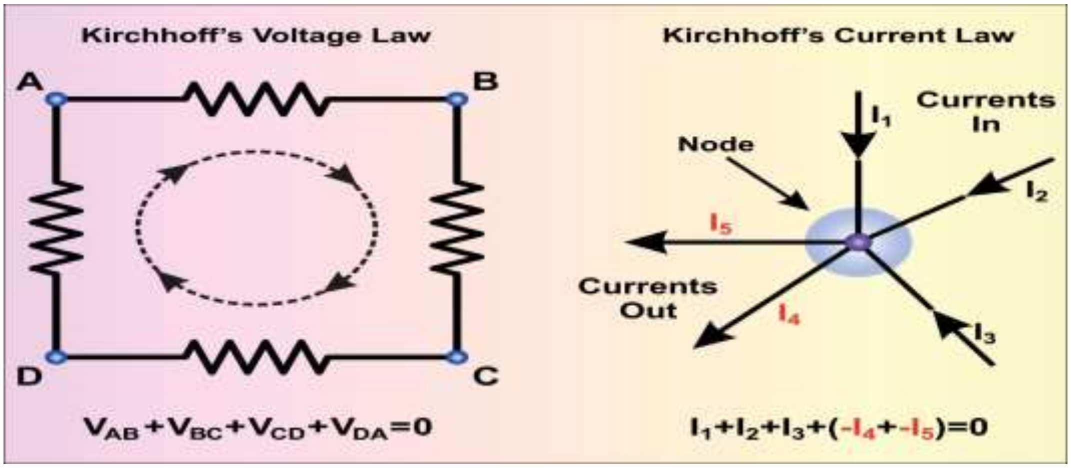
KIRCHHOFF’S LAWS – EXAM NOTES

1. Kirchhoff’s Voltage Law (KVL)

Statement:
The algebraic sum of all voltages in any closed loop of an electrical network is zero.
$\Sigma V = 0$

Principle:
This law is based on the law of conservation of energy. Energy supplied by sources is equal to energy absorbed by circuit elements.

Sign Convention:
- Voltage rise → Positive
- Voltage drop → Negative
- Across resistor in direction of current → $-IR$



Application:
Used for mesh or loop analysis. Suitable for series circuits.

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2. Kirchhoff’s Current Law (KCL)

Statement:
The algebraic sum of currents at a node (junction) in an electrical network is zero.
$\Sigma I = 0$

Principle:
This law is based on the law of conservation of charge. Total current entering a node is equal to total current leaving the node.

Sign Convention:
- Current entering node → Positive
- Current leaving node → Negative

Application:
Used for nodal analysis. Suitable for parallel circuits.

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3. Comparison Between KVL and KCL

KVL:
- Applied to loops
- Based on conservation of energy
- Equation: $\Sigma V = 0$

KCL:
- Applied to nodes
- Based on conservation of charge
- Equation: $\Sigma I = 0$

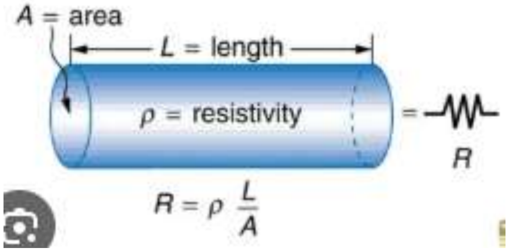
Exam Notes / Key Points

- Current direction can be assumed arbitrarily.
- Negative sign indicates opposite direction.
- Always draw circuit diagram neatly.
- Combine Kirchhoff's laws with Ohm's law for numerical problems.

RESISTANCE LAW – UNIVERSITY EXAM NOTES

Statement:
The resistance of a conductor is directly proportional to its length and inversely proportional to its cross-sectional area, provided temperature remains constant.

$R \propto L$
$R \propto 1/A$



Combining,
$R = \rho L / A$

where,
R = Resistance (ohms)
L = Length of conductor (meters)
A = Cross-sectional area (m^2)

ρ = Resistivity of material (ohm-meter)

Explanation:
When the length of a conductor increases, electrons travel a longer path, causing more collisions and increasing resistance. Increasing cross-sectional area allows more electrons to flow, thereby reducing resistance.

Factors Affecting Resistance:
- Length of conductor
- Cross-sectional area
- Nature of material (resistivity)
- Temperature

Units:
Resistance → Ohm (Ω)
Resistivity → Ohm-meter (Ω·m)

Applications:
- Design of electrical wires and cables
- Selection of materials for resistors
- Electrical and electronic circuit design

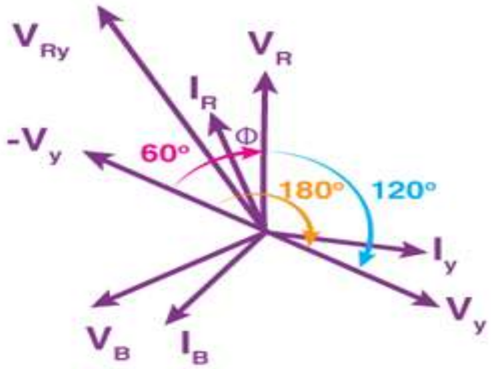
Exam Points:
- State resistance law clearly
- Write formula $R = \rho L/A$
- Mention assumptions (constant temperature)
- Define resistivity with unit

Line voltage and Phase Voltage in a Star connection

For any polyphase system, Line voltage is defined as the voltage between two given phase. Whereas the phase voltage is the voltage between the given phase and neutral. The relation between line voltage and phase voltage are proportionate.

Three phase voltage or star connection generally consists of voltage flowing through three different channels, for our simplicity we name it Voltage in the red line (V_R), Voltage in Yellow line(V_Y), the voltage in blue line(V_B). The voltage in all three channels is equal. Mathematically given as-

$$V_{ph} = V_R = V_Y = V_B$$



Here, line current = Phase current

$$\Rightarrow I_R = I_Y = I_B = I_l$$

If we extend V_Y backward we get $-V_Y$ and draw a resultant voltage of V_R and V_Y we get-

$$V_{RY} = V_R + (-V_Y)$$
$$\Rightarrow V_l = |V_{RY}| = \sqrt{V_R^2 + V_Y^2 + 2V_RV_YCos60}$$
$$= \sqrt{V_{ph}^2 + V_{ph}^2 + 2V_{ph}V_{ph}\tfrac{1}{2}}$$

Because

$$cos60 = \frac{1}{2}$$

Thus, we arrive at the **relation between line voltage and phase voltage in star connection** in an electric circuit –

$$V_l = \sqrt{3}V_{ph}$$

Where,

- V_l is the **Line voltage**.
- V_{ph} is the **Phase voltage.**
- Measure using the unit of voltage Volt (V).

Hope you understood the relation between line voltage and phase voltage in a polyphase system or connection.

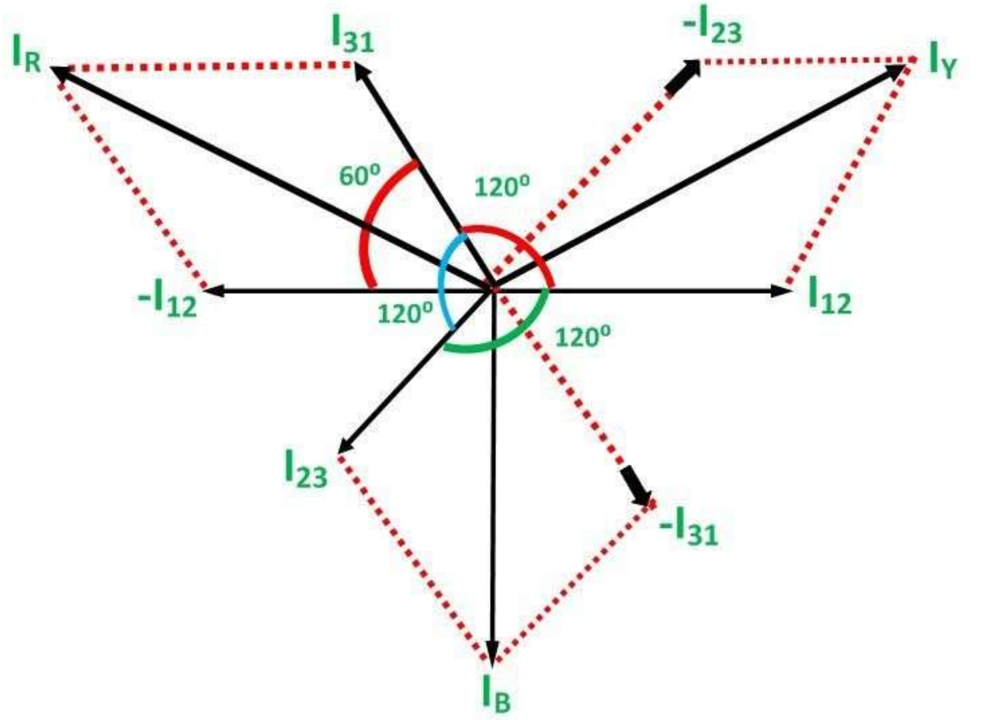
Relation Between Phase Current and Line Current in Delta Connection

Delta Connection In a 3 Phase System

In Delta (Δ) or Mesh connection, the finished terminal of one winding is connected to start terminal of the other phase and so on which gives a closed circuit. The three-line conductors are run from the three junctions of the mesh called Line Conductors.

As in the balanced system the three-phase current I_{12}, I_{23} and I_{31} are equal in magnitude but are displaced from one another by 120° electrical.

The phasor diagram is shown below:



Circuit Globe

Hence,

$$I_{12} = I_{23} = I_{31} = I_{ph}$$

If we look at figure A, it is seen that the current is divided at every junction 1, 2 and 3. Applying Kirchhoff's Law at junction 1,

The Incoming currents are equal to outgoing currents.

$$\overline{I_{31}} = \overline{I_R} + \overline{I_{12}}$$

And their vector difference will be given as:

$$\overline{I_R} = \overline{I_{31}} - \overline{I_{12}}$$

The vector I_{12} is reversed and is added in the vector I_{31} to get the vector sum of I_{31} and –I_{12} as shown above in the phasor diagram. Therefore,

$$I_R = \sqrt{I_{31}^2 + I_{12}^2 + 2I_{31}I_{12}\cos 60^\circ} \quad \text{or}$$

$$I_L = \sqrt{I_{ph}^2 + I_{ph}^2 + 2I_{ph}I_{ph} \times 0.5}$$

As we know, $I_R = I_L$, therefore,

$$I_L = \sqrt{3I_{ph}^2} = \sqrt{3}I_{ph}$$

Similarly,

$$\overline{I_Y} = \overline{I_{12}} - \overline{I_{23}} \quad \text{or} \quad I_L = \sqrt{3}I_{ph} \quad \text{and}$$

$$\overline{I_B} = \overline{I_{23}} - \overline{I_{31}} \quad \text{or} \quad I_L = \sqrt{3}I_{ph}$$

Hence, in delta connection line current is root three times of phase current.

$$\text{Line Current} = \sqrt{3} \text{ x Phase Current}$$

This is all about Delta Connection In a 3 Phase System.

Transformer

A transformer is a device used in the power transmission of electric energy. The transmission current is AC. It is commonly used to increase or decrease the supply voltage without a change in the frequency of AC between circuits. The transformer works on the basic principles of electromagnetic induction and mutual induction.

A transformer works on the principle of Faraday's Law of Electromagnetic Induction, using mutual induction to transfer electrical energy between circuits without a direct connection, changing voltage levels (stepping up or down) while keeping frequency constant. An alternating current (AC) in the primary coil creates a continuously changing magnetic flux in the iron core, which then induces a corresponding voltage in the secondary coil, with the voltage ratio determined by the turns ratio of the coils.

Construction of a transformer

A transformer's basic construction features two insulated copper wire coils (primary and secondary) wound around a laminated soft iron core, which provides a path for magnetic flux, enabling energy transfer via mutual induction from AC input (primary) to AC output (secondary) by changing voltage based on the turns ratio. The laminations reduce energy loss, and insulation between coils and core prevents short circuits, allowing for step-up (more secondary turns) or step-down (fewer secondary turns) voltage changes.

