Basics of Electronics Engineering (EC142)

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Semiconductor Diodes and Applications

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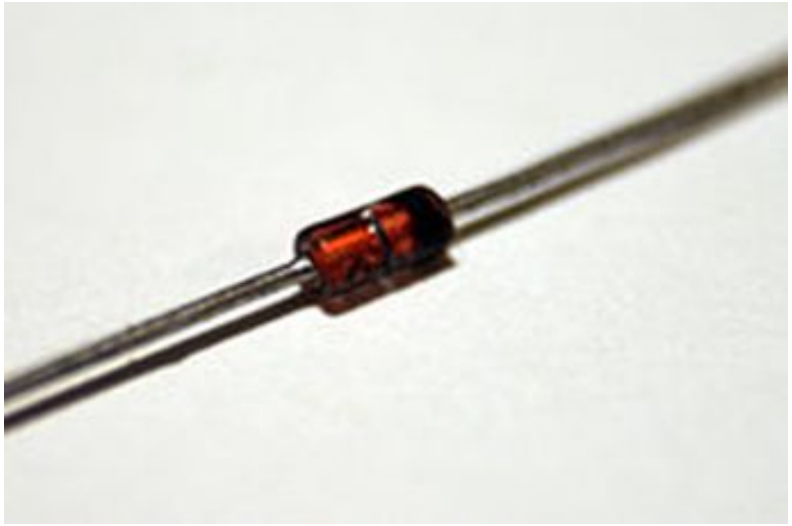
- Introduction to Electronics
- Familiarization with basic electronic components.
- Semiconductor Theory
- Review of PN junction operation
- Plot and analyse V-I Characteristics of PN-Junction Diode
- Diode Applications – Rectifier, Clipper
- Special purpose diodes
  - Light Emitting Diode
  - Zener Diode
  - Varactor Diode
  - Photodiode

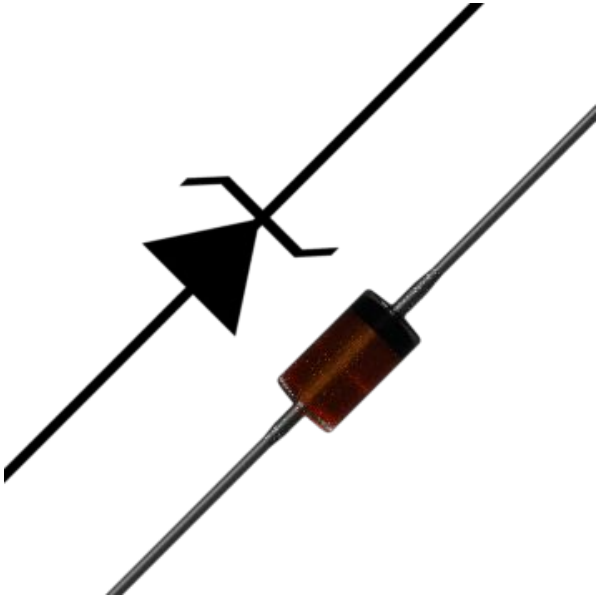
Zener Diode

- Zener diode is like an ordinary PN junction diode but normally operated in reverse biased condition.
- But ordinary PN junction diode connected in reverse biased condition is not used as Zener diode practically.



Zener Diode

- A Zener diode is a specially designed, highly doped PN junction diode.
- Zener diodes are designed to operate in the breakdown region without damage.
- By varying doping levels, it is possible to produce Zener diodes with breakdown voltages from about 2 V to 200 V.



Zener Diode

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- When a PN junction diode is highly doped, the concentration of impurity atoms will be high in the crystal.
- This higher concentration of impurity atoms causes the higher concentration of ions in the depletion layer.
- Hence for same applied reverse biased voltage, the width of the depletion layer becomes thinner than that in a normally doped diode.

Working Principle

- When a PN diode is reverse biased, the depletion layer becomes wider.
- If this reverse biased voltage across the diode is increased continually, the depletion layer becomes more and more wider.
- At the same time, there will be a constant reverse saturation current due to minority carriers.
- After certain reverse voltage across the junction, the minority carriers get sufficient kinetic energy due to the strong electric field.

