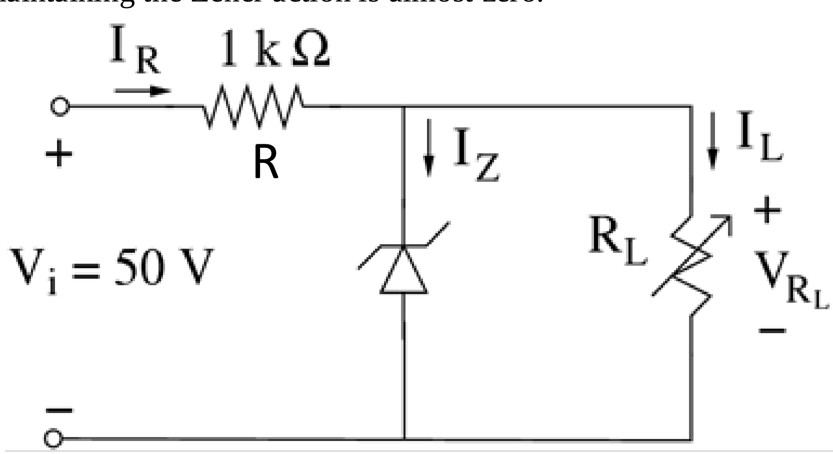
EE101
Tutorial-1 (07 Aug 2014)

<table>
<tr><td>Q1.</td><td>A Si diode operating at 27°C having the ideality factor of 1 is forward biased by a voltage of 0.8 V. If the operating temperature changes to 47 °C, what voltage should now be applied across the diode so that the current through the diode remains constant?
[Given that Boltzmann's constant k = 1.38 × 10^{-23} J/K and the magnitude of electronic charge q = 1.6 × 10^{-19} C]</td></tr>
<tr><td>Q2.</td><td>For the network shown below, determine the range of R_L and I_L that will result in the load voltage V_{R_L} being maintained at 10 V. The Zener diode in the circuit has a breakdown voltage of 10 V and the maximum wattage rating of 320 mW. Assume that the minimum current required for maintaining the Zener action is almost zero.

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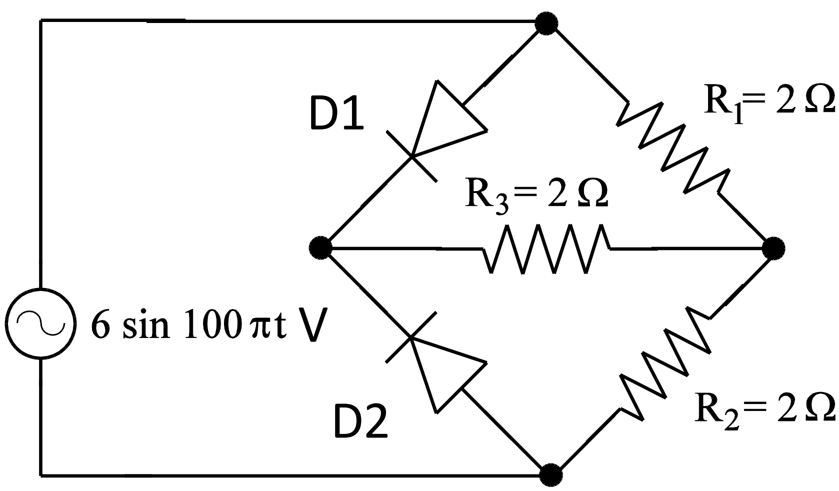
<tr><td>Q3.</td><td>For the circuit shown below, sketch the voltage developed across the resistance R_3 and also determine the dc voltage available at R_3. Assume that the diodes are ideal.

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Solutions

1. The current I_D through a diode for a forward voltage of V_D is given by

$$I_D = I_S\left\{\exp\left(\frac{V_D}{\eta V_T}\right) - 1\right\}$$

where I_S is the reverse saturation current, η is the ideality factor (given as 1), and $V_T = \frac{kT}{q}$ is the thermal voltage at operating temperature of T.