Key Components

- Core:

Made from thin, laminated silicon steel sheets stacked together. This creates a low-reluctance path for magnetic flux and reduces eddy current losses, improving efficiency.

- Primary Winding:

The input coil connected to the AC power source. An alternating current here creates a changing magnetic field in the core.

- Secondary Winding:

The output coil connected to the load. The changing magnetic flux from the core induces a voltage in this coil.

- Insulation:

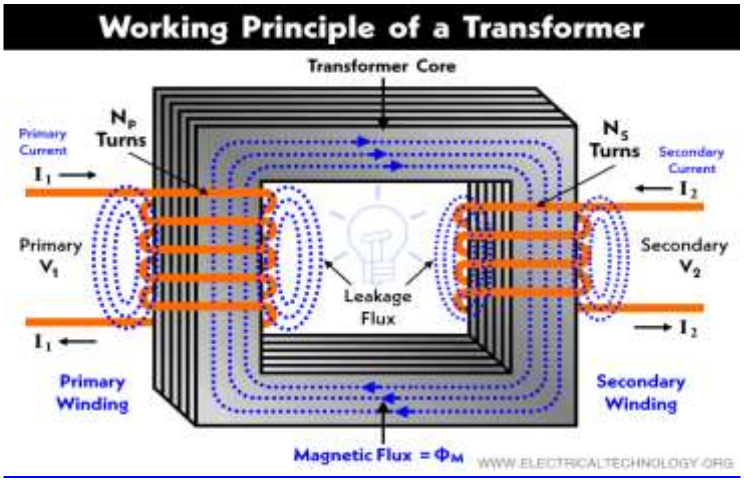
High-grade insulation separates the primary and secondary coils and insulates them from the core, preventing electrical breakdown.

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 Law’s 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 laws of electromagnetic induction.

The transformer is based on two principles: first, that an electric current can produce a magnetic field (electromagnetism), and, second that a changing magnetic field within a coil of wire induces a voltage across the ends of the coil (electromagnetic induction). Changing the current in the primary coil changes the magnetic flux that is developed. The changing magnetic flux induces a voltage in the secondary coil.



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.

EMF Equation of a Transformer

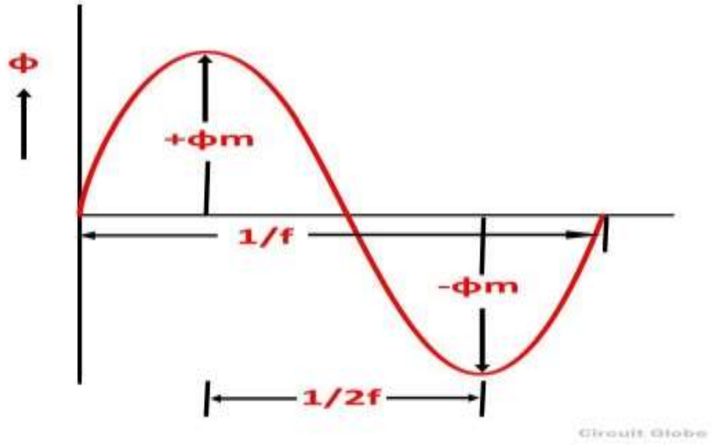
When a sinusoidal voltage is applied to the primary winding of a transformer, alternating flux ϕ_m sets up in the iron core of the transformer. This sinusoidal flux links with both primary and secondary winding. The function of flux is a sine function.

The rate of change of flux with respect to time is derived mathematically.

The derivation of the **EMF Equation** of the transformer is shown below. Let

- ϕ_m be the maximum value of flux in Weber
- f be the supply frequency in Hz
- N_1 is the number of turns in the primary winding
- N_2 is the number of turns in the secondary winding

Φ is the flux per turn in Weber



As shown in the above figure that the flux changes from + ϕ_m to – ϕ_m in half a cycle of 1/2f seconds.

By Faraday's Law

Let E_1 be the emf induced in the primary winding

$$E_1 = -\frac{d\psi}{dt} \dots\dots\dots (1)$$

Where $\Psi = N_1\phi$

$$\text{Therefore, } E_1 = -N_1 \frac{d\varphi}{dt} \quad \dots\dots\dots(2)$$

Since ϕ is due to AC supply $\phi = \phi_m \text{Sinwt}$

$$E_1 = -N_1 \frac{d}{dt} (\varphi_m \text{ Sinwt})$$

$$E_1 = -N_1 w\varphi_m \text{ Coswt}$$

$$E_1 = N_1 w\varphi_m \text{ Sin}(wt - \pi/2) \dots\dots\dots.(3)$$

So the induced emf lags flux by 90 degrees.

Maximum valve of emf

$$E_1\text{max} = N_1 w\varphi_m \dots\dots\dots.(4)$$

But $w = 2\pi f$

$$E_1\text{max} = 2\pi f N_1 \varphi_m \dots\dots\dots.(5)$$

Root mean square RMS value is

$$E_1 = \frac{E_{1max}}{\sqrt{2}} \dots\dots\dots..(6)$$

Putting the value of E_1max in equation (6) we get

$$E_1 = \sqrt{2}\pi f N_1 \varphi_m \dots\dots.(7)$$

Putting the value of $\pi = 3.14$ in the equation (7) we will get the value of E_1 as

$$E_1 = 4.44 f N_1 \varphi_m \dots\dots\dots(8)$$

Similarly

$$E_2 = \sqrt{2}\pi f N_2 \varphi_m$$

Or

$$E_2 = 4.44 f N_2 \varphi_m \dots\dots\dots(9)$$

Now, equating the equation (8) and (9) we get

$$\frac{E_2}{E_1} = \frac{4.44 f N_2 \varphi_m}{4.44 f N_1 \varphi_m}$$

Or

$$\frac{E_2}{E_1} = \frac{N_2}{N_1} = K$$

The above equation is called the **turn ratio** where K is known as the transformation ratio.

The equation (8) and (9) can also be written as shown below using the relation

($\phi m = B_m \times A_i$) where A_i is the iron area and B_m is the maximum value of flux density.

$$E_1 = 4.44 N_1 f B_m A_i \quad \text{Volts} \quad \text{and} \quad E_2 = 4.44 N_2 f B_m A_i \quad \text{Volts}$$

$$\frac{\text{R.M.S value}}{\text{Average value}} = \text{Form factor} = 1.11$$

For a sinusoidal wave

Here 1.11 is the form factor.

DC Generator

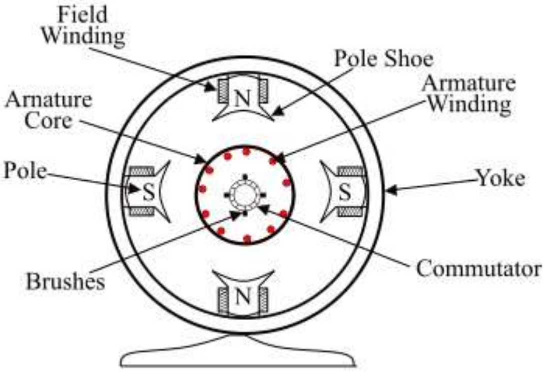
A DC generator is an electromechanical energy conversion device that converts mechanical power into DC electrical power through the process of electromagnetic induction.

A DC generator 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 generator has a field winding and an armature winding.

The EMF induced in the armature winding of a DC generator is alternating one and is converted into direct voltage using a commutator mounted on the shaft of the generator. The armature winding of DC Generator is placed on the rotor whereas the field winding is placed on the stator.

Construction of a DC Generator

Here is the schematic diagram of a DC Generator



A DC generator consists of six main parts, which are as follows

Yoke

The outer frame of a DC generator is a hollow cylinder made up of cast steel or rolled steel is known as yoke. The yoke serves following two purposes

- It supports the field pole core and acts as a protecting cover to the machine.

- It provides a path for the magnetic flux produced by the field winding.

Magnetic Field System

The magnetic field system of a DC generator is the stationary part of the machine. It produces the main magnetic flux in the generator. It consists of an even number of pole cores bolted to the yoke and field winding wound around the pole core. The field system of DC generator has salient poles i.e. the poles project inwards and each pole core has a pole shoe having a curved surface. The pole shoe serves two purposes

- It provides support to the field coils.
- It reduces the reluctance of magnetic circuit by increasing the cross-sectional area of it.

The pole cores are made of thin laminations of sheet steel which are insulated from each other to reduce the eddy current loss. The field coils are connected in series with one another such that when the current flows through the coils, alternate north and south poles are produced in the direction of rotation.

Armature Core

The armature core of DC generator is mounted on the shaft and rotates between the field poles. It has slots on its outer surface and the armature conductors are put in these slots. The armature core is a made up of soft iron laminations which are insulated from each other and tightly clamped together. In small machines, the laminations are keyed directly to the shaft, whereas in large machines, they are mounted on a spider. The laminated armature core is used to reduce the eddy current loss.

Armature Winding

The insulated conductors are put into the slots of the armature core. The conductors are suitably connected. This connected arrangement of conductors is known as armature winding. There are two types of armature windings are used - wave winding and lap winding.

Commutator

A commutator is a mechanical rectifier which converts the alternating emf generated in the armature winding into the direct voltage across the load terminals. The commutator is made of wedge-shaped copper segments insulated from each other and from the shaft by mica sheets. Each segment of commutator is connected to the ends of the armature coils.

Brushes

The brushes are mounted on the commutator and are used to collect the current from the armature winding. The brushes are made of carbon and is supported by a metal box called brush holder. The pressure exerted by the brushes on the commutator is adjusted and maintained at constant value by means of springs. The current flows from the armature winding to the external circuit through the commutator and carbon brushes.

Working Principle of DC Generator

The working principle of DC generator is based on the **Faradays law of electromagnetic induction**. According to this law, when the magnetic flux liked to a conductor or coil changes an EMF is induced in the conductor or coil. The magnitude of this induced EMF is given by,

$e=Nd\phi dt\cdots(1)$

Where, ϕ is the flux linkage of the coil and N is the number of turns in the coil.

In case of a DC generator, the magnetic flux (ϕ) remains stationary and the coil rotates. The EMF induced where the coil is rotating and flux is stationary, is known as **dynamically induced EMF**.

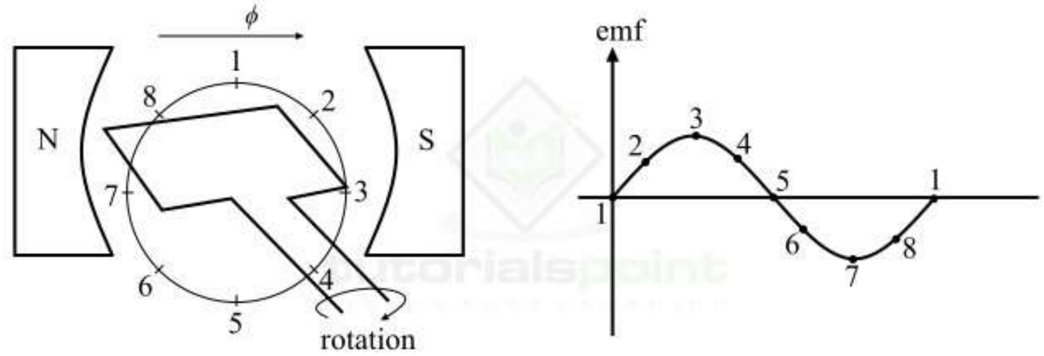


Figure - Working Principle of DC Generator

In order to understand the working principle of a DC generator, we consider a single loop DC generator (i.e. $N = 1$) as shown in above figure. Here, the coil is rotated by some prime mover (a source of mechanical energy), and there is a change in the magnetic flux linkage to the coil.