Zener Breakdown

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- Due to thinner depletion layer in Zener diode, voltage gradient or electric field strength across the depletion layer is quite high.
- If the reverse voltage is continued to increase, after a certain applied voltage, the electrons from the covalent bonds within the depletion region come out and make the depletion region conductive.
- This breakdown is called Zener breakdown.

Zener Breakdown

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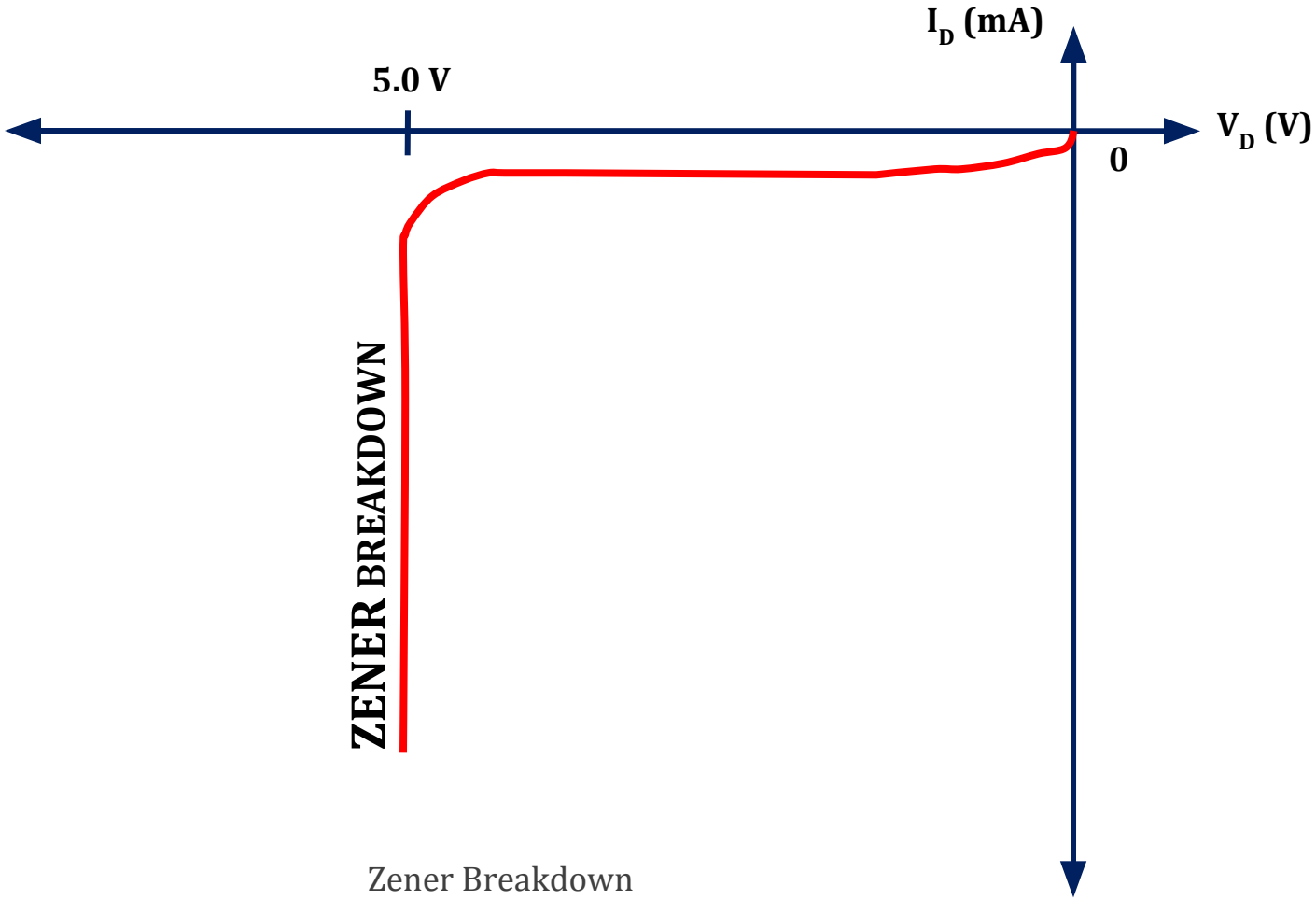
CHARACTERISTICS:

