EEE1024: Fundamentals of Electrical and Electronics Engineering

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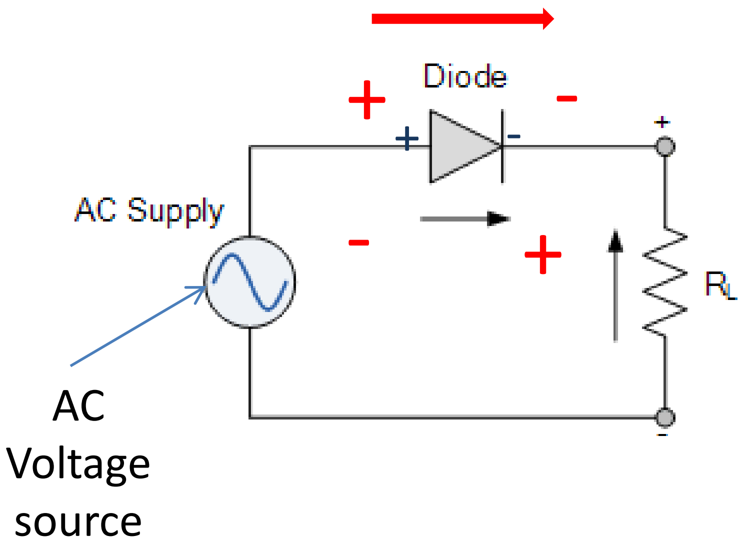
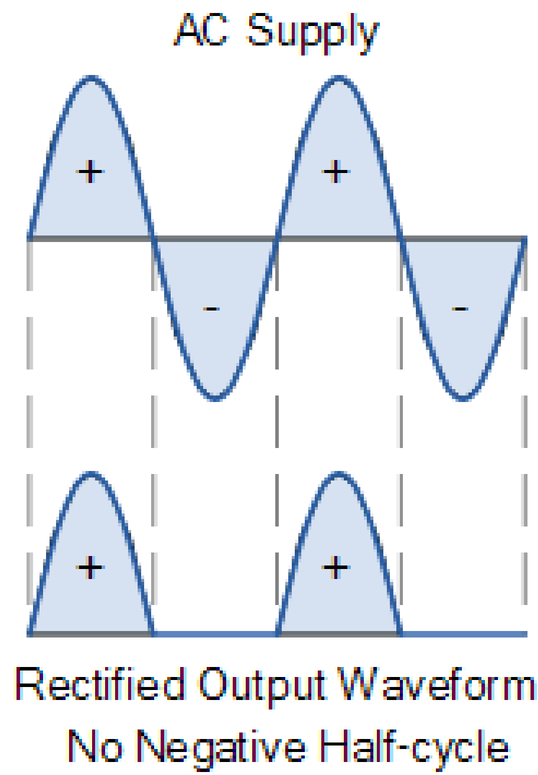
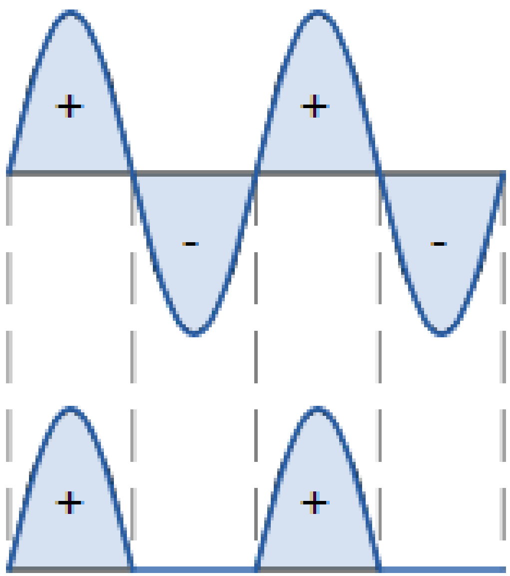
Half wave Rectifier



Unique feature of a pn-junction diode utilized to convert the ***bi-directional*** alternating supply into a ***one-way unidirectional*** current by eliminating one-half of the supply.