Let ϕ be the average magnetic flux produced by each magnetic pole of the machine, then the average induced EMF in the generator is given by,

$Eav=d\phi dt=\text{Fluxcutpersecbythecoil}$

$\Rightarrow Eav=\text{Fluxcutinonerotation}\times\text{No.ofrotationspersec}$

$\Rightarrow Eav=(\text{Fluxperpole}\times\text{No.ofpoles})\times\text{No.ofrotationspersec}$

$\therefore Eav=\phi\times P\times n\cdots(2)$

Where, P is the total number of poles in the generator and n is the speed of the coil in rotation per second. The expression in the Equation-(2) gives the average induced EMF in a single loop DC generator.

The following points explain the working principle of a DC generator −

- **Position 1** − The induced EMF is zero because, the movement of coil sides is parallel to the magnetic flux.
- **Position 2** − The coil sides are moving at an angle to the magnetic flux, and hence a small EMF is generated in the loop.

- **Position 3** − The coil sides are moving at right angle to the magnetic flux, therefore the induced EMF is maximum.
- **Position 4** − The coil sides are cutting the magnetic flux at an angle, thus a reduced EMF is induced in the coil sides.
- **Position 5** − No flux linkage with the coil side and the coil sides are moving parallel to the magnetic flux. Therefore, no EMF is induced in the coil.
- **Position 6** − The coil sides move under a pole of opposite polarity and hence the polarity of induced EMF is reversed. The maximum EMF will induce in this direction at position 7 and zero when it is at position 1. This cycle repeats with rotation of the coil.

In this way, EMF is induced in a DC generator. Though, this induced EMF is alternating in nature, which is then converted in the unidirectional EMF by using a device called **commutator**.

The direction of induced EMF in the armature conductor of the DC generator is determined by the **Fleming right hand rule (FRHR)** which we discussed in the *module-1 (basic concepts)* of this tutorial.

The expression which gives the magnitude of EMF generated in a DC generator is called **EMF equation of DC generator**. We shall now drive the expression for the EMF induced in a DC generator.

Let,

- ϕ = flux per pole
- P = number of poles in the generator
- Z = no.of armature coductors
- A = no.of parallel paths
- N = speed of armature in RPM
- E = EMF generated

Thus, the magnetic flux (*in weber*) cut by a conductor in one revolution of the armature is given by,

$d\phi=P\times\phi$

If N is the number of revolution per minute, then the time (*in seconds*) taken complete one revolution is,

$dt=60/N$

According to Faradays law of electromagnetic induction, the EMF induced per conductor is given by,

$$\text{EMF/conductor} = \frac{d\phi}{dt} = \frac{P\phi}{(60/N)} = \frac{P\phi N}{60}$$

The total EMF generated in the generator is equal to the EMF per parallel path, which is the product of EMF per conductor and the number of conductors in series per parallel path, i.e.,

E=(EMF/Conductor)×(No. of conductors/parallel path)

$$\Rightarrow E = \frac{P\phi N}{60} \times \frac{Z}{A}$$

$$\therefore E = \frac{NP\phi N}{60A} \cdots (1)$$

Equation (1) is called *the EMF equation of DC generator*.

For wave winding,

Number of parllel paths, A=2

$$\text{Number of parllel paths}, A = 2$$

$$\therefore E = \frac{NP\phi Z}{120}$$

∴

For lap winding,

Numberofparllelpaths,A=P

$$\text{Number of parllel paths}, A = P$$

$$\therefore E = \frac{N\phi Z}{60}$$

For a given DC generator, *Z, P* and *A* are constant so that the generated EMF (E) is directly proportional to flux per pole (ϕ) and speed of armature rotation (*N*)

Cathode Ray Oscilloscope (CRO)

Definition: The cathode ray oscilloscope (CRO) is a type of electrical instrument which is used for showing the measurement and analysis of waveforms and others electronic and electrical phenomenon. It is a very fast X-Y plotter shows the input signal versus another signal or versus time. The CROs are used to analyse the waveforms, transient, phenomena, and other time-varying quantities from a very low-frequency range to the radio frequencies.

The CRO is mainly operated on voltages. Thus, the other physical quantity like current, strain, acceleration, pressure, are converted into the voltage with the help of the transducer and thus represent on a CRO. It is also used for knowing the waveforms, transient phenomenon, and other time-varying quantity from a very low-frequency range to the radio frequencies.

The CRO has Stylus (i.e., a luminous spot) which move over the display area in response to an input voltage. This luminous spot is produced by a beam of electrons striking on a fluorescent screen. The normal form of the CRO uses a horizontal input voltage which is an internally generated ramp voltage called “time base”.

The horizontal voltage moves the luminous spot periodically in a horizontal direction from left to right over the display area or screen. The vertical voltage is the voltage under investigation. The vertical voltage moves the luminous spot up and down on the screen. When the input voltage moves very fast on the screen, the display on the screen appears stationary. Thus, CRO provides a means of the visualising time-varying voltage.

Construction of Cathode Ray Oscilloscope

The main parts of the cathode ray oscilloscope are as follows.

1. Cathode Ray Tube
2. Electronic Gun Assembly
3. Deflecting Plate
4. Fluorescent Screen For CRT
5. Glass Envelop

Their parts are explained below in details.

1. Cathode Ray Tube

The cathode ray tube is the vacuum tube which converts the electrical signal into the visual signal. The cathode ray tube mainly consists the electron gun and the electrostatic deflection plates (vertical and horizontal).The electron gun produces a focused beam of the electron which is accelerated to high frequency.

The vertical deflection plate moves the beams up and down and the horizontal beam moved the electrons beams left to right. These movements are independent to each other and hence the beam may be positioned anywhere on the screen.

2. Electronic Gun Assembly

The electron gun emits the electrons and forms them into a beam. The electron gun mainly consists a heater, cathode, a grid, a pre-accelerating anode, a focusing anode and an accelerating anode. For gaining the high emission of electrons at the moderate temperature, the layers of barium and strontium is deposited on the end of the cathode.

After the emission of an electron from the cathode grid, it passes through the control grid. The control grid is usually a nickel cylinder with a centrally located co-axial with the CRT axis. It controls the intensity of the emitted electron from the cathode.

The electron while passing through the control grid is accelerated by a high positive potential which is applied to the pre-accelerating or accelerating nodes.

The electron beam is focused on focusing electrodes and then passes through the vertical and horizontal deflection plates and then goes on to the fluorescent lamp. The pre-accelerating and accelerating anode are connected to 1500v, and the focusing electrode is connected to 500 v. There are two methods of focusing on the electron beam. These methods are

- Electrostatic focusing
- Electromagnetic focusing.

The CRO uses an electrostatic focusing tube.

3. Deflecting Plate

The electron beam after leaving the electron gun passes through the two pairs of the deflecting plate. The pair of plate producing the vertical deflection is called a vertical deflecting plate or Y plates, and the pair of the plate which is used for horizontal deflection is called horizontal deflection plate or X plates.

4. Fluorescent Screen for CRT

The front of the CRT is called the face plate. It is flat for screen sized up to about 100mm×100mm. The screen of the CRT is slightly curved for larger displays. The face plate is formed by pressing the molten glass into a mould and then annealing it.

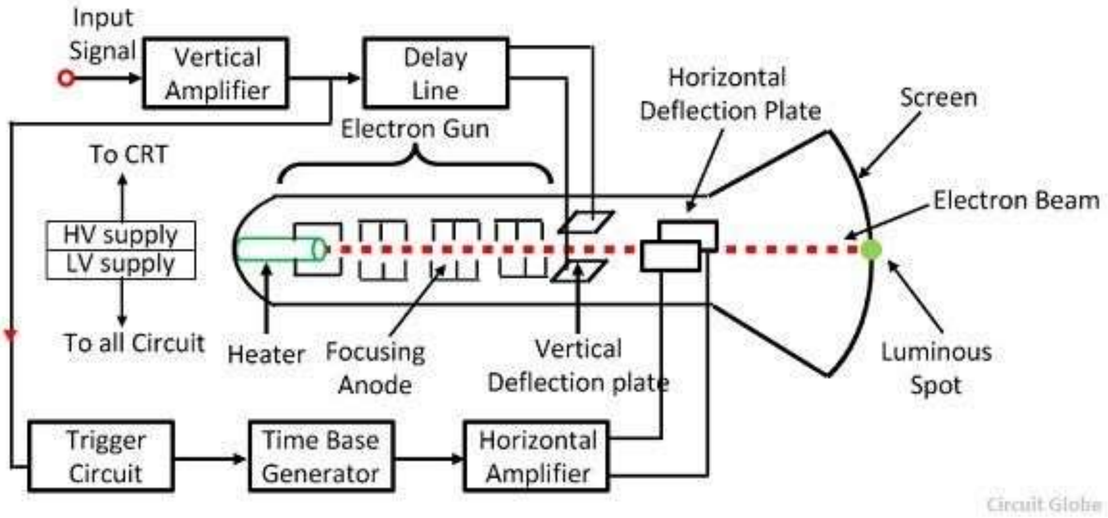
The inside surface of the faceplate is coated with phosphor crystal. The phosphor converts electrical energy into light energy. When an electronics beam strike phosphor crystal, it raises their energy level and hence light is emitted during phosphorous crystallisation. This phenomenon is called fluorescence.

5. Glass Envelope

It is a highly evacuated conical shape structure. The inner surface of the CRT between the neck and the screen is coated with the aquadag. The aquadag is a conducting material and act as a high-voltage electrode. The coating surface is electrically connected to the accelerating anode and hence help the electron to be the focus.

Working of Cathode Ray Oscilloscope

When the electron is injected through the electron gun, it passes through the control grid. The control grid controls the intensity of electron in the vacuum tube. If the control grid has high negative potential, then it allows only a few electrons to pass through it. Thus, the dim spot is produced on the lightning screen. If the negative potential on the control grid is low, then the bright spot is produced. Hence the intensity of light depends on the negative potential of the control grid.



After moving the control grid the electron beam passing through the focusing and accelerating anodes. The accelerating anodes are at a high positive potential and hence they converge the beam at a point on the screen.

After moving from the accelerating anode, the beam comes under the effect of the deflecting plates. When the deflecting plate is at zero potential, the beam produces a spot at the centre.If the voltage is applied to the vertical deflecting plate, the electron beam focuses at the upward and when the voltage is applied horizontally the spot of light will be deflected horizontally.

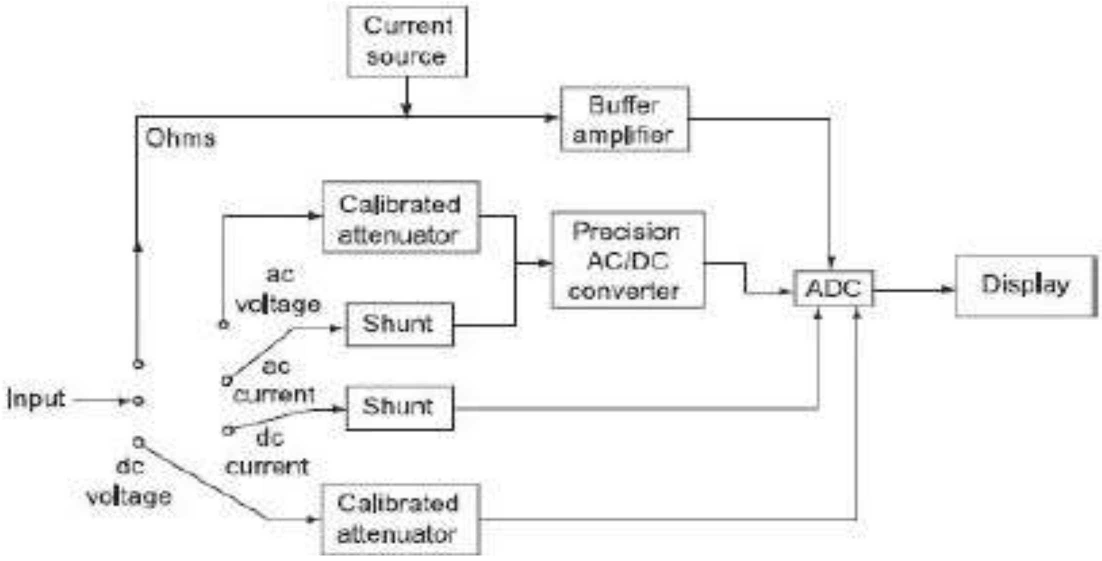
Digital Multimeter: Principle of Operation and How it is used

A Multimeter or volt-ohm-milliammeter (VOM) is an instrument used to measure current, voltage, and resistance. It can be used for measuring dc as well as ac voltages and currents. The two common types of multimeters include the analog multimeter and the digital multimeter. Analog multimeters employs a moving pointer mechanism that swings a long a calibrated scale, on the other hand digital multimeters utilizes some complex digital circuitry to convert input measurements into a digitally displayed reading. Our focus in this article is the digital multimeter.