- **Occurs in Heavily Doped Diodes**
- **Has Negative Temperature Coefficient**



Avalanche Breakdown

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- Free electrons with sufficient kinetic energy collide with stationary ions of the depletion layer and knock out more free electrons.
- These newly created free electrons also get sufficient kinetic energy due to the same electric field, and they create more free electrons by collision cumulatively.
- Due to this commutative phenomenon, very soon, huge free electrons get created in the depletion layer, and the entire diode will become conductive.
- This type of breakdown of the depletion layer is known as avalanche breakdown, but this breakdown is not quite sharp.

Avalanche Breakdown

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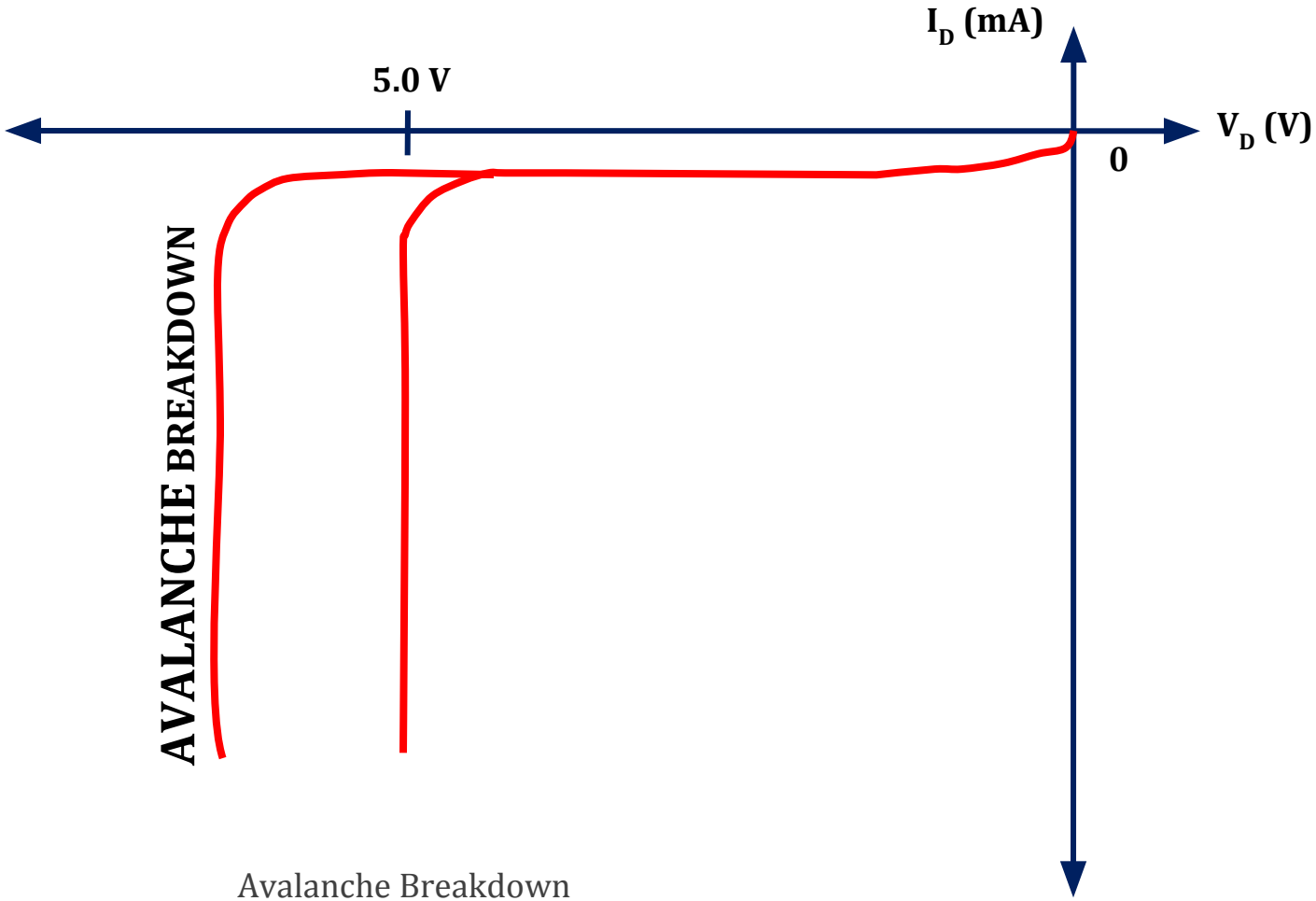
CHARACTERISTICS:

- **Occurs in Lightly Doped Diodes**
- **Has Positive Temperature Coefficient**



S.No.	Avalanche breakdown	Zener breakdown
1.	The doping in the formation of P-N Junction is low	The doping in the formation of P-N junction is high
2.	The covalent bonds break as a result of collision of electrons and holes with the valence electrons	In this the covalent bonds break spontaneously.
3.	Higher reverse potential is required for breakdown.	Low reverse potential is required for breakdown
4.	In this the thermally generated electrons due to electric field ionize other atoms and release electrons.	In this the covalent bonds near the junction break due to high reverse potential ~20 V and consequently electrons become free.

Occurs at higher voltages.

Occurs even with less than 5V.

After breakdown voltage across the pn diode is not constant.

After the breakdown voltage across the zener diode is constant.

Zener Diode Specifications

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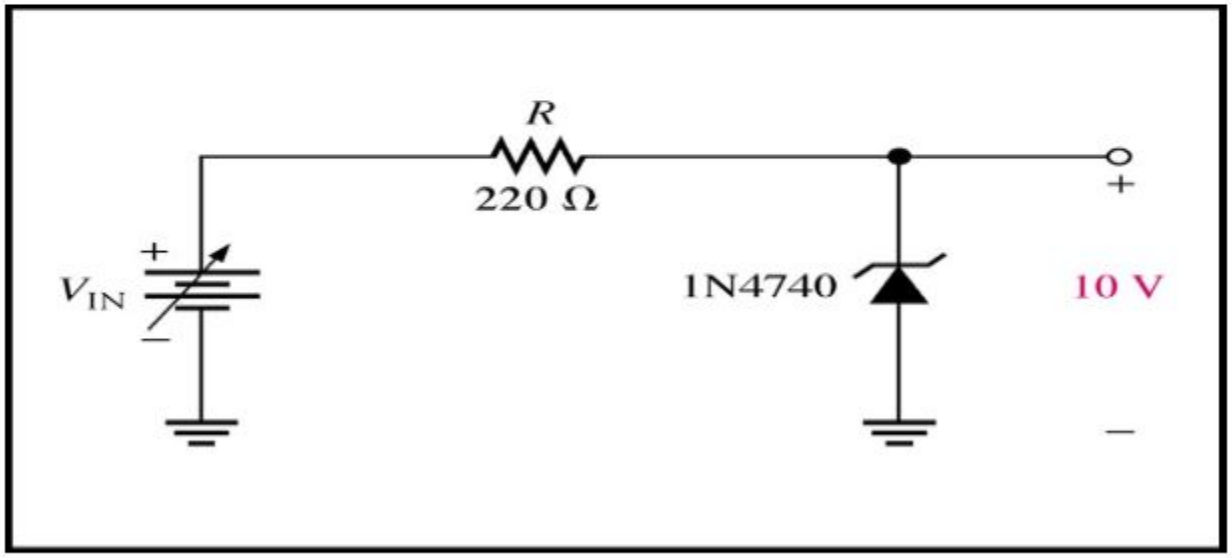
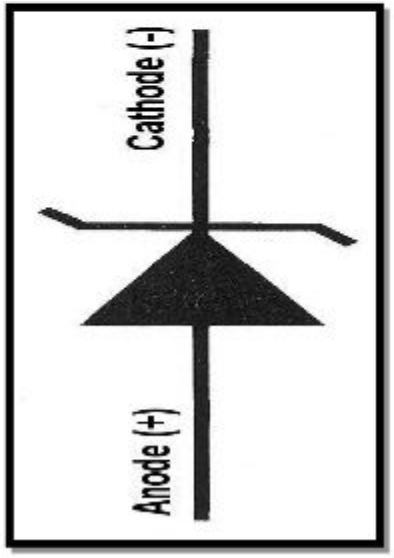
- **Zener/Breakdown Voltage** – The Zener or the reverse breakdown voltage ranges from 2 V to 200 V, sometimes it can go up to 1 kV while the maximum for the surface-mounted device is 47 V.
- **Current Iz (max)** – It is the maximum current at the rated Zener Voltage (Vz – 200μA to 200 A)
- **Current Iz (min)** – It is the minimum value of current required for the diode to 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**
- **Voltage Tolerance** – It is typically ±5%
- **Zener Resistance (Rz)** – It is the resistance, the Zener diode exhibits.