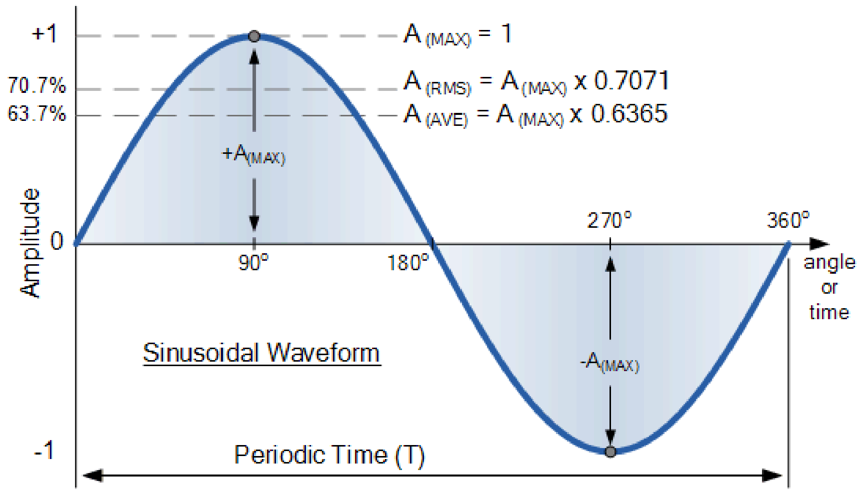
Half wave Rectifier



Rectified Output Waveform

No Negative Half-cycle

AC Sinusoidal Waveform



$$A_{AVG} = \frac{0.637}{2} \times A_{MAX} = \frac{A_{MAX}}{\pi} = 0.318 A_{MAX}$$

$$V_{AVG} = 0.318 * V_{MAX}$$

$$I_{AVG} = 0.318 * I_{MAX}$$

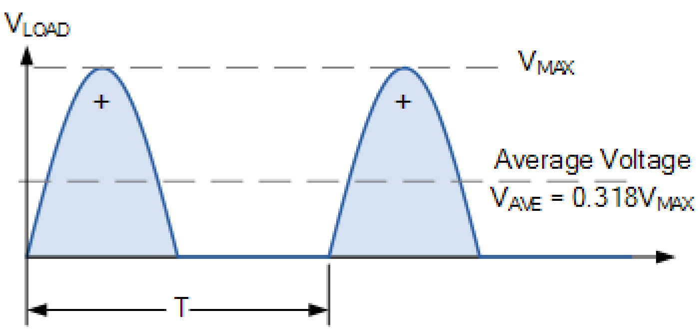
$$\frac{V_{AVG}}{V_{RMS}} = 0.9$$

$$V_{AVG} = 0.45 * V_{RMS}$$

$$I_{AVG} = 0.45 * I_{RMS}$$

Half wave Rectifier

Example A single phase half-wave rectifier is connected to a 50V RMS 50Hz AC supply. If the rectifier is used to supply a resistive load of 150 Ohms. Calculate the equivalent DC voltage developed across the load, the load current and power dissipated by the load. Assume ideal diode characteristics.



$$V_{RMS} = 50 volts$$ Given

$$V_{\max} = V_P = 1.414 * V_{RMS} = 1.414 * 50 = 70.7 \text{ volts}$$

$$\mathbf{V_{RMS} = V_{PK} \times 0.707} \quad \frac{V_{RMS}}{V_P} = 0.707 \quad \frac{V_P}{V_{RMS}} = \frac{1}{0.707} = 1.414$$