Principle of Operation of a Digital Multimeter

A digital multimeter can measure very precisely the dc and ac voltage, current (dc and ac) and resistance. All quantities save for dc voltage is first converted into an equivalent dc voltage and then measured with the help of a digital voltmeter.

The block diagram of a digital multimeter is demonstrated below:



Voltage Measurement

With reference to the figure above, the input ac voltage is fed through a calibrated attenuator, to a precision full-wave rectifier circuit followed by a ripple reduction filter. The resulting dc is fed to an analog digital converter (ADC) and the following display system. In case of dc voltage input, the process is similar to what is described above, except that that the precision AC/DC converter is not involved here.

Current Measurement

For current measurement, the drop across an internal calibrated shunt is measured directly by the analog digital converter (ADC) in the "dc current mode", and after ac to dc conversion in the "ac current mode". This drop is often in the range of 200 mV (corresponding to full scale).Since there is the lack of precision in the ac-dc conversions, the accuracy in the ac range is typically of the order of 0.2 to 0.5 %. Furthermore, the measurement range is often limited to about 50 Hz at the lower frequency end due to the ripple in the rectified signal becoming a non-negligible percentage of the display and hence results in fluctuation of the displayed number. At the higher frequency end, deterioration of the performance of the ADC converter limits the accuracy. In ac measurement the reading is often average or rms values of the unknown current.he current under measurement is applied to the summing junction at the input of the op-amp. The current in the feedback resistor I_R is equal to the input current I_{IN} because of very high input impedance of the op-amp. The current I_R causes a voltage drop across one of the resistors, which is proportional to the input I_{IN}. Different resistors are used for different ranges.

Resistance Measurement

In the case of resistance measurement the digital multimeter operates by measuring the voltage across the externally connected resistance, resulting from a current forced through it from a calibrated internal current source. The accuracy of the resistance measurement is of the order 0.1% to 0.5% depending on the accuracy and stability of the internal current sources.

How to Measure Voltages, Currents & Resistances with a Digital Multimeter

Measuring Voltages

To measure voltages with a multimeter, turn the selector knob to the voltage setting. If you want to measure dc voltage, the knob is turned to the appropriate dc voltage-level setting. If you wish to measure an ac voltage, the knob is turned to the ac voltage setting (the displayed voltage in the V_{ac} setting is the RMS voltage).

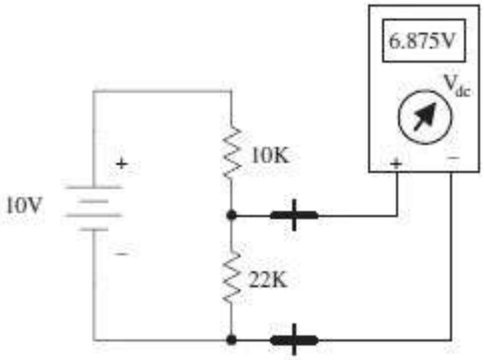


Figure 1.2: Measuring voltage across a resistor with a multimeter.

Once the multimeter is set properly as illustrated above, the voltage between two points in a circuit can be measured by touching the multimeter probes on these points. The multimeter is placed in parallel.

Measuring Currents

To measure current with a multimeter, you turn the selector knob to current setting (choosing either dc or ac); also you have to break the test circuit at the location where you wish to make a current reading.

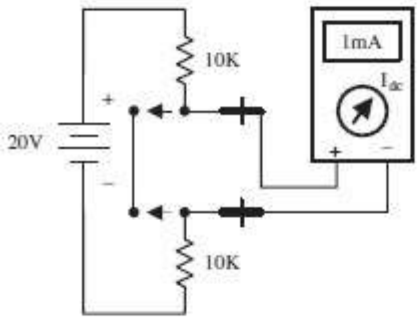


Figure 1.3: Measuring current in a circuit with a Multimeter.

Once the circuit is open, the two probes of the multimeter are placed across the break to complete the circuit i.e. the multimeter is placed in series. When measuring ac currents, the multimeter must be set to RMS current setting.

Measuring Resistances

To measure resistance with a multimeter, turn the multimeter selector knob to the ohms setting, remove the power to the resistive section of interest, then place the probes across the section.

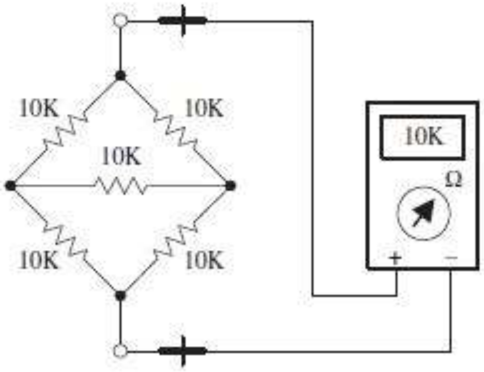


Figure 1.4: Measuring resistance with a multimeter.

Analog vs. Digital Multimeters

The comparison between analog and digital multimeters is given in the table below:

Analog Multimeter	**Digital Multimeter**
No external power needed.	An external power is needed.
Visual indication of change in reading is better observable.	Less observable of change in reading.
Interface of the output with external equipment is not possible.	Possible to connect to an external instrument with the output reading.
Less effect of electronic noise.	It affected more by electronic noise.
Less isolation problems.	It has more isolation problems.
It has less accuracy.	Highly accurate instrument.

Function Generator

Definition: Function Generator is basically a signal generator that **produces different types of waveforms at the output**. It has the ability to produce waveforms such as sine wave, square wave, a triangular wave, sawtooth wave etc. An adjustable frequency range is provided by the function generator which is in the range of some **Hz to several 100KHz**.

There exist various function generators that have the ability to produce two different waveforms simultaneously by using two different output terminals.

Function Generator is a **versatile instrument** as an extensive variety of frequencies and waveforms are produced by it. The various waveforms generated by the function generator are suitable for various applications. It provides adjustment of wave shape, frequency, magnitude and offset but requires a load connected before adjustment.

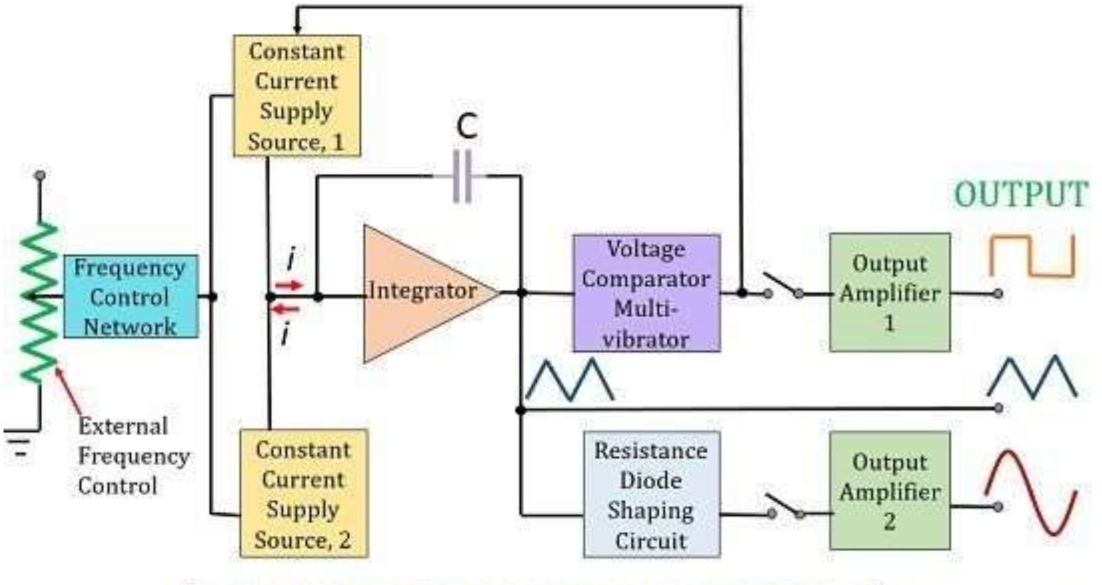
This instrument not only varies the characteristics of the waveform but also has the capability to add a **dc offset** to the signal. Mostly these are only able to operate at low frequency but some costly models can also be operated at the higher frequency.

As we have discussed earlier that it can generate 2 different waveforms simultaneously at the two different terminals. So, it can be a useful feature as different output are required for particular applications. It provides another important feature as they have the capability of phase locking to an external source.

This implies that a function generator can phase lock another function generator and the output of both can be displaced in phase.

Block Diagram and Working of Function Generator

The figure below shows the block diagram of the function generator-



Block Diagram Of Function Generator Electronics Coach

A frequency control network used here whose frequency is controlled by the variation in the magnitude of current. The current sources 1 and 2 drives the integrator.

By using Function Generator, we can have a wide variety of waveforms whose frequency changes from 0.01 Hz to 100 KHz. The two current sources are regulated by the frequency controlled voltage.

A constant current is supplied to the integrator by current supply source 1. Due to this, the voltage of the integrator rises linearly with respect to time. This linear rise is according to the

$$V_{out} = \frac{-1}{C}\int_0^t i\,dt$$

output signal voltage equation: Any increase or decrease in the current will resultantly increase or decrease the slope of the voltage at the output and thus controls the frequency.

The **Voltage Comparator Multi-vibrator present here cause variation in the state** of the integrator output voltage at a previously determined maximum level. Due to this change of state, the current supply from source 1 cuts off and switches to supply source 2.

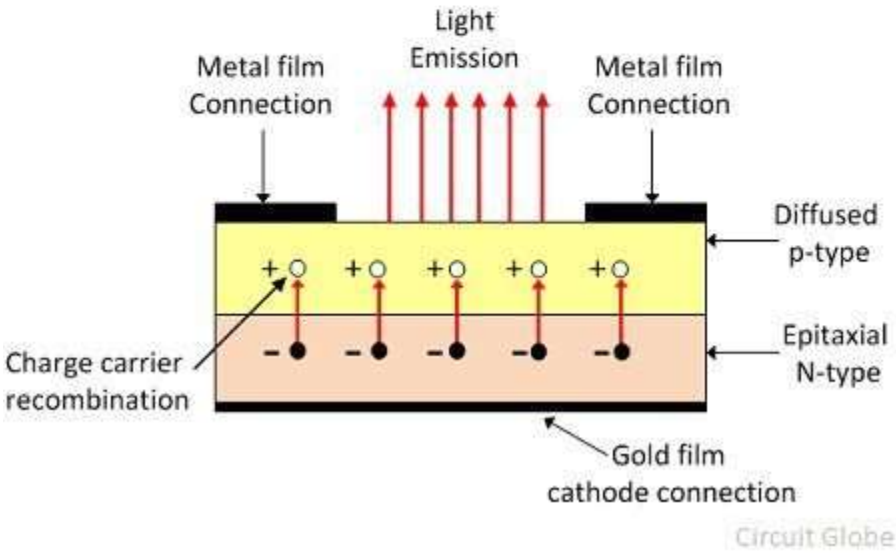
A reverse current is supplied to the integrator by current source 2. This reverse current cause drops in the output of integrator linearly with time. As before this time also, when the output attains a predetermined level, the comparator again changes its state and switches to current supply source 1.

Thus we will have a triangular wave at the output of the integrator whose frequency depends on current by the supply sources as we can see in the block diagram shown above. A square wave signal is obtained at the output of the comparator.

The **resistance diode network** employed in the circuit **changes the slope of that triangular wave** with distortion less than 1%. The output amplifier thus helps to provide two waves at the output simultaneously. This captured signal can be displayed by using an oscilloscope.

Definition of LED

The full form of LED is Light Emitting Diode. The LED is a PN junction diode which emits light when an electric current flows through it in the forward direction. The LED is constructed by doping the p-type and n-type material. When the power is applied across the LED the recombination of P-type and N-type material charges takes places. The recombination of charges gives energy in the form of heat and light.

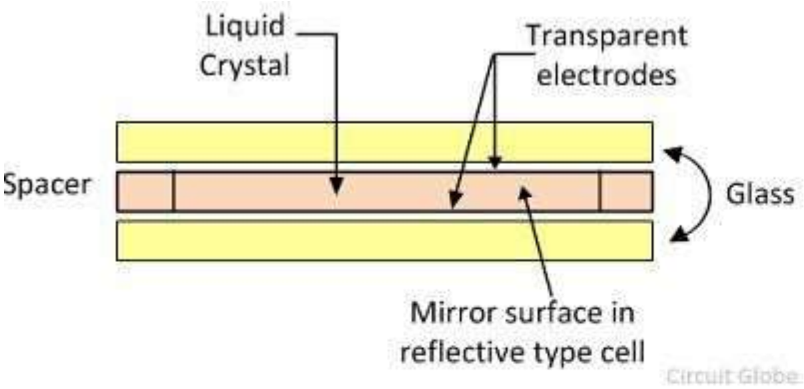


The semiconductor material is translucent (allow light to pass) and it emits light through their junction.The semiconductor material used galvanised arsenides, which generates red or yellow light. It is also available in green, red, and amber colour. The several LED is used for representing the one segment and the decimal points are represented by the single LED.

Definition of LCD

The LCD is used for displaying the texts and images in the form of dot matrix or segments. The LCD has liquid crystal filament which is filled between the transparent electrodes. When the current passes between the electrodes, the filaments become energised and emits visible light.

The construction of liquid crystal display is shown in the figure below. The liquid crystal used in the display has the property of both the solid and the liquid. When the potential is not applied across the liquid crystal, it becomes transparent but after activation, the crystal scatters light in all directions and appears to be bright.



The LCD consumes less power and also have seven segment displays. But it is a slow device and requires more times for switching.The dc reduces their lifespan and hence mostly they are used with AC having a frequency less than 500 Hz.

Key Differences Between LED and LCD

1. The LED is a PN junction diode which emits visible light when the forward bias applies across it. Whereas the LCD uses liquid filaments which are filled between glass electrodes for the emission of light.
2. The LED stands for Light Emitting Diode whereas the LCD stands for Liquid Crystal Display
3. The LCD uses cold cathode fluorescent lamp which provides the backlight of the screen, whereas the LED uses the PN-junction diodes for displaying the light. The backlight refers to the turning on and off of the displays for better vision.
4. The resolution of the LED is much better than that of LCD. The resolution is the number of pixels on the display of the screen.

5. The LED consumes more power as compared to LCD because of the plasma. The filament used in LCD is made up of plasma, which requires less power for activation.
6. The display area of the LED is less as compared to the LCD because LED use PN-junction diode which displays light only in the one direction, whereas, the LCD display lights in all the directions.
7. The cost of the LED is more as compared to LCD.
8. The LED uses gallium arsenides which when heated emits light whereas LCD uses liquid crystals which are energised and provides light.
9. The switching time of the LED is less as compared to LCD. The switching time is the active and deactivated time of their display.
10. The direct current reduces the lifespan of LCD whereas the LED has no effect on it.
11. The contrast ratio of the LED is less as compared to the LCD. The contrast ratio is the ratio of the luminance of the visible and darker light of the screen.
12. The LCD uses mercury which pollutes the environments whereas the LED does not use mercury.

P-N Junction

semiconductors are materials whose conductivity lies between conductors and insulators. Semiconductors are classified as intrinsic semiconductors and extrinsic semiconductors. Extrinsic semiconductors are further classified as N-type and P-type semiconductors.

The P-N junction is formed between the p-type and the n-type semiconductors. In this session, let us know more about the P-N Junction.

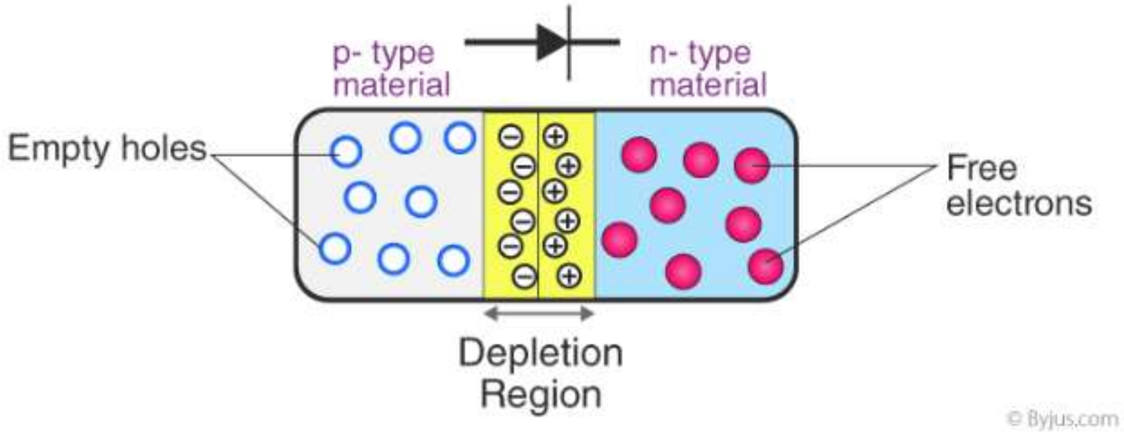
P-N Junction

Definition: *A P-N junction is an interface or a boundary between two semiconductor material types, namely the p-type and the n-type, inside a semiconductor.*

In a semiconductor, the P-N junction is created by the method of doping. The p-side or the positive side of the semiconductor has an excess of holes, and the n-side or the negative side has an excess of electrons. The process of doping is explained in further detail in the next section.

Formation of P-N Junction

As we know, if we use different semiconductor materials to make a P-N junction, there will be a grain boundary that would inhibit the movement of electrons from one side to the other by scattering the electrons and holes and thus, we use the process of doping. We will understand the process of doping with the help of this example. Let us consider a thin p-type silicon semiconductor sheet. If we add a small amount of pentavalent impurity to this, a part of the p-type Si will get converted to n-type silicon. This sheet will now contain both the p-type region and the n-type region and a junction between these two regions. The processes that follow after forming a P-N junction are of two types – diffusion and drift. There is a difference in the concentration of holes and electrons at the two sides of a junction. The holes from the p-side diffuse to the n-side, and the electrons from the n-side diffuse to the p-side. These give rise to a diffusion current across the junction.



Also, when an electron diffuses from the n-side to the p-side, an ionised donor is left behind on the n-side, which is immobile. As the process goes on, a layer of positive charge is developed on the n-side of the junction. Similarly, when a hole goes from the p-side to the n-side, an ionized acceptor is left behind on the p-side, resulting in the formation of a layer of negative charges in the p-side of the junction. This region of positive charge and negative charge on either side of the junction is termed as the depletion region. Due to this positive space charge region on either side of the junction, an electric field with the direction from a positive charge towards the negative charge is developed. Due to this electric field, an electron on the p-side of the junction moves to the n-side of the junction. This motion is termed the drift. Here, we see that the direction of the drift current is opposite to that of the diffusion current.

Biasing Conditions for the P-N Junction Diode

There are two operating regions in the P-N junction diode:

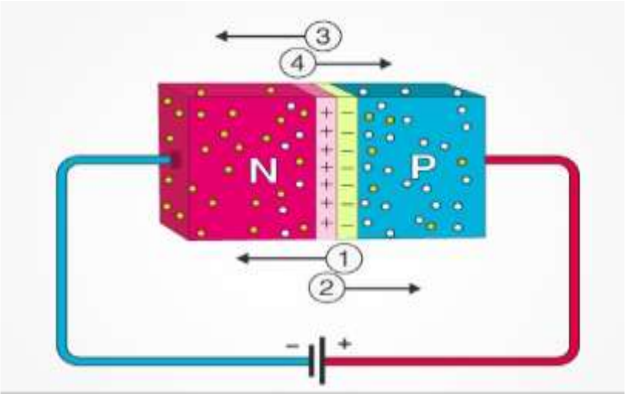
- P-type
- N-type

There are three biasing conditions for the P-N junction diode, and this is based on the voltage applied:

- Zero bias: No external voltage is applied to the P-N junction diode.
- Forward bias: The positive terminal of the voltage potential is connected to the p-type while the negative terminal is connected to the n-type.
- Reverse bias: The negative terminal of the voltage potential is connected to the p-type and the positive is connected to the n-type.

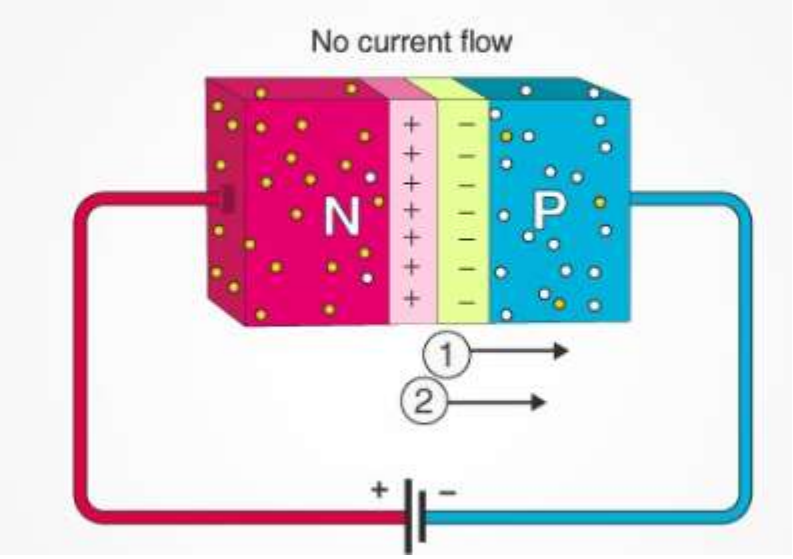
Forward Bias

When the p-type is connected to the battery's positive terminal and the n-type to the negative terminal, then the P-N junction is said to be forward-biased. When the P-N junction is forward biased, the built-in electric field at the P-N junction and the applied electric field are in opposite directions. When both the electric fields add up, the resultant electric field has a magnitude lesser than the built-in electric field. This results in a less resistive and thinner depletion region. The depletion region's resistance becomes negligible when the applied voltage is large. In silicon, at the voltage of 0.6 V, the resistance of the depletion region becomes completely negligible, and the current flows across it unimpeded.



Reverse Bias

When the p-type is connected to the battery's negative terminal and the n-type is connected to the positive side, the P-N junction is reverse biased. In this case, the built-in electric field and the applied electric field are in the same direction. When the two fields are added, the resultant electric field is in the same direction as the built-in electric field, creating a more resistive, thicker depletion region. The depletion region becomes more resistive and thicker if the applied voltage becomes larger.



How does current flow in the PN junction diode?

The flow of electrons from the n-side towards the p-side of the junction takes place when there is an increase in the voltage. Similarly, the flow of holes from the p-side towards the n-side of the junction takes place along with the increase in the voltage. This results in the concentration gradient between both sides of the terminals. Due to the concentration gradient formation, charge carriers will flow from higher-concentration regions to lower-concentration regions. The movement of charge carriers inside the P-N junction is the reason behind the current flow in the circuit.