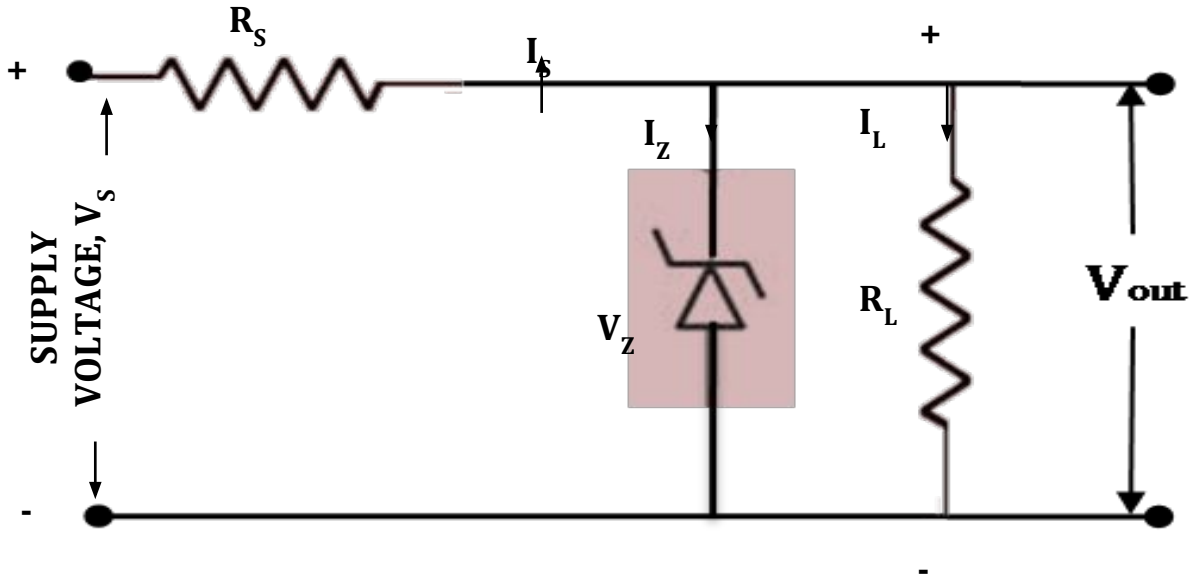
The **zener diode** is a silicon pn junction devices that differs from rectifier diodes because *it is designed for operation in the reverse-breakdown region*. The breakdown voltage of a zener diode is set by carefully controlling the level during manufacture. The basic function of **zener diode** is to maintain a specific voltage across it's terminals within given limits of line or load change. Typically it is used for providing a stable reference voltage for use in power supplies and other equipment.





This particular zener circuit will work to maintain 10 V across the load.