$$V_m = V_p = V_{PK} = V_{MAX}$$

$$V_{rms} = \frac{V_m}{\sqrt{2}}$$

Equivalent DC voltage = $V_{AVG} = 0.318 * V_P = 0.318 * 70.7 = 22.5$ volts

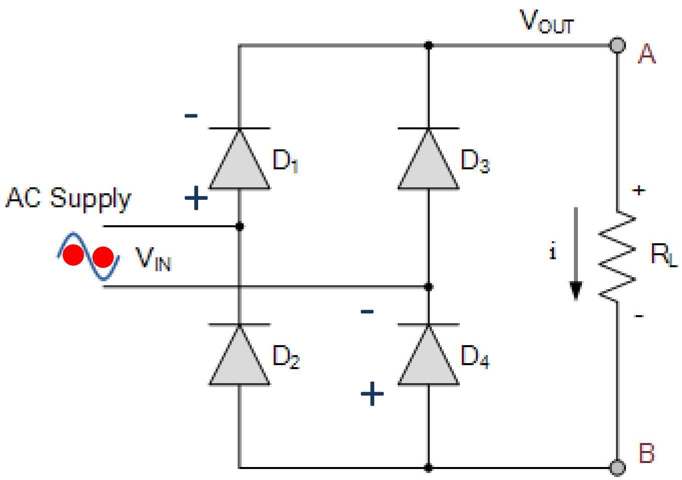
Load current $I_L = \dfrac{V_{AVG} or V_{DC}}{R_L} = 22.5/150 = 0.15A$ or 150mA

Power dissipated by load $P_L = V_{DC} \times I$ or $I^2 * R_L = 22.5 * 0.15 = 3.375W \cong 3.4W$

Full wave Rectifier

Full wave
BRIDGE Rectifier

This bridge configuration of diodes provides full-wave rectification because at any time two of the four diodes are forward biased while the other two are reverse biased.



During +ve half cycle of V_{IN},

D_1 and D_4 are forward biased, whereas,

D_2 and D_3 are reverse biased

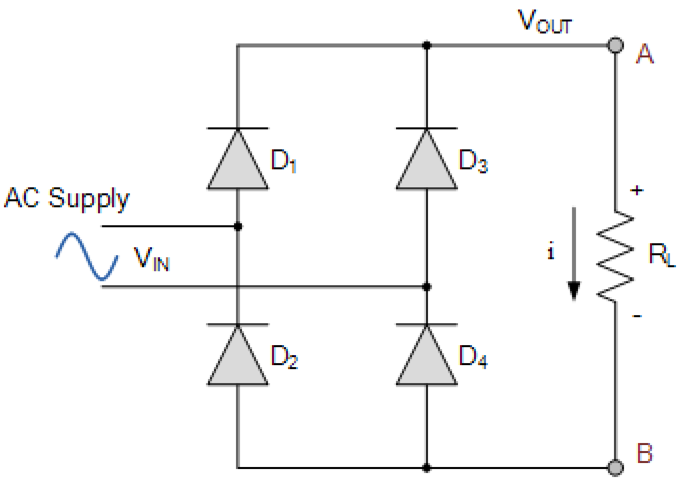
During -ve half cycle of V_{IN},

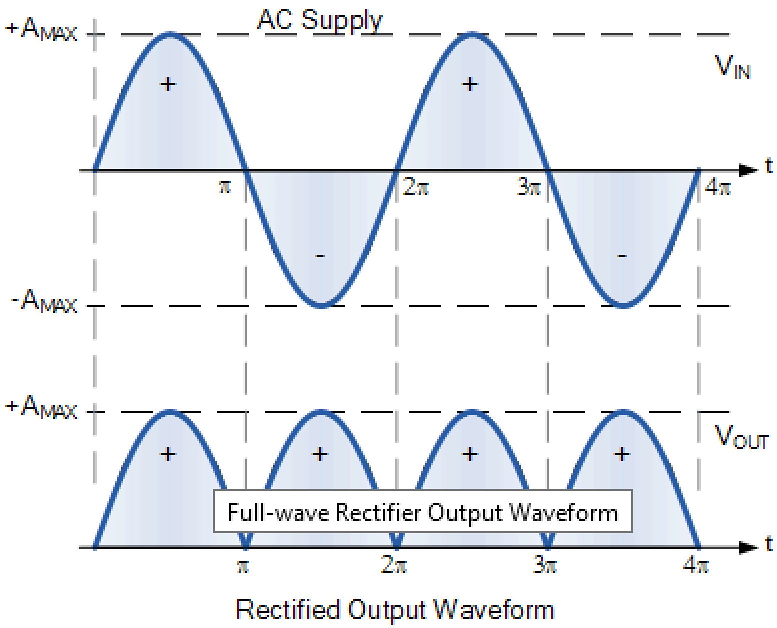
D_2 and D_3 are forward biased, whereas,

