Rectifier

In a large number of electronic circuits, we require DC voltage for operation. We can easily convert the AC voltage or AC current into DC voltage or DC current by using a device called P-N junction diode.

One of the most important applications of a P-N junction diode is the rectification of Alternating Current (AC) into Direct Current (DC). A P-N junction diode allows electric current in only forward bias condition and blocks electric current in reverse bias condition. In simple words, a diode allows electric current in one direction. This unique property of the diode allows it to acts like a rectifier.

Rectifier definition

A rectifier is an electrical device that converts an Alternating Current (AC) into a Direct Current (DC) by using one or more P-N junction diodes.

Rectifiers can take a wide variety of physical forms, from vacuum tube diodes and crystal radio receivers to modern silicon-based designs. There are two primary methods of diode rectification:

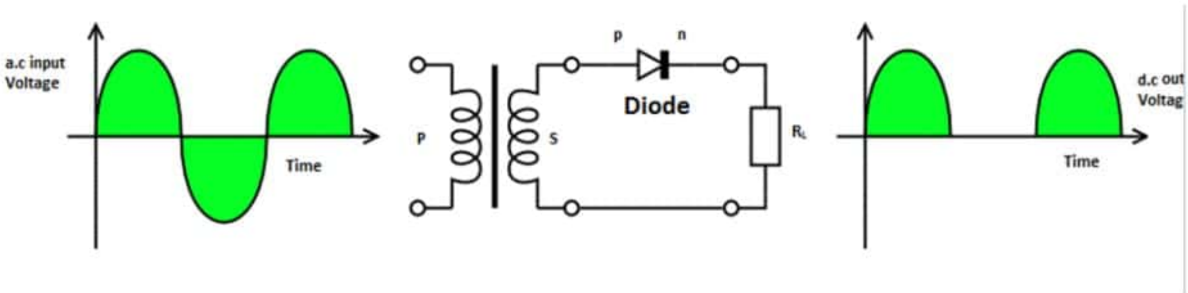
- Half Wave Rectifier
- Full Wave Rectifier

Half Wave Rectifier

The simplest rectifiers, called half-wave rectifiers, work by eliminating one side of the AC, thereby only allowing one direction of current to pass through. In a half-wave rectifier, one half of each a.c input cycle is rectified. When the p-n junction diode is forward biased, it gives little resistance and when it is reversing biased it provides high resistance. During one-half cycles, the diode is forward biased when the input voltage is applied and in the opposite half cycle, it is reverse biased. During alternate half cycles, the optimum result can be obtained.

Working of Half Wave Rectifier

The half wave rectifier has both positive and negative cycles. During the positive half of the input, the current will flow from positive to negative which will generate only positive half cycle of the a.c supply. When a.c supply is applied to the transformer, the voltage will be decreasing at the secondary winding of the diode. All the variations in the a.c supply will reduce and we will get the pulsating d.c voltage to the load resistor.



In the second half cycle, current will flow from negative to positive and the diode will be reverse biased. Thus, at the output side, there will be no current generated and we cannot get power at the load resistance. A small amount of reverse current will flow during reverse bias due to minority carriers.

Advantages of Half Wave Rectifier

- Affordable
- Simple connections
- Easy to use as the connections are simple
- Number of components used are less

Disadvantages of Half Wave Rectifier

- Ripple production is more
- Harmonics are generated
- Utilization of transformer is very low
- Efficiency of rectification is low

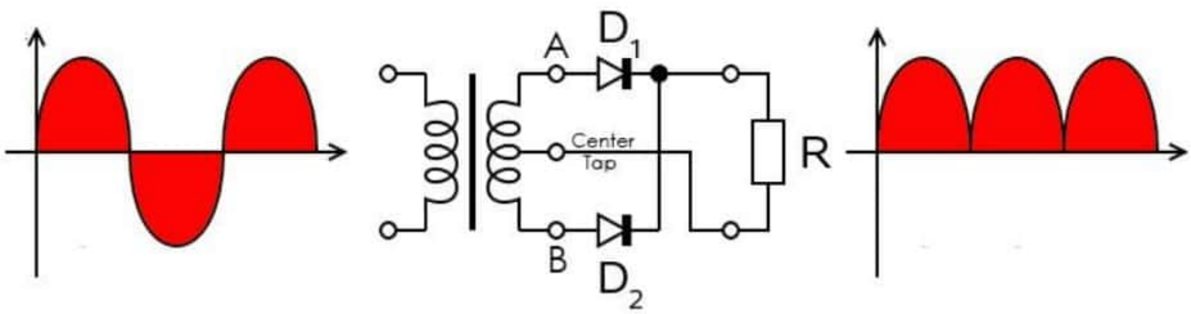
Since half of the AC power input goes unused, half-wave rectifiers produce a very inefficient conversion. A more efficient conversion alternative is a full-wave rectifier, which uses both sides of the AC waveform.

