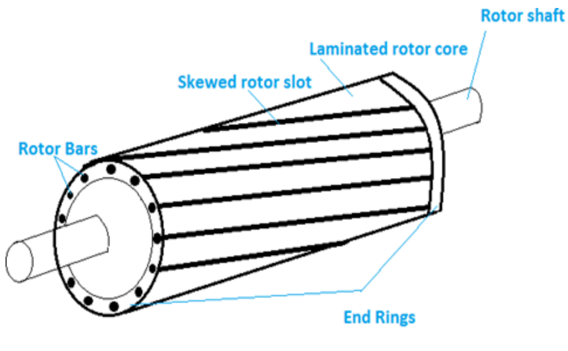
The stator core is built up of thin sheets laminations which are usually 0.3 to 0.5 mm thick. The stator core carries alternating flux which produces eddy currents and hysteresis losses.

Stator Winding:

The stator core carries the stator windings connected across a single phase A.C. supply which produces a rotating magnetic field.

Rotor:





Squirrel Cage Rotor

It is the rotating part of the motor. This rotor is called squirrel cage, as appear like cage. The rotor has aluminum or copper bars which are permanently circuited at both ends by conductingend rings.

A single-phase induction motor is inherently not self-staring can be shown easily. Consider a single-phase induction motor whose rotor is at rest. Let a single phase a.c. source be connected to the stator winding (it is assumed that there is no starting winding). Let the stator be wound for two poles. When power supply for the stator is switched on, an alternatingcurrent flow through the stator winding. This sets up an alternating flux. This flux crosses theair gap and links with the rotor conductors. By electromagnetic induction e.m.f. are induced in the rotor conductors. Since the rotor forms a closed circuit, currents are induced in the rotor bars.

`

Due to interaction between the rotor induced currents and the stator flux, a torque is produced. It is readily seen that if all rotor conductors in the upper half come under a stator N pole, all rotor conductors in the lower half come under a stator S pole. Hence, the upper half of the rotor is subjected to a torque which tends to rotate it in one direction and the lower half of the rotor is acted upon by an equal torque which tends to rotate it in the opposite direction. The two equal and opposite torques cancel out, with the result that the net driving torque is zero.

Hence the rotor remains stationary. Thus, the single-phase motor fails to develop starting torque. This argument holds good irrespective of the number of stator poles and the polarity of the stator winding. The net torque acting on the rotor at standstill is zero.

If, however, the rotor is in motion in any direction when supply for the stator is switched on, it can be shown that the rotor develops more torque in that direction. The net torque then, would have non-zero value, and under its impact the rotor would speed up in its direction.

(B) WORKING OF D.C. REGULATED POWER SUPPLY:

A D.C. power supply consists of electronic circuit which provide a constant regulated D.C. voltage of pre-determined value across a load irrespective of A.C. mains fluctuations or load variations.

A regulated power supply consists of the following stages.

1.Unregulated power supply

2.Regulator (for regulated power supply)

1.Unregulated or Ordinary Power Supply:

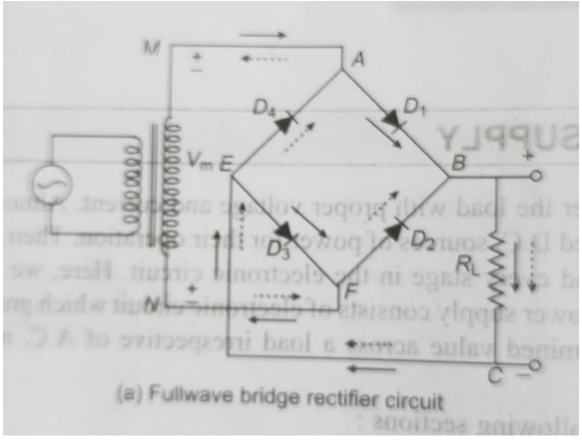
Construction & Working

An unregulated power supply or ordinary D.C. power supply consists of a transformer, a rectifier and a filter circuit.

1.A step- down transformer which reduces the d.c. voltage in the range of 2-24 volt is required for the operation of different electronic circuits.

2.A rectifier converts the sinusoidal A.C. voltage into pulsating D.C. For the process of rectification, a bridge rectifier is used.

Consider a full wave bridge rectifier in which four diodes are used.



(a) Fullwave bridge rectifier circuit

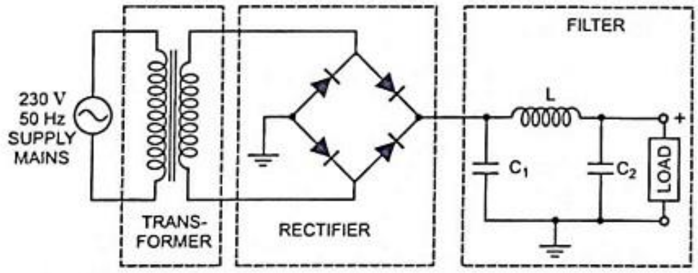
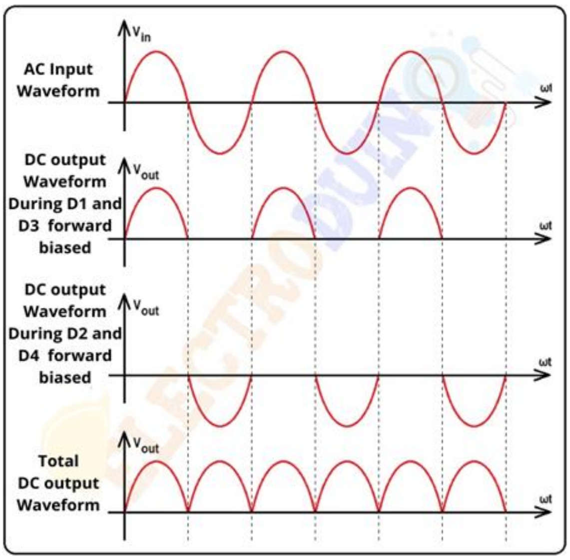