D_1 and D_4 are reverse biased

Full wave Rectifier

Full wave BRIDGE Rectifier





$V_{AVG} = 0.637 * V_{MAX}$

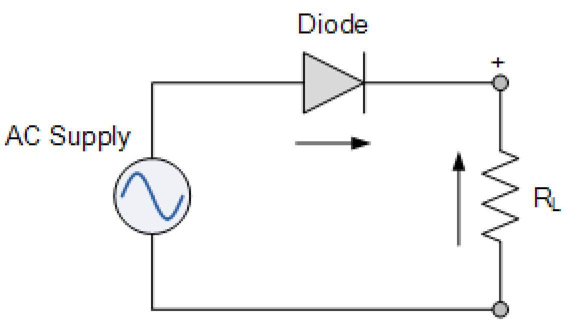
$I_{AVG} = 0.637 * I_{MAX}$

$V_{AVG} = 0.9 * V_{RMS}$

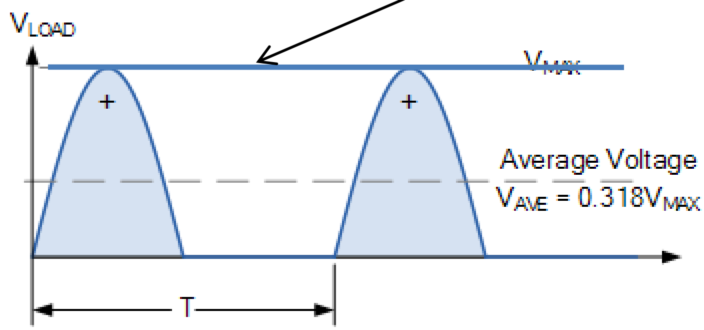
$I_{AVG} = 0.9 * I_{RMS}$

Ripple Factor

Half wave (HW) Rectifier



Desired DC waveform



Actual o/p of a HW rectifier

O/p of HW rectifier which is filtered using a capacitor

DC Output (Filtered)

Ripple Factor γ – Unwanted AC component remaining while converting AC waveform into DC

$$\gamma = \sqrt{\left(\frac{V_{rms}}{V_{DC}}\right)^2 - 1}$$

$$= \frac{\sqrt{(\boldsymbol{Vrms})^2 - (\boldsymbol{Vdc})^2}}{\boldsymbol{Vdc}}$$

$$\boldsymbol{\gamma} = \frac{\sqrt{(\boldsymbol{Irms})^2 - (\boldsymbol{Idc})^2}}{\boldsymbol{Idc}}$$

