Lecture Outline:

1. Introduction.

2. Fixed $V_i$, Fixed $R_L$.

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

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3 Fixed $V_i$, Variable $R_L$. 
The Zener diode has three regions of operations. Each region has its 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.
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Fixed $V_i$, Fixed $R_L$:

Example

For the Zener diode regulator,

2. If the load is changed to $R_L = 3 \, k\Omega$, repeat the above problem.
Fixed $V_i$, Fixed $R_L$:

Solution:

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

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

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

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

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

$$I_Z = 0$$

$$P_Z = 0 \text{ Watts}$$
Fixed $V_i$, Fixed $R_L$:

Solution:

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

\[
V_{\text{zener}} = V_i \frac{R_L}{R + R_L} = \frac{16 \times 3}{1 + 3} = 12 \, V
\]

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 $V_Z$:

\[
V_L = V_Z = 10 \, V
\]

\[
V_R = V_i - V_L = 16 - 10 = 6 \, V
\]

\[
I_R = \frac{V_R}{R} = \frac{6 \, V}{1 \, k\Omega} = 6 \, mA
\]
Fixed $V_i$, Fixed $R_L$:

Solution:

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

$$I_Z = I_R - I_L = 6 - 3.33 = 2.67\, \text{mA}$$

The power dissipated by the Zener diode is:

$$P_Z = I_Z \times V_Z = 26.7\, \text{mW}$$
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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 load 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 greater 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, $R_{L_{\text{max}}}$:

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 $I_{Z_{\text{M}}}$ from the data sheet.

$$I_{L_{\text{min}}} = I_R - I_{Z_{\text{M}}}$$

$$R_{L_{\text{max}}} = \frac{V_Z}{I_{L_{\text{min}}}}$$
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:

\[
R_{Lmin} = \frac{R \ V_Z}{V_i - V_Z} = \frac{1 \ k\Omega \times 10\ V}{50\ V - 10\ V} = 250 \ \Omega
\]

\[
I_{Lmax} = \frac{V_L}{R_L} = \frac{V_Z}{R_{Lmin}} = \frac{10}{250} = 40mA
\]
Fixed $V_i$, Variable $R_L$:

**Solution:**

$$V_R = V_i - V_Z = 50 - 10 = 40 \text{ V}$$

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

$$I_{L_{\text{min}}} = I_R - I_{Z_{\text{M}}} = 40 - 32 = 8 \text{ mA}$$

$$R_{L_{\text{max}}} = \frac{V_Z}{I_{L_{\text{min}}}} = \frac{10 \text{ V}}{8 \text{ mA}}$$
Fixed $V_i$, Variable $R_L$:

- **Graph 1:**
  - $V_L$: 10 V
  - $R_L$: 0 to 1.25 kΩ

- **Graph 2:**
  - $V_L$: 10 V
  - $I_L$: 0 to 40 mA

**Diagram:**
- $V_i = 50$ V
- $V_Z = 10$ V
- $I_{ZM} = 32$ mA
Fixed $V_i$, Variable $R_L$:

Solution:

$$P_{Z_{\text{max}}} = V_Z I_{Z_{\text{M}}} = (10 \text{ V})(32 \text{ mA}) = 320 \text{ mW}$$
End of Lecture

Best Wishes

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