Fig. 43.1 *Block Diagram of an Unregulated Power Supply*



During the positive input half cycle, terminal M of the secondary of the transformer is positive while the terminal N is negative. The diodes D_1 and D_3 are forward biased (ON position) i.e., they conduct whereas diodes D_2 and D_4 are reverse biased (OFF position), i.e., they do not conduct. So, a current flow along MABCEFN as shown by arrow. There will be a voltage drop across R_L.

During the negative input half cycle, terminal N of the secondary of the transformer is positive while the terminal M is negative. The diodes D_2 and D_4 are forward biased (ON position) i.e., they conduct whereas diodes D_1 and D_3 are reverse biased (OFF position), i.e., they do not conduct. So, a current flow along NFBCEAM as shown by dotted arrow. The current produces a voltage drop across R_L.

The current through load resistance R_L is in the same direction AB during both half cycle of the input a.c. supply.

A filter section is attached to bridge rectifier. A π or (C-L-C) filter is used to remove the A.C. harmonics from D.C. obtained from bridge rectifier.

(B) ***Regulated (Regulator Power Supply)***

A regulated circuit (Voltage regulated device) is used after filter section. The functions of the regulated Power Supply are

(i) The output of regulated circuit has much less ripple voltage.
(ii) The out voltage remains constant even if the input D.C. voltage varies or the load connected at the output D.C. voltage changes.

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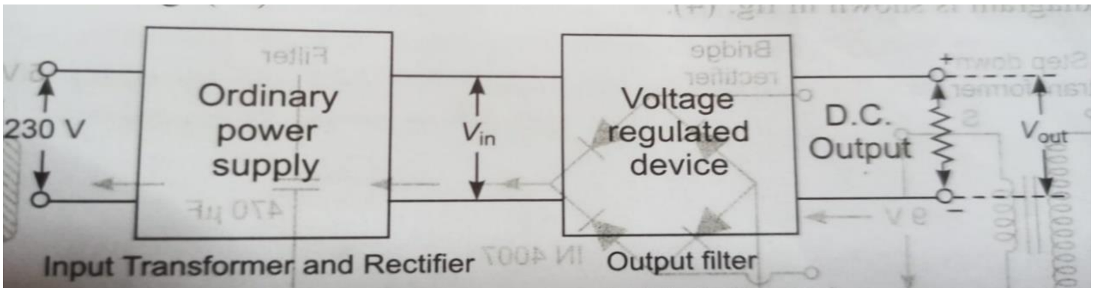
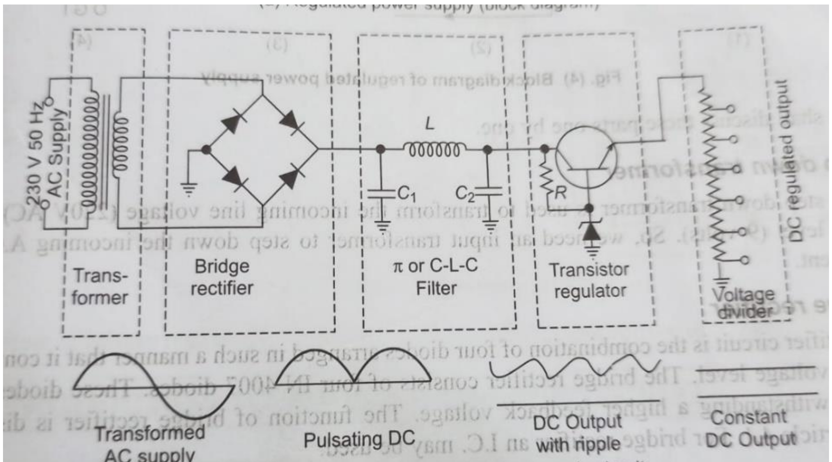
After transistor regulation a voltage divider is used. More often a D.C. voltage is required for operation of electronic circuits.



(a) Regulated power supply (block diagram)

The complete block diagram of regulated power supply is,



(b) Complete regulated DC power supply circuit

CONSTRUCTION OF A 5 VOLT REGULATED POWER SUPPLY:

Power supply converts the output from alternating current power to a steady direct current output. Generally, an A.C. voltage is rectified to give a pulsating D.C., then it is filtered to give a smooth voltage and finally the voltage is regulated to give a constant D.C. output of required level.

