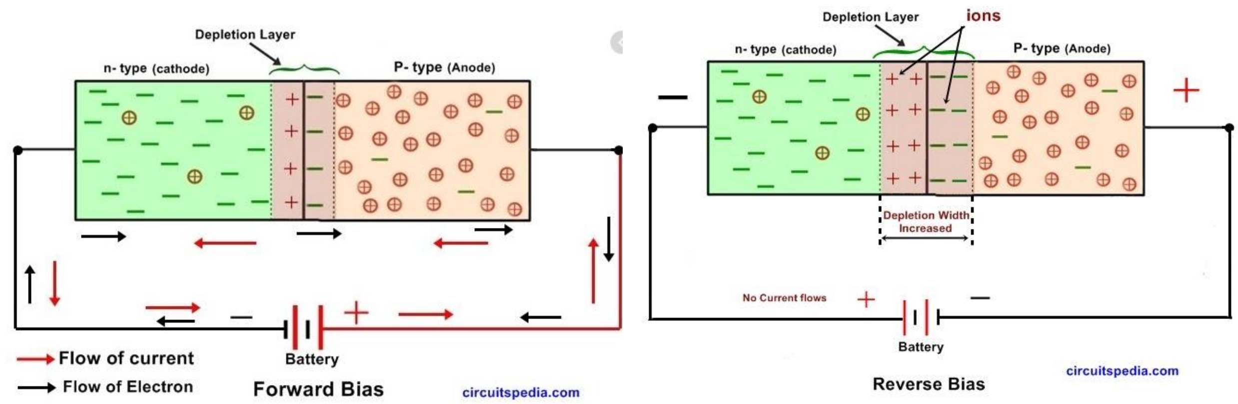
Unit -1

PN Junction diode

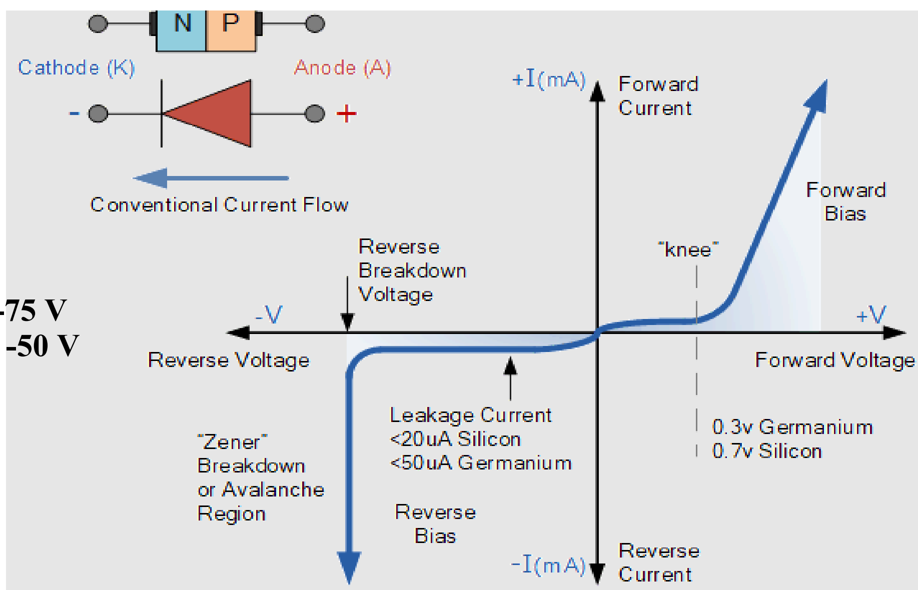
A **diode** is defined as a two-terminal electronic component that only conducts current in one direction. Ideal diode will have zero resistance in one direction, and infinite resistance in the reverse direction.

Biasing PN Junction diode



VI Characteristics of PN Junction diode

Si= -75 V
Ge= -50 V



Junction Diode Summary

The PN junction region of a **Junction Diode** has the following important characteristics:

- Semiconductors contain two types of mobile charge carriers, “Holes” and “Electrons”.
- The holes are positively charged while the electrons negatively charged.
- A semiconductor may be doped with donor impurities such as Antimony (N-type doping), so that it contains mobile charges which are primarily electrons.

- A semiconductor may be doped with acceptor impurities such as Boron (P-type doping), so that it contains mobile charges which are mainly holes.
- The junction region itself has no charge carriers and is known as the depletion region.
- The junction (depletion) region has a physical thickness that varies with the applied voltage.
- When a diode is **Zero Biased** no external energy source is applied and a natural **Potential Barrier** is developed across a depletion layer which is approximately 0.5 to 0.7v for silicon diodes and approximately 0.3 of a volt for germanium diodes.
- When a junction diode is **Forward Biased** the thickness of the depletion region reduces and the diode acts like a short circuit allowing full circuit current to flow.
- When a junction diode is **Reverse Biased** the thickness of the depletion region increases and the diode acts like an open circuit blocking any current flow, (only a very small leakage current will flow).

Application of diode

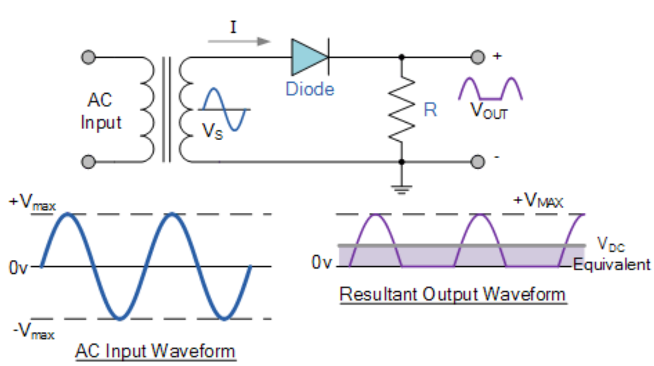
- Rectifiers
- Clipper Circuits
- Clamping Circuits
- Reverse Current Protection Circuits
- In Logic Gates
- Voltage Multipliers.

Rectifier

A rectifier is a circuit which converts the *Alternating Current* (AC) input power into a *Direct Current* (DC) output power.

Types of rectifier: Half wave, full wave and bridge rectifier

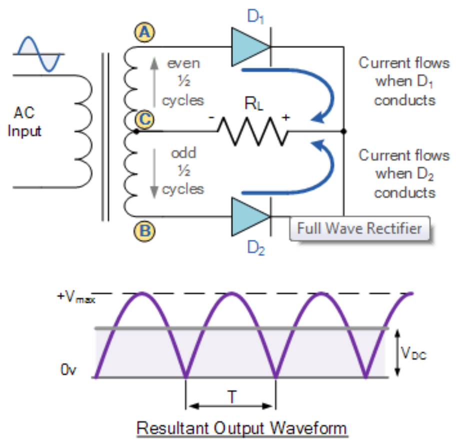
Half wave rectifier: The power diode in a half wave rectifier circuit passes just one half of each complete sine wave of the AC supply in order to convert it into a DC supply.

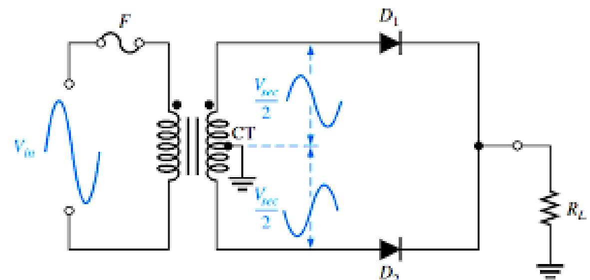


Operation

- During each "positive" half cycle of the AC sine wave, the diode is *forward biased* as the anode is positive with respect to the cathode resulting in current flowing through the diode.
- During each "negative" half cycle of the AC sinusoidal input waveform, the diode is *reverse biased* as the anode is negative with respect to the cathode. Therefore, NO current flows through the diode or circuit. Then in the negative half cycle of the supply, no current flows in the load resistor as no voltage appears across it so therefore, Vout = 0.
- The current on the DC side of the circuit flows in one direction only making the circuit **Unidirectional**.

Full wave rectifier



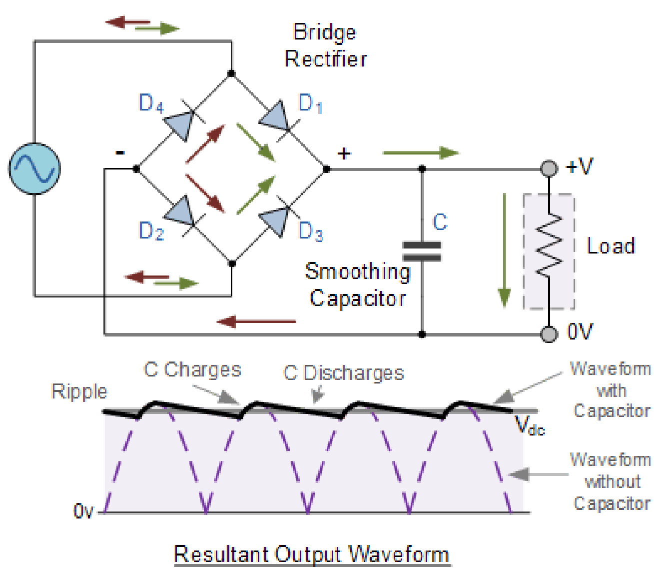


A center-tapped full-wave rectifier

The full wave rectifier circuit consists of two *power diodes* connected to a single load resistance (R_L) with each diode taking it in turn to supply current to the load. When point A of the transformer is positive with respect to point C, diode D_1 conducts in the forward direction as indicated by the arrows.

When point B is positive (in the negative half of the cycle) with respect to point C, diode D_2 conducts in the forward direction and the current flowing through resistor R is in the same direction for both half-cycles. As the output voltage across the resistor R is the phasor sum of the two waveforms combined, this type of full wave rectifier circuit is also known as a "bi-phase" circuit.

Bridge rectifier



Another type of circuit that produces the same output waveform as the full wave rectifier circuit above, is that of the **Full Wave Bridge Rectifier**. This type of single phase rectifier uses four individual rectifying diodes connected in a closed loop "bridge" configuration to produce the desired output.

The main advantage of this bridge circuit is that it does not require a special centre tapped transformer, thereby reducing its size and cost. The single secondary winding is connected to one side of the diode bridge network and the load to the other side as shown below.

Operation

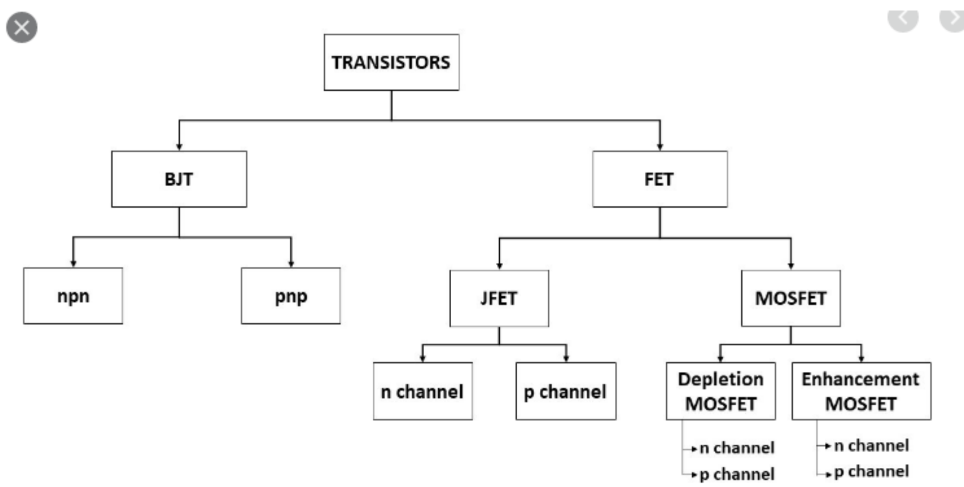
- The four diodes labeled D_1 to D_4 are arranged in "series pairs" with only two diodes conducting current during each half cycle. During the positive half cycle of the supply, diodes D1 and D2 conduct in series while diodes D3 and D4 are reverse biased and the current flows through the load as shown below.

- During the negative half cycle of the supply, diodes D3 and D4 conduct in series, but diodes D1 and D2 switch “OFF” as they are now reverse biased. The current flowing through the load is the same direction as before.

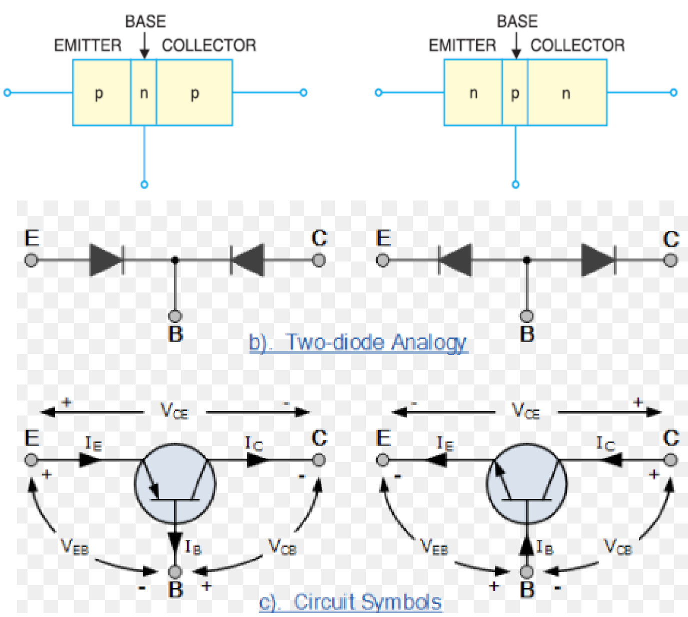
As the current flowing through the load is unidirectional, so the voltage developed across the load is also unidirectional the same as for the previous two diode full-wave rectifier,

Transistor

Transistor is a three terminal electronic device used for amplifier and switching



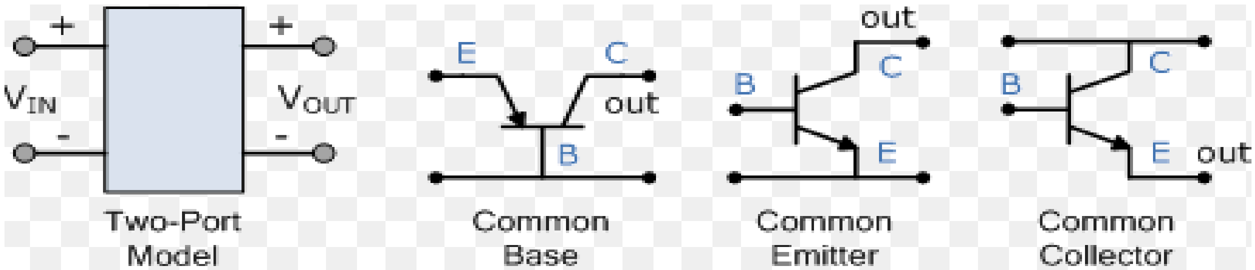
Bipolar Junction Transistor(BJT)



The transistor has three regions, namely ; *emitter, base* and *collector*. The base is much thinner than the emitter while collector is wider than both as shown in figure. sake of convenience, it is customary to show emitter and collector to be of equal size.

(ii) The emitter is heavily doped so that it can inject a large number of charge carriers (electrons or holes) into the base. The base is lightly doped and very thin; it passes most of the emitter injected charge carriers to the collector. The collector is moderately doped.

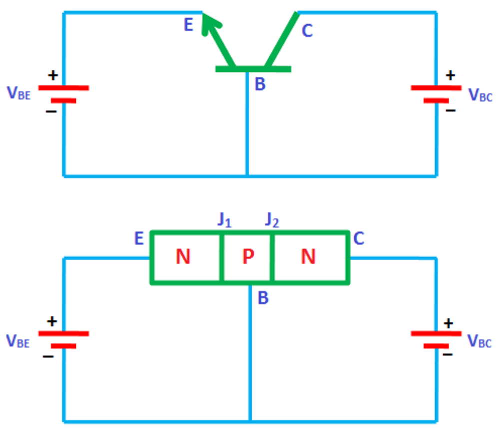
Transistor Circuit Configurations



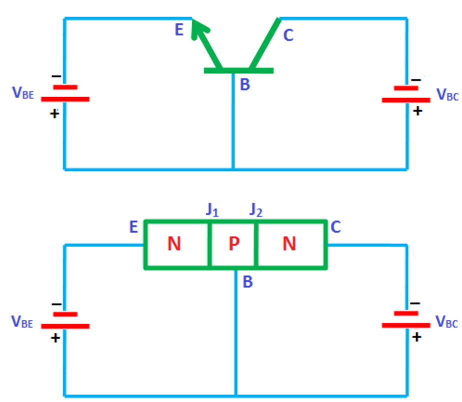
Operating modes of transistor

Modes	EBJ	CBJ	Application
Cutoff	Reverse	Reverse	Switching application in digital circuits
Saturation	Forward	Forward	
Active	Forward	Reverse	Amplifier
Reverse active	Reverse	Forward	Performance degradation

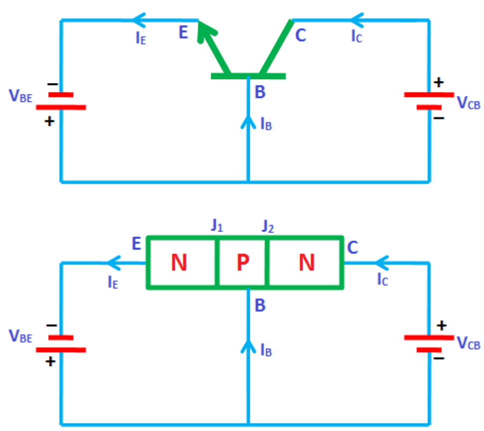
very Limited applications



Cutoff mode

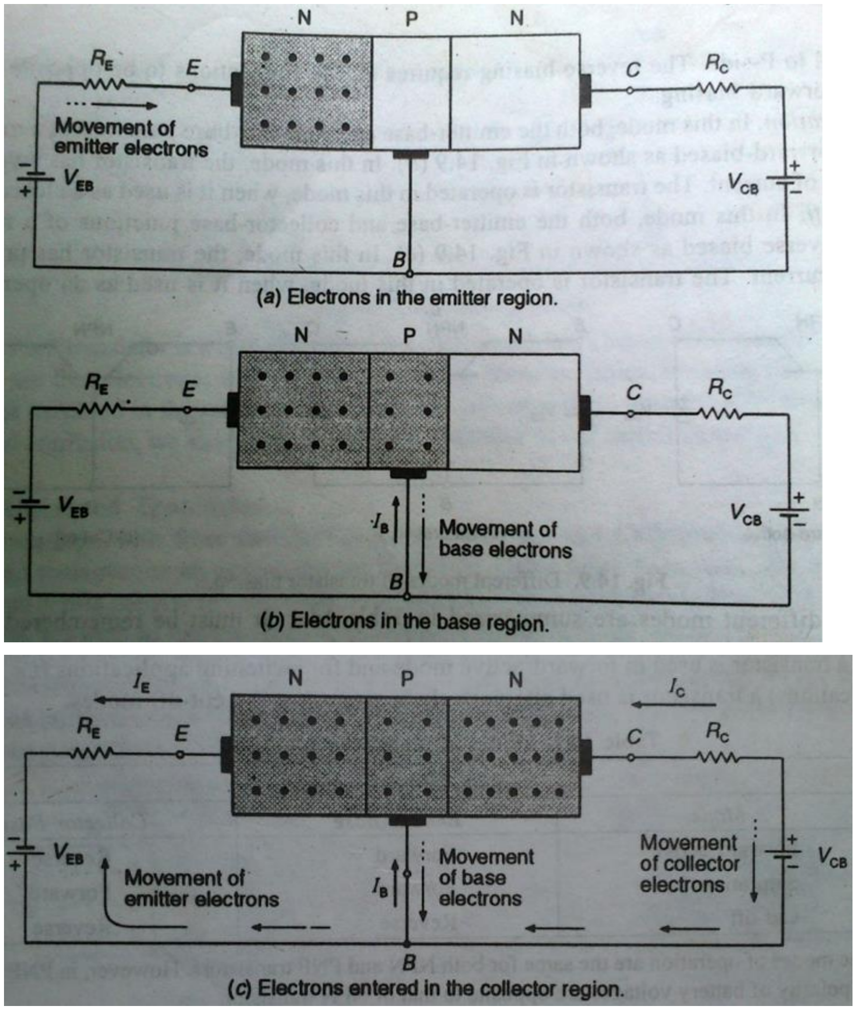


Saturation mode



Active mode

Working principle of NPN Transistor



(a) Electrons in the emitter region.

(b) Electrons in the base region.

(c) Electrons entered in the collector region.

Working of NPN transistor. Figure shows the *npn* transistor with forward bias to emitter base junction and reverse bias to collector-base junction. The forward bias causes the electrons in the *n*-type emitter to flow towards the base. This constitutes the emitter current I_E. As these electrons flow through the *p*-type base, they tend to combine with holes. As the base is lightly doped and very thin, therefore, only a few electrons (less than 5%) combine with holes to constitute base current I_B. The remainder (more than 95%) cross over into the collector region to constitute collector current I_C. In this way, almost the entire emitter current flows in the collector circuit. It is clear that emitter current is the sum of collector and base currents *i.e.* $I_E = I_B + I_C$

Junction Field Effect Transistor(JFET)

A **junction field effect transistor** is a three terminal semiconductor device in which current conduction is by one type of carrier i.e., electrons or holes.

The JFET was developed about the same time as the transistor but it came into general use only in the late 1960s. In a JFET, the current conduction is either by electrons or holes and is controlled by means of an electric field between the gate electrode and the conducting channel of the device. The JFET has high input impedance and low noise level.

unit -1

Half wave rectifier	Full wave rectifier	Bridge rectifier
Average dc current $I_{dc}= I_m/\pi$	Average dc current $I_{dc}= 2I_m/\pi$	
RMS value $I_{rms} = I_m/2$	RMS value $I_{rms} = I_m/2$	
Efficiency (η) = 40.6%	Efficiency (η) = 81.2%	
Ripple factor (γ) = 1.21	Ripple factor (γ) = 0.48	
$PIV=E_m$	$PIV=2E_m$	

Important Applications of Diodes

i. **Clipper and ii. Clamper**

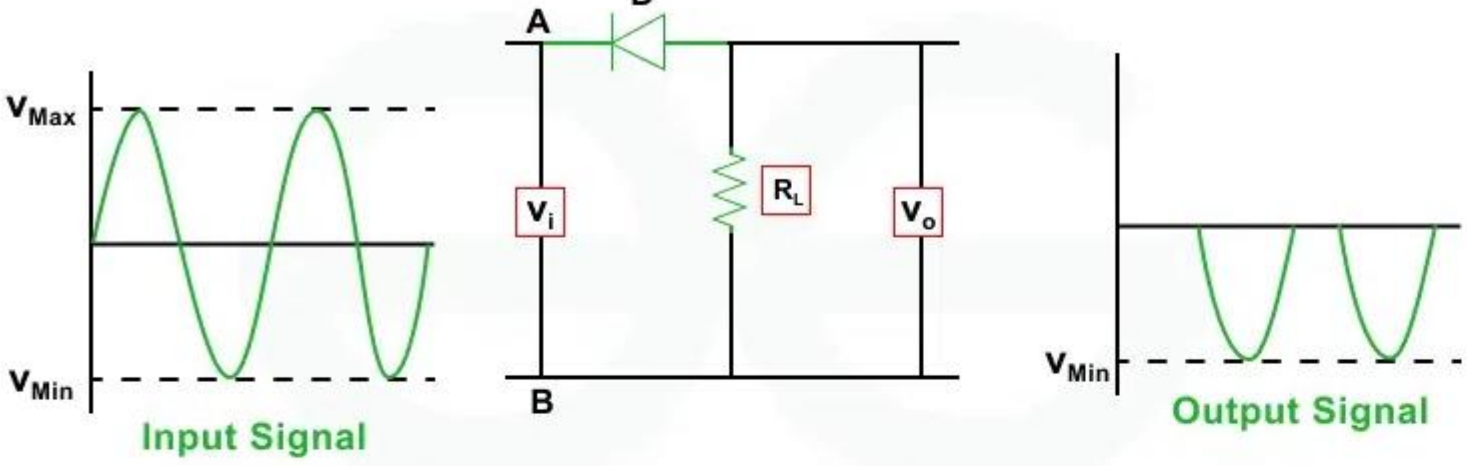
i. Clipper : Wave shapping circuits, and remove a portion of a.c. signal.

ii. Clamper: D.C. restorer, it is used to restore or change the a.c. signal to d.c signal.

Clipper is extensively used in Radar, Digital and Other electronic systems. Further, it is classified as iA. Positive Clipper, iB. Negative Clipper, iC. Biased Clipper and iD. Combination Clipper.

Clamper

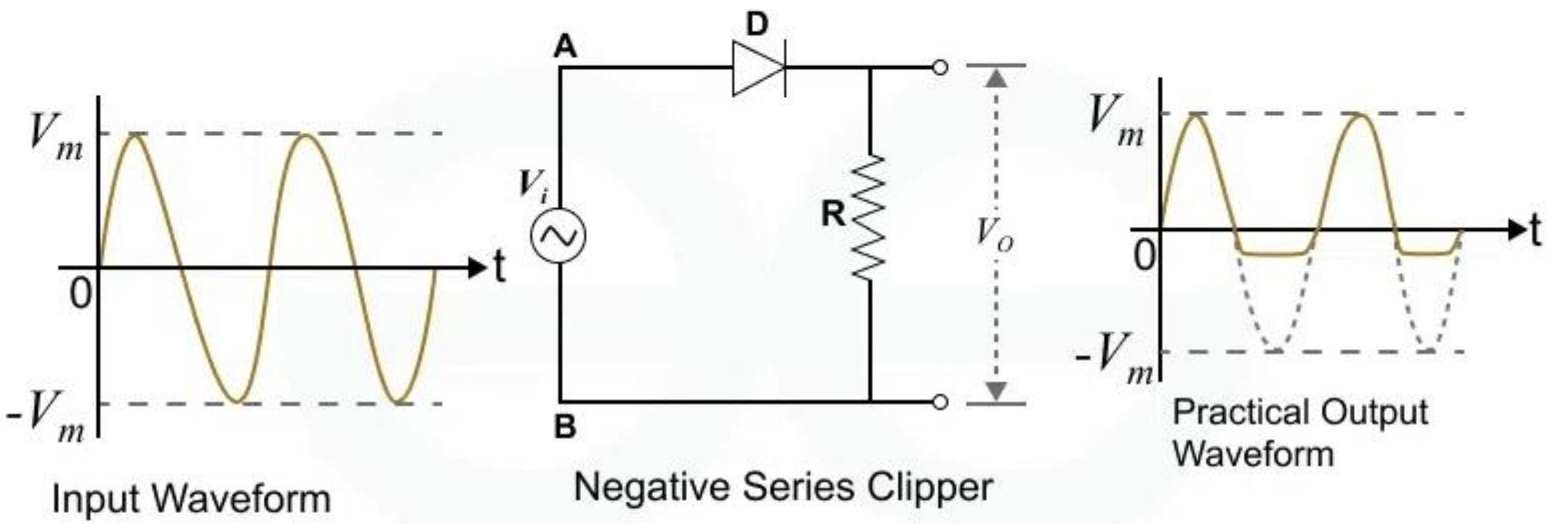
Positive clipper



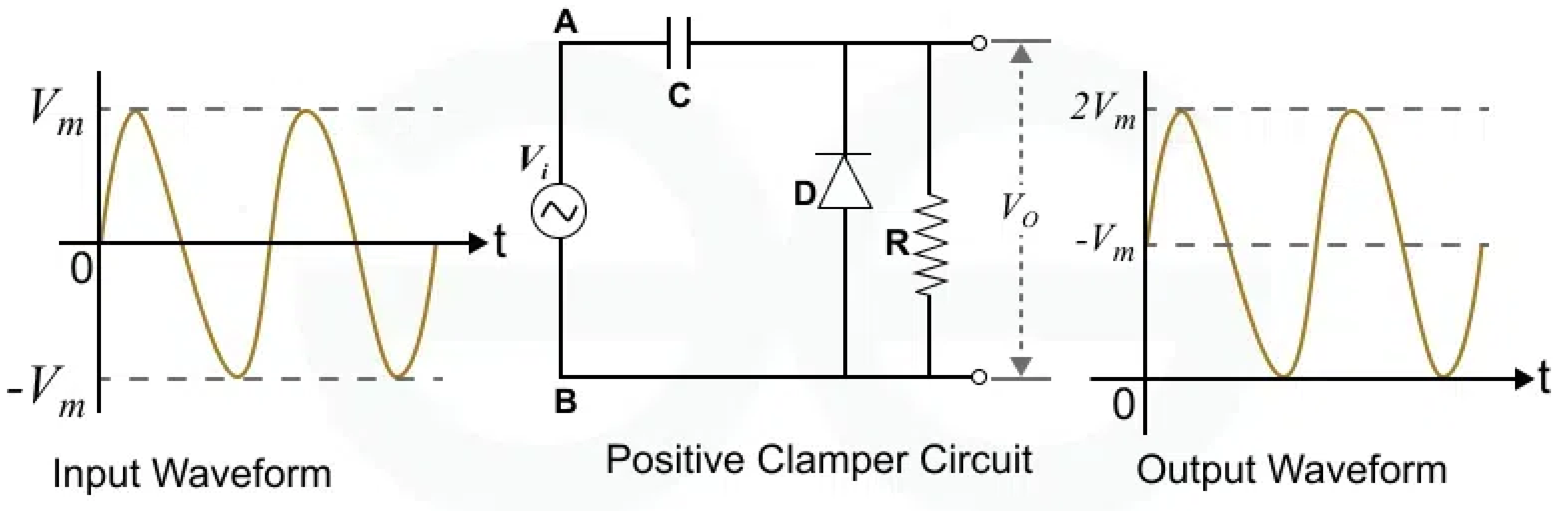
It removes the positive portion of an input signal's waveform, essentially "cutting off" the positive half-cycle while allowing the negative half-cycle to pass through. This is achieved by using a diode in series with the input signal.

Negative clipper

It removes the negative portion of an input signal's waveform. It effectively "clips off" or eliminates the negative half-cycles of the input voltage.



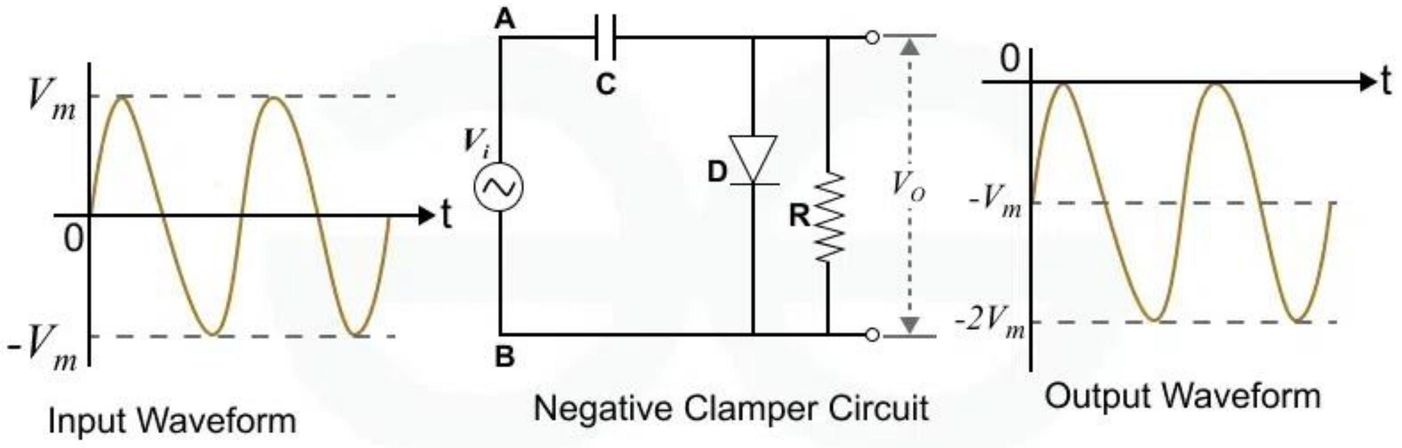
A **clamper**, also called a ***DC restorer or level shifter, is to move the whole waveform either up or down without changing its shape***. It can be done by adding a capacitor and a diode to the circuit, making it possible for energy storage or release.



A positive clamper is a type of clamper circuit that shifts the entire waveform in the positive direction.

Negative clamper

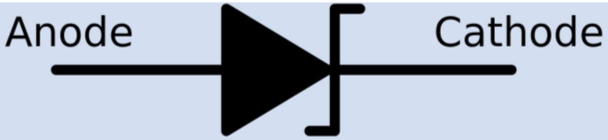
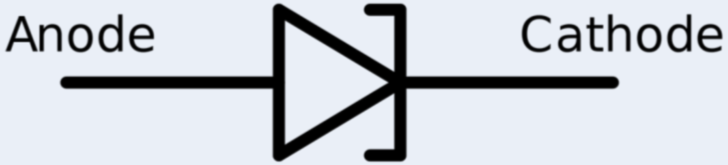
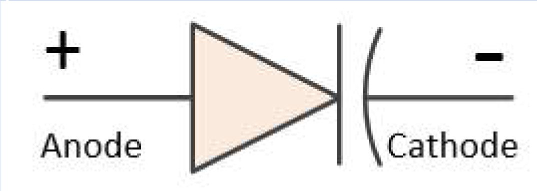
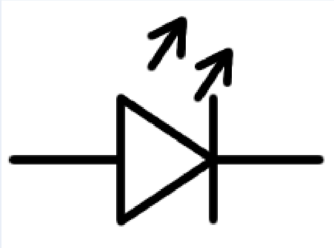
❑ It shifts the entire waveform in the negative direction. It adds a negative DC component to the input signal during the charging phase, leading to a downward shift of the waveform.



Applications

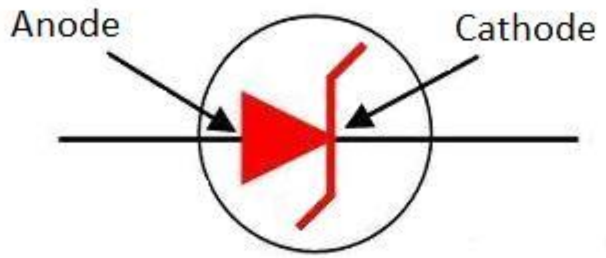
❑ Frequently used in test equipment, sonar, and radar systems.
❑ Used voltage doubler or voltage multipliers
❑ It can be used for removing distortion.

Special Diodes

Types of special diodes	Symbols	Application
1. Zener diode		Voltage regulator in power supplies.
2. Tunnel diode		It used in oscillator circuits
3. Varactor diode		It used in Tunning circuits
4. Light emitting diode		It used in Lamps, TV, and indicators
5. Photodiode		It is used in sensor systems

Zener Diode

- A Zener Diode is a special kind of diode which permits current to flow in the forward direction as normal, but will also allow it to flow in the reverse direction when the voltage is above the breakdown voltage or ‘zener’ voltage.