$$= \frac{\sqrt{(0.5Im)^2 - (0.318Im)^2}}{0.318Im}$$

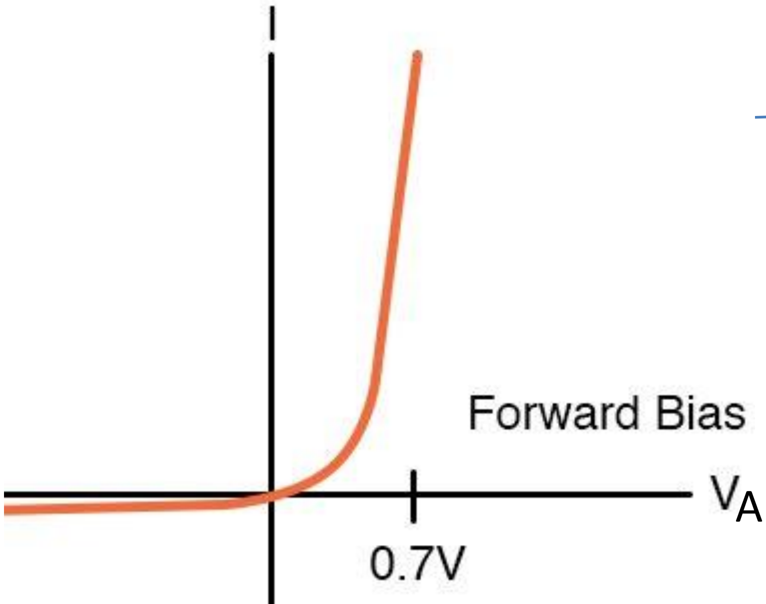
$$= 1.21$$

For a half-wave rectifier

$$V_{rms} = \frac{V_m}{\sqrt{2}}$$

$$V_{rms}^{\;2} = \frac{V_m^{\;2}}{\left(\sqrt{2}\right)^2} = \frac{V_m^{\;2}}{2}$$

“p-n” Junction Diode: *Breakdown*



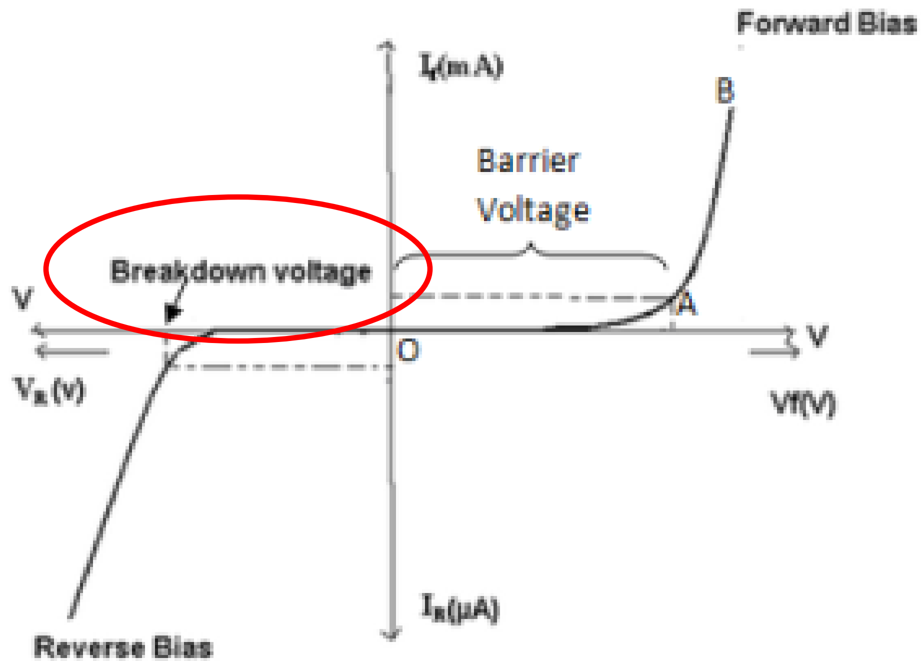
$$I = I_o(e^{\frac{qV_A}{kT}} - 1)$$

Ideal diode equation for Forward bias

$$\frac{kT}{q} = 0.026V$$

$$I = -I_o$$

Ideal diode equation for Reverse bias



"p-n" Junction Diode: Breakdown

Causes of BREAKDOWN

Zener effect

Zener breakdown –

- If the doping of either p type or n-type is more, depletion region is thin
- Number of free electrons is more
- In reverse bias – these free electrons gain velocity and collide, breaking bonds and setting more electrons "free"

Avalanche effect

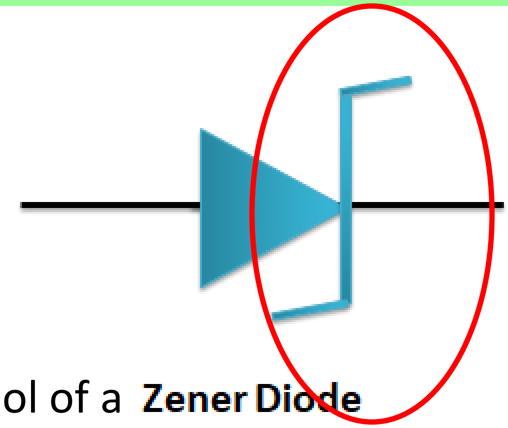
Avalanche breakdown –

- Reverse bias – Depletion region (Electric field) increases
- Velocity of the few electrons that cross the junction increases
- These electrons collide and break the covalent bonds
- Breaking of bonds sets electrons "free"

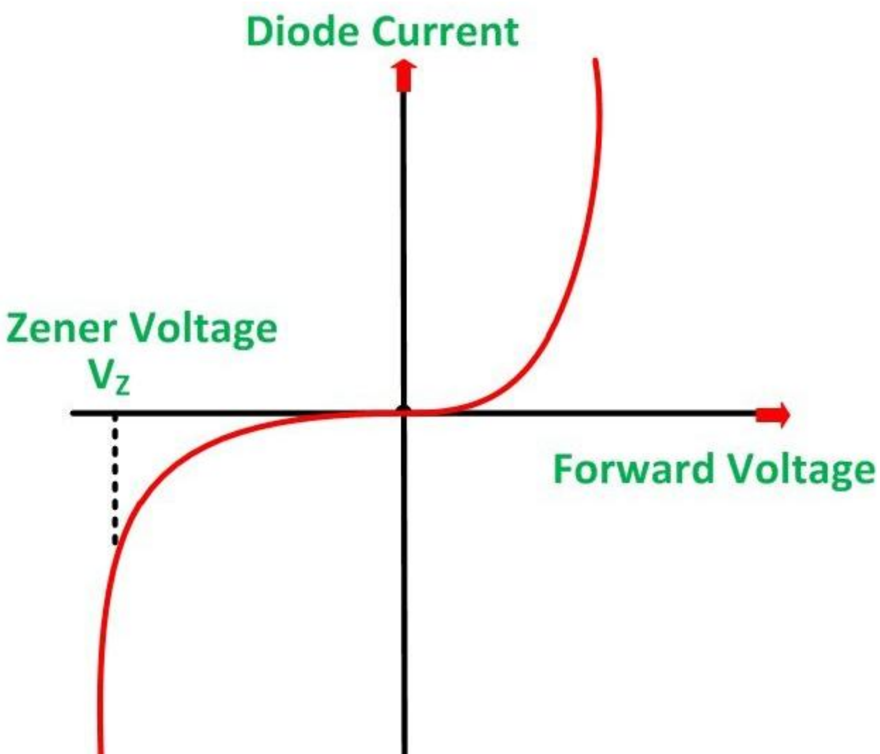
ZENER Diode

✓ Zener diode is basically like an ordinary PN junction diode but normally operated only in reverse biased condition.

✓ It is a highly doped pn junction diode.



Symbol of a **Zener Diode**

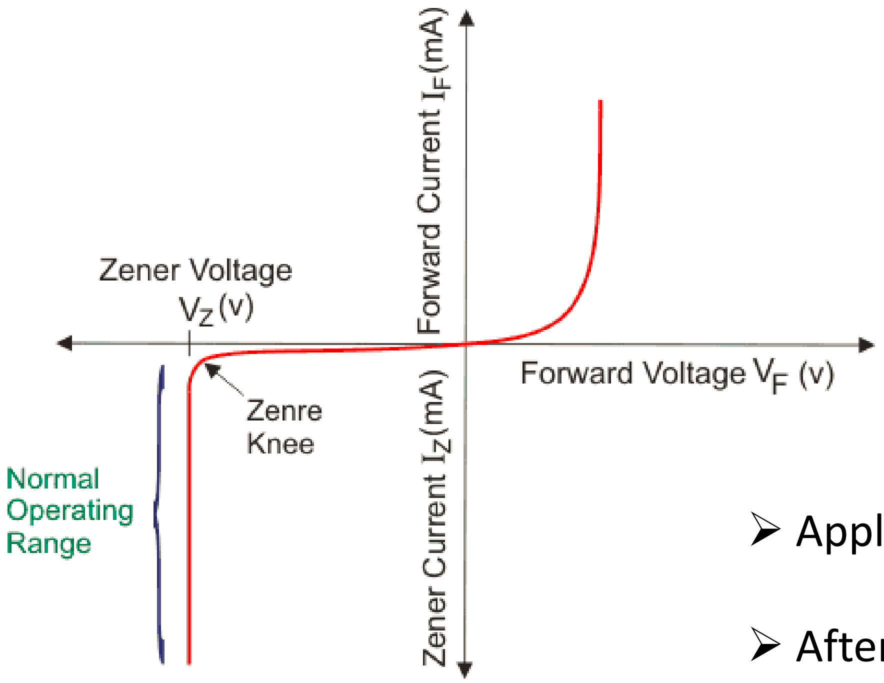


Normal diode – gets damaged at larger reverse biases, i.e. in breakdown

Zener diode – designed to sustain breakdown

Zener diode is ***bi-directional device*** as it can operate in forward bias as well as large reverse bias (breakdown)

ZENER Diode – *Interesting Application*



- Apply reverse voltage, negligible current flows till V_Z

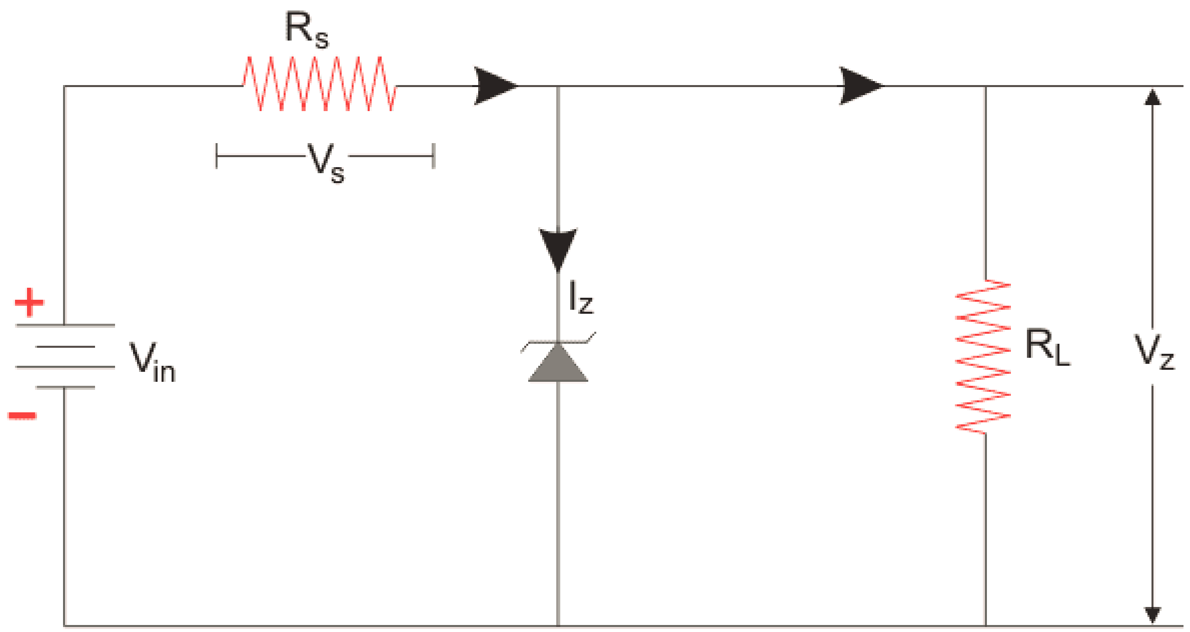
- After V_Z ,enormous amount of current flows in opposite direction.

- This current keeps on flowing even though there is any increase in voltage.

- Even if we increase the reverse voltage further, the voltage across the diode remains at the same value of Zener breakdown voltage!!!

ZENER Diode – *Voltage Regulation I*

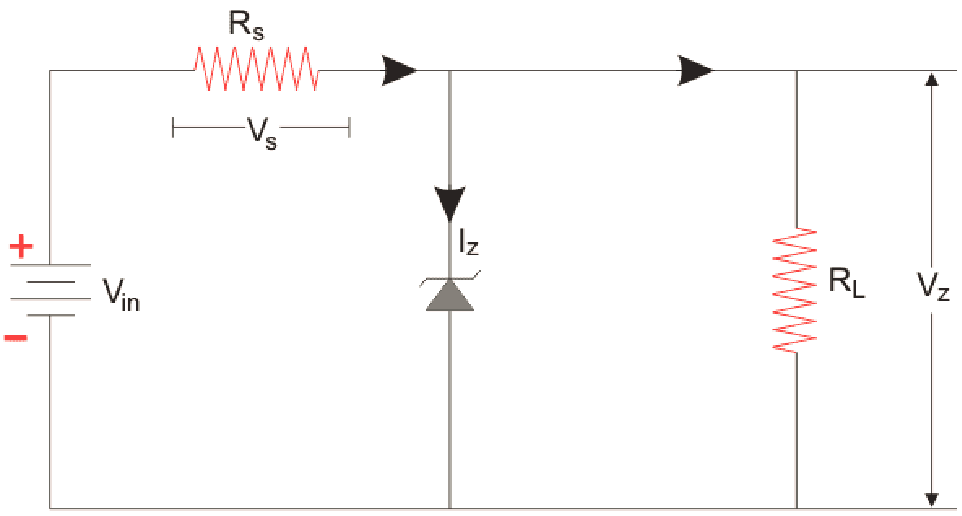
✓ For example, we want that the voltage across a load in our circuit does not exceed, let's say, 12 volts.

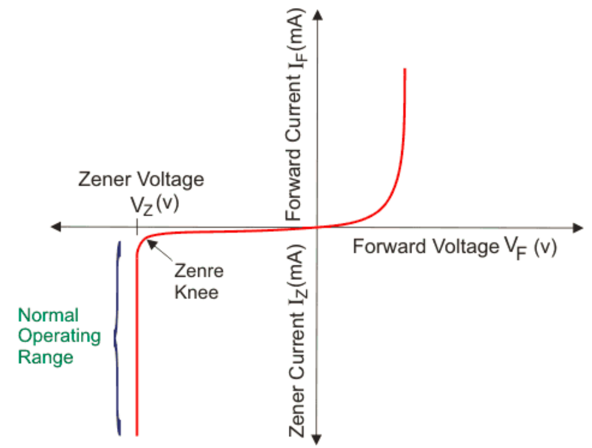


✓ Select a Zener diode with a breakdown voltage of 12 volts and connect it across the load, ***in parallel***!

✓ Then even if the input voltage exceeds that value, the voltage across the load will never exceed 12 volts.

ZENER Diode – *Voltage Regulation -II*





1. Zener diode – connected in ***reverse bias***
2. *Load and Zener diode – in parallel => voltage across both load and Zener – same*

3. When the voltage across the diode exceeds the Zener breakdown voltage, a significant amount of current starts flowing through the diode.

4. The Zener diode provides a path for the current to flow and hence the load gets protected from excessive currents.

Zener diode, thus, provides two uses –

a) Acts like a voltage regulator
b) Prevents excessive currents from reaching the load

Acknowledgements

1. https://electricalbaba.com/ripple-factor-half-wave-rectifier/
2. https://electronicspost.com/v-i-characteristics-of-p-n-junction-diode/
3. https://www.electrical4u.com/what-is-zener-diode/
4. https://www.electrical4u.com/zener-diode-as-voltage-regulator/
5. https://circuitglobe.com/zener-breakdown-and-avalanche-breakdown.html
6. https://www.electronics-tutorials.ws/power/single-phase-rectification.html