The main components to construct a 5-volt regulated power supply are,

1. Step down transformer (9V)
2. Bridge rectifier (4 diode as four IN 4007 or suitable IC)
3. Capacitive filter (470 μf, & 0.1 μf)
4. Voltage regulator circuit (IC LM7805)

1.Step Down Transformer.

The step-down transformer is used to transform the incoming line voltage (220 V AC) down to required level (9 Volts). So, an input transformer to step down incoming A.C. to our requirement.

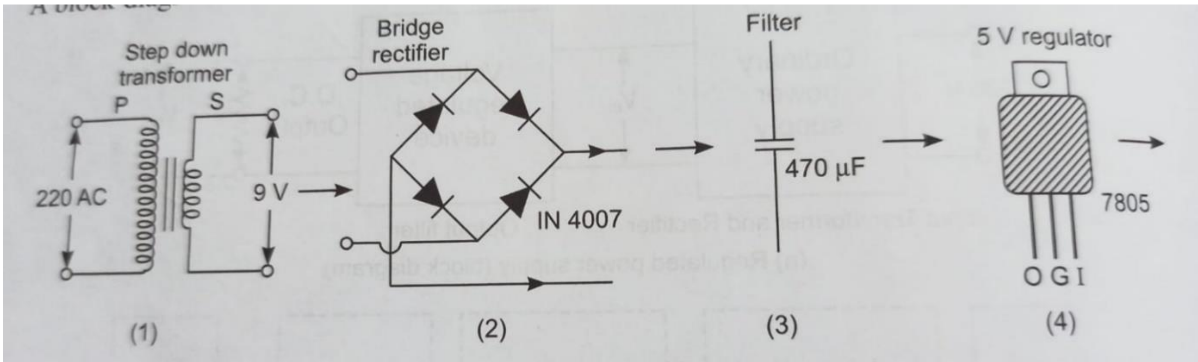


Fig. (4) Block diagram of regulated power supply

2. **Bridge Rectifier**.

A rectifier circuit is the combination of four diodes arranged in such a manner that it converts A.C. into D.C. voltage level. The bridge rectifier consists of four IN 4007 diodes. These diodes have the ability of withstanding a higher feedback voltage.

During the positive input half cycle, the diodes D_1 and D_3 are forward biased (ON position) i.e., they conduct whereas diodes D_2 and D_4 are reverse biased (OFF position), i.e., they do not conduct.

During the negative input half cycle, the diodes D_2 and D_4 are forward biased (ON position) i.e., they conduct whereas diodes D_1 and D_3 are reverse biased (OFF position), i.e., they do not conduct.

The diode selected should have a current rating more than the load current (i.e., nearly 250 mA) and peak reverse voltage should be more than peak secondary transformer voltage. (Peak reverse voltage is the voltage which a diode can sustain when it is reverse biased).

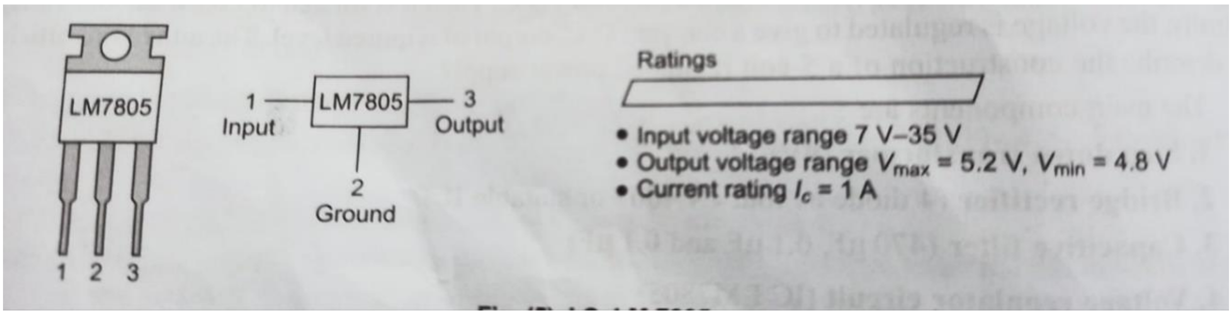
Example: A diode IN 4007 has a current rating of more than 1 amp and peak reverse voltage of 50V.

3.Capacitive Filter:

The rectifier circuit converts the incoming A.C. to D.C. but it does not make a pure D.C. The rectified D.C. has more ripples. The function of the filter is to filter out these ripples. The filter removes the ripples and smoothens the signal. A capacitor of 470 μf is used.

4.Voltage Regulation Circuit:

A voltage is the linear integrated circuit used to provide a regulated constant output voltage.



Voltage regulation is very important because there should be no change in the output even when, there is a change in load, producing a constant output. Voltage regulator uses an IC LM 7805.

LM uses a capacitor 0.1 μf at the output to avoid transient changes in the voltages.