At a forward voltage of 0.8 V and the operating temperature of 27°C (=300 K) , the diode current be

$$I_D = I_S\left\{\exp\left(\frac{0.8q}{300k}\right) - 1\right\}$$

For the changed operating temperature of 47°C (=320 K), the reverse saturation current would be increased by a factor of 4. Now let the voltage V_D' need to be applied across diode to keep the diode current unchanged, then

$$I_D = I_S\left\{\exp\left(\frac{0.8q}{300k}\right) - 1\right\} = 4I_S\left\{\exp\left(\frac{V_D'q}{320k}\right) - 1\right\}$$

Since $I_D \gg I_S$,

$$\exp\left(\frac{0.8q}{300k}\right) = 4\exp\left(\frac{V_D'q}{320k}\right)$$

$$\frac{0.8q}{300k} = \ln 4 + \frac{V_D'q}{320k}$$

$$V_D' = \frac{320k}{q}\left(\frac{0.8q}{300k} - \ln 4\right) = \frac{320 \times 0.8}{300} - \frac{320k}{q}\ln 4$$

$$V_D' = \frac{320 \times 0.8}{300} - \frac{320 \times 1.38 \times 10^{-23}}{1.6 \times 10^{-19}}\ln 4 = 0.8533 - 0.0383 = 0.815\ V$$

Remark: You will find in text book, it is mentioned that the diode forward biased characteristic shifts left with the increase in temperature, i.e., for a given voltage drop across the diode more current passes through it with increase in the temperature. Note the above solution appears to **contradict** the same. This contradiction has arisen due to the fact that the voltage drop across diode of 0.8 V taken in this problem is too large. Even with the assumption of reverse saturation current I_s of 1 pA at 27°C, for 0.8 V voltage drop the diode current turns out to be 26.7 A which is unrealistic. Actually the voltage drop across diode should have been in the range of 0.3-0.5 V. On taking the diode voltage drop at 27°C in that range, the above analysis would show that a **smaller** the voltage drop would be needed at 47°C for maintaining the same current that flows through the diode at 27°C.

2. Since $P_Z = V_Z I_Z$, where I_Z is the current through the Zener diode, we have

$$I_{Z_{max}} = \frac{P_{Z_{max}}}{V_Z} = \frac{320\ mW}{10\ V} = 32\ mA$$

The voltage drop across the load should be just enough to keep the Zener diode in the breakdown condition. Thus the minimum value of load resistance given by

$$R_{L_{min}} = \frac{RV_Z}{V_i - V_Z} = \frac{1\ k\Omega \times 10\ V}{50\ V - 10\ V} = 250\ \Omega$$

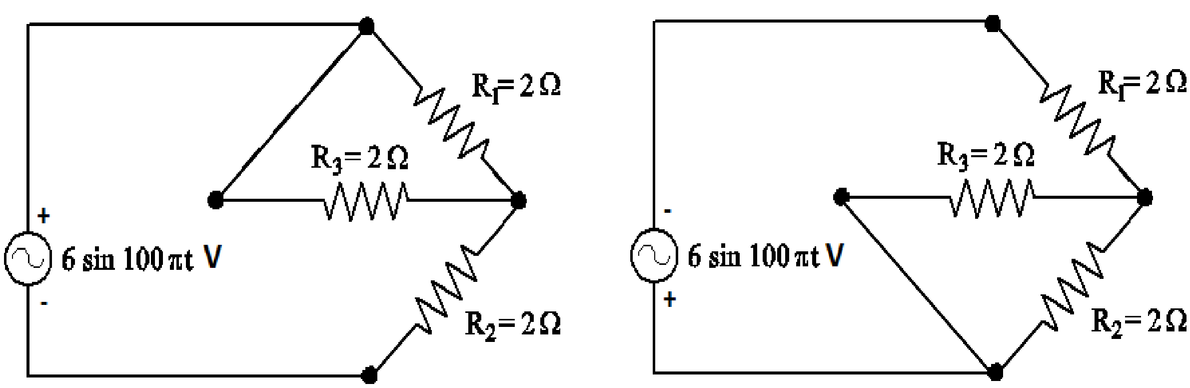
$$V_R = V_i - V_R = 50 - 10 = 40\ V\ ; \qquad I_R = \frac{V_R}{R} = \frac{40\ V}{1\ k\Omega} = 40\ mA$$

Given that $I_{Z_{min}} \approx 0$, so $I_{L_{max}} = I_R = 40\ mA$

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

$$R_{L_{max}} = \frac{V_Z}{I_{L_{min}}} = \frac{10\ V}{8\ mA} = 1.25\ k\Omega$$

3. For the positive and the negative cycle of the sinusoidal excitation, the given circuit reduces to as shown below,



Thus the peak value of the sinusoidal voltage drop across R_3 is given by

$$(V_{R3})_{peak} = \frac{V_m}{3} = 2\ V$$

As the direction of the current remains through R_3 and therefore the voltage drop remains same for both the cycles, thus its full-wave rectified having the peak value of 2 V.
For full-wave rectified voltage across R_3, the dc value is given by

$$(V_{R3})_{dc} = \frac{2}{\pi}(V_{R3})_{peak} = 0.636 \times 2 = 1.272\ V$$