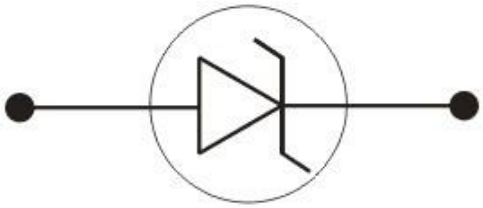
Zener Diode: Circuit & Its Working

The diode is one of the basic components in electronic circuits. When you want to know about voltage considerations you should know about the diodes. The diode is basically made up of semiconductors that have two characteristics, 'P' type and 'N' type. The 'P'type and 'N' type semiconductors represent positive and negative type semiconductors. 'P'type semiconductor will have an excess amount of holes in configuration and 'N' type semiconductor will have an excess amount of electrons. If both types of characteristics present in a single crystal then it can be termed as a diode. The positive terminal of the battery connects with the 'P' side and the negative side is connected with the 'N' side. Let's discuss Zener diode working, It is nothing but a simple diode connecting in reverse bias.

What is a Zener Diode?

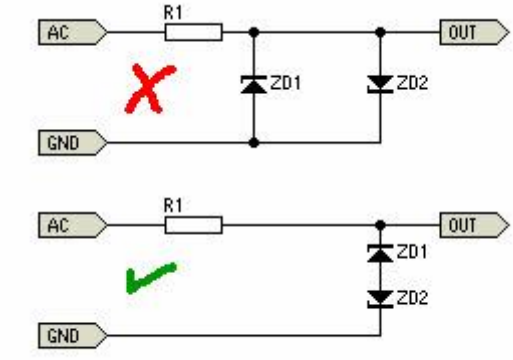
It is mainly a special property of the diode rather than any special type of equipment. The person named Clearance Zener invented this property of the diode that's why it is named after him as a remembrance. The special property of the diode is that there will be a breakdown in the circuit if the voltage applied across a reversely biased circuit.



Zener Diode

This does not allow the current to flow across it. When the voltage across the diode is increased, temperature also increases and the crystal ions vibrate with greater amplitude, and all these leads to the breakdown of the depletion layer. The layer at the junction of 'P' type and 'N' type. When the applied voltage exceeds a specific amount Zener breakdown takes place.
This is nothing but a single diode connected in a reverse bias mode and the Zener diode can be connected in reverse bias positive in a circuit as shown in the picture. We can connect it for different applications.

The circuit symbol of the Zener diode is shown in the figure. For convenience, it is used normally. When discussing the diode circuits we should look through the graphical representation of the operation of the Zener diode. It is called the V-I characteristics of a general p – n junction diode.



Connection of Diode

Zener Diode Symbol

There are many methods for packaging this diode which is mainly used for high ranges of power dissipation & others include surface mount formats. The common type of Zener diode is enclosed in a glass encapsulation. At one end of this glass includes a band around and marked at the cathode side of the diode.

From the above diagram, we can notice that the band around the package corresponds to the row on the symbol so that diode ends can be easily remembered. The circuit symbol of the Zener diode includes two tags at the finish of the bar where one is in the direction of upward and the other one is in the lower direction. So that it helps in differentiating these diodes from other types of diodes in the circuit.

Construction

The **Zener diode construction** is shown below. This is a diffused structure because both the substrates like P and N are diffused together. The junction area can be coated with a SiO2 (silicon dioxide) layer.

Simultaneously throughout construction, the entire construction can be metalized for generating anode & cathode connections. So, the SiO2 layer mainly assists to stop the contagion of the junctions. Therefore, it is used while constructing a Zener diode.
This diode operation mainly depends on the range of doping in the PN junction. For a little reverse bias voltage, the depletion region is extremely thin & the electric field is extremely high. It permits the electrons to flow from the valence band to the conduction band.

The Zener diodes breakdown voltage can be controlled precisely at the time of the doping level. The breakdown voltage of Zener diodes can range from 1.2 V- 200 V. The diodes which are doped lightly & the breakdown voltage is low than 5.6 V, the breakdown signified by the effect of avalanche rather than the Zener effect.

Types of Zener Diodes

The categorization of the Zener diode can be done based on several parameters like the following

- Nominal Voltage
- Maximum Reverse Current
- Power Dissipation
- Packaging type
- Forward drive current
- Forward voltage

How does a Zener Diode Work?

The working of the Zener diode mainly depends on biasing modes like forward and reverse. Once this diode is connected in forwarding bias then it works like a normal diode whereas it is connected in reverse biased then a small leakage of the flow of current will be there in the diode.

When reverse voltage raises than the fixed breakdown voltage (Vz), then-current flows throughout the diode. So the current flow enhances to a maximum level that is verified by the series resistor, once it is stabilized & remains stable over an extensive range of applied voltage. For a Zener diode, there are two kinds of breakdowns like the avalanche breakdown and the Zener breakdown.