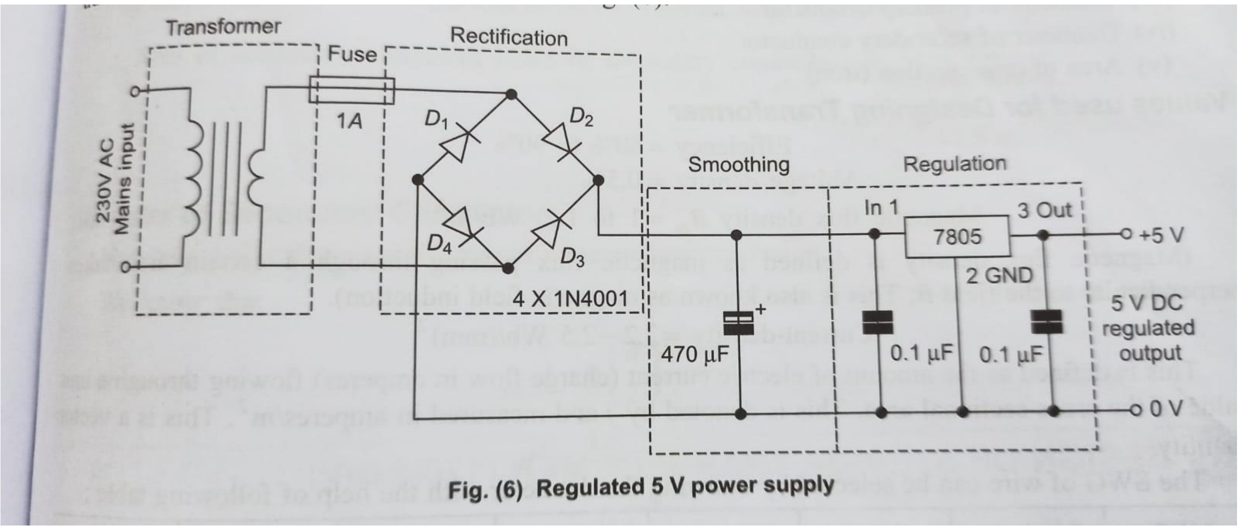


Fig. (6) Regulated 5 V power supply

The output of voltage regulator is 5 V D.C. i.e., 5 V regulated output voltage.

INTRODUCTION TO TRANSFORMER DESIGNING:

The step-up and step-down transformers plays a vital role in the world. Let us consider the designing and calculation of step-up and step-down transformers.

Symbols used for the calculation,

Number of turns used in primary = N_p

Number of turns used in secondary = N_s

Frequency of a.c. in Hz = f

Maximum flux density in core = B_m

Maximum flux in the core = $\emptyset_m$ = B_m x A

Area of cross section of the core = A

Primary voltage = E_p

Secondary Voltage = E_s

Equations used for the calculation of the

Primary Voltage $E_p = 4.44 \times f\,(B_m A) \times N_p$

and

Secondary Voltage $E_s = 4.44 \times f\,(B_m A) \times N_s$

Formula used $\frac{E_p}{E_s} = \frac{N_p}{N_s}$

`

The above relation gives the relation between primary turns and secondary turns with e.m.f.

Designing calculations

(i) Number of primary turns
(ii) Number of secondary turns
(iii) Diameter of the primary conductor
(iv) Diameter of the secondary conductor
(v) Area of cross section (iron)

Values used for the Designing Transformer

Efficiency = 80 % to 90%
Voltage density = 0.5 %
Magnetic flux density B_m = 1 to 2 wb/m^2
(Magnetic flux density is defined as magnetic flux passing through a certain area taken perpendicular to the field B is also known as magnetic field induction).
Current Density = 2.2 – 2.5 wb/(mm)^2
It is defined as the amount of electric current (Charge flow in amperes) flowing through unit value of cross -sectional area denoted by j and measures in amperes/ m^2.
This is a vector quantity.

Area (A) Calculation

Primary (VA) = $\frac{Secondary(VA)}{Efficieny}$

Net area of cross-section = $\sqrt{Primary\ (VA)}$

DESIGN OF STEP-DOWN TRANFORMERCALCULATION (220V -12V):

Let the power rating of the transformer be 50VA.

Primary voltage = 220 V

Secondary Voltage = 12 V

Secondary side Calculation:

Secondary winding current = $\frac{Voltage\ rating}{Secondary\ voltage}$

∴ Secondary winding current = $\frac{50}{12}$ = 4.2 A

We know that, Current density = $\frac{Current}{Area\ of\ conductor}$

`

∴ Area of Secondary conductor (size of secondary conductor) = $\frac{Current}{Current\ Density}$

$= \frac{4.2}{2.3} = 1.8\ \text{mm}^2$

Diameter of secondary Conductor.

To calculate the diameter of secondary conductor.

We know that area of the conductor A = πr^2 (r = radius of the conductor)

or A = $\pi \left(\frac{d}{2}\right)^2 = \frac{\pi d^2}{4}$

$$d^2 = \frac{4A}{\pi}$$

$$d = \sqrt{\frac{4A}{\pi}} = \sqrt{\frac{4\ x\ 18}{3.14}} = \sqrt{2.2930} = 1.5142\ \text{mm}$$

So, the standard wire gauge is 1.5142 mm.

