Solution for Exam-4, 12 June, 2020 Electronics II, Spring 2020

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#1

(a)

$$R_1 = 38.6\ \text{K} \Rightarrow$$

$$I_1 = \frac{10 - 0.7 - (-10)}{R_1} = 0.5$$

$$R_2 = \frac{0.026}{0.14} \ln\left(\frac{0.5}{0.14}\right) \Rightarrow \underline{R_2 = 236\ \Omega}$$

(b)

$$R_{icm} \approx (1+\beta) R_o$$

$$R_o = r_{o4}\left(1 + g_{m4} R_E'\right) \quad g_{m4} = \frac{0.14}{0.026} = 5.385\ \text{mA/V}$$

$$r_{\pi 4} = \frac{(180)(0.026)}{0.14} = 33.4\ \text{K}$$

$$R_E' = 33.4 \| 0.236 = 0.234\ \text{K}$$

$$r_{o4} = \frac{100}{0.14} = 714\ \text{K}$$

$$R_o = 714\left[1 + (5.385)(0.234)\right]$$

$$= 1614\ \text{K}$$

$$R_{icm} = (181)(1614) \approx 292\ \text{M}\Omega$$

(c)

$$A_{cm} = \frac{-g_{m1} R_C}{1 + \dfrac{2(1+\beta) R_o}{r_{\pi 1}}} \quad g_{m1} = \frac{0.07}{0.026} = 2.692\ \text{mA/V}$$

$$r_{\pi 1} = \frac{(180)(0.026)}{0.07} = 66.86\ \text{K}$$

$$A_{cm} = \frac{-(2.692)(40)}{1 + \dfrac{2(181)(1614)}{66.86}}$$

$$\underline{A_{cm} = -0.0123}$$

#2

(a) (b)

$$R_i = r_{\pi 1} + (1+\beta) r_{\pi 2}$$

$$r_{\pi 2} = \frac{(100)(0.026)}{0.5} = 5.2\ \text{k}\Omega$$

