2023 Electronics II Ex4 Solution

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1.

a. Neglecting base currents

$$I_1 = I_3 = 400\ \mu\text{A} \Rightarrow \text{R}_1 = \frac{30-0.7}{0.4} \Rightarrow \underline{R_1 = 73.25\ \text{k}\Omega}$$

$$V_{CE1} = 10\ \text{V} \Rightarrow \text{V}_{C1} = 9.3\ \text{V}$$

$$R_C = \frac{15-9.3}{0.2} \Rightarrow \underline{R_C = 28.5\ \text{k}\Omega}$$

b.

$$r_\pi = \frac{(100)(0.026)}{0.2} = 13\ \text{k}\Omega$$

$$r_0(Q_3) = \frac{50}{0.4} = 125\ \text{k}\Omega$$

We have

$$A_d = \frac{\beta R_C}{2(r_\pi + R_B)} = \frac{(100)(28.5)}{2(13+10)} \Rightarrow \underline{A_d = 62}$$

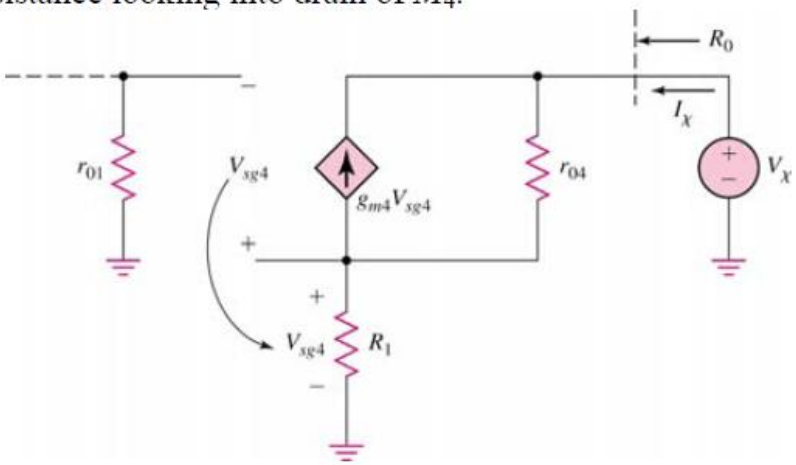
$$A_{cm} = -\frac{\beta R_C}{r_\pi + R_B}\left\{\frac{1}{1+\frac{2r_0(1+\beta)}{r_\pi + R_B}}\right\}$$

$$= -\frac{(100)(28.5)}{13+10}\left\{\frac{1}{1+\frac{2(125)(101)}{13+10}}\right\} \Rightarrow \underline{A_{cm} = -0.113}$$

$$CMRR_{dB} = 20\log_{10}\left(\frac{62}{0.113}\right) \Rightarrow \underline{CMRR_{dB} = 54.8\ \text{dB}}$$

2.

Resistance looking into drain of M_4.



$$V_{sg4} \cong I_X R_1$$

$$I_X + g_{m4}V_{sg4} = \frac{V_X - V_{sg4}}{r_{o4}}$$

$$I_X\left[1 + g_{m4}R_1 + \frac{R_1}{r_{o4}}\right] = \frac{V_X}{r_{o4}}$$

Or $$R_o = r_{o4}\left[1 + g_{m4}R_1 + \frac{R_1}{r_{o4}}\right]$$

$$A_d = g_{m2}\left(r_{o2} \| R_o\right)$$

$$g_{m2} = 2\sqrt{K_n I_{DQ}} = 2\sqrt{(0.080)(0.1)}$$
$$= 0.179\ mA/V$$

$$r_{o2} = \frac{1}{\lambda_n I_{DQ}} = \frac{1}{(0.015)(0.1)} = 667\ k\Omega$$

$$g_{m4} = 2\sqrt{K_P I_{DQ}} = 2\sqrt{(0.080)(0.1)}$$
$$= 0.179\ mA/V$$

$$r_{o4} = \frac{1}{\lambda_p I_{DQ}} = \frac{1}{(0.02)(0.1)} = 500\ k\Omega$$

$$R_0 = 500\left[1 + (0.179)(1) + \frac{1}{500}\right] = 590.5\ \text{k}\Omega$$

$$A_d = (0.179)\left[667 \| 590.5\right] \Rightarrow \underline{A_d = 56.06}$$

3.

$I_{CQ3} = 0.25\,\text{mA},\ \text{and}\ I_{CQ4} = 2\,\text{mA}.$

$$A_{d1} = \frac{\upsilon_{o2}}{\upsilon_d} = \frac{g_{m1}}{2}\left(R \| r_{\pi 3}\right)$$

$$g_{m1} = \frac{0.25}{0.026} = 9.615\,\text{mA/V}$$

$$r_{\pi 3} = \frac{(120)(0.026)}{0.25} = 12.48\,\text{k}\Omega$$

$$A_{d1} = \frac{(9.615)}{2}(20 \| 12.48) = 36.94$$

$$A_3 = -g_{m3}\left(R_C \| R_{i4}\right)$$

$$R_{i4} = r_{\pi 4} + (1+\beta)R_{E2}$$

$$g_{m3} = \frac{0.25}{0.026} = 9.615\,\text{mA/V}$$

$$r_{\pi 4} = \frac{(120)(0.026)}{2} = 1.56\,\text{k}\Omega$$

$$R_{i4} = 1.56 + (121)(2.5) = 304\,\text{k}\Omega$$

$$A_3 = -(9.615)(17.2 \| 304) = -156.5$$

$$A_4 = \frac{(1+\beta)R_{E2}}{r_{\pi 4} + (1+\beta)R_{E2}} = \frac{(121)(2.5)}{1.56 + (121)(2.5)} = 0.995$$

Now $A_d = \dfrac{\upsilon_o}{\upsilon_d} = A_{d1} \cdot A_3 \cdot A_4 = (36.94)(-156.5)(0.995) = -5752$

4.

$$\upsilon_{o1} = -g_{m1}\left(r_{o1} \| R_{o3}\right)\left(\frac{\upsilon_d}{2}\right)$$

$$A_{d1} = \frac{\upsilon_{o1}}{\upsilon_d} = -\frac{1}{2} g_{m1}\left(r_{o1} \| R_{o3}\right)$$

$$g_{m1} = \frac{I_{CQ}}{V_T} = \frac{0.2}{0.026} = 7.692 \text{ mA/V}$$

$$r_{o1} = \frac{V_{A1}}{I_{CQ}} = \frac{120}{0.2} = 600 \text{ k}\Omega$$

$$R_{o3} = r_{o3} \| r_{\pi 3} \left\| \frac{1}{g_{m3}} \right., \text{ where } g_{m3} = 7.692 \text{ mA/V},$$

$$r_{\pi 3} = \frac{(120)(0.026)}{0.2} = 15.6 \text{ k}\Omega, \; r_{o3} = 400 \text{ k}\Omega$$

Then $R_{o3} = 400 \left\| 15.6 \right\| \frac{1}{7.692} = 15.014 \| 0.130 = 0.1289 \text{ k}\Omega$

$$A_{d1} = -\frac{1}{2}(7.692)(600 \| 0.1289) = -0.4956$$

$$A_{d2} = +\frac{1}{2} g_{m2}\left(r_{o2} \| R_{o4}\right) = +0.4956$$