Primary Side Calculation

Primary winding current = $\frac{\textbf{Voltage rating}}{\textbf{Primary voltage}}$

∴ Primary winding current = $\frac{50VA}{220\ V}$

Primary winding current = 0.22727∼0.23 A

Size (or area) of primary conductor = $\frac{Current}{Current\ Density} = \frac{0.23}{2.3}$ =0.1 mm^2

Diameter of Primary Conductor

A = $\pi \left(\frac{d}{2}\right)^2 = \frac{\pi d^2}{4}$

$$d^2 = \frac{4A}{\pi}$$

$$d = \sqrt{\frac{4A}{\pi}} = \sqrt{\frac{4\ x\ 0.1}{3.14}} = \sqrt{0.1274} = 0.357\ \text{mm}$$

`

Calculation of number of turns in primary and secondary

Using e.m.f. per turn formula,

e.m.f. per turn = 4.44 x N x B_m x f x A

Turn per volt = $\frac{1}{4.44\ x\ N\ x\ B_m\ x\ f\ x\ A}$

Substituting the values, we get,

Turn per volt = $\frac{1}{(4.44\ x\ 2.3\ x\ 50\ x\ 0.001451)}$ = 2.6 turns /volt

Number of turns = $\frac{Turns}{Volt}$ x volt

∴ Number of turns in Primary = 2.6 x 220 = 572 turns

Number of turns in Secondary = 2.6 x 12 = 32 turns

DESIGN OF STEP-UP TRANSFORMER (120 -240)

Let the power rating of the transformer be 120VA

Primary Side calculations

Primary winding current = $\frac{Voltage\ rating}{Primary\ voltage}$

∴ Primary winding current = $\frac{120VA}{120\ V}$ = 1A

Size (or area) of primary conductor = $\frac{Current}{Current\ Density}$ = $\frac{1}{2.5}$ =0.4 mm^2

We know that area of the conductor A = πr^2 (r = radius of the conductor)

or A = $\pi\left(\frac{d}{2}\right)^2 = \frac{\pi d^2}{4}$

$4A = \pi d^2$ or $d^2 = \frac{4A}{\pi}$

d = $\sqrt{\frac{4A}{\pi}} = \sqrt{\frac{4\ x\ 0.4}{3.14}} = \sqrt{0.5096}$ = 0.71 mm

So, the standard wire gauge (SWG) is 1.5426 mm.

`

Secondary Side Calculation

Secondary winding current = $\frac{Voltage\ rating}{Secondary\ voltage} = \frac{120\ VA}{240\ V}$ = 0.5A

∴ Area of Secondary conductor = $\frac{Current}{Current\ Density} = \frac{0.5}{2.5}$= 0.2 mm^2

Diameter of secondary Conductor.

$$d = \sqrt{\frac{4A}{\pi}} = \sqrt{\frac{4\ x\ 0.2}{3.14}} = 0.5048\ mm$$

Number of Turns in Primary and Secondary

For Primary

Let e.m.f. per turn = 4.44 x N x B_{max} x f x A

For A Primary (VA) = $\frac{Secondary\ VA}{Efficiency} = \frac{120}{0.8}$ = 150 (VA)

Net area of cross-section = $\sqrt{Primary\ (VA)} = \sqrt{150}$ = 12.25 mm^2

Number of terms in primary $N_p = \frac{emf}{4.44 \text{ x N x Bmax x } f \text{ x A}}$

$$N_p = \frac{120}{4.44\ x\ 1.2\ x 12.25 mm^2\ x\ 50}$$

Changing (mm)^2 into (m)^2 and solving we get, N_p = 368

For secondary, $N_p = \frac{240}{4.44\ x\ 1.2\ x 1225 mm^2\ x\ 50}$ = 736.

No of turns in the Secondary N_s = 736.

DESIGN OF FM RADIO CIRCUIT USING LCR SERIES RESONANCE CIRCUIT:

FM Radio Circuit

FM Radio circuit is the simple circuit that can be tuned to the required frequency locally.

Principle:

Radio is the reception of electromagnetic wave through air. The main principle of this circuit is to tune the circuit to the nearest frequency using the tank circuit. Data to be transmitted is frequency modulated at the transmission and is demodulated at the receiver side.