Full Wave Rectifier

Full wave rectifier circuits are used for producing an output voltage or output current which is purely DC. The main advantage of full wave rectifier over half wave rectifier is that such as the average output voltage is higher in full wave rectifier, there is less ripple produced in full wave rectifier when compared to half wave rectifier.

Working of Full Wave Rectifier

Full wave rectifier utilizes both halves of each a.c input. When the p-n junction is forward biased, the diode offers low resistance and when it is reversing biased it gives high resistance. The circuit is designed in such a manner that in the first half cycle if the diode is forward biased then in the second half cycle it is reverse biased and so on.



In the above circuit, two junction diodes are connected to a load. This circuit gives out in both positive and negative halves of the AC cycle. Hence, it is a Full-wave Rectifier. In this circuit, the p-sides of both the diodes are connected to the input. And, the n-sides are connected together and connected to the load.

Also, the mid-point of the transformer is connected to the load to complete the circuit. This mid-point of connection is also called Center tap and hence, the transformer is called Center tap transformer.

The reason two diodes are connected is very simple. One diode rectifies the voltage for one half of the cycle while the other diode rectifies it for the other half. Therefore, the output between their common terminals and the centre-tap of the transformer becomes a full-wave rectifier output. Let's see how this works-

If the voltage at point A is positive, then that at point B is negative. In such a scenario, the diode D1 is forward biased while D2 is negatively biased. Hence, D1 conducts while D2 blocks the current. Hence, during the positive half of the input AC cycle, we get output current.

Subsequently, the voltage at point A becomes negative and that at point B becomes positive. In such a scenario, D2 conducts while D1 blocks the current. Hence, we get an output current in the negative half of the input AC cycle too.

Since the circuit rectifies both the halves of the input voltage, it is called Full-wave Rectifier. But, the output is pulsating and not steady. To derive a steady DC output, a capacitor is connected across the output terminals (parallel to the load).

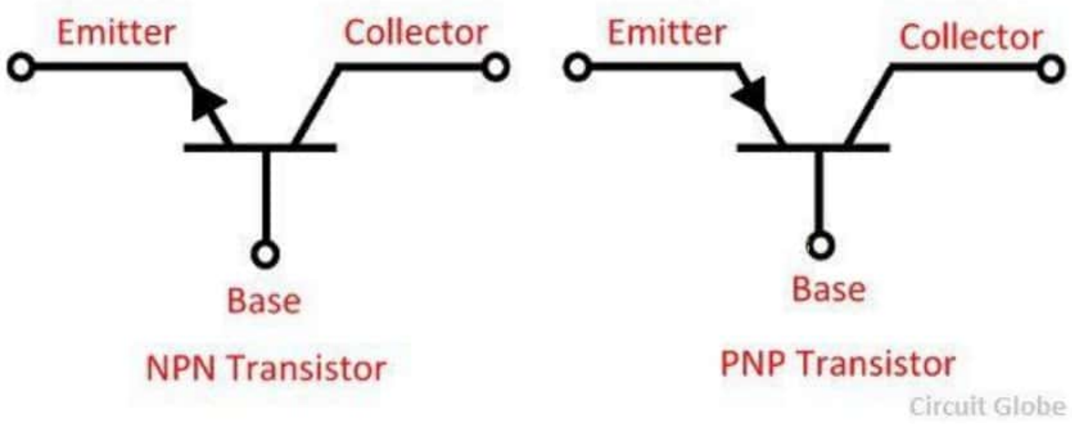
Transistor

Definition: The transistor is a semiconductor device which transfers a weak signal from low resistance circuit to high resistance circuit. The word 'trans' mean transfer property and 'istor' mean resistance property offered to the junctions. In other words, it is a switching device which regulates and amplifies the electrical signal likes voltage or current.

The transistor consists of two PN diode connected back to back. It has three terminals namely emitter, base and collector. The base is the middle section which is made up of thin layers. The right part of the diode is called emitter diode and the left part is called collector-base diode. These names are given as per the common terminal of the transistor. The emitter based junction of the transistor is connected to forward biased and the collector-base junction is connected in reverse bias which offers a high resistance.

Transistor Symbols

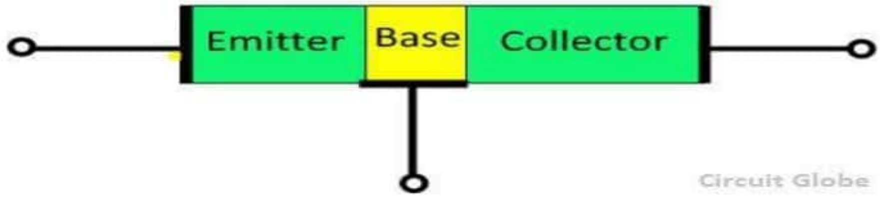
There are two types of transistor, namely NPN transistor and PNP transistor. The transistor which has two blocks of n-type semiconductor material and one block of P-type semiconductor material is known as NPN transistor. Similarly, if the material has one layer of N-type material and two layers of P-type material then it is called PNP transistor. The symbol of NPN and PNP is shown in the figure below.