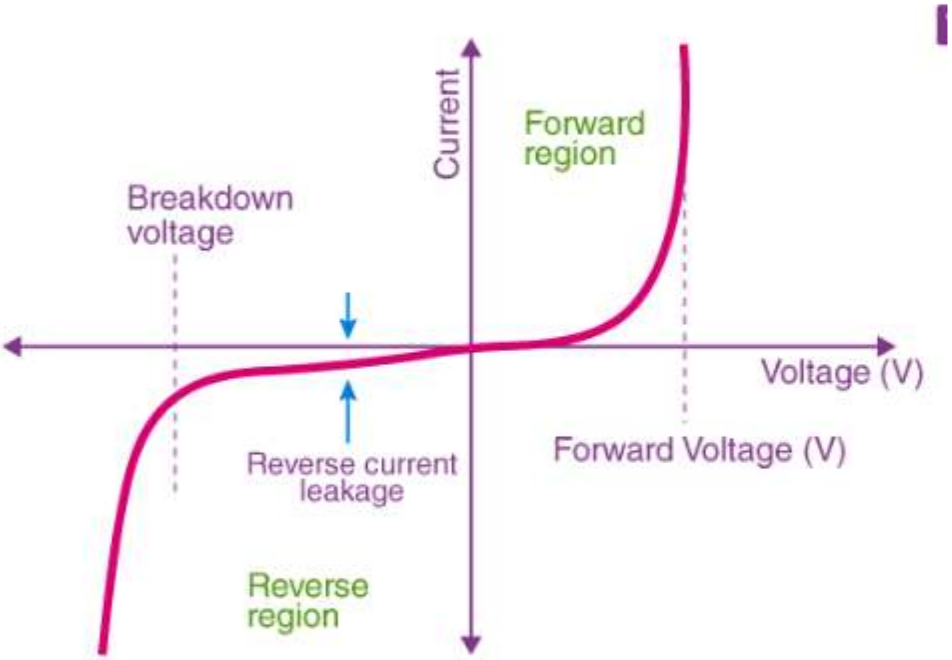
V-I Characteristics of P-N Junction Diode

VI characteristics of P-N junction diodes is a curve between the voltage and current through the circuit. Voltage is taken along the x-axis while the current is taken along the y-axis. The above graph is the V-I characteristics curve of the P-N junction diode. With the help of the curve, we can understand that there are three regions in which the diode works, and they are:

- Zero bias
- Forward bias
- Reverse bias

When the P-N junction diode is in zero bias condition, there is no external voltage applied and this means that the potential barrier at the junction does not allow the flow of current.

When the P-N junction diode is in forward bias condition, the p-type is connected to the positive terminal while the n-type is connected to the negative terminal of the external voltage. When the diode is arranged in this manner, there is a reduction in the potential barrier. For silicone diodes, when the voltage is 0.7 V and for germanium diodes, when the voltage is 0.3 V, the potential barriers decrease, and there is a flow of current.



When the diode is in forward bias, the current increases slowly, and the curve obtained is non-linear as the voltage applied to the diode overcomes the potential barrier. Once the diode overcomes the potential barrier, the diode behaves normally, and the curve rises sharply as the external voltage increases, and the curve obtained is linear.

When the P-N junction diode is in negative bias condition, the p-type is connected to the negative terminal while the n-type is connected to the positive terminal of the external voltage. This results in an increase in the potential barrier. Reverse saturation current flows in the beginning as minority carriers are present in the junction.

When the applied voltage is increased, the minority charges will have increased kinetic energy which affects the majority charges. This is the stage when the diode breaks down. This may also destroy the diode.

Applications of P-N Junction Diode

- P-N junction diode can be used as a photodiode as the diode is sensitive to the light when the configuration of the diode is reverse-biased.
- It can be used as a solar cell.
- When the diode is forward-biased, it can be used in LED lighting applications.
- It is used as rectifier in many electric circuits and as a voltage-controlled oscillator in varactors.

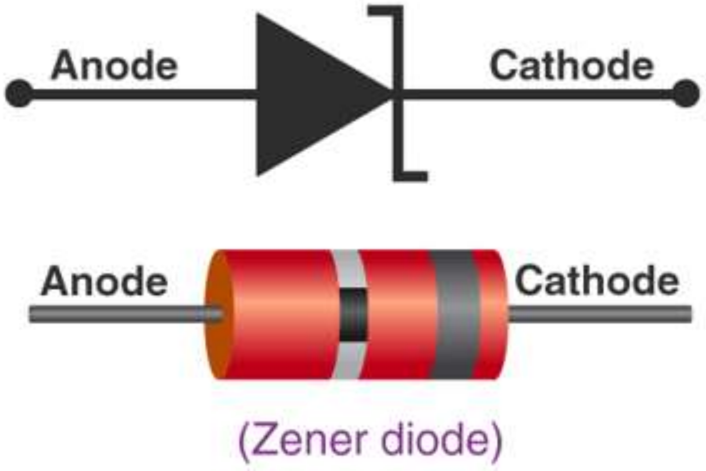
Zener Diode

Definition

A Zener diode is a highly doped semiconductor device specifically designed to function in the reverse direction. It is engineered with a wide range of Zener voltages (Vz), and certain types are even adjustable to achieve variable voltage regulation.

Zener Diode

Zener diodes come in various packaging options, depending on their power dissipation requirements. Some are designed for high-power applications, while others are available in surface mount formats. The most commonly used Zener diode is packaged in a small glass enclosure, with a distinctive band indicating the cathode side of the diode.

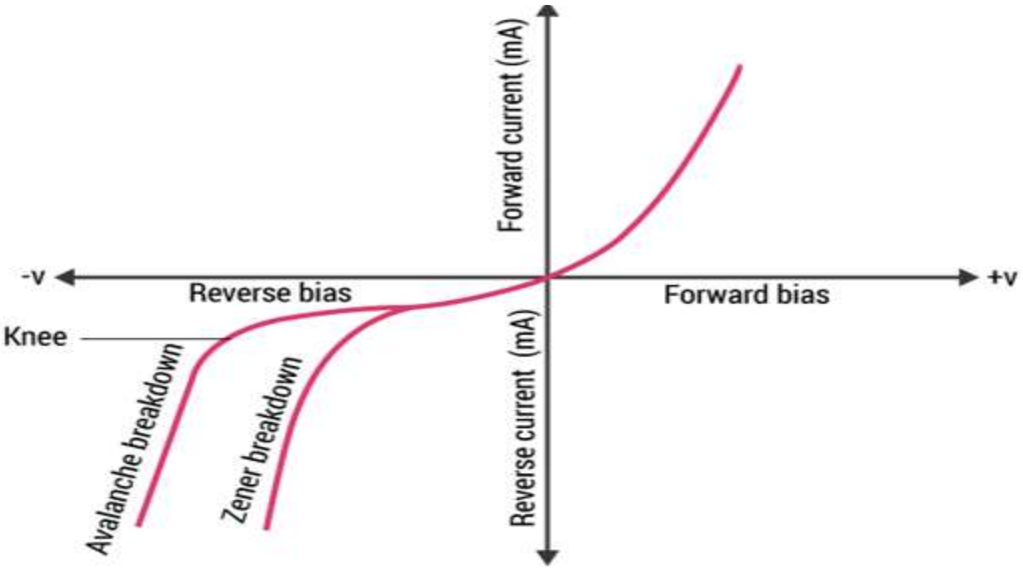


Zener diode symbol and package outlines

The symbol used to represent a Zener diode in circuit diagrams is similar to that of a regular diode, but with a unique addition. It consists of a triangle or arrowhead pointing towards the cathode side (the side with the band) of the diode. This triangle is accompanied by two perpendicular lines at the cathode end, one extending upwards and the other extending downwards. These lines indicate the specific behaviour of the Zener diode and help distinguish it from other types of diodes in circuit diagrams. The symbol provides a visual representation that allows engineers and technicians to easily identify and understand the presence of a Zener diode in a circuit.

V-I Characteristics of Zener Diode

The diagram given below shows the V-I characteristics of the Zener diode.



When reverse-biased voltage is applied to a Zener diode, it allows only a small amount of leakage current until the voltage is less than Zener voltage.

The V-I characteristics of a Zener diode can be divided into two parts as follows:
(i) Forward Characteristics
(ii) Reverse Characteristics

Forward Characteristics of Zener Diode

The first quadrant in the graph represents the forward characteristics of a Zener diode. From the graph, we understand that it is almost identical to the forward characteristics of P-N junction diode.

Reverse Characteristics of Zener Diode

When a reverse voltage is applied to a Zener voltage, a small reverse saturation current Io flows across the diode. This current is due to thermally generated minority carriers. As the reverse voltage increases, at a certain value of reverse voltage, the reverse current increases drastically and sharply. This is an indication that the breakdown has occurred. We call this voltage breakdown voltage or Zener voltage, and Vz denotes it.

Some commonly used specifications for Zener diodes are as follows:

- **Zener/Breakdown Voltage** – The Zener or the reverse breakdown voltage ranges from 2.4 V to 200 V, sometimes it can go up to 1 kV while the maximum for the surface-mounted device is 47 V.
- **Current Iz (max)** – It is the maximum current at the rated Zener Voltage (Vz – 200µA to 200 A)

- **Current Iz (min)** – It is the minimum value of current required for the diode to break down.
- **Power Rating** – It denotes the maximum power the Zener diode can dissipate. It is given by the product of the voltage of the diode and the current flowing through it.
- **Temperature Stability** – Diodes around 5 V have the best stability
- **Voltage Tolerance** – It is typically ±5%
- **Zener Resistance (Rz)** – It is the resistance to the Zener diode exhibits.

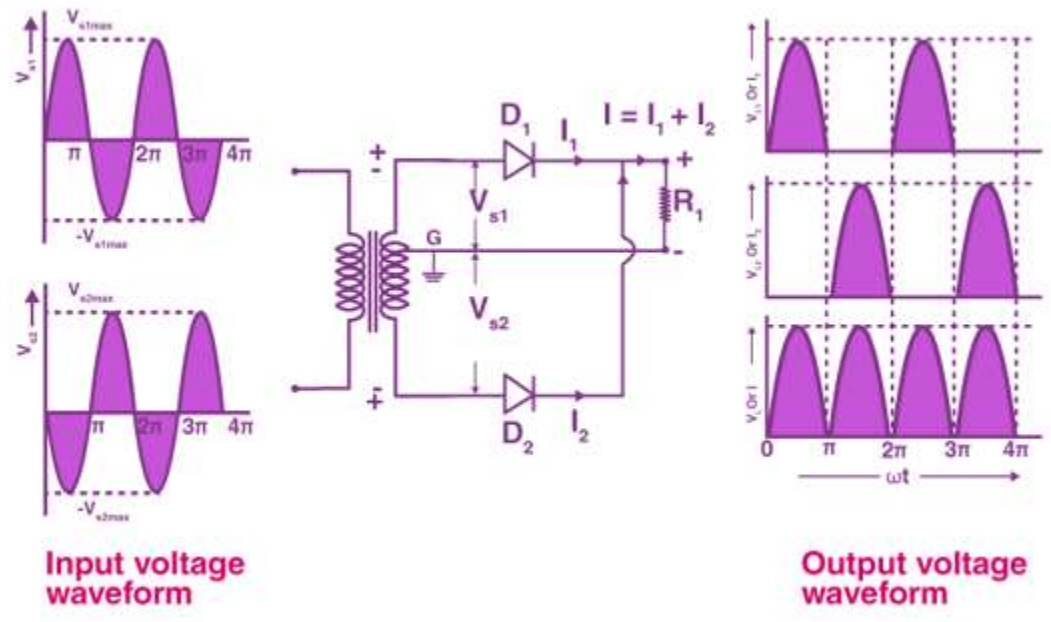
Defining Full Wave Rectifiers

A full wave rectifier is defined as a rectifier that converts the complete cycle of alternating current into pulsating DC.

