ECE121: Electronics (1)

Lecture 7: Zener Diodes

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Spring 2017

Lecture Outline:

1. Introduction.
2. Fixed V_i, Fixed R_L.
3. Fixed V_i, Variable R_L.

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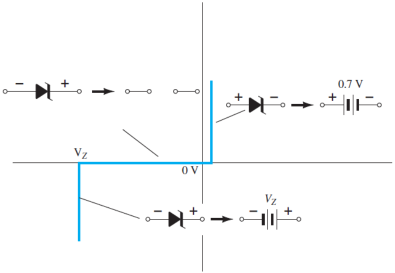
Introduction:

- The Zener diode has three regions of operations. Each region has it own approximation model.
- It can be used as a part of protection circuit or as a voltage regulator.
- The use of the Zener diode as a regulator is so common that three conditions surrounding the analysis of the basic Zener regulator are considered:
  1. Fixed load and fixed supply voltage.
  2. Fixed supply voltage and variable load.
  3. Variable supply voltage and fixed load.
- The first case is already studied in the previous semester and will briefly reviewed.



Zener diode characteristics

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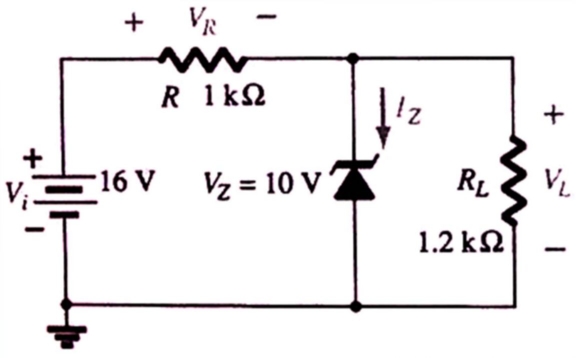
Fixed V_i, Fixed R_L:

Example

Example

For the Zener diode regulator,

1. Determine V_L , V_R , I_Z and P_Z.
2. If the load is changed to $R_L = 3\ k\Omega$, repeat the above problem.



Example

Fixed V_i, Fixed R_L:

Solution:

1. Determine the voltage across the Zener diode to determine its state:

$$V_{zener} = V_L = \frac{V_i \ R_L}{R_L + R} = 16\frac{1.2}{1+1.2} = 8.73 \ V$$

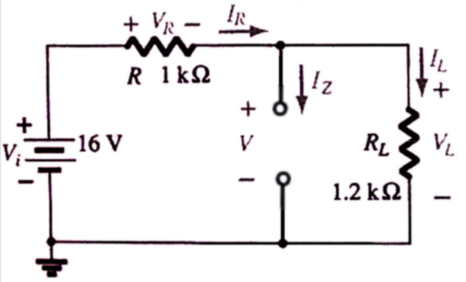
Since the voltage across the Zener is smaller than V_Z and the diode is reverse, then the Zener is OFF.

$$V_L = V_{zener} = 8.73 \ V$$

$$V_R = V_i - V_L = 16 - 8.73 = 7.27 \ V$$

$$I_Z = 0$$

$$P_Z = 0 \text{ Watts}$$



Example

Fixed V_i, Fixed R_L:

Solution:

2. If $R_L = 3\ k\Omega$:

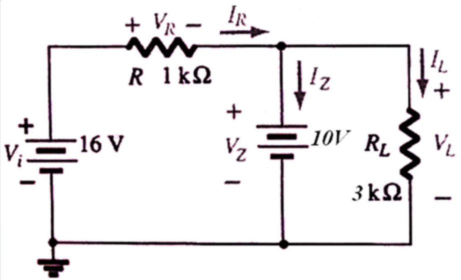
$$V_{zener} = V_i \frac{R_L}{R + R_L} = \frac{16 \times 3}{1 + 3} = 12\ V$$

Since the voltage across the zener is greater than V_Z then the zener is operating in the zener region and can be approximated as battery with V_Z:

$$V_L = V_Z = 10V$$

$$V_R = V_i - V_L = 16 - 10 = 6V$$

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



Example

Fixed V_i, Fixed R_L:

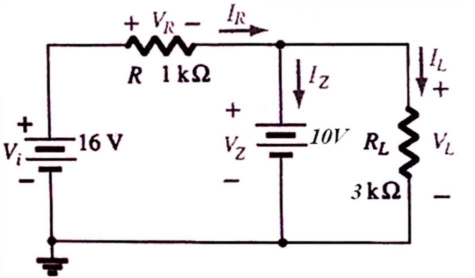
Solution:

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

$$I_Z = I_R - I_L = 6 - 3.33 = 2.67\ mA$$

The power dissipated by the Zener diode is:

$$P_Z = I_Z \times V_Z = 26.7\ mW$$



Example

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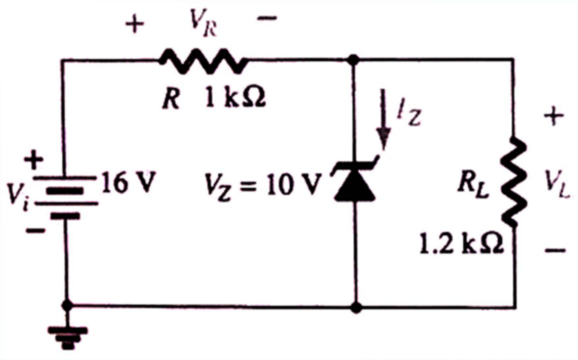
Fixed V_i, Variable R_L:

- The load resistance R_L determines the state of the Zener (on or off).
- Too small a R_L will result in a voltage V_L across the load resistor less than V_Z , and the Zener device will be in the "off" state.
- We need to find the range of load resistance that ensure the on state for the zener diode



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

Fixed V_i, Variable R_L:

To determine the minimum load resistance, R_{Lmin}:

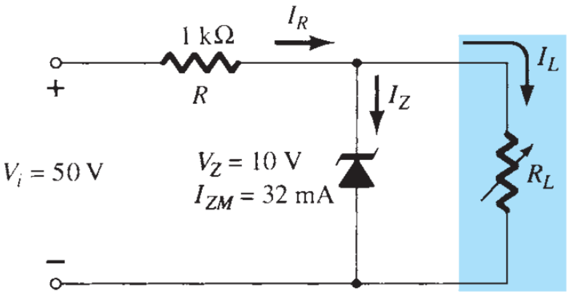
It is the resistance that will result in a lad voltage $V_L = V_Z$:

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

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

So, if a load resistance is grater than R_{Lmin} then the Zener will be on and:

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



Fixed V_i, Variable R_L:

To determine the maximum load resistance, R_{Lmax}:

Once the diode is ON, the voltage across R is fixed at:

$$V_R = V_i - V_Z$$

and,

$$I_R = \frac{V_R}{R}$$

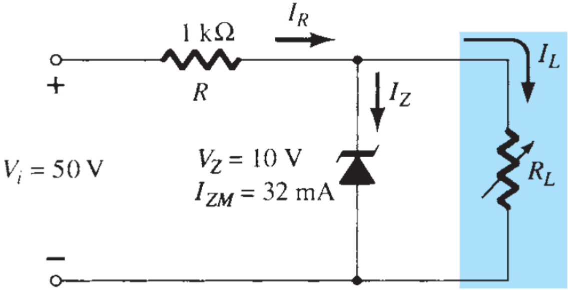
The Zener current is:

$$I_Z = I_R - I_L$$

I_Z is limited to the maximum zener current I_{ZM} from the data sheet.

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

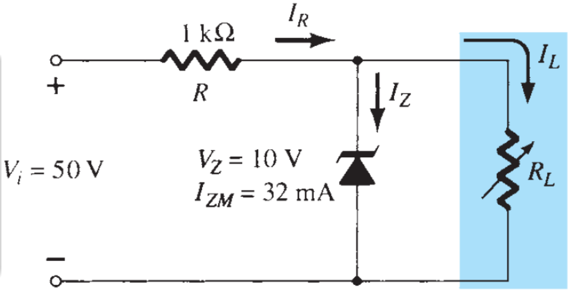
$$R_{Lmax} = \frac{V_Z}{I_{Lmin}}$$



Fixed V_i, Variable R_L:

Example:

1. For the shown network, determine the range of R_L and I_L that will result in V_L being maintained at 10 V.
2. Determine the maximum wattage rating of the diode.