The arrow in the symbol indicates the direction of flow of conventional current in the emitter with forward biasing applied to the emitter-base junction. The only difference between the NPN and PNP transistor is in the direction of the current.

Transistor Terminals

The transistor has three terminals namely, emitter, collector and base. The terminals of the diode are explained below in details.



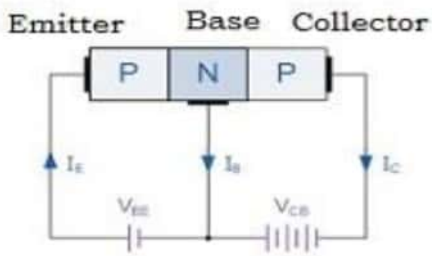
Emitter – The section that supplies the large section of majority charge carrier is called emitter. The emitter is alway connected in forward biased with respect to the base so that it supplies the majority charge carrier to the base. The emitter-base junction injects a large amount of majority charge carrier into the base because it is heavily doped and moderate in size.

Collector – The section which collects the major portion of the majority charge carrier supplied by the emitter is called a collector. The collector-base junction is always in reverse bias. Its main function is to remove the majority charges from its junction with the base. The collector section of the transistor is moderately doped, but larger in size so that it can collect most of the charge carrier supplied by the emitter.

Base – The middle section of the transistor is known as the base. The base forms two circuits, the input circuit with the emitter and the output circuit with the collector. The emitter-base circuit is in forward biased and offered the low resistance to the circuit. The collector-base junction is in reverse bias and offers the higher resistance to the circuit. The base of the transistor is lightly doped and very thin due to which it offers the majority charge carrier to the base. There are two types of transistors, namely, (a) n-p-n transistor (b) p-n-p transistor.

p-n-p transistor

Circuit Diagram



Biasing –

Forward bias- The emitter base junction is forward biased which means the p type emitter is connected to the positive pole of the battery and the n type base is connected to the negative pole of the same battery V_{EE}

Reverse bias – The collector base junction is reverse biased which means the n type base is connected to the positive pole of the battery and the p type emitter is connected to the negative pole of the same batter V_{cc}

Current –The emitter current I_E, base current I_B and the collector current is as indicated in the circuit diagram

Resistance –The emitter-base junction has low resistance while the base-collector junction has a high resistance.

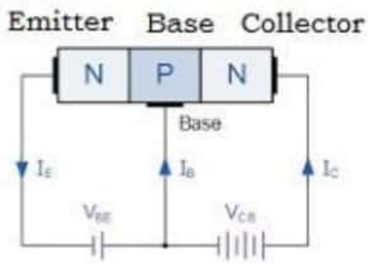
Working

- The holes are the majority carriers in the emitter p type semiconductor. This is repelled by the positive terminal of the battery V_{EE} resulting in emitter current I_E
- The base being lightly doped and thin, the electron density is less. Hence, only 5% of the holes entering the base combine with the electrons resulting in base current I_B. The base current is 5% of I_E

- The remaining 95% of the holes pass over to the collector on account of the high negative potential of the battery V_{cc}. This results in collector current I_c which is 95% of I_E
- When the hole coming from the emitter combines with the electron in the base, the deficiency of electron in the base is compensated by the flow of electrons from the negative terminal of the battery V_{EE} to the base through the connecting wire
- The current in the p-n-p transistor is due to holes however the concentration is maintained at any time; In the external circuit, the current is due to flow of electrons
- From the circuit, we find $I_E = I_B + I_c$

n-p-n transistor

Circuit Diagram



Biasing –

Forward bias- The emitter base junction is forward biased which means the n type emitter is connected to the negative pole of the battery and the p type base is connected to the positive pole of the same battery V_{EE}

Reverse bias – The collector base junction is reverse biased which means the ptype base is connected to the negative pole of the battery and the n type emitter is connected to the positive pole of the same batter V_{cc}

Current –The emitter current I_E, base current I_B and the collector current is as indicated in the circuit diagram

