2023 Electronics II Ex2 Solution

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1.

(A) $\frac{R_4}{R_3} = \frac{R_6}{R_5}$.

$V_o = \frac{R_4}{R_3}(V_{O2} - V_{O1})$ by (9.52).

$$\begin{cases} V_{O1} = (1+\frac{R_2}{R_1})V_{I1} - \frac{R_2}{R_1}V_{I2} \\ V_{O2} = (1+\frac{R_2}{R_1})V_{I2} - \frac{R_2}{R_1}V_{I1} \end{cases}$$ by (9.65).

$$\underbrace{V_O = \frac{R_4}{R_3}(1+\frac{2R_2}{R_1})(V_{I2} - V_{I1})}$$ ※

(b) $\frac{R_2}{R_1} = 1$, $\frac{R_4}{R_3} = 10$, $\frac{R_6}{R_5} = 12$.

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

$$= 11 \times \frac{12}{1+12} V_{O2} - 10V_{O1}$$

$$= 10.1538 V_{O2} - 10V_{O1}.$$

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

$$V_O = 10.1538(2V_{I2} - V_{I1}) - 10(2V_{I1} - V_{I2})$$

$$= 30.308 V_{I2} - 30.1538 V_{I1}$$

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

$$= A_{cm} V_{cm} + A_d \cdot V_d.$$

$$A_{cm} = 30.308 - 30.1538 = 0.1542$$

$$A_d = \frac{1}{2}(30.308 + 30.1538) = 30.2309.$$

$$\text{CMRR (dB)} = 20\log_{10}\left(\frac{30.2309}{0.1542}\right) = \underbrace{45.8473 \text{ dB}}$$ ※

2.

$$v_0 = \left(\frac{333}{20}\right)(v_{01} - v_{02}) = 16.65(v_{01} - v_{02})$$

$$v_{01} = -v_{BE1} = -V_T \ln\left(\frac{i_{C1}}{I_S}\right)$$

$$v_{02} = -v_{BE2} = -V_T \ln\left(\frac{i_{C2}}{I_S}\right)$$

$$v_{01} - v_{02} = -V_T \ln\left(\frac{i_{C1}}{i_{C2}}\right) = V_T \ln\left(\frac{i_{C2}}{i_{C1}}\right)$$

$$i_{C2} = \frac{v_2}{R_2}, \quad i_{C1} = \frac{v_1}{R_1}$$

So $v_{01} - v_{02} = V_T \ln\left(\frac{v_2}{R_2} \cdot \frac{R_1}{v_1}\right)$

Then

$$v_0 = (16.65)(0.026)\ln\left(\frac{v_2}{v_1} \cdot \frac{R_1}{R_2}\right)$$

$$v_0 = 0.4329 \ln\left(\frac{v_2}{v_1} \cdot \frac{R_1}{R_2}\right)$$

3.

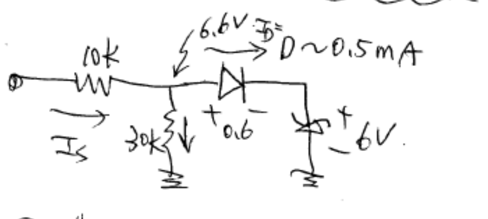
(a). $V_Z = 6V$.

$$\frac{V_o}{V_Z} = \frac{10}{6} = 1 + \frac{R_2}{R_1}$$

$$\frac{R_2}{R_1} = 0.667. \text{ ※}$$

$$1\,mA = \frac{10-6}{R_F} \Rightarrow R_F = 4K\Omega \text{ ※}$$

(b)



① when $I_D = 0$

$$I_S = \frac{6.6}{30K} = 0.22mA \text{ (min) ※}$$

② when $I_D = 0.5mA$

$$I_S = \frac{6.6}{30K} + 0.5 = 0.72\,mA \text{ (max) ※}$$

4.

(a)

When no heat sink is used,

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

When a heat sink is used,

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

(b)

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

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

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

5.

$$V_{CEQ} = 6 = V_{CC} - I_{CQ}R_L = 12 - I_{CQ}(1) \Rightarrow I_{CQ} = 6\text{ mA}$$

$$\overline{P_L} = \frac{1}{2} \cdot \frac{V_P^2}{R_L} = \frac{1}{2}\frac{(4.5)^2}{1} = 10.1\text{ mW}$$

$$\eta = \frac{10.1}{I_{CQ}V_{CC}} \times 100\% = \frac{10.1}{(6)(12)} \times 100\% = 14.1\%$$