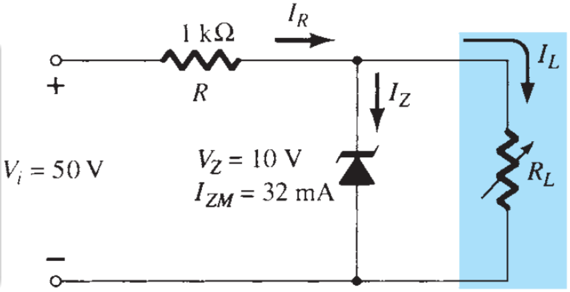
Fixed V_i, Variable R_L:

Solution:

$$R_{Lmin} = \frac{R\ V_Z}{V_i - V_Z} = \frac{1\ k\Omega\ 10V}{50V - 10V}$$

$$R_{Lmin} = 250\ \Omega$$

$$I_{Lmax} = \frac{V_L}{R_L} = \frac{V_Z}{R_{Lmin}} = \frac{10}{250} = 40mA$$



Fixed V_i, Variable R_L:

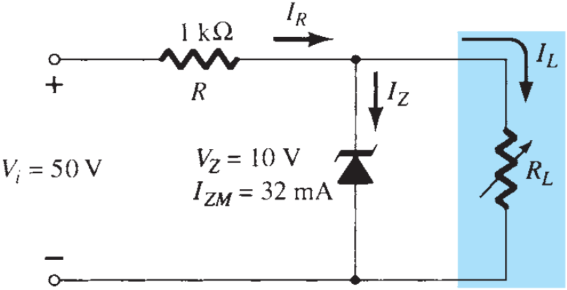
Solution:

$$V_R = V_i - V_Z = 50 - 10 = 40\ \ V$$

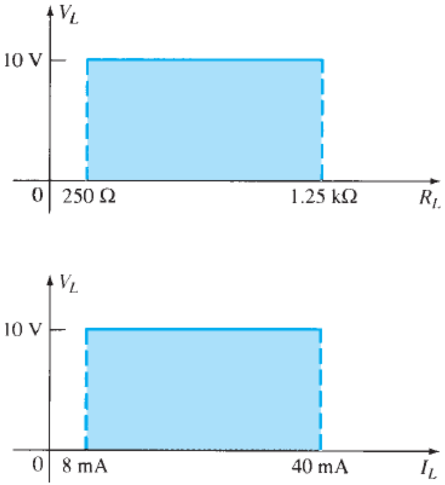
$$I_R = \frac{V_R}{R} = \frac{40V}{1\ k\Omega} = 40mA$$

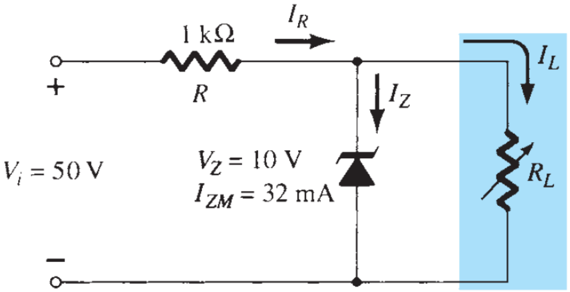
$$I_{Lmin} = I_R - I_{ZM} = 40 - 32 = 8mA$$

$$R_{Lmax} = \frac{V_Z}{I_{Lmin}} = \frac{10\ \ V}{8\ \ mA}$$



Fixed V_i, Variable R_L:

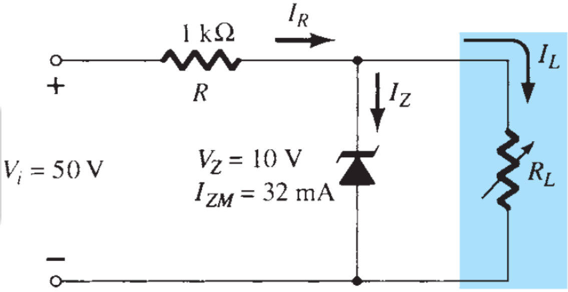




Fixed V_i, Variable R_L:

Solution:

$$P_{Zmax} = V_Z \ I_{ZM} = (10 \ V)(32 \ mA) = 320mW$$



End of Lecture

Best Wishes

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