Avalanche Breakdown

This kind of breakdown mainly occurs in both the diodes like normal and Zener at maximum reverse voltage. Once a maximum reverse voltage is given to the PN-junction, then electrons will get adequate energy to accelerate at high velocities.

These electrons will start moving at high velocity to crash other atoms and blow off more electrons. Because of this nonstop crash, a number of free electrons will be generated and the current within the diode increases rapidly.

So this unexpected increase within electric current may destroy the normal diode permanently, but, the designing of this diode can be done in such a way that it works under avalanche breakdown & can maintain the unexpected current spike. This kind of breakdown mainly happens in Zener diodes through Zener voltage (Vz) higher than 6V.

Zener Breakdown

Whenever the applied voltage reaches nearer to the Zener voltage, the electric field within the depletion region gets strong to drag electrons from their valence band. So the electrons in the valence will gain sufficient energy from the electric field of the depletion region and escape from the main atom. At the region of Zener breakdown, when voltage increases then electric current also be increased.

There are many ways in which a 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.

Specifications

The **specifications of the Zener diode** include the following.

Voltage (Vz)

The Zener voltage is the reverse breakdown voltage that ranges from 2.4V -200 V and it can raise go upto 1 kV whereas the highest for the SMD (surface-mounted device) is about 47 V.

Maximum Current Iz (max)

The Maximum current required at the rated Zener voltage is Vz which ranges from 200 uA – 200 A.

Minimum Current Iz (min)

The required Minimum current of this diode to break down that ranges from 5 mA -10 mA.

Power Rating
The highest power dissipated by this diode is given through the product of voltage across the diode as well as the flow of current through it. The typical values mainly include 400 mW, 500 mW, 1 W & 5 W. Similarly, for SMD the values are 200 mW, 350 mW, 500 mW & 1 W.

Voltage Tolerance
The voltage tolerance of this diode is ±5%.

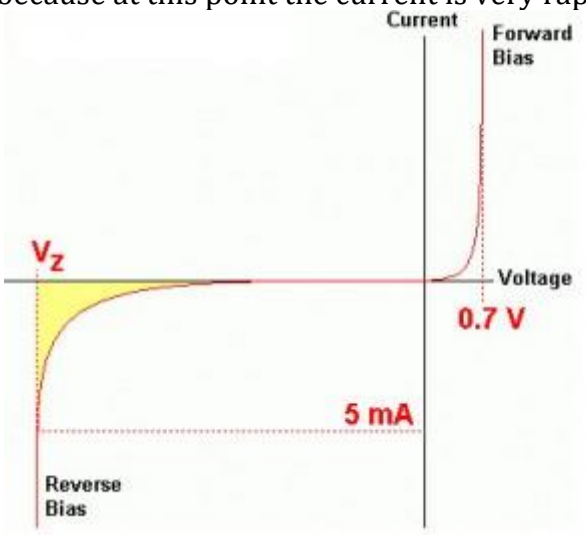
Temperature Stability
The best stability of the diode is approximately 5 V

Package
Leaded devices, as well as the surface, mount either like discrete devices otherwise in integrated circuits.

Zener Resistance (Rz)
The diode shows some resistance as evident from the VI characteristics.

Characteristics of a Zener Diode

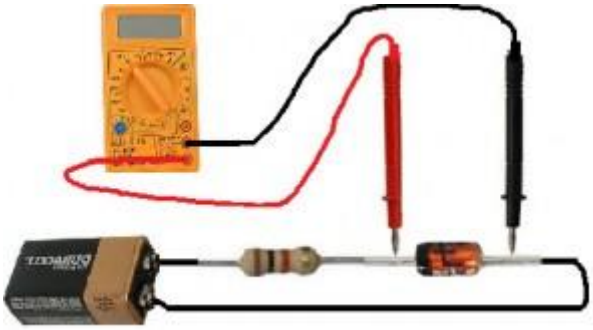
The above diagram shows the V-I characteristics of the Zener diode behavior. When the diode is connected in forwarding bias diode acts as a normal diode. When the reverse bias voltage is greater than a predetermined voltage then the Zener breakdown voltage occurs. To get breakdown voltage sharp and distinct doping is controlled and the surface imperfections are avoided. In the V-I characteristics above Vz is the Zener voltage. And also the knee voltage because at this point the current is very rapid.



Characteristics

Application of Zener Diode

Zener diode is popularly used as Shunt Regulator or Voltage Regulator. As we have gone through the first part of the article we know what is Zener diode and what is the basic principle of operation. Here the question arises where this type of diodes can be useful. The main application of this type of diodes is as a voltage regulator, overvoltage protector, and voltage reference.

