

# Introduction to Zener Diode and Its Working as a Voltage Regulator

# Introduction

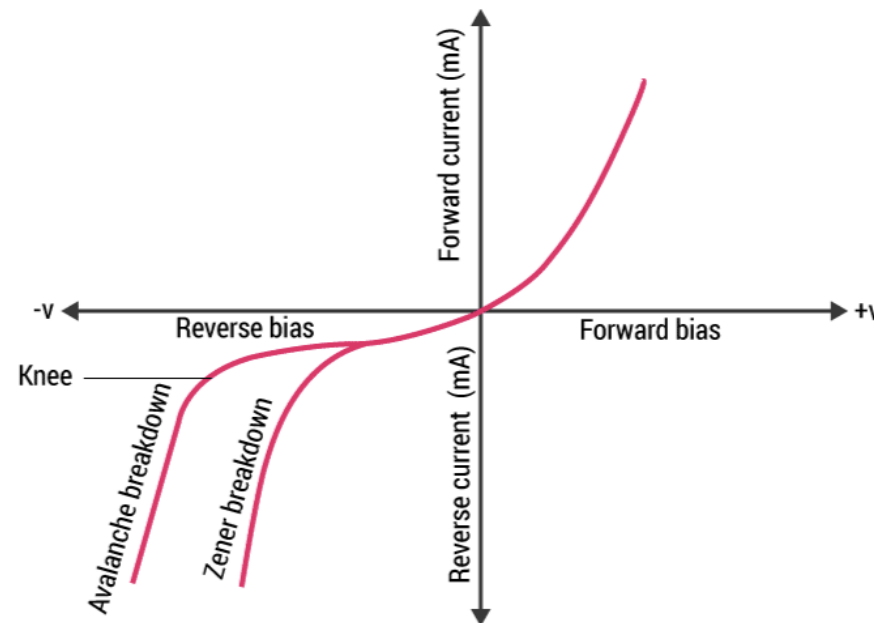
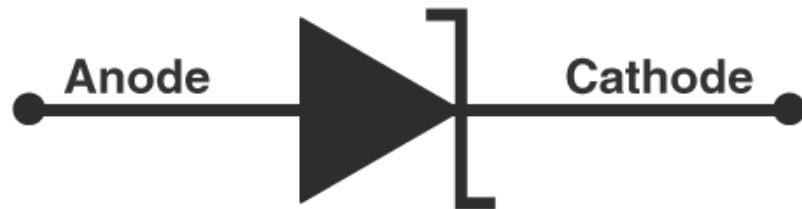
- ▶ A Zener diode is a semiconductor device that allows current to flow in the reverse direction once it reaches a specific breakdown voltage called the Zener voltage ( $V_z$ ).
- ▶ It is essentially a heavily doped diode designed to exploit the Zener effect, which occurs when a high electric field is applied across a narrow depletion region in a p-n junction.

# The Zener Effect

- ▶ The Zener effect is a quantum mechanical phenomenon that leads to a sharp increase in the electric current through a reverse-biased p-n junction when the applied voltage reaches the Zener voltage.
- ▶ At the Zener voltage, the electric field across the depletion region becomes strong enough to enable the quantum tunneling of charge carriers, resulting in a controlled breakdown and a rapid increase in current.

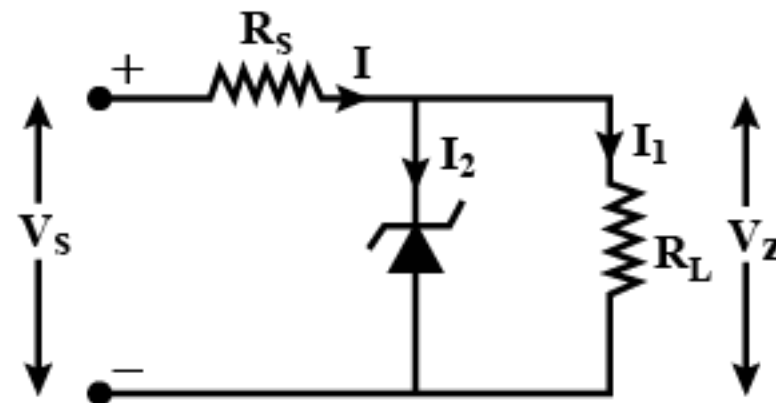
# Zener Diode Symbol and Characteristics

- ▶ The symbol of a Zener diode consists of a regular diode arrowhead pointing towards a vertical line representing the Zener breakdown.
- ▶ Zener diodes are characterized by their Zener voltage ( $V_z$ ) and Zener current ( $I_z$ ) ratings, which indicate the voltage at which breakdown occurs and the maximum current the diode can handle while in the breakdown region.



# Zener Diode as a Voltage Regulator

- ▶ Zener diodes find wide application as voltage regulators, maintaining a constant output voltage despite variations in the input voltage or load conditions.
- ▶ The Zener diode is connected in parallel to the load and is reverse-biased, allowing it to regulate the voltage across the load.



**Zener diode as a voltage regulator**

# Zener Diode Voltage Regulation

- ▶ When the input voltage ( $V_{in}$ ) is greater than the Zener voltage ( $V_z$ ), the diode enters the breakdown region and acts as a low impedance path.
- ▶ As a result, the excess current flows through the diode, limiting the voltage across the load ( $V_{out}$ ) to the Zener voltage ( $V_z$ ).
- ▶ Conversely, when the input voltage ( $V_{in}$ ) is lower than the Zener voltage ( $V_z$ ), the diode remains in the normal forward bias region and allows current to pass through it.
- ▶ In this case, the voltage across the load ( $V_{out}$ ) is equal to the input voltage ( $V_{in}$ ) minus the forward voltage drop of the diode.

# Advantages of Zener Diode Voltage Regulation

- ▶ Zener diodes offer several advantages as voltage regulators:
- ▶ **Simplicity:** Zener diode voltage regulators are straightforward to design and implement.
- ▶ **Cost-effectiveness:** Zener diodes are relatively inexpensive compared to other voltage regulation solutions.
- ▶ **Efficiency:** Zener diodes provide efficient voltage regulation with low power dissipation.
- ▶ **Compactness:** Zener diodes are available in small packages, making them suitable for compact electronic devices.

# Applications of Zener Diodes

- ▶ Voltage regulation in power supplies.
- ▶ Overvoltage protection for sensitive electronic components.
- ▶ Voltage clamping and level shifting circuits.
- ▶ Voltage reference circuits.
- ▶ Signal limiting and clipping circuits.