Unlike halfwave rectifiers that utilize only the halfwave of the input AC cycle, full wave rectifiers utilize the full cycle. The lower efficiency of the half wave rectifier can be overcome by the full wave rectifier.

Full Wave Center Tap Rectifier Circuit

The circuit of the full wave rectifier can be constructed in two ways. The first method uses a centre tapped transformer and two diodes. This arrangement is known as a centre tapped full wave rectifier. The second method uses a standard transformer with four diodes arranged as a bridge. This is known as a bridge rectifier. In the next section, we will restrict the discussion to the centre tapped full wave rectifier only.



The circuit of the full wave rectifier consists of a step-down transformer and two diodes that are connected and centre tapped. The output voltage is obtained across the connected load resistor.

Working of Full Wave Rectifier

The input AC supplied to the full wave rectifier is very high. The step-down transformer in the rectifier circuit converts the high voltage AC into low voltage AC. The anode of the centre tapped diodes is connected to the transformer's secondary winding and connected to the load resistor. During the positive half cycle of the alternating current, the top half of the secondary winding becomes positive while the second half of the secondary winding becomes negative.

During the positive half cycle, diode D_1 is forward biased as it is connected to the top of the secondary winding while diode D_2 is reverse biased as it is connected to the bottom of the secondary winding. Due to this, diode D_1 will conduct acting as a short circuit and D_2 will not conduct acting as an open circuit

During the negative half cycle, the diode D_1 is reverse biased and the diode D_2 is forward biased because the top half of the secondary circuit becomes negative and the bottom half of the circuit becomes positive. Thus in a full wave rectifiers, DC voltage is obtained for both positive and negative half cycle.

Advantages of Full Wave Rectifier

- The rectification efficiency of full wave rectifiers is double that of half wave rectifiers. The efficiency of half wave rectifiers is 40.6% while the rectification efficiency of full wave rectifiers is 81.2%.

- The ripple factor in full wave rectifiers is low hence a simple filter is required. The value of ripple factor in full wave rectifier is 0.482 while in half wave rectifier it is about 1.21.
- The output voltage and the output power obtained in full wave rectifiers are higher than that obtained using half wave rectifiers.

The only disadvantage of the full wave rectifier is that they need more circuit elements than the half wave rectifier which makes, making it costlier.

Full Wave Bridge Rectifier

We can define bridge rectifiers as a type of full-wave rectifier that uses four or more diodes in a bridge circuit configuration to efficiently convert alternating (AC) current to a direct (DC) current. In the next few sections, let us learn more about its construction, working, and more.

Construction

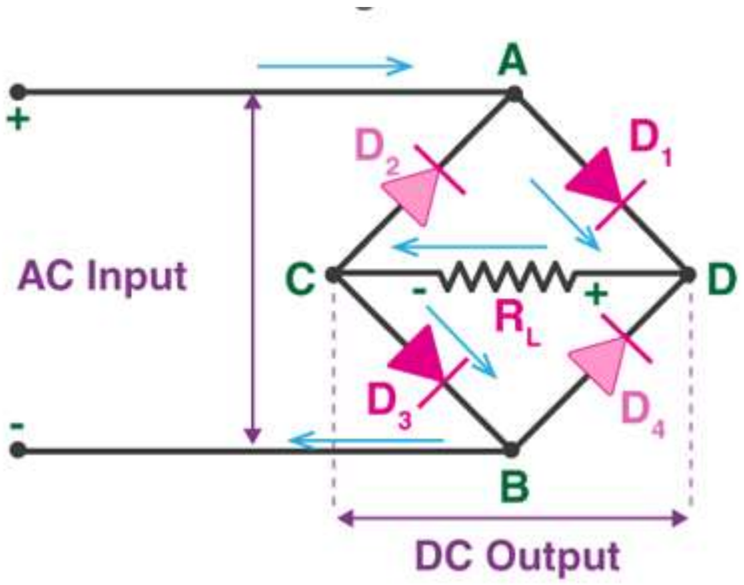
The construction of a bridge rectifier is shown in the figure below. The bridge rectifier circuit is made of four diodes D_1, D_2, D_3, $D_{4,}$ and a load resistor R_L. The four diodes are connected in a closed-loop configuration to efficiently convert the alternating current (AC) into Direct Current (DC). The main advantage of this configuration is the absence of the expensive centre-tapped transformer. Therefore, the size and cost are reduced.

The input signal is applied across terminals A and B, and the output DC signal is obtained across the load resistor R_L connected between terminals C and D. The four diodes are arranged in such a way that only two diodes conduct electricity during each half cycle. D_1 and D_3 are pairs that conduct electric current during the positive half cycle/. Likewise, diodes D_2 and D_4 conduct electric current during a negative half cycle.

Working

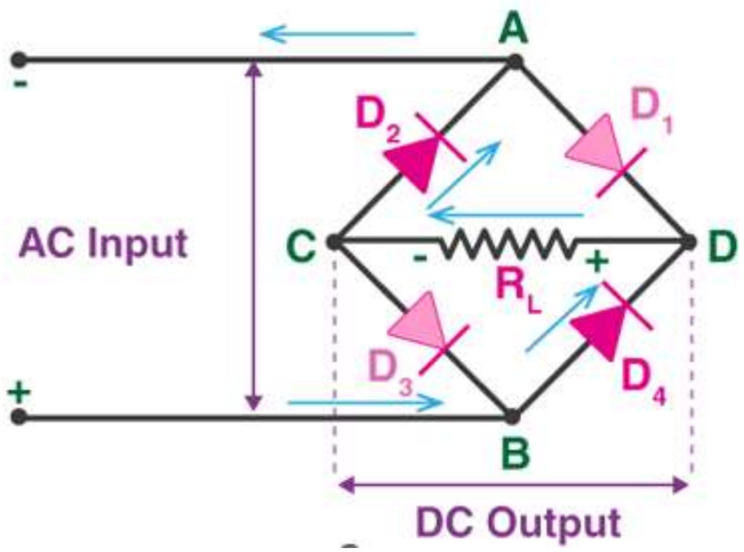
When an AC signal is applied across the bridge rectifier, terminal A becomes positive during the positive half cycle while terminal B becomes negative. This results in diodes D_1 and D_3 becoming forward biased while D_2 and D_4 becoming reverse biased.

The current flow during the positive half-cycle is shown in the figure below:



During the negative half-cycle, terminal B becomes positive while terminal A becomes negative. This causes diodes D_2 and D_4 to become forward biased and diode D_1 and D_3 to be reverse biased.

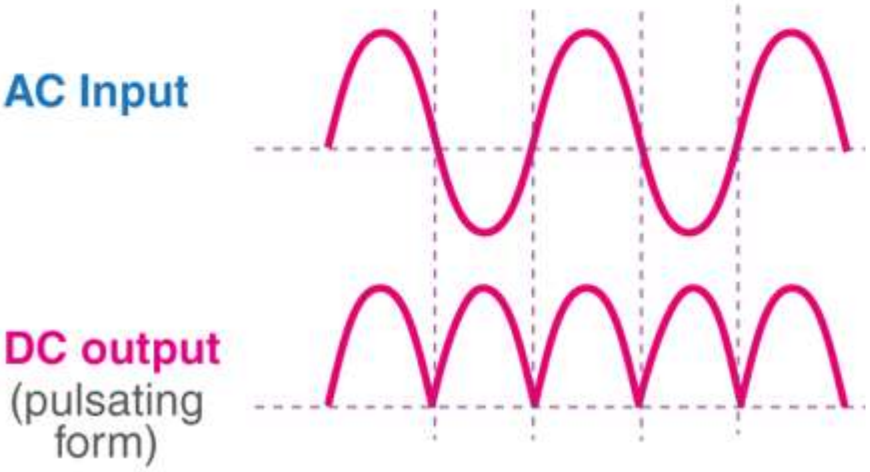
The current flow during the negative half cycle is shown in the figure below:



From the figures given above, we notice that the current flow across load resistor R_L is the same during the positive and negative half-cycles. The output DC signal polarity may be either completely positive or negative. In our case, it is completely positive. If the diodes' direction is reversed, we get a complete negative DC voltage.

Thus, a bridge rectifier allows electric current during both positive and negative half cycles of the input AC signal.

The output waveforms of the bridge rectifier are shown in the below figure.



Advantages

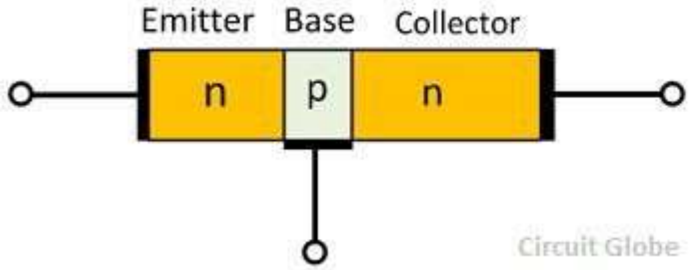
- The efficiency of the bridge rectifier is higher than the efficiency of a half-wave rectifier. However, the rectifier efficiency of the bridge rectifier and the centre-tapped full-wave rectifier is the same.
- The DC output signal of the bridge rectifier is smoother than the output DC signal of a half-wave rectifier.
- In a half-wave rectifier, only half of the input AC signal is used, and the other half is blocked. Half of the input signal is wasted in a half-wave rectifier. However, in a bridge rectifier, the electric current is allowed during both positive and negative half cycles of the input AC signal. Hence, the output DC signal is almost equal to the input AC signal.

NPN Transistor

Definition: The transistor in which one p-type material is placed between two n-type materials is known as **NPN transistor**. The NPN transistor **amplifies the weak signal** enter into the base and produces strong amplify signals at the collector end. In NPN transistor, the direction of **movement of an electron** is from the **emitter to collector** region due to which the current constitutes in the transistor. Such type of transistor is mostly used in the circuit because their majority charge carriers are electrons which have high mobility as compared to holes.

Construction of NPN Transistor

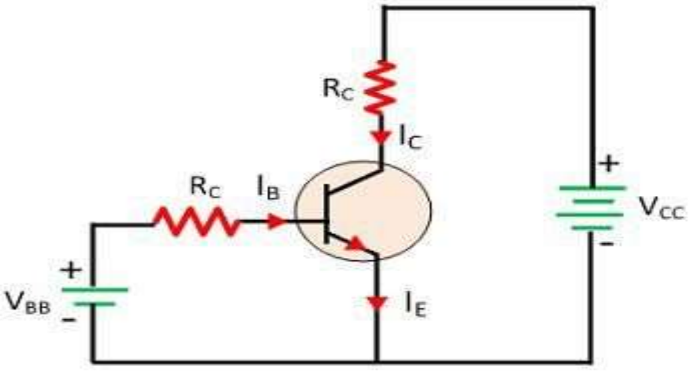
The NPN transistor has two diodes connected back to back. The diode on the left side is called an emitter-base diode, and the diodes on the left side are called collector-base diode. These names are given as per the name of the terminals.



The NPN transistor has three terminals, namely emitter, collector and base. The middle section of the NPN transistor is lightly doped, and it is the most important factor of the working of the transistor. The emitter is moderately doped, and the collector is heavily doped.

Circuit Diagram of NPN Transistor

The circuit diagram of the NPN transistor is shown in the figure below. The collector and the base circuit is connected in reverse biased while the emitter and base circuit is connected in forward biased. The collector is always connected to the positive supply, and the base is in negative supply for controlling the ON/OFF states of the transistor.

