
EEE 1217

Analog Electronic Circuits

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PPT# 2: Diode Applications



Series Diode Configurations

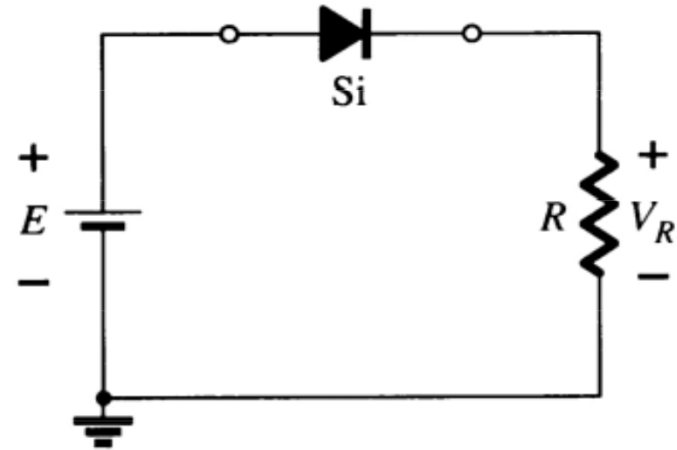
Forward Bias

Constants

- Silicon Diode: $V_D = 0.7 \text{ V}$
- Germanium Diode: $V_D = 0.3 \text{ V}$

Analysis (for silicon)

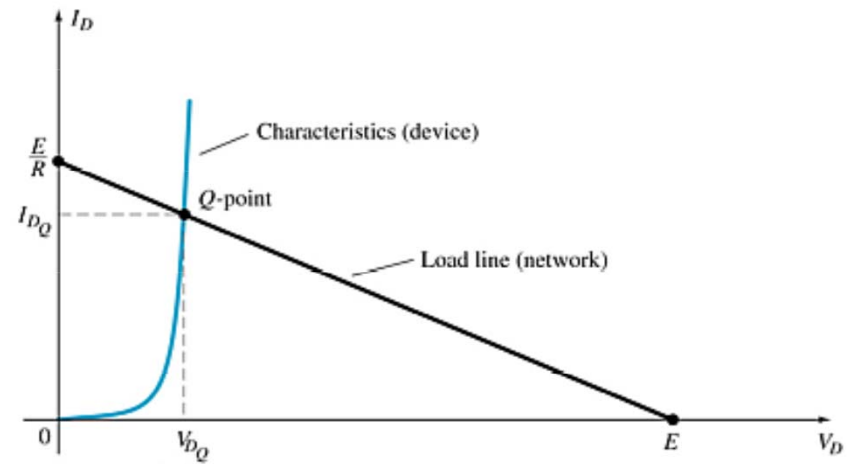
- $V_D = 0.7 \text{ V}$ (or $V_D = E$ if $E < 0.7 \text{ V}$)
- $V_R = E - V_D$, $V_D = E - I_D R$
- $I_D = I_R = I_T = V_R / R$



Load-Line Analysis

The load line plots all possible combinations of diode current (I_D) and voltage (V_D) for a given circuit. The maximum I_D equals E/R , and the maximum V_D equals E .

The point where the load line and the characteristic curve intersect is the Q-point, which identifies I_D and V_D for a particular diode in a given circuit.



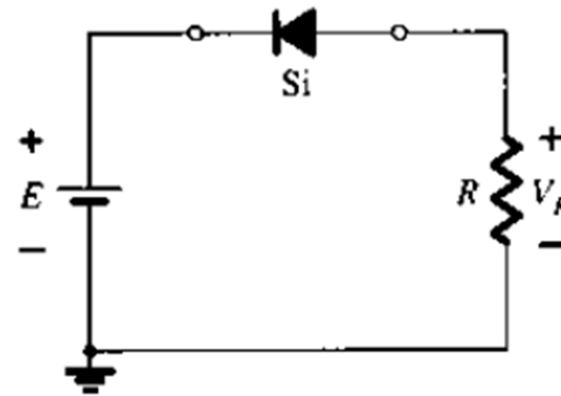
Series Diode Configurations

Reverse Bias

Diodes ideally behave as open circuits

Analysis

- $V_D = E$
- $V_R = 0 \text{ V}$
- $I_D = 0 \text{ A}$



Problem

- For the series diode configuration of Fig. 2.3a employing the diode characteristics of Fig. 2.3b determine:
- (a) V_{DQ} and I_{DQ} . (b) V_R .

