Reference Solution

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#1

Solution (Maximum Power): When no heat sink is used, the maximum device power dissipation is found from Equation (8.7) as

$$P_{D,\max} = \frac{T_{j,\max} - T_{\text{amb}}}{\theta_{\text{dev-case}} + \theta_{\text{case-amb}}} = \frac{150 - 30}{1.75 + 50} = 2.32\,\text{W}$$

When a heat sink is used, the maximum device power dissipation is found from Equation (8.6) as

$$P_{D,\max} = \frac{T_{j,\max} - T_{\text{amb}}}{\theta_{\text{dev-case}} + \theta_{\text{case-snk}} + \theta_{\text{snk-amb}}} = \frac{150 - 30}{1.75 + 1 + 5} = 15.5\,\text{W}$$

Solution (Temperature): The device temperature is $T = 150$ °C and the ambient temperature is $T_{\text{amb}} = 30$ °C. The heat flow is $P_D = 15.5$ W. The heat sink temperature (see Figure 8.11) is found from

$$T_{\text{snk}} - T_{\text{amb}} = P_D \cdot \theta_{\text{snk-amb}}$$

or

$$T_{\text{snk}} = 30 + (15.5)(5) \Rightarrow T_{\text{snk}} = 107.5\,^\circ\text{C}$$

The case temperature is found from

$$T_{\text{case}} - T_{\text{amb}} = P_D \cdot (\theta_{\text{case-snk}} + \theta_{\text{snk-case}})$$

or

$$T_{\text{case}} = 30 + (15.5)(1 + 5) \Rightarrow T = 123\,^\circ\text{C}$$

#2

(a)

$$V_{DS} \geq V_{DS}(sat) = V_{GS} - V_{TN} = V_{GS}$$

$$V_{DS} = 10 - V_o(\max) \text{ and } I_D = I_L = K_n(V_{GS})^2$$

$$\frac{V_o(\max)}{R_L} = K_n(V_{GS})^2$$

$$V_{GS} = \sqrt{\frac{V_o(\max)}{R_L \cdot K_n}}$$

$$\text{So } 10 - V_o(\max) = \sqrt{\frac{V_o(\max)}{R_L \cdot K_n}} = \sqrt{\frac{V_o(\max)}{(5)(0.4)}}$$

$$\left[10 - V_0(\max)\right]^2 = \frac{V_0(\max)}{2}$$

$$100 - 20V_0(\max) + V_0^2(\max) = \frac{V_0(\max)}{2}$$

$$V_0^2(\max) - 20.5V_0(\max) + 100 = 0$$

$$V_0(\max) = \frac{20.5 \pm \sqrt{(20.5)^2 - 4(100)}}{2} \Rightarrow \underline{V_0(\max) = 8 \text{ V}}$$

$$i_L = \frac{8}{5} \Rightarrow \underline{i_L = 1.6 \text{ mA}}$$

$$V_{GS} = \sqrt{\frac{i_L}{K_n}} = \sqrt{\frac{1.6}{0.4}} = 2V \Rightarrow \underline{V_I = 10 \text{ V}}$$

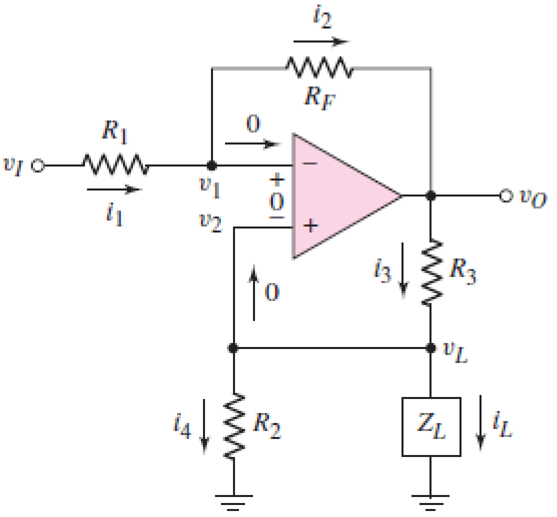
b.

$$\overline{P_L} = \frac{1}{2} \cdot \frac{(8)^2}{5} = 6.4 \text{ mW}$$

$$\overline{P_S} = \frac{20(1.6)}{\pi} = 10.2 \text{ mW}$$

$$\eta = \frac{\overline{P_L}}{\overline{P_S}} = \frac{6.4}{10.2} \Rightarrow \underline{\eta = 62.7\%}$$