Zener diode as Voltage Regulator



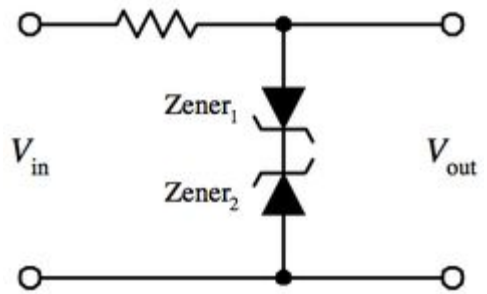
Zener diode is used as a Shunt voltage regulator for regulating voltage across small loads. The breakdown voltage of Zener diodes will be constant for a wide range of current. Therefore, the voltage across the load will become constant.

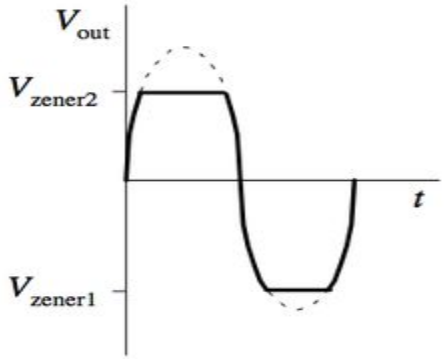
$$I_S = I_Z + I_L$$

Other Applications

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.

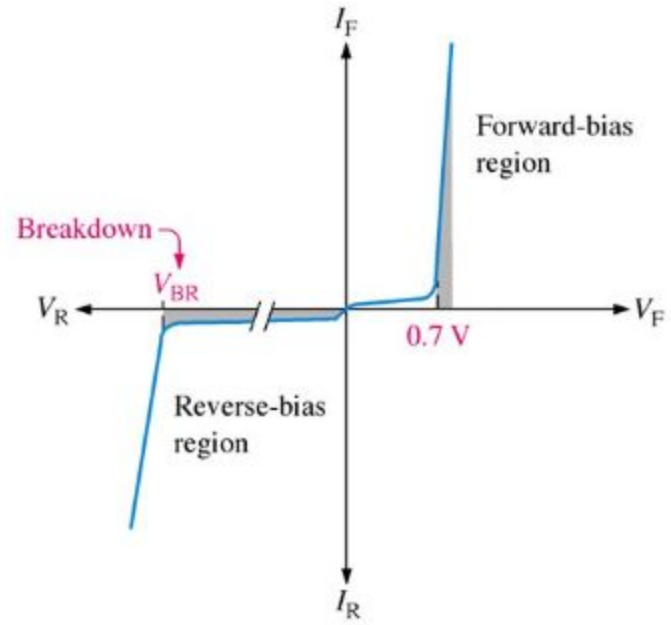
Zener diode in clipping circuits:
Zener diode is used for modifying AC waveform clipping circuits by limiting the parts of either one or both the half cycles of an AC waveform.



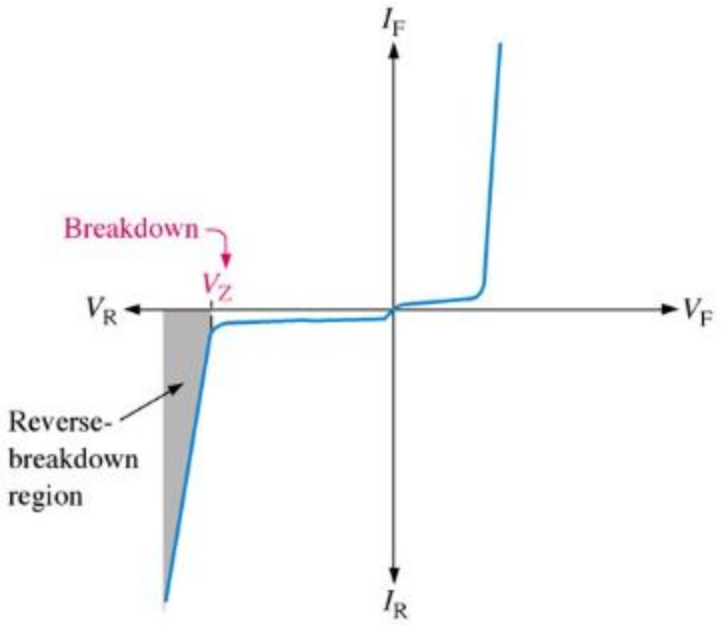


Zener diode compared with PN diode

A **zener diode** is much like a normal diode. The exception being is that it is placed in the circuit in reverse bias and operates in reverse breakdown. This typical characteristic curve illustrates the operating range for a zener. Note that it's forward characteristics are just like a normal diode.

