Zener Diode Applications

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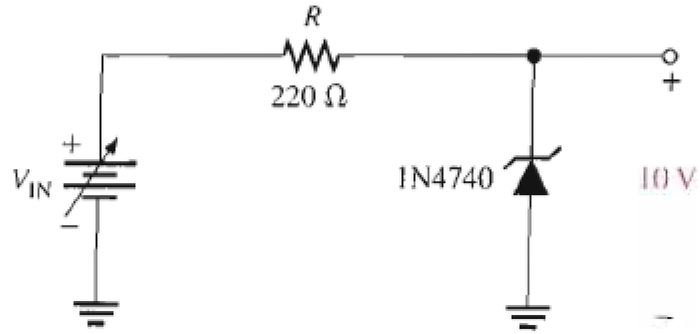
ZENER DIODE APPLICATIONS



To illustrate regulation, suppose that the 1N4740 10 V zener diode in Figure 3–9 can maintain regulation over a range of zener current values from $I_{ZK} = 0.25$ mA to $I_{ZM} =$ 100 mA. From the data sheet in Figure 3–7, $P_{D(max)} = 1$ W and $V_Z = 10$ V.

$$I_{ZM} = \frac{P_{D(max)}}{V_Z} = \frac{1\ \text{W}}{10\ \text{V}} = 100\ \text{mA}$$

For the minimum zener current, the voltage across the 220 Ω resistor is

$$V_R = I_{ZK}R = (0.25\ \text{mA})(220\ \Omega) = 55\ \text{mV}$$

Since $V_R = V_{IN} - V_Z$,

$$V_{IN(min)} \cong V_R + V_Z = 55\ \text{mV} + 10\ \text{V} = 10.055\ \text{V}$$

For the maximum zener current, the voltage across the 220 Ω resistor is

$$V_R = I_{ZM}R = (100 \text{ mA})(220\ \Omega) = 22 \text{ V}$$

Therefore,

$$V_{IN(max)} \cong 22 \text{ V} + 10 \text{ V} = 32 \text{ V}$$

This shows that this zener diode can regulate an input voltage from 10.055 V to 32 V and maintain an approximate 10 V output. The output will vary slightly because of the zener impedance, which has been neglected in these calculations.

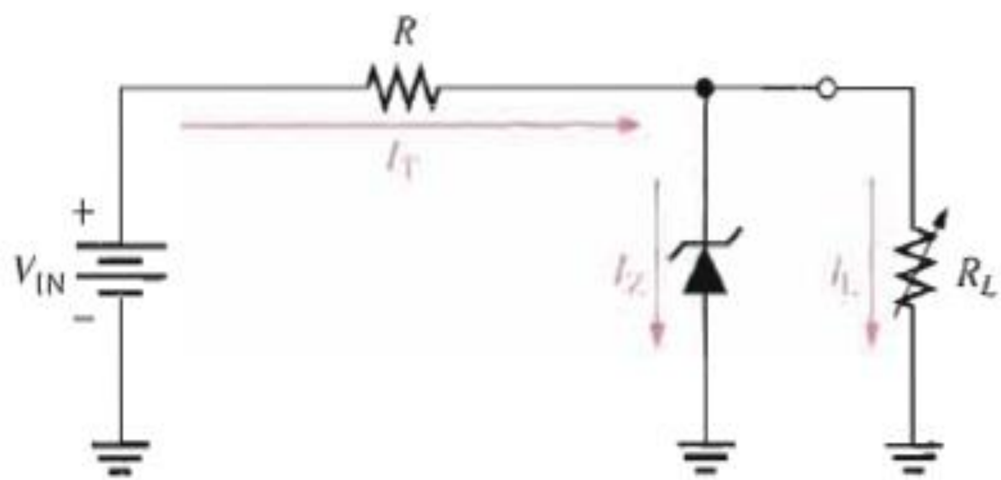
The Key to keeping the load voltage constant is to keep the zener current within its specified range i.e. between $\mathbf{I_{ZK}}$ and $\mathbf{I_{ZM}}$.

Zener Regulation with a Variable Load

Figure 3–12 shows a zener voltage regulator with a variable load resistor across the terminals. The zener diode maintains a nearly constant voltage across R_L as long as the zener current is greater than I_{ZK} and less than I_{ZM}.

