

Zener Diode

A Zener diode not only allows current to flow from anode to cathode but also, in the reverse direction on reaching the Zener voltage. Due to this functionality, Zener diodes are the most commonly used semiconductor diodes. In this article, let us learn the function of Zener diodes along with its construction, operation and more.

Zener Diode Explanation

A Zener Diode, also known as a breakdown diode, is a heavily doped semiconductor device that is designed to operate in the reverse direction. When the voltage across the terminals of a Zener diode is reversed and the potential reaches the Zener Voltage (knee voltage), the junction breaks down and the current flows in the reverse direction. This effect is known as the Zener Effect.

Zener Diode Definition

A Zener diode is a heavily doped semiconductor device that is designed to operate in the reverse direction.

Zener diodes are manufactured with a great variety of Zener voltages (V_z) and some are even made variable.

How does a Zener Diode work in reverse bias?

A Zener diode operates just like a normal diode when it is forward-biased. However, when connected in reverse biased mode, a small leakage current flows through the diode. As the reverse voltage increases to the predetermined breakdown voltage (V_Z), current starts flowing through the diode. The current increases to a maximum, which is determined by the series resistor, after which it stabilizes and remains constant over a wide range of applied voltage.

There are two types of breakdowns for a Zener Diode:

- **Avalanche Breakdown**
- **Zener Breakdown**

Avalanche Breakdown in Zener Diode

Avalanche breakdown occurs both in normal diode and Zener Diode at high reverse voltage. When a high value of reverse voltage is applied to the PN junction, the free electrons gain sufficient energy and accelerate at high velocities. These free electrons moving at high velocity collides other atoms and knocks off more electrons. Due to this continuous collision, a large number of free electrons are generated as a result of electric current in the diode rapidly increases. This sudden increase in electric current may permanently destroy the normal diode, however, a Zener diode is designed to operate under avalanche breakdown and can sustain the sudden spike of current. Avalanche breakdown occurs in Zener diodes with Zener voltage (V_Z) greater than 6V.

Zener Breakdown in Zener Diode

When the applied reverse bias voltage reaches closer to the Zener voltage, the electric field in the depletion region gets strong enough to pull electrons from their valence band. The valence electrons that gain sufficient energy from the strong electric field of the depletion region break free from the parent atom. At the Zener breakdown region, a small increase in the voltage results in the rapid increase of the electric current.

Avalanche Breakdown vs Zener Breakdown

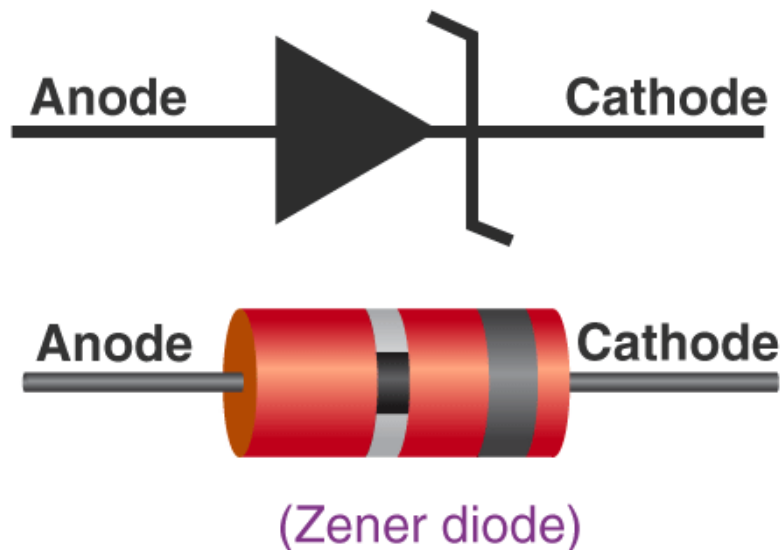
- The Zener effect is dominant in voltages up to 5.6 volts and the avalanche effect takes over above that.
- They are both similar effects, the difference being that the Zener effect is a quantum phenomenon and the avalanche effect is the movement of electrons in the valence band like in any electric current.
- Avalanche effect also allows a larger current through the diode than what a Zener breakdown would allow.

Read More: [Difference Between Zener Breakdown and Avalanche Breakdown](#)

Circuit Symbol of Zener Diode

There are many ways in which a Zener diode is packaged. Some are used for high levels of power dissipation and the others are contained

with surface mount formats. The most common type of Zener diode is contained within a small glass encapsulation. It has a band around one end marking the cathode side of the diode.



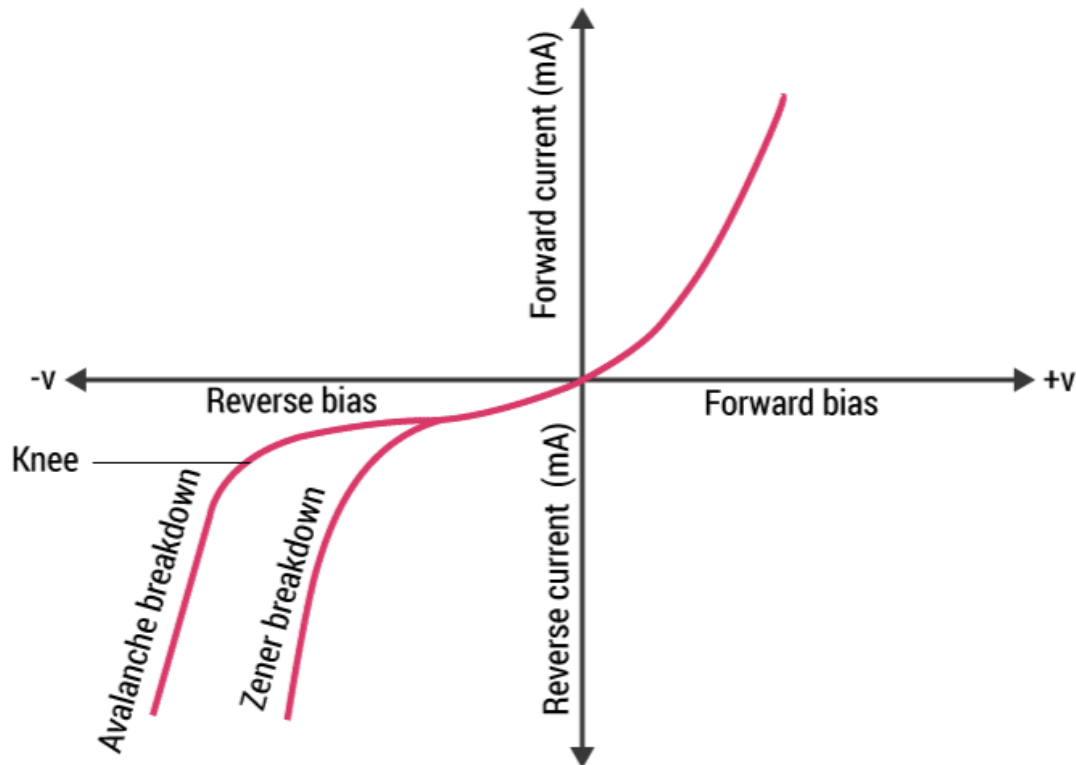
Zener diode symbol and package outlines

From the diagram, we can see that the band around the package corresponds to the line on the diode circuit symbol and this can be an easy way of remembering which end is for which.

The Zener diode circuit symbol places two tags at the end of the bar – one in the upward direction and the other in the lower direction as shown in the figure. This helps in distinguishing Zener diodes from other forms of diodes within the 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 any other P-N junction diode.

Reverse Characteristics of Zener Diode

When a reverse voltage is applied to a Zener voltage, initially a small reverse saturation current I_o flows across the diode. This current is due to thermally generated minority carriers. As the reverse voltage is increased, 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 it is denoted by V_z .

Zener Diode Specifications

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 I_z (max)** – It is the maximum current at the rated Zener Voltage ($V_z - 200\mu\text{A}$ to 200 A)
- **Current I_z (min)** – It is the minimum value of current required for the diode to breakdown.

- **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 $\pm 5\%$
- **Zener Resistance (R_z)** – It is the resistance to the Zener diode exhibits.

Application of Zener Diode

Following are the applications of Zener diode:

Zener diode as a voltage regulator:

Zener diode is used as a Shunt voltage regulator for regulating voltage across small loads. The breakdown voltage of Zener diodes will be constant for a wide range of current. Zener diode is connected parallel to the load to make it reverse bias and once the Zener diode exceeds knee voltage, the voltage across the load will become constant.

Read More: [Zener Diode as a Voltage Regulator](#)

Zener diode in over-voltage protection:

When the input voltage is higher than the Zener breakage voltage, the voltage across the resistor drops resulting in a short circuit. This can be avoided by using the Zener diode.

Zener diode in clipping circuits:

Zener diode is used for modifying AC waveform clipping circuits by limiting the parts of either one or both the half cycles of an AC waveform.

Frequently Asked Questions – FAQs

How do you define Zener diode?

A Zener diode is a semiconductor device that allows current to flow either in a forward or reverse direction.

Why is Zener Diode used a regulator?

Zener diode is used as a shunt voltage regulator. Zener diode is connected parallel to the load to make it reverse bias and once the Zener diode exceeds knee voltage, the voltage across the load becomes constant.

Does Zener Diode exhibit a controlled breakdown?

Yes, Zener Diode does exhibit a controlled breakdown.

Does Zener Diode work in forward biased mode?

What is the difference between a Zener diode and a normal diode?

What is the difference between a Zener diode and a normal diode?

The main difference between a Zener diode and a normal diode lies in the passage of current. A normal diode allows current to flow only in one direction while Zener diode allows current to flow in both directions.