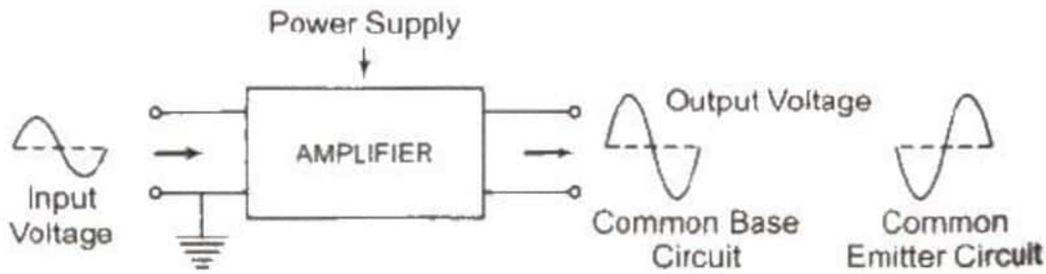
Resistance –The emitter-base junction has low resistance while the base-collector junction has a high resistance

Working

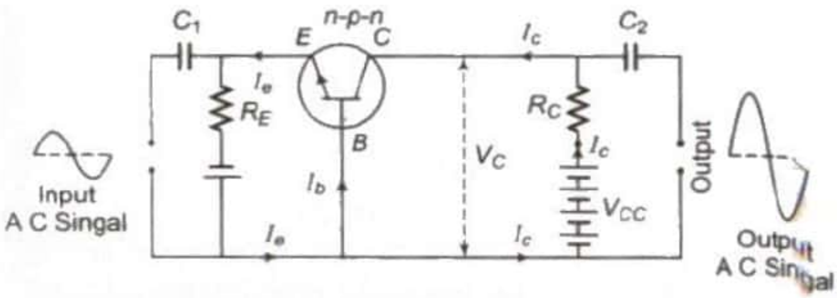
- The electrons are the majority carriers in the emitter n type semiconductor. This is repelled by the negative terminal of the battery V_{EE} resulting in emitter current I_E
- The base being lightly doped and thin, the electron density is less. Hence, only 5% of the electrons entering the base combine with the holes resulting in base current I_B. The base current is 5% of I_E
- The remaining 95% of the electrons pass over to the collector on account of the high positive potential of the battery V_{cc}. This results in collector current I_c which is 95% of I_E
- When the electron coming from the emitter combines with the hole in the base, the deficiency of hole in the base is compensated by the flow of holes from the positive terminal of the battery V_{EE} to the base through the connecting wire
- The current in the n-p-n transistor and the external circuit is due to the flow of electrons
- From the circuit, we fine $I_E = I_B + I_c$

Transistor as an Amplifier

- An amplifier is a device which is used for increasing the amplitude of variation of alternating voltage, current or power.
- The amplifier thus produces an enlarged version of the input signal.
- The general concept of amplification is represented in figure. There are two input terminals for the signal to be amplified and two output terminals for connecting the load; and a means of supplying power to the amplifier.



Common Base Amplifier



AC current gain (α_{AC}) = $\Delta I_c / \Delta I_e$,

where ΔI_c is change in collector current and ΔI_e change in emitter current.

AC voltage gain (A_V) = Output voltage / Input voltage

= α_{AC} * Resistance gain = α_{AC} * R_o / R_i

where R_o is output resistance of the circuit and R_i is input resistance of the circuit.

AC power gain = Change in output power / Change in input power

= AC voltage gain * AC current gain

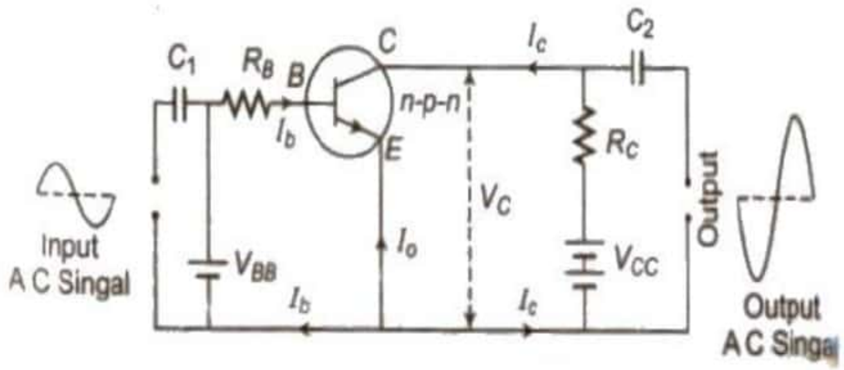
= α^2_{AC} * resistance gain

The input and output signals are in the same phase. There is no amplification in current of a given signal. There is amplification in voltage and power of the given signal.

Common Emitter Amplifier

AC current gain ($ß_{AC}$) = $\Delta I_c / \Delta I_e$

where ΔI_c is change in collector current and ΔI_e change in base current.



AC voltage gain (A_V) = $ß_{AC}$ * resistance gain

AC power gain = $ß^2_{AC}$ * Resistance gain

<u>Relation between the current gain of common base and common emitter amplifier.</u>

$\beta = \alpha / 1 - \alpha = I_c / I_e$

The input and output signals are out of phase by π or 180°

There is amplification in current, voltage and power of the given signal.