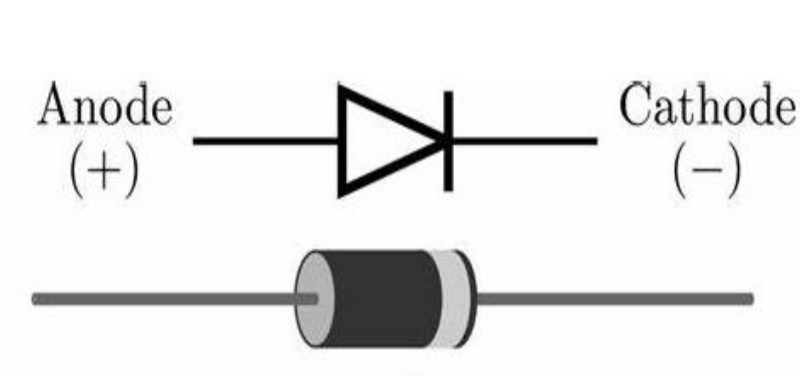


(a) The normal operating regions for a rectifier diode are shown as shaded areas.



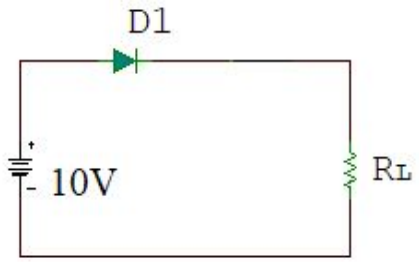
(b) The normal operating region for a zener diode is shaded.

Zener diode compared with PN diode

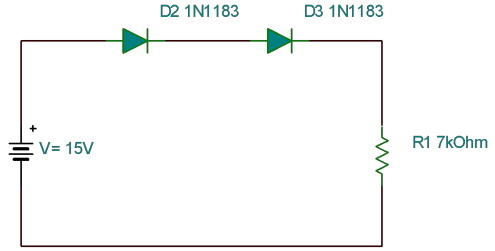


Exam Questions

- Zener diodes are special type of semiconductor diodes that are designed to operate in the breakdown region without damage. Discuss the mechanisms due to which sharp increasing current flows through Zener diode under breakdown conditions. What will be the effect of increasing temperature on these mechanisms?
- The silicon diode D1, shown in given figure is rated for a maximum current of 50 mA. Calculate the minimum value of resistor R_L. Assume the forward voltage drop across the diode to be 0.4 V.

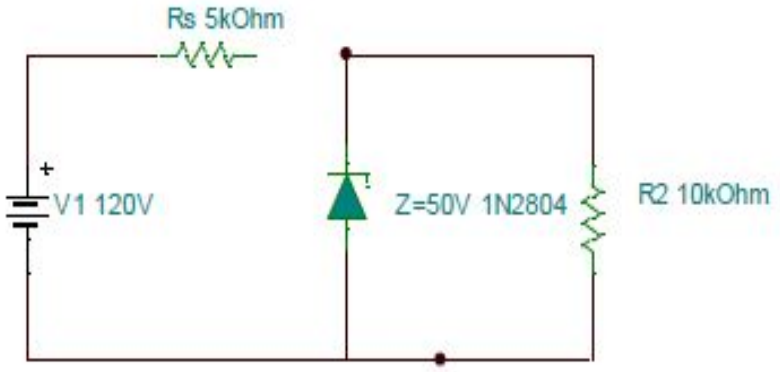


- Find the current through the circuit as shown in Figure:



Exam Questions

- Find the current through the series Resistance, Zener diode and Load resistance in the following circuit:



Useful links

- https://www.electrical4u.com/what-is-zener-diode/
- http://vlabs.iitkgp.ernet.in/be/exp10/index.html

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Thank You