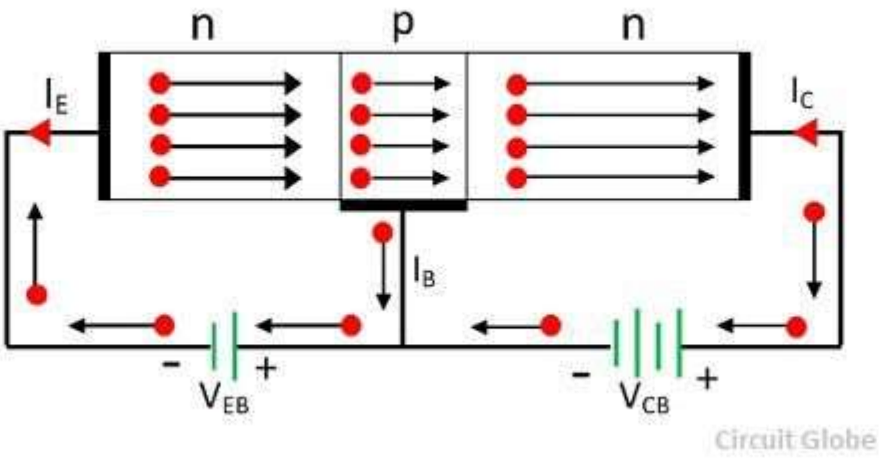


NPN Transistor

Circuit Globe

Working of NPN Transistor

The circuit diagram of the NPN transistor is shown in the figure below. The forward biased is applied across the emitter-base junction, and the reversed biased is applied across the collector-base junction. The forward biased voltage V_{EB} is small as compared to the reverse bias voltage V_{CB}.



The emitter of the NPN transistor is heavily doped. When the forward bias is applied across the emitter, the majority charge carriers move towards the base. This causes the emitter current I_E. The electrons enter into the P-type material and combine with the holes.

The base of the NPN transistor is lightly doped. Due to which only a few electrons are combined and remaining constitutes the base current I_B. This base current enters into the collector region. The reversed bias potential of the collector region applies the high attractive force on the electrons reaching collector junction. Thus attract or collect the electrons at the collector.

The whole of the emitter current is entered into the base. Thus, we can say that the emitter current is the sum of the collector and the base current.

PNP Transistor

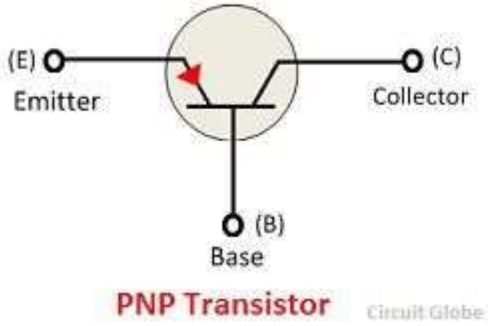
Definition: The transistor in which one n-type material is doped with two p-type materials such type of transistor is known as PNP transistor. It is a current controlled device. The small amount of base current controlled both the emitter and collector current. The PNP transistor has two crystal diodes connected back to back. The left side of the diode in known as the emitter-base diode and the right side of the diode is known as the collector-base diode.

The hole is the majority carriers of the PNP transistors which constitute the current in it. The current inside the transistor is constituted because of the changing position of holes and in the leads of the transistor it is because of the flow of the electrons. The PNP transistor turns on when a small current flows through the base. The direction of current in PNP transistor is from the emitter to collector.

The letter of the PNP transistor indicates the voltage requires by the emitter, collector and the base of the transistor. The base of the PNP transistor has always been negative with respect to the emitter and collector. In PNP transistor, the electrons are taken from the base terminal. The current which enters into the base is amplified into the collector ends.

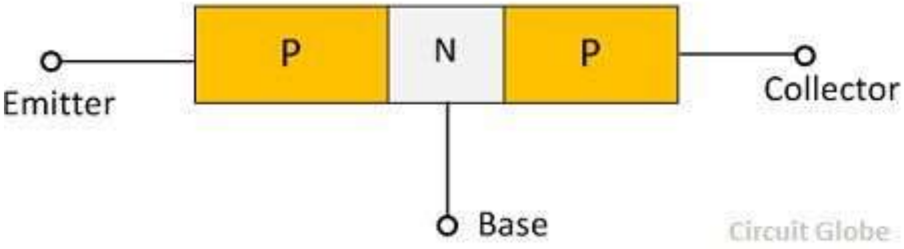
Symbol of PNP Transistor

The symbol of PNP transistor is shown in the figure below. The inward arrow shows that the direction of current in PNP transistor is from the emitter to collector.



Construction of PNP Transistor

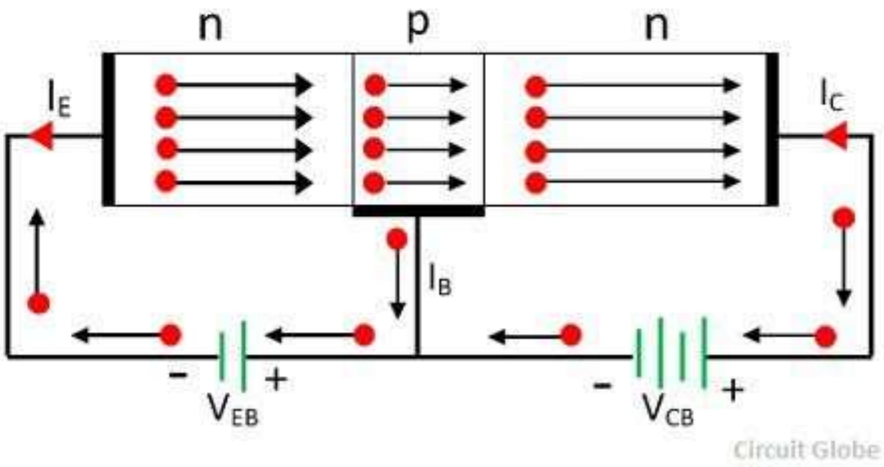
The construction of PNP transistor is shown in the figure below. The emitter-base junction is connected in forward biased, and the collector-base junction is connected in reverse biased. The emitter which is connected in the forward biased attracts the electrons towards the battery and hence constitutes the current to flow from emitter to collector.



The base of the transistor is always kept positive with respect to the collector so that the hole from the collector junction cannot enter into the base. And the base-emitter is kept in forward due to which the holes from the emitter region enter into the base and then into the collector region by crossing the depletion region.

Working of PNP Transistor

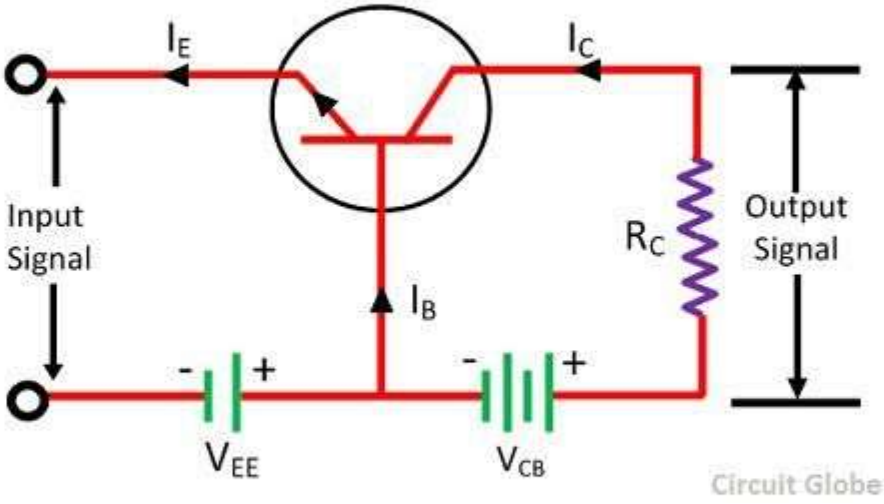
The emitter-base junction is connected in forward biased due to which the emitter pushes the holes in the base region. These holes constitute the emitter current. When these electrons move into the N-type semiconductor material or base, they combined with the electrons. The base of the transistor is thin and very lightly doped. Hence only a few holes combined with the electrons and the remaining are moved towards the collector space charge layer. Hence develops the base current.



The collector base region is connected in reverse biased. The holes which collect around the depletion region when coming under the impact of negative polarity collected or attracted by the collector. This develops the collector current. The complete emitter current flows through the collector current I_C.

Transistor

The transistor raises the strength of a weak signal and hence acts an amplifier. The transistor amplifier circuit is shown in the figure below. The transistor has three terminals namely emitter, base and collector. The emitter and base of the transistor are connected in forward biased and the collector base region is in reverse bias. The forward bias means the P-region of the transistor is connected to the positive terminal of the supply and the negative region is connected to the N-terminal and in reverse bias just opposite of it has occurred.



The input signal or weak signal is applied across the emitter base and the output is obtained to the load resistor R_C which is connected in the collector circuit. The DC voltage V_{EE} is applied to the input circuit along with the input signal to achieve the amplification. The DC voltage V_{EE} keeps the emitter-base junction under the forward biased condition regardless of the polarity of the input signal and is known as a bias voltage.

When a weak signal is applied to the input, a small change in signal voltage causes a change in emitter current (or we can say a change of 0.1V in signal voltage causes a change of 1mA in the emitter current) because the input circuit has very low resistance. This change is almost the same in collector current because of the transmitter action.

In the collector circuit, a load resistor R_C of high value is connected. When collector current flows through such a high resistance, it produces a large voltage drop across it. Thus, a weak signal (0.1V) applied to the input circuit appears in the amplified form (10V) in the collector circuit.

Single Stage Transistor Amplifier? – Circuit Diagram and its Workings

When only one transistor with associated circuit is used for increasing the strength of a weak signal, the circuit is known as single stage transistor amplifier.

Single Stage Transistor Amplifier Practical Circuit:

A practical circuit of a single stage transistor amplifier in CE configuration and using self-biasing is shown in Fig. 14.2. The resistors R_1, R_2 and R_E form the biasing and stabilization circuit.

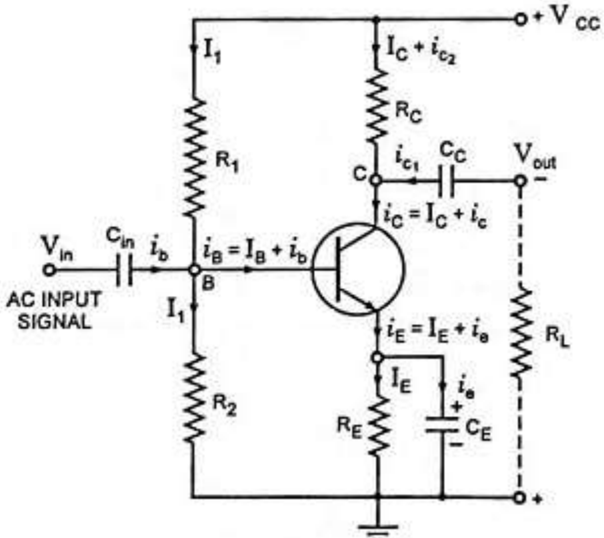


Fig. 14.2 *Practical Circuit of a Transistor Amplifier in CE Configuration With Self-Biasing*

The biasing circuit must establish a proper operating point otherwise a part of the -ve half cycle of the signal may be cut off in the output. The resistor R_L connected across the output terminals is called the load. When a number of stages are employed then R_L represents the input resistance for the next stage.

An electrolytic capacitor, called the **input capacitor**, C_{in} of capacity of about 10 μF is used to couple the signal to the transistor base. In the absence of this capacitor, the signal source resistance will come across R_2 and thus change the bias. This capacitor allows only ac signal to flow but isolates the signal source from R_2. Another capacitor, called the emitter bypass capacitor C_E, of capacity of about 100 μF is used in parallel with emitter resistance R_E in order to provide a low reactance path to the amplified ac signal. In the absence of this capacitor, amplified ac signal flowing through R_E will cause a voltage drop across it which in turn will feedback the input side and reduce the output voltage.

For coupling of one stage of amplifier to the next stage another capacitor C_C, called the **coupling** or **blocking capacitor**, of capacity of about 10 μF is used. Because of its presence, the output across the load resistance R_L is free from the collector dc voltage. In its absence R_C will come in parallel with the resistor R_1 of the biasing network of next stage and thereby change the biasing conditions of the next stage.