#3



$$\frac{v_I - i_L Z_L}{R_1} = \frac{i_L Z_L - v_O}{R_F}$$

$$\frac{v_O - i_L Z_L}{R_3} = i_L + \frac{i_L Z_L}{R_2}$$

$$\frac{R_F}{R_1} \cdot \frac{(i_L Z_L - v_I)}{R_3} = i_L + \frac{i_L Z_L}{R_2}$$

$$i_L \left(\frac{R_F Z_L}{R_1 R_3} - 1 - \frac{Z_L}{R_2} \right) = v_I \left(\frac{R_F}{R_1 R_3} \right)$$

In order to make i_L independent of Z_L, we can design the circuit such that the coefficient of Z_L is zero, or

$$\frac{R_F}{R_1 R_3} = \frac{1}{R_2}$$

$$i_L = -v_I \left(\frac{R_F}{R_1 R_3} \right) = \frac{-v_I}{R_2}$$

#4

(a) $\upsilon_X = \left(\dfrac{\upsilon_I}{R}\right)(2R) + \upsilon_I = 3\upsilon_I$

$$\frac{\upsilon_X - \upsilon_I}{2R} + \frac{\upsilon_X}{R} + \frac{\upsilon_X - \upsilon_O}{2R} = 0$$

$$\upsilon_X\left(\frac{1}{2R} + \frac{1}{R} + \frac{1}{2R}\right) - \frac{\upsilon_I}{2R} = \frac{\upsilon_O}{2R}$$

$$3\upsilon_I\left(\frac{2}{R}\right) - \frac{\upsilon_I}{2R} = \frac{\upsilon_O}{2R}$$

so $\dfrac{\upsilon_O}{\upsilon_I} = 11$

(b)

$R = 30\ \text{k}\Omega\ ,\quad \upsilon_I = -0.15\ \text{V}$

For R_1 : $|i| = \dfrac{0.15}{30} \Rightarrow 5\ \mu\,\text{A}$

For R_2 : $|i| = 5\ \mu\,\text{A}$

$\upsilon_X = 3\upsilon_I = -0.45\ \text{V}$

For R_4 : $|i| = \dfrac{0.45}{30} \Rightarrow 15\ \mu\,\text{A}$

$\upsilon_O = (11)(-0.15) = -1.65\ \text{V}$

For R_3: $|i| = \dfrac{1.65 - 0.45}{60} \Rightarrow 20\ \mu\,\text{A}$

#5

(b) $\frac{R_2}{R_1} = 2$, $\frac{R_4}{R_3} = 10$, $\frac{R_6}{R_5} = 11$

$$V_O = \left(1+\frac{R_4}{R_3}\right)\left(\frac{R_6/R_5}{1+R_6/R_5}\right)\cdot V_{O2} - \frac{R_4}{R_3} V_{O1}$$

$$= 11 \times \frac{11}{12} V_{O2} - 10 V_{O1}$$

$$= 10.083\, V_{O2} - 10 V_{O1}$$

$$\begin{cases} V_{O1} = 3V_{I1} - 2V_{I2} \\ V_{O2} = 3V_{I2} - 2V_{I1} \end{cases}$$

$$\Rightarrow V_O = 10.0833(3V_{I2} - 2V_{I1}) - 10(3V_{I1} - 2V_{I2})$$

$$= 50.25\, V_{I2} - 50.167\, V_{I1}$$

$$= A_{cm} \cdot \frac{V_{I1}+V_{I2}}{2} + A_d \cdot (V_{I2} - V_{I1})$$

$$= \left(A_d + \frac{A_{cm}}{2}\right) V_{I2} - \left(A_d - \frac{A_{cm}}{2}\right) V_{I1}$$

$$\Rightarrow \begin{cases} A_d + \frac{A_{cm}}{2} = 50.25 \\ A_d - \frac{A_{cm}}{2} = 50.167 \end{cases} \Rightarrow \begin{matrix} A_d = 50.2085 \\ A_{cm} = 0.083 \end{matrix}$$

$$CMRR(dB) = 20\log_{10}\left(\frac{50.2085}{0.083}\right) = 20\log_{10}(604.92)$$

$$= 55.634\ (dB)$$