2023 Electronics II Ex3 Solution

DCChang

1.

$$I_0 R_E = V_T \ln\left(\frac{I_{REF}}{I_0}\right)$$

$$R_E = \frac{0.026}{0.025}\ln\left(\frac{0.70}{0.025}\right) \Rightarrow R_E = 3.465\ \text{k}\Omega$$

$$g_{m2} = \frac{I_0}{V_T} = \frac{0.025}{0.026} \Rightarrow g_{m2} = 0.9615\ \text{mA/V}$$

$$r_{\pi 2} = \frac{\beta V_T}{I_0} = \frac{(150)(0.026)}{0.025} = 156\ \text{k}\Omega$$

$$r_{02} = \frac{V_A}{I_0} = \frac{100}{0.025} = 4000\ \text{k}\Omega$$

$$R_E' = R_E \,||\, r_{\pi 2} = 3.47\,||\,156 = 3.39\ \text{k}\Omega$$

$$R_0 = r_{02}\left(1 + g_{m2}R_E'\right) = 4000\left[1 + (0.962)(3.39)\right]$$

$$R_0 = 17.04\ \text{M}\Omega$$

$$dI_0 = \frac{1}{R_0}\cdot dV_{C2} = \frac{3}{17{,}040} \Rightarrow \underline{dI_0 = 0.176\ \mu\text{A}}$$

2.

$$V_{DS2}(sat) = 0.4 = V_{GS2} - 0.4 \Rightarrow V_{GS2} = 0.8\ \text{V}$$

$$I_O = \left(\frac{k_n'}{2}\right)\left(\frac{W}{L}\right)_2 (V_{GS2} - V_{TN})^2$$

$$0.1 = \left(\frac{0.1}{2}\right)\left(\frac{W}{L}\right)_2 (0.8 - 0.4)^2 \Rightarrow \left(\frac{W}{L}\right)_2 = 12.5$$

$$I_{REF} = 0.5 = \left(\frac{0.1}{2}\right)\left(\frac{W}{L}\right)_1 (0.8 - 0.4)^2 \Rightarrow \left(\frac{W}{L}\right)_1 = 62.5$$

$$V_{GS3} = (V^+ - V^-) - V_{GS1} = 1.8 - (-1.8) - 0.8 = 2.8\ \text{V}$$

$$I_{REF} = 0.5 = \left(\frac{0.1}{2}\right)\left(\frac{W}{L}\right)_3 (2.8 - 0.4)^2 \Rightarrow \left(\frac{W}{L}\right)_3 = 1.74$$

3.

$$g_{m1} = 2\sqrt{\left(\frac{k_n'}{2}\right)\left(\frac{W}{L}\right)_1 I_{D1}} = 2\sqrt{\left(\frac{0.1}{2}\right)(20)(0.1)} = 0.6325 \text{ mA/V}$$

$$r_{o1} = \frac{1}{\lambda_n I_{D1}} = \frac{1}{(0.02)(0.1)} = 500 \text{ k}\Omega$$

$$R_{o2} = r_{o2} + r_{o3}\left(1 + g_{m2} r_{o2}\right)$$

$$g_{m2} = 2\sqrt{\left(\frac{0.06}{2}\right)(80)(0.1)} = 0.9798 \text{ mA/V}$$

$$r_{o2} = r_{o3} = \frac{1}{(0.02)(0.1)} = 500 \text{ k}\Omega$$

$$R_{o2} = 500 + 500\left[1 + (0.9798)(500)\right] = 245{,}949 \text{ k}\Omega$$

$$A_v = -g_{m1}\left(r_{o1} \| R_{o2}\right) = -(0.6325)(500 \| 245{,}949) = -316$$

4.

(a) For M_O: $I_{DQ} = \left(\frac{k_n'}{2}\right)\left(\frac{W}{L}\right)_O (V_I - V_{TN})^2 (1 + \lambda_n V_{DSO})$

$$100 = \left(\frac{100}{2}\right)\left(\frac{W}{L}\right)_O (1.2 - 0.5)^2 \left[1 + (0.02)(1.5)\right] \Rightarrow \left(\frac{W}{L}\right)_O = 3.96$$

For M_1, M_2: For $I_{REF} = I_O \Rightarrow V_{SD2} = V_{SD1} = V_{SG} = 1.5$ V

$$100 = \left(\frac{60}{2}\right)\left(\frac{W}{L}\right)_2 (1.5 - 0.5)^2 \left[1 + (0.02)(1.5)\right] \Rightarrow \left(\frac{W}{L}\right)_2 = \left(\frac{W}{L}\right)_1 = 3.24$$

For M_3: $V_{SG3} = 3 - 1.5 = 1.5 \text{ V} = V_{SD3} \Rightarrow \left(\frac{W}{L}\right)_3 = 3.24$

(b) $A_v = -g_{mO}\left(r_{oO} \| r_{o2}\right)$

$$g_{mO} = 2\sqrt{\left(\frac{k_n'}{2}\right)\left(\frac{W}{L}\right)_O I_{DQ}} = 2\sqrt{\left(\frac{0.1}{2}\right)(3.96)(0.1)} = 0.2814 \text{ mA/V}$$

$$r_{oO} = r_{o2} = \frac{1}{\lambda I_{DQ}} = \frac{1}{(0.02)(0.1)} = 500 \text{ k}\Omega$$

$$A_v = -(0.2814)(500 \| 500) = -70.35$$