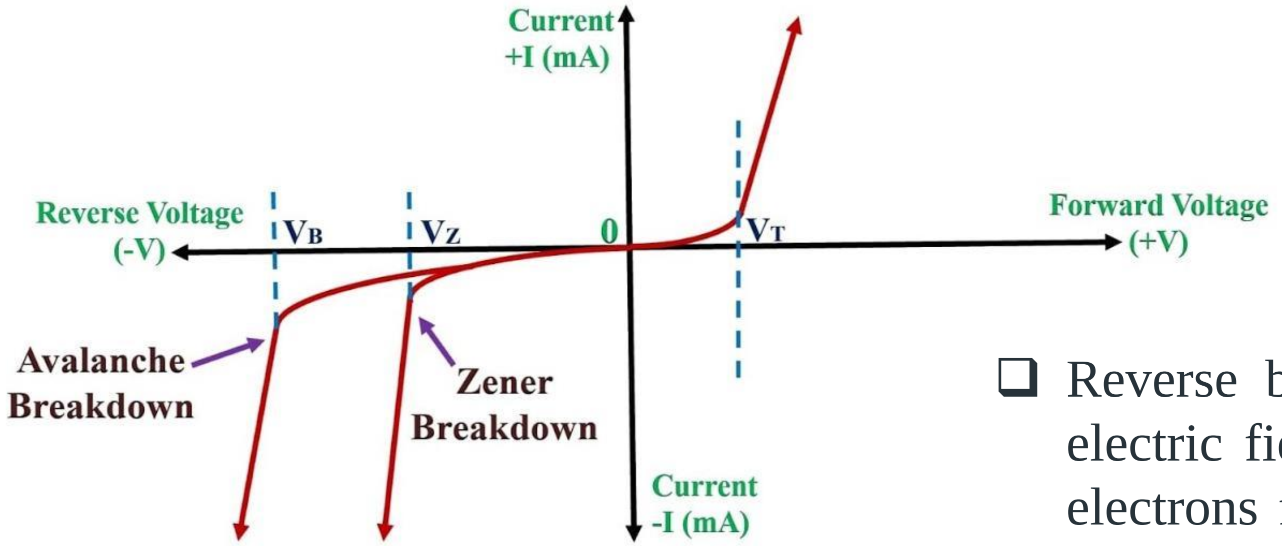


- As we keep increasing the reverse voltage it reaches a point where the reverse voltage equals the breakdown voltage. The breakdown voltage is represented as V_z and in this condition the current start flowing in the diode.

- In reverse bias condition, two kinds of breakdowns occur for Zener Diode which are,

  - Avalanche Breakdown
  - Zener Breakdown

VI Characteristics of Avalanche and Zener breakdown



- **Zener breakdown** happens in heavily doped PN junction diodes.

- Reverse bias voltages reach closer to Zener Voltage, the electric field gets stronger and is sufficient enough to pull electrons from the valance band. These electrons then gain energy from the electric field and break free from the atom.

- It slight increase in the voltage causes a sudden increase in the current.

- **Avalanche breakdown** occurs both in the ordinary diode and Zener Diode at high reverse voltage.

- High value of reverse voltage, the free electron in the PN junction diode gains energy and acquires high velocity and these high-velocity electrons collide with other atoms

- Collision continues and new electrons are available for conducting current thus the current increase rapidly in the diode

- The phenomenon of a sudden increase in the current is called the Avalanche breakdown.

Application

- It is used in Clipping circuits.
- It is used in Voltage regulator.
- It is used in over voltage protection.

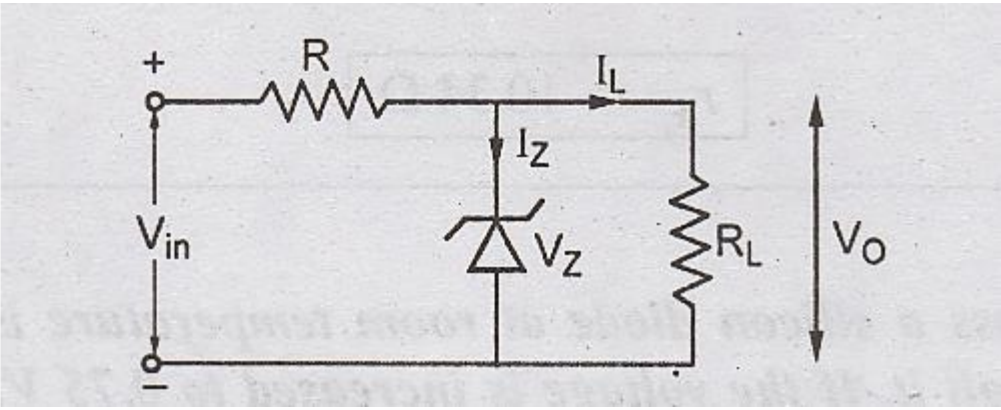
S.NO.	Zener Breakdown	Avalanche Breakdown
1.	It is observed in diodes that are highly doped.	It is observed in diodes that are lightly doped.
2.	Breakdown voltage in the range of 5 to 8 volts	Breakdown voltage greater than 8 volts
3.		

Zener diode as voltage regulator

- When reverse bias is applied, the voltage across the diode remains constant and, the current through the diode increases.

- The voltage across the Zener diode acts as reference voltage and the diode can be used as a voltage regulator.

- Zener diode is reverse biased and if the input voltage is not less than Zener breakdown voltage (V_z) then the voltage across the diode will be constant and thus the load voltage is also constant.



Applications of Zener Diode

i. Voltage regulators.
ii. Zener limiters to clip the unwanted portion of the voltage waveform.
iii. Over voltage protection.