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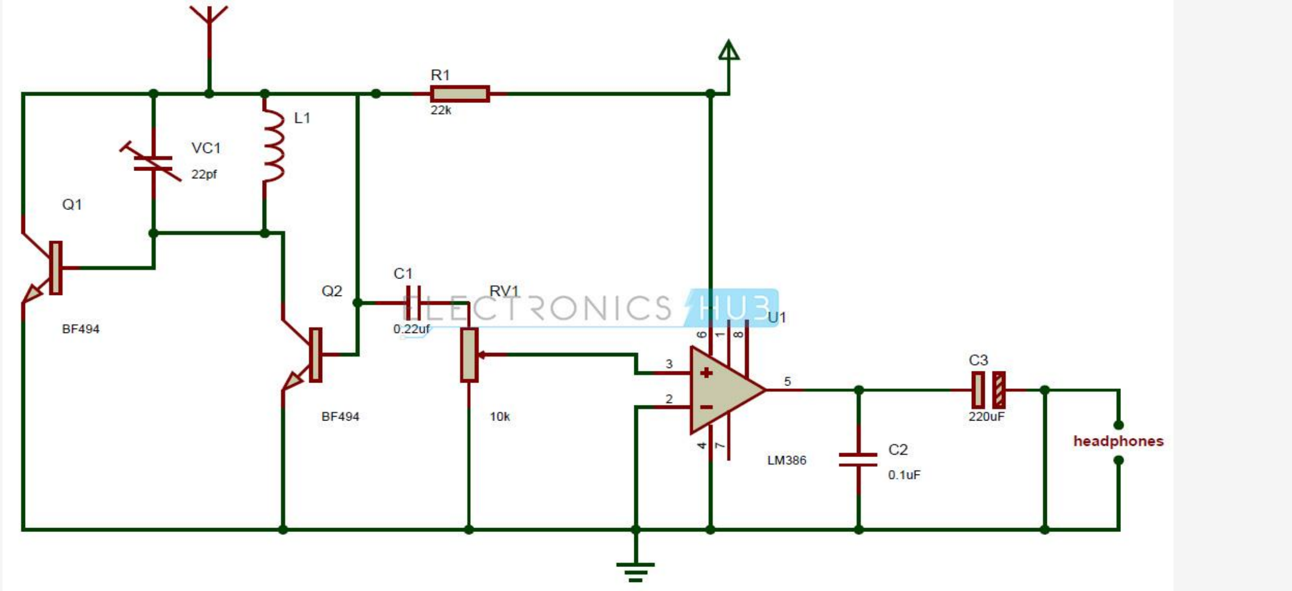
Modulation is the changing the property of the message signal with the respect to the carrier frequency. Frequency range of FM signal is 87.5MHz to 108.0MHz. The output is heard using a speaker.

FM Radio Circuit Diagram:



FM Radio Circuit Diagram

Circuit Components:

- LM 386 IC.
- BF 494 transistor T1, T2.
- Variable resistor.
- Variable capacitor.
- Inductor coil.

FM Radio Circuit Design:

The FM Radio circuit mainly consists of LM386 IC. This is a low voltage audio power amplifier. It has 8 pins. It operates at a supply voltage of 4-12 volts. It has an op-amp internally, which acts as an amplifier. The non-inverting pin is connected to the variable resistor of 10K ohms. Inverting pin of the LM386 IC is connected to the ground. Sixth pin is connected to the V_{CC}. Fourth pin is connected to the ground. Fifth pin is output and is connected to the capacitor which is connected to the speaker or microphone. Another capacitor is connected to ground pin. Sixth pin is the supply pin connected to the supply voltage. This amplifies the incoming frequency modulated signal.

BF494 is an NPN RF transistor. Initially it is open circuited. It starts conducting only when base gets the required cut off voltage. Base of the transistor is connected to the base of the variable resistor through a capacitor of 0.22μF. Emitter pin is connected to the ground. Collector is connected to the tank circuit. Base of transistor Q_2 is connected to the tank circuit. Emitter pin is connected to the ground and collector is connected to the supply through a resistor of 22K ohms. The variable resistor controls the volume to the input amplifier. These transistors are used for detecting the frequency modulated signals.

`

Output of the IC is connected to the headphones or speaker through a capacitor of 220μf, 25V rated. The head phone or speaker will have two wires out. One is connected to the output of the capacitor and the other pin is connected to the ground pin.

Tank circuit consists of a coil and a variable capacitor. This is connected to the antenna. This is the main part of the circuit as it tunes the radio to the required local frequency. In this tank circuit coil plays a main role. Coil is a copper wire wind into fixed number of turns.

Operation of The Radio Circuit:

To operate the FM Radio circuit following steps are to be followed:

- Initially connect the circuit as shown in the figure.
- Connect the power supply to the circuit.
- Now press the switch.
- Now adjust the frequency of the circuit by varying the trim pot (variable capacitor) of the tank circuit.
- Thus, the circuit starts tuning to the nearest frequency.
- When the frequency of incoming signal is matched sound can be heard through the headphone or speaker.
- Now tune the circuit to another frequency using tank circuit.
- You can listen another sound incoming at that particular frequency.
- Adjust the variable resistor to increase or decrease the volume.

Applications of FM Radio Circuit

1.The circuit acts as a pocket-sized radio, by tuning to the particular frequency.

2.With a little modification it can be used in applications of voice transmission.

Limitations of the Circuit:

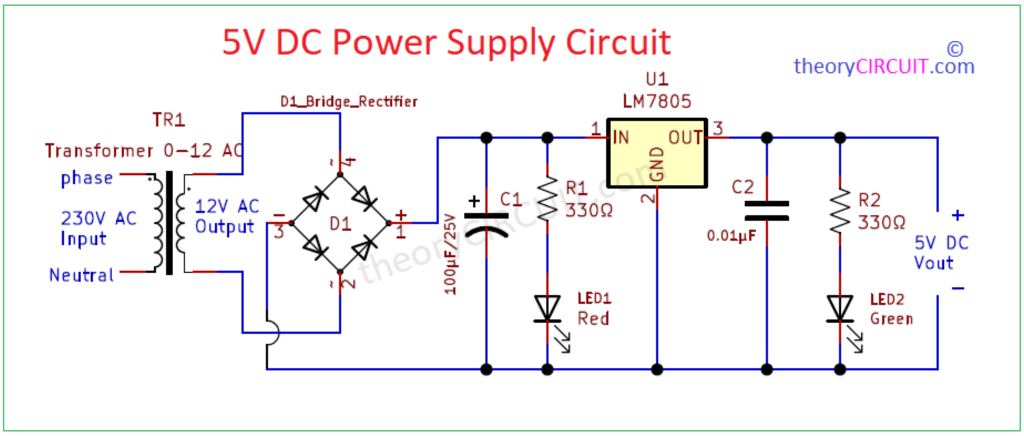
This is a theoretical circuit and it requires some changes to implement it practically.

DESIGN OF A SIMPLE 5 VOLTS DC CHARGER:

Common Electronic Circuits and Devices or Microcontrollers Requires 5V DC power supply. We use Integrated Circuit LM7805 (Positive Voltage Regulator) to give Regulated Constant 5 Volt DC from unregulated DC supply.

To indicate the presence of Input Voltage and Output Voltage here we use two LEDs. This Circuit designed to work as an Independent power source for electronic devices and circuits.

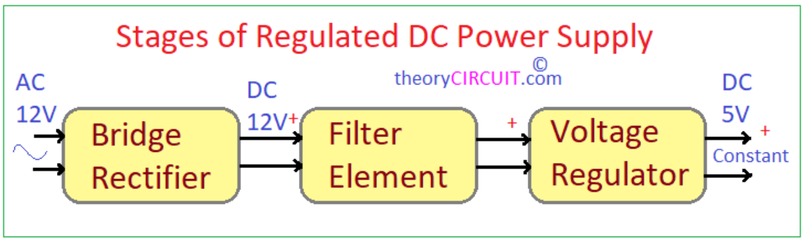
Circuit Diagram



Components Required (BOM)

S. No	Designator	Value	Part Number	QUANTITY
1	TR1	230V to 0-12V AC	0-12V Stepdown Transformer	1
2	R1, R2	330Ω	–	1
3	C1 C2	100µF/25V 0.01µF	Electrolytic Disc capacitor	1 1
4	D1	–	Bridge Rectifier Module	1
5	U1	LM7805	LM7805_TO220	1
6	**LED1** **LED2**	**Red** **Green**	– –	**1** **1**

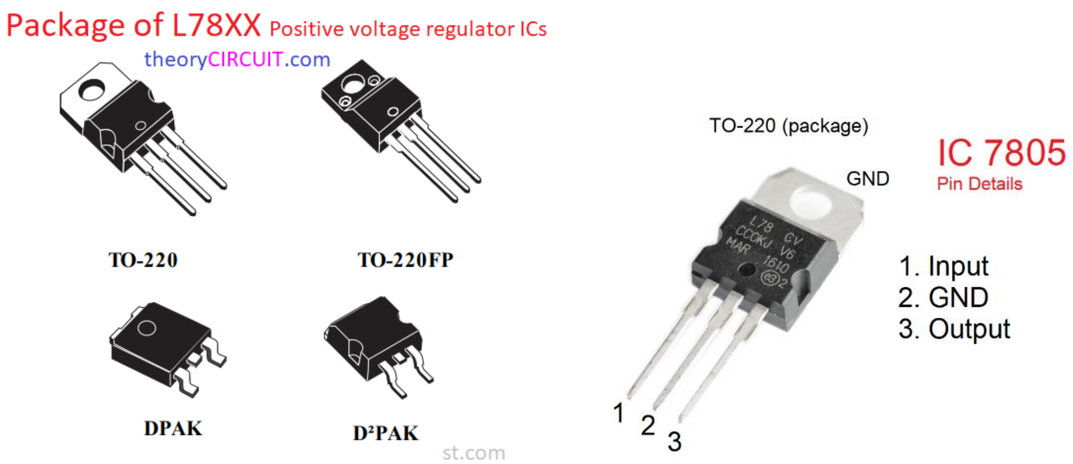
Construction & Working:

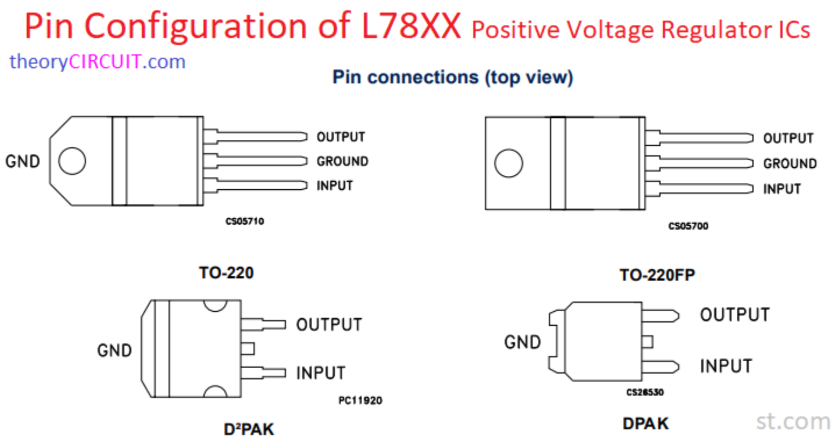


Every DC power supply circuit have these stages to give Regulated Constant DC power supply. Here 230V AC main supply step down to 12V AC by using Step down Transformer then Bridge Rectifier module converts AC supply to DC supply after that to remove unwanted AC ripples from DC supply filter elements (Capacitor C_1) used. After filter element we get 12 Volt DC supply, to Reduce this supply IC LM7805 employed here, at the output terminal of LM7805 we get constant Regulated 5V DC supply.

IC LM7805

This LM78XX series of fixed-voltage integrated-circuit voltage regulators is designed for a wide range of Regulator applications. These applications include on PCB board regulation for elimination of noise and distribution problems associated with single point regulation. Each of these regulators can deliver up to 1.5 A of output current. The internal current-limiting and thermal shut down features of these regulators essentially make them immune to overload.





Some notable features of LM7805 Positive voltage regulator are,
3-Terminal Regulators
Output Current up to 1.5 A
Internal Thermal-Overload Protection
High Power-Dissipation Capability
Internal Short-Circuit
Output Transistor Safe Area Compensation.

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P.B. SIDDHARTHA COLLEGE OF ARTS & SCIENCE: VIJAYAWADA-10

QUESTION BANK

SEMESTER-VI

Course Code: PHYSET01

Title of the Paper: APPLICATIONS OF ELECTRICITY & ELECTRONICS

Programme: III B. Sc (MPC-B & MPCS)

UNIT-I:

INTRODUCTION TO PASSIVE ELEMENTS

(a)PASSIVE ELEMENTS

ESSAY QUESTIONS

1. Explain the construction, working of any four types of resistors. Mention their applications.
2. Discuss colour coding in resistance. Give Examples.
3. Explain the principle of Inductors. Explain any four types of Inductors.
4. Explain the principle of Capacitor. Explain any four types of capacitors.
5. Obtain the expressions for charging & discharging of capacitors.

(a)Applications of Passive Elements.

SHORT QUESTIONS

1. Explain the role of capacitors in the electronic circuits.
2. What is a resistor? How a resistor is used in a heating element in heaters.
3. How does a resistor act as a fuse element?
4. Discuss the application of inductors in radio tuning circuit.
5. Explain briefly parallel combination of resistors (Current Division).
6. Explain briefly series combination of resistors (Voltage Division).

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UNIT-II:

POWER SOURCES (BATTERIES)

Power Sources:

ESSAY QUESTIONS

1. Explain the construction, working principle of Lead -Acid battery. Write any four applications.

2. Describe the working principle of Li-ion battery. Write any four applications.

SHORT QUESTIONS

1.Obtain equations for the Series & Parallel combination of batteries.
2.Obtain equations for the Series - Parallel combination of batteries.

B. Network Theorems for DC Circuits

ESSAY QUESTIONS

1. State and prove Thevenin's Theorem
2. Briefly explain constant voltage & constant current sources and also write their applications.

SHORT QUESTIONS

1. State and prove Norton's Theorem.
2. State and prove Maximum Power Transfer Theorem.

UNIT-III:

ALTERNATING & DIRECT CURRENTS

ESSAY QUESTIONS

1. Explain the construction, principle and working of AC. generator. Write any two advantages & disadvantages.
2. Explain the construction, principle and working of DC. generator. Write any two advantages & disadvantages.

SHORT QUESTIONS

1.Write any five differences between DC and AC generators.

(A) TRANSFORMERS

ESSAY QUESTIONS

1. Explain the construction and working principle of a transformer.

2. (a) What is meant by a regulated power supply?
   (b) Explain the role of transformer in a regulated power supply.
3. Write a short note on Open circuit and short circuit tests in a transformer.

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SHORT QUESTIONS

1. Write a short note on Step -up and step-down transformers
2. Obtain the relation between primary and secondary turns of the transformer with EMF of a transformer.

UNIT-IV:

MODULATION CIRCUITS (SKILL BASED)

ESSAY QUESTIONS

1.Explain how A.M. signals are detected using a diode detector.

2.Explain the functioning of A.M. transmitter.

3.Discuss briefly the functioning of A.M. receiver.

SHORT QUESTIONS

1. Obtain the expression for modulation index of Amplitude Modulation.
2. Derive the Power relations in an amplitude modulated wave.

B. FREQUENCY MODULATION:

ESSAY QUESTIONS

1.Explain with a block diagram the functioning of FM transmitter.

SHORT QUESTIONS

1. Obtain the expression for Frequency Modulated Wave & modulation index of Frequency Modulation
2. Explain briefly the working of FM receiver

UNIT-V:

APPLICATIONS OF EM INDUCTION & POWER SUPPLIES (SKILL BASED)

ESSAY QUESTIONS

1. Describe the construction & working principle of a DC Motor.

SHORT QUESTIONS

1. Obtain the expressions for the calculation of Power, Voltage and Current in a DC motor.

(B) ESSAY QUESTIONS

1. Explain the construction & working of D.C. regulated power supply.

2. Describe the construction of a 5-Volt regulated power supply.

3. Explain the design of FM Radio circuit using LCR series resonance circuit.

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SHORT QUESTIONS

1. Give the calculation of design of a step- down transformer (range 220-12 V)

2. Give the calculation of design of a step- up transformer (range 120-240 V)

3. How do you design a simple 5 V DC Charger?