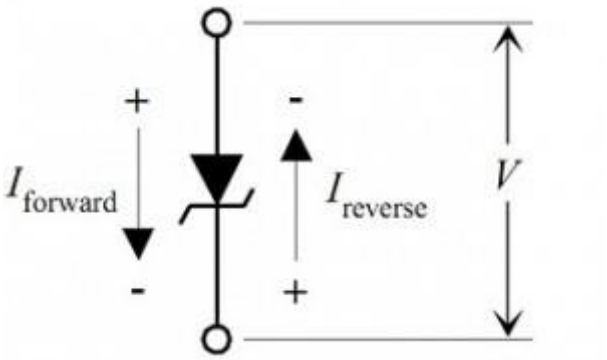


Diode Checking

We have discussed the application of the **Zener diode as the voltage regulator** and now we will discuss the other two points.

Overvoltage Protector

Overvoltage protection is done by using Zener diodes because there is current flowing through the diode after the reverse bias voltage exceeds a certain voltage. This circuit provides safety for the equipment connected at the terminals. Normally the current should not exceed the normal valve but if due to any fault in the circuit the current exceeds the maximum allowable voltage, then the equipment of the system can be damaged.
An SCR is used, by it the output voltage is quickly cut down and a fuse blows which disconnects the input source power. The circuit arrangement is shown below for better understanding,



Zener Diode Circuit

Voltage reference determines the constant supply of power current or voltage as the Zener voltage works. If the supply of current is the same then to avoid unstable performance we use Zener diodes. These are used where voltage reference is required like ammeters, ohmmeters, and voltmeters.

Zener Diode as Voltage Regulator

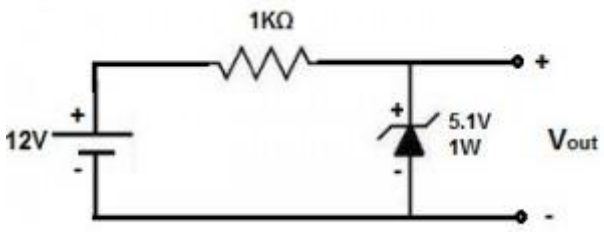
The term regulator means which regulates. This diode can work as a voltage regulator if it is introduced in a circuit. The output across the diode will be constant. It is driven by a current source. As we know if the voltage across the diode exceeds a certain value it would draw excessive current from the supply. The basic diagram of Zener diode as voltage regulator is given below,

To fix the current through this diode series resistance 'R' is introduced whose value can be chosen from the following equation

Resistor value (ohms) = (V1 – V2) / (Zener current + load current)
The above diagram is of shunt regulators because the regulating element is parallel to the load element. This diode produces a stable reference voltage across the load which fulfills the criteria of regulator requirement.

This diode allows current to flow in the forward direction in the same manner as an ideal diode. It also permits to flow in the reverse direction when the voltage is above a certain value known as the breakdown voltage.

This device is named after Zener and it discovered this electrical property. A Zener diode is one in which the reverse breakdown occurs due to electron quantum tunneling under high electric field strength called the Zener effect. Many diodes described as Zener diodes rely instead on avalanche breakdown. Both types are used with the Zener effect predominating under 5.6 V and avalanche breakdown above. Regular applications include providing a reference voltage for voltage regulators. This is to protect devices from momentary voltage pulses.



Circuit Connectivity

These devices are also encountered in series with a base-emitter junction. At transistor stages where the selective choice of a device centered around the avalanche or Zener point. It can be used to introduce compensating temperature coefficient balancing of the transistor. DC error amplifier used in a regulated power supply circuit feedback loop system is one of the examples.

These are also used in surge protectors to limit transient voltage spike systems and another application of the diode is the use of noise caused by its avalanche breakdown in a random number generator. Can you tell me some more uses of Zener diode? By commenting.

Difference between PN Junction Diode and Zener Diode

The difference between PN Junction Diode and Zener Diode includes the following.

PN Junction Diode	**Zener Diode**
The PN-junction diode is a semiconductor diode that conducts simply in a single direction that is the forward direction.	The diode which allows the current to flow in both the direction i.e., forward and reverse, such type of diode is known as the Zener diode.

The junction can be damaged with the reverse current effect	It does not damage the junction
The doping level of the pn-junction diode is low	The doping level of this diode is high
In this junction, Brekdown mainly occurs within higher voltage.	In this diode, breakdown occurs mainly in lower voltage.
PN junction obeys the ohms law	This diode does not obey ohms law.
The applications of a PN-junction diode are mainly for rectification	This diode is used in Voltage stabilizer, waveshaping & motor protection

Advantages

The **advantages of the Zener diod**e include the following.

- As compared to normal diodes, Zener is expensive
- Used in smaller circuits
- Capable for shifting voltage
- Overflow current control
- Simply compatible &accessible across systems
- The circuit voltage can be changed & stabilized
- It provides high performance
- It protects from over-voltage

Disadvantages

The **disadvantages of the Zener diode** include the following.

- For large load current, this diode is not suitable
- The DC o/p voltage can be changed slightly because of Zener resistance.
- The adjustment of the output voltage cannot be done
- Changes within load current generate changes within Zener current.
- Less voltage regulation
- The circuit's internal impedance is high.