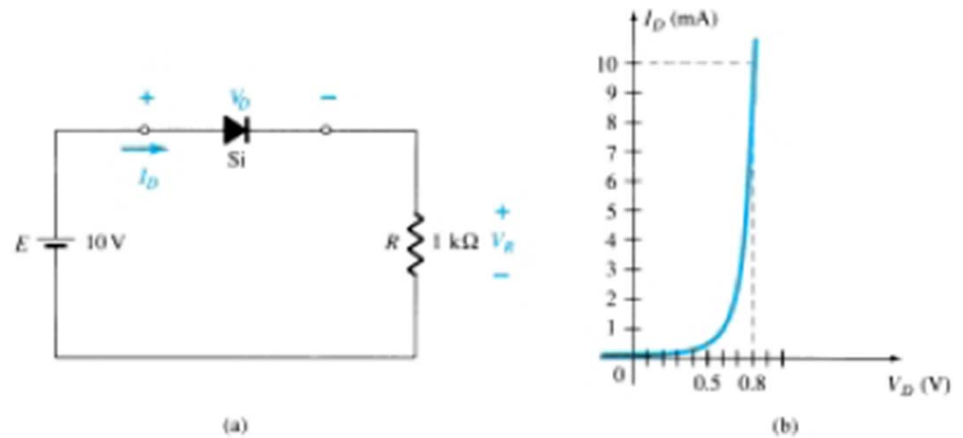
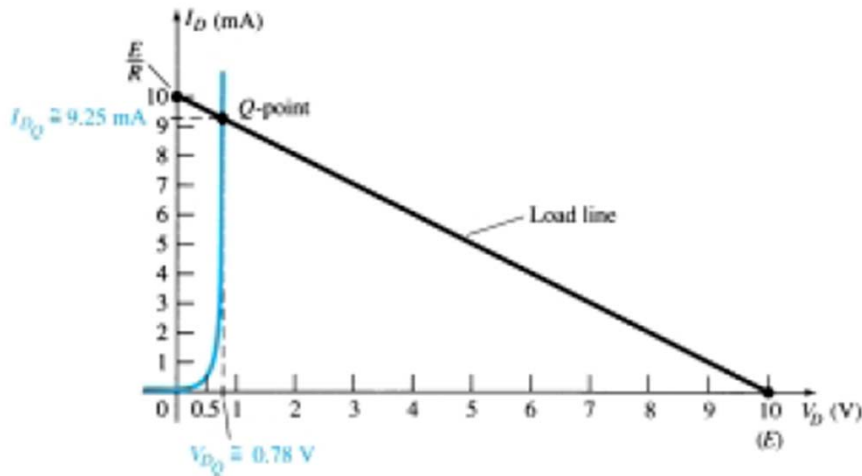


Figure 2.3 (a) Circuit; (b) characteristics.



$$V_{DQ} \cong 0.78 \text{ V}$$

$$I_{DQ} \cong 9.25 \text{ mA}$$

$$V_R = I_R R = I_{DQ} R = (9.25 \text{ mA})(1 \text{ k}\Omega) = 9.25 \text{ V}$$

$$V_R = E - V_D = 10 \text{ V} - 0.78 \text{ V} = 9.22 \text{ V}$$



Problem

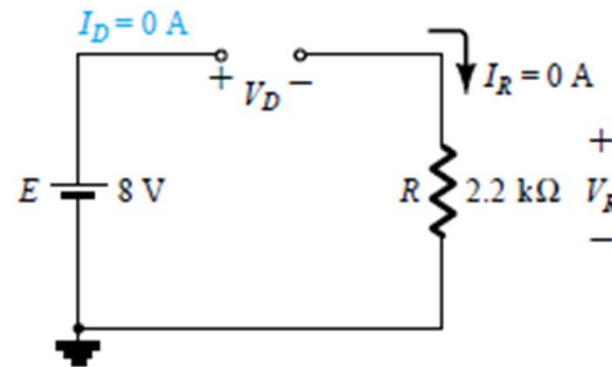
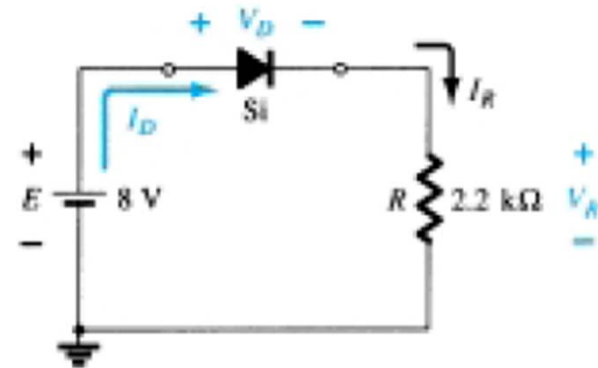
- For the series diode configuration, determine V_D , V_R , and I_D .

$$V_D = 0.7 \text{ V}$$

$$V_R = E - V_D = 8 \text{ V} - 0.7 \text{ V} = 7.3 \text{ V}$$

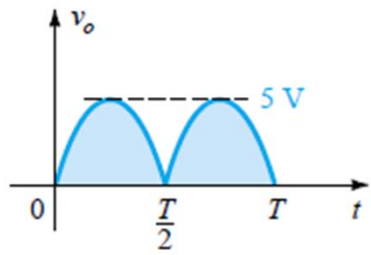
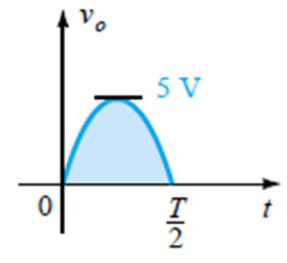
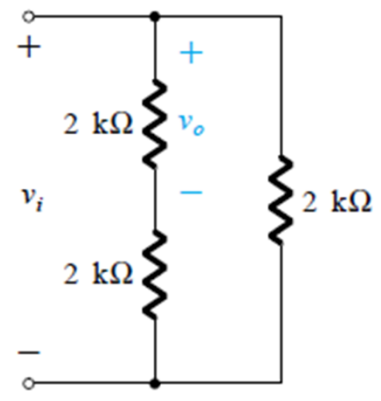
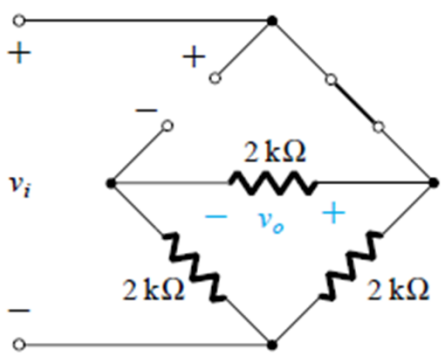
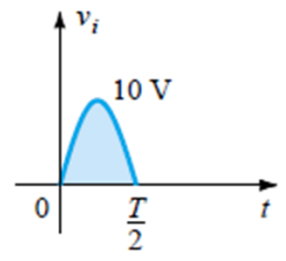
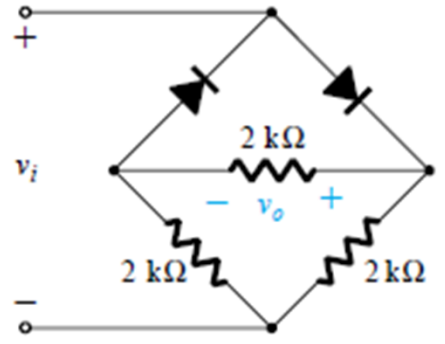
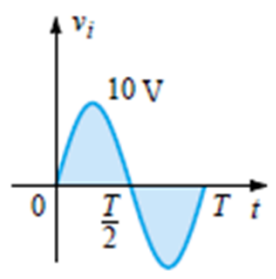
$$I_D = I_R = \frac{V_R}{R} = \frac{7.3 \text{ V}}{2.2 \text{ k}\Omega} \cong 3.32 \text{ mA}$$

- Repeat the problem with the diode reversed.



Problem

➤ Determine the output waveform for the network and calculate the output dc level and the required PIV of each diode.

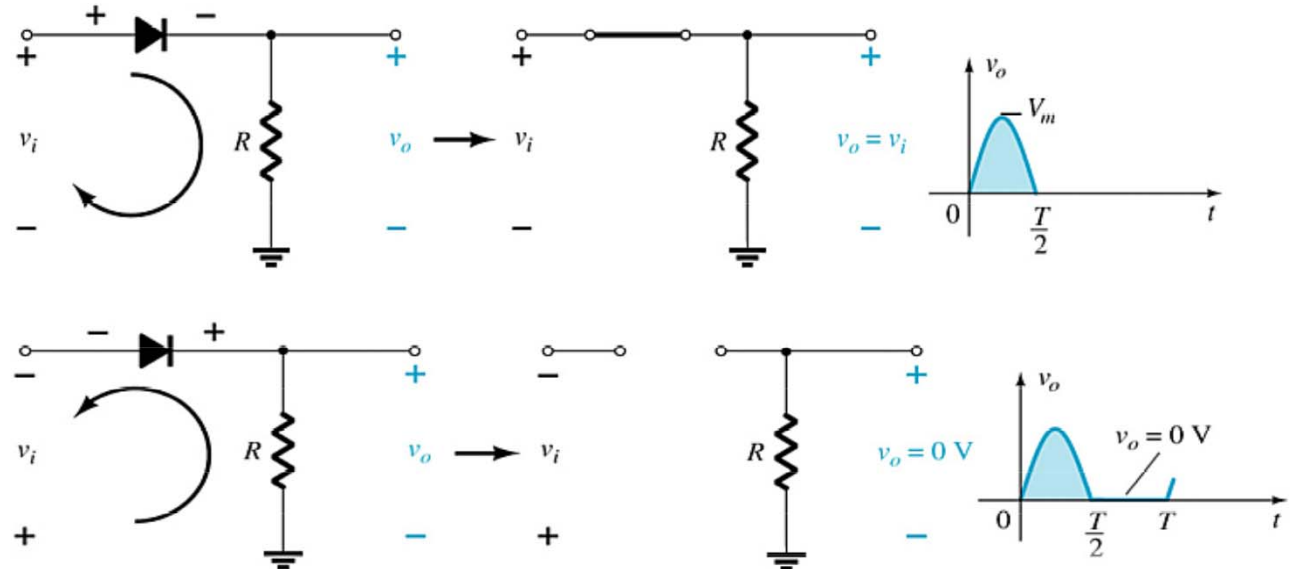


Resulting output



Half-Wave Rectification

The diode only conducts when it is forward biased, therefore only half of the AC cycle passes through the diode to the output.



The DC output voltage is $0.318V_m$, where V_m = the peak AC voltage.



PIV (PRV)

Because the diode is only forward biased for one-half of the AC cycle, it is also reverse biased for one-half cycle.

It is important that the reverse breakdown voltage rating of the diode be high enough to withstand the peak, reverse-biasing AC voltage.

$$\text{PIV (or PRV)} > V_m$$

- **PIV = Peak inverse voltage**
- **PRV = Peak reverse voltage**
- **V_m = Peak AC voltage**

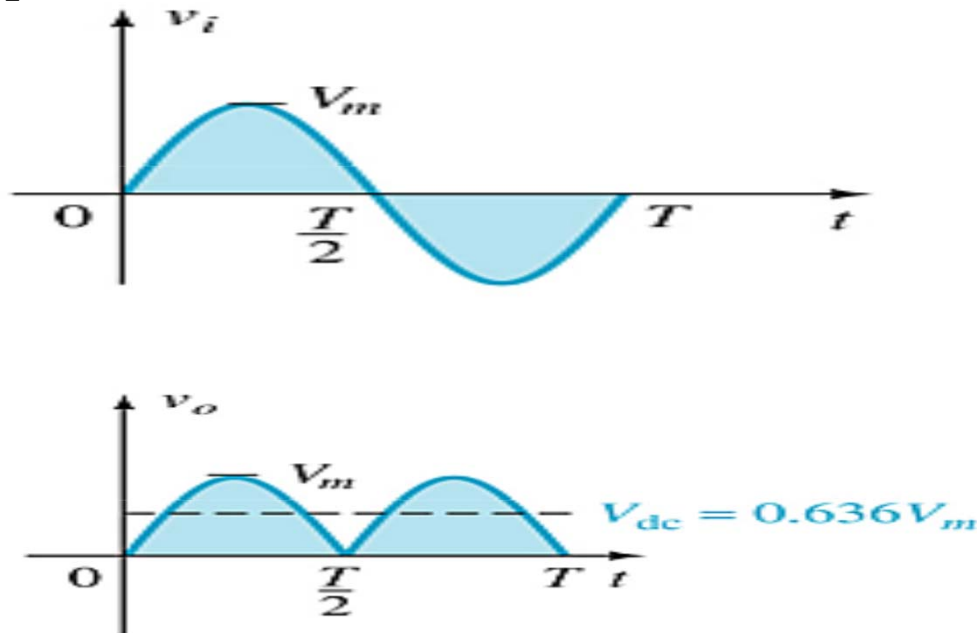


Full-Wave Rectification

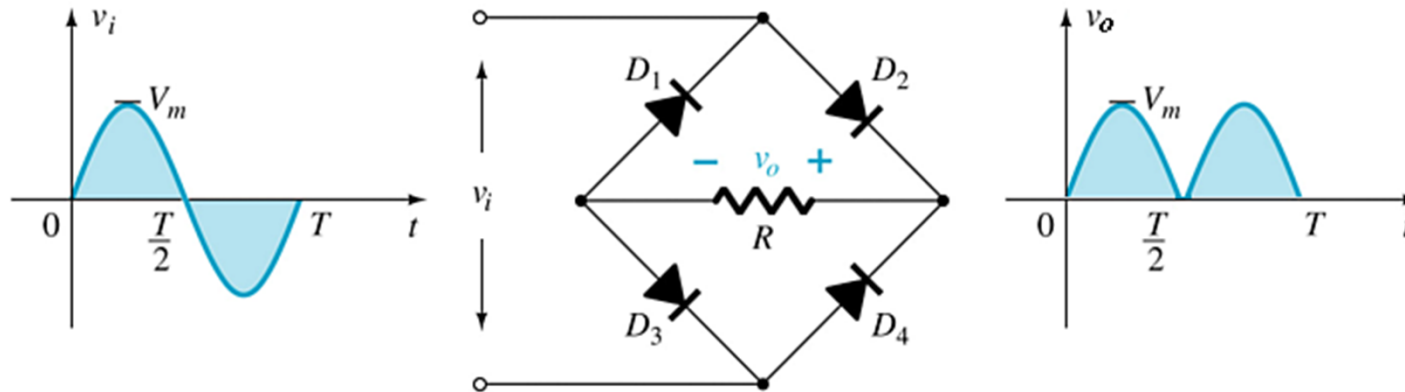
The rectification process can be improved by using a full-wave rectifier circuit.

Full-wave rectification produces a greater DC output:

- Half-wave: $V_{dc} = 0.318V_m$
- Full-wave: $V_{dc} = 0.636V_m$

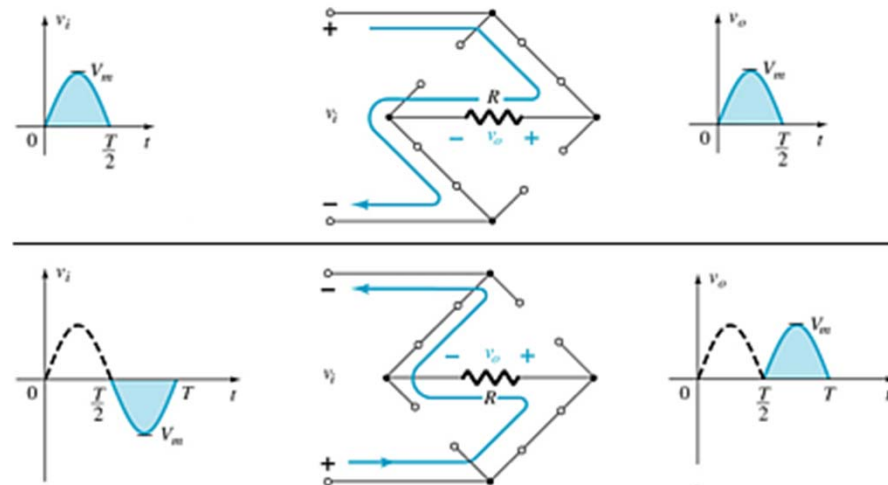


Full-Wave Rectification

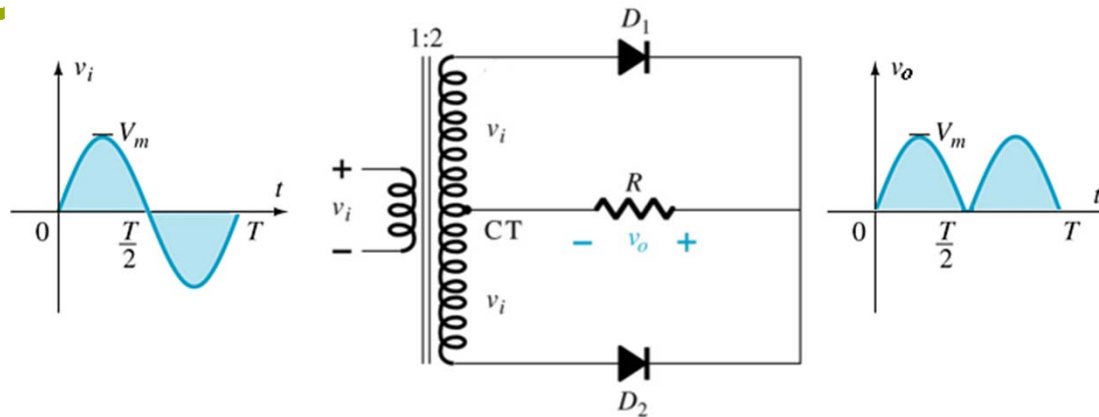


Bridge Rectifier

- Four diodes are connected in a bridge configuration
- $V_{DC} = 0.636V_m$
- $PIV > V_m$



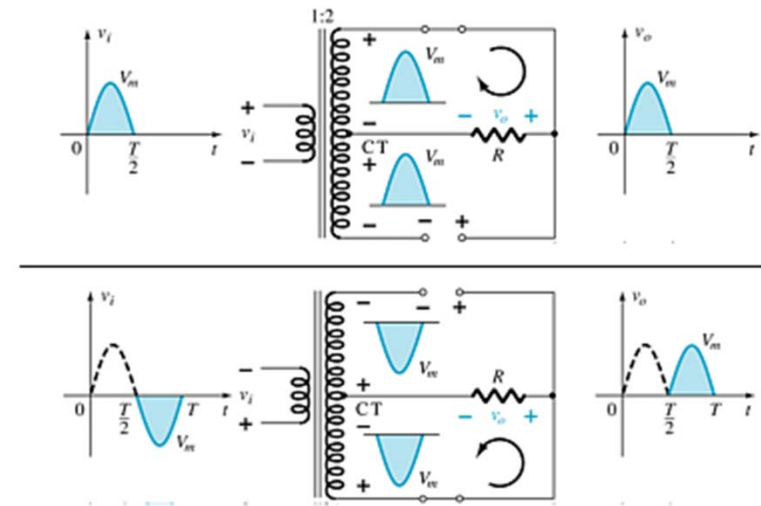
Full-Wave Rectification



Center-Tapped Transformer Rectifier

Requires

- Two diodes
- Center-tapped transformer
- $PIV > 2V_m$
- $V_{DC} = 0.636V_m$



Summary of Rectifier Circuits

Rectifier	Ideal V_{DC}	Realistic V_{DC}
Half Wave Rectifier	$V_{DC} = 0.318V_m$	$V_{DC} = 0.318V_m - 0.7$
Bridge Rectifier	$V_{DC} = 0.636V_m$	$V_{DC} = 0.636V_m - 2(0.7 \text{ V})$
Center-Tapped Transformer Rectifier	$V_{DC} = 0.636V_m$	$V_{DC} = 0.636V_m - 0.7 \text{ V}$

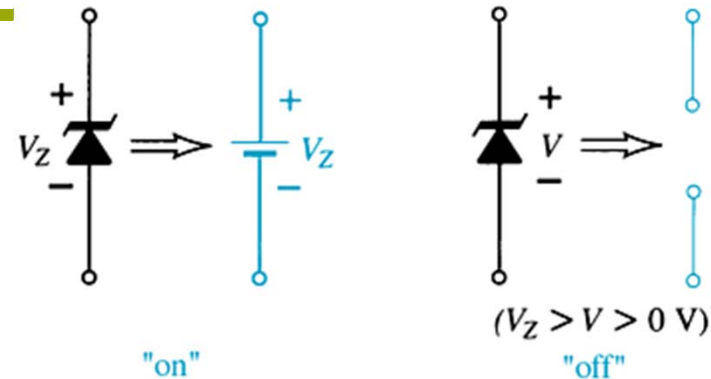
V_m = peak of the AC voltage.

In the center tapped transformer rectifier circuit, the peak AC voltage is the transformer secondary voltage to the tap.

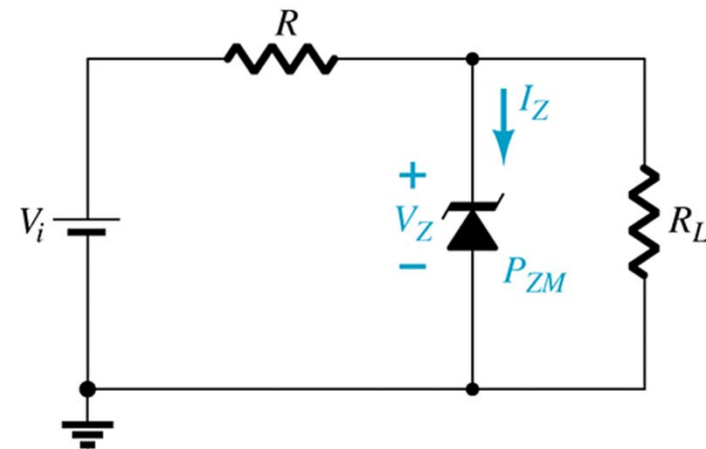


Zener Diodes

The Zener is a diode operated in reverse bias at the Zener Voltage (V_Z).



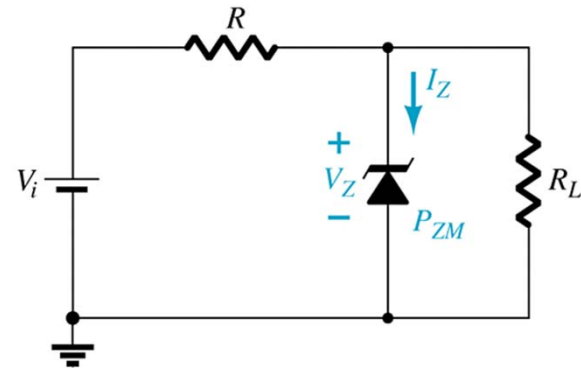
- When $V_i \geq V_Z$
 - ❖ The Zener is on
 - ❖ Voltage across the Zener is V_Z
 - ❖ Zener current: $I_Z = I_R - I_{RL}$
 - ❖ The Zener Power: $P_Z = V_Z I_Z$
- When $V_i < V_Z$
 - ❖ The Zener is off
 - ❖ The Zener acts as an open circuit



Zener Resistor Values

$$V = V_L = \frac{R_L V_i}{R + R_L}$$

$$I_Z = I_R - I_L$$



The power dissipated by the Zener diode is determined by

$$P_Z = V_Z I_Z$$

$$I_{L_{\max}} = \frac{V_L}{R_L} = \frac{V_Z}{R_{L_{\min}}}$$

$$R_{L_{\min}} = \frac{R V_Z}{V_i - V_Z}$$



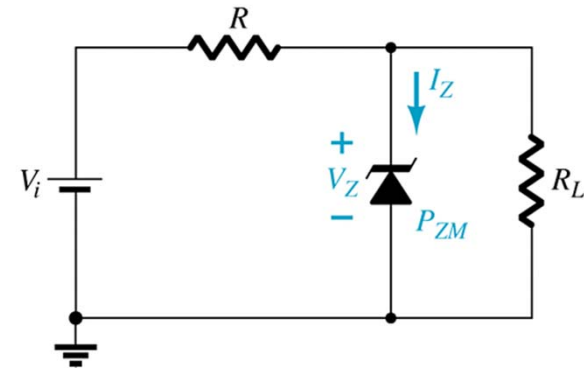
Zener Resistor Values

If R is too large, the Zener diode cannot conduct because the available amount of current is less than the minimum current rating, I_{ZK} . The minimum current is given by:

$$I_{Lmin} = I_R - I_{ZK}$$

The *maximum* value of resistance is:

$$R_{Lmax} = \frac{V_Z}{I_{Lmin}}$$



If R is too small, the Zener current exceeds the maximum current rating, I_{ZM} . The maximum current for the circuit is given by:

$$I_{Lmax} = \frac{V_L}{R_L} = \frac{V_Z}{R_{Lmin}}$$

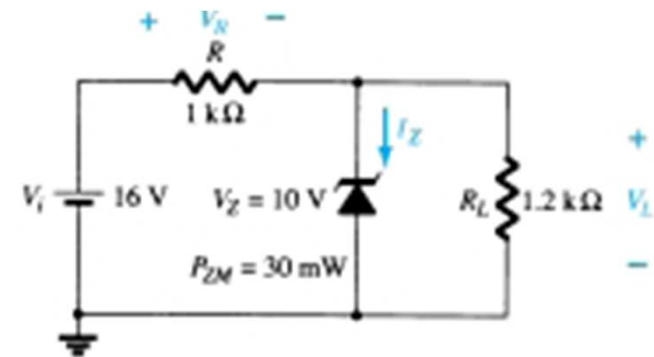
The *minimum* value of resistance is:

$$R_{Lmin} = \frac{RV_Z}{V_i - V_Z}$$



EXAMPLE 2.26

- (a) For the Zener diode network of Fig. 2.109, determine V_L , V_R , I_Z , and P_Z .
- (b) Repeat part (a) with $R_L = 3 \text{ k}$.



$$V = \frac{R_L V_i}{R + R_L} = \frac{1.2 \text{ k}\Omega (16 \text{ V})}{1 \text{ k}\Omega + 1.2 \text{ k}\Omega} = 8.73 \text{ V}$$

Since $V = 8.73 \text{ V}$ is less than $V_Z = 10 \text{ V}$, the diode is in the “off” state

$$V_L = V = 8.73 \text{ V}$$

$$V_R = V_i - V_L = 16 \text{ V} - 8.73 \text{ V} = 7.27 \text{ V}$$

$$I_Z = 0 \text{ A}$$

$$P_Z = V_Z I_Z = V_Z (0 \text{ A}) = 0 \text{ W}$$



EXAMPLE 2.26 (cont.)

➤ (b)

$$V = \frac{R_L V_i}{R + R_L} = \frac{3 \text{ k}\Omega (16 \text{ V})}{1 \text{ k}\Omega + 3 \text{ k}\Omega} = 12 \text{ V}$$

Since $V = 12 \text{ V}$ is greater than $V_Z = 10 \text{ V}$, the diode is in the “on” state

$$V_L = V_Z = 10 \text{ V}$$

$$V_R = V_i - V_L = 16 \text{ V} - 10 \text{ V} = 6 \text{ V}$$

$$I_L = \frac{V_L}{R_L} = \frac{10 \text{ V}}{3 \text{ k}\Omega} = 3.33 \text{ mA}$$

$$I_R = \frac{V_R}{R} = \frac{6 \text{ V}}{1 \text{ k}\Omega} = 6 \text{ mA}$$

$$\begin{aligned} I_Z &= I_R - I_L \text{ [Eq. (2.18)]} \\ &= 6 \text{ mA} - 3.33 \text{ mA} \\ &= 2.67 \text{ mA} \end{aligned}$$

$$P_Z = V_Z I_Z = (10 \text{ V})(2.67 \text{ mA}) = 26.7 \text{ mW}$$



Practical Applications

➤ Rectifier Circuits

- ❖ Conversions of AC to DC for DC operated circuits
- ❖ Battery Charging Circuits

➤ Simple Diode Circuits

- ❖ Protective Circuits against
- ❖ Overcurrent
- ❖ Polarity Reversal
- ❖ Currents caused by an inductive kick in a relay circuit

➤ Zener Circuits

- ❖ Overvoltage Protection
- ❖ Setting Reference Voltages