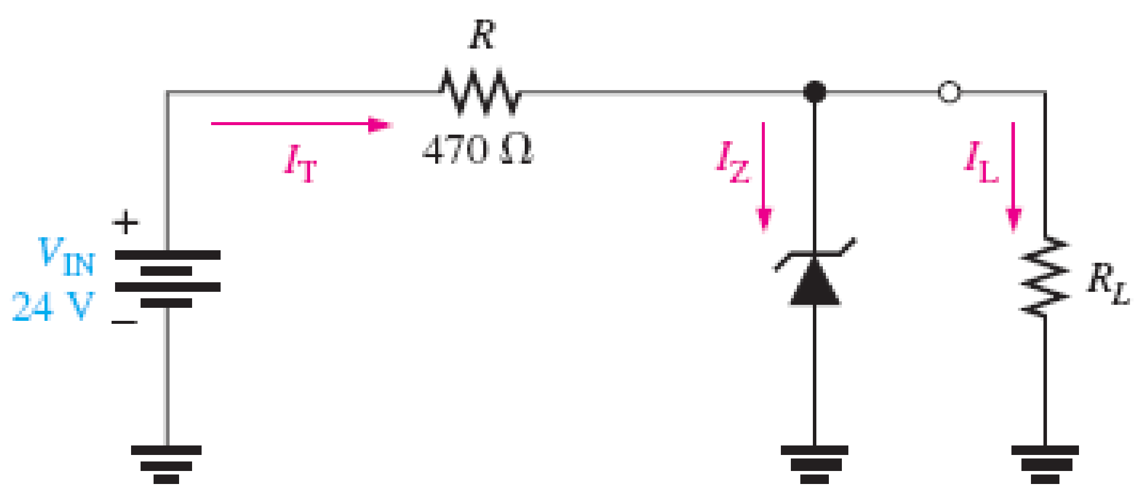
FIGURE 3–12

Zener regulation with a variable load.



From No Load to Full Load

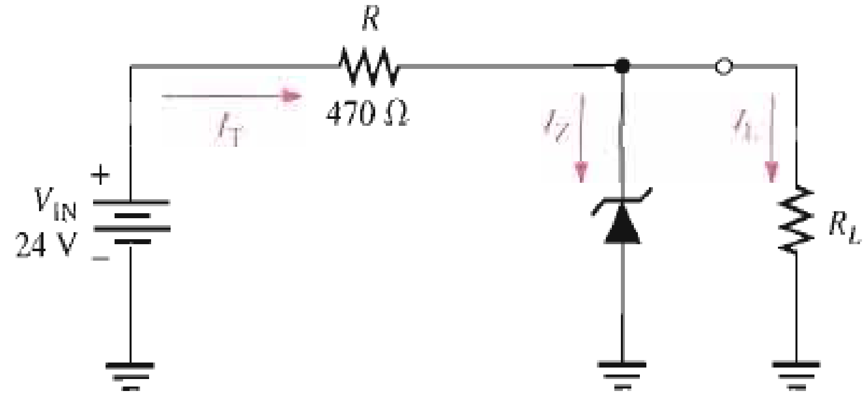
When the output terminals of the zener regulator are open ($R_L = \infty$), the load current is zero and *all* of the current is through the zener; this is a no-load condition. When a load resistor (R_L) is connected, part of the total current is through the zener and part through R_L. The total current through R remains essentially constant as long as the zener is regulating. As R_L is decreased, the load current, I_L, increases and I_Z decreases. The zener diode continues to regulate the voltage until I_Z reaches its minimum value, I_{ZK}. At this point the load current is maximum, and a full-load condition exists. The following example will illustrate this.



Example

Determine the minimum and the maximum load currents for which the zener diode in Figure 3–13 will maintain regulation. What is the minimum value of RL that can be used? V_Z=12V, I_{ZK}=1mA and I_{ZM}=50mA. Assume an ideal zener diode where Z_Z=0Ω remains a constant 12 V over the range of current values, for simplicity.

FIGURE 3–13



Solution When $I_L = 0$ A ($R_L = \infty$), I_Z is maximum and equal to the total circuit current I_T.

$$I_{Z(max)} = I_T = \frac{V_{IN} - V_Z}{R} = \frac{24\text{ V} - 12\text{ V}}{470\ \Omega} = 25.5\text{ mA}$$

Since $I_{Z(max)}$ is less than I_{ZM}, 0 A is an acceptable minimum value for I_L because the zener can handle all of the 25.5 mA. If R_L is removed from the circuit, the load current is 0 A.

$$I_{L(min)} = \mathbf{0\ A}$$

The maximum value of I_L occurs when I_Z is minimum ($I_Z = I_{ZK}$), so

$$I_{L(max)} = I_T - I_{ZK} = 25.5\text{ mA} - 1\text{ mA} = \mathbf{24.5\ mA}$$

The minimum value of R_L is

$$R_{L(min)} = \frac{V_Z}{I_{L(max)}} = \frac{12\text{ V}}{24.5\text{ mA}} = \mathbf{490\ \Omega}$$

Therefore, if R_L is less than 490 Ω, R_L will draw more of the total current away from the zener and I_Z will be reduced below I_{ZK}. This will cause the zener to lose regulation. Regulation is maintained for any value of R_L between 490 Ω and infinity.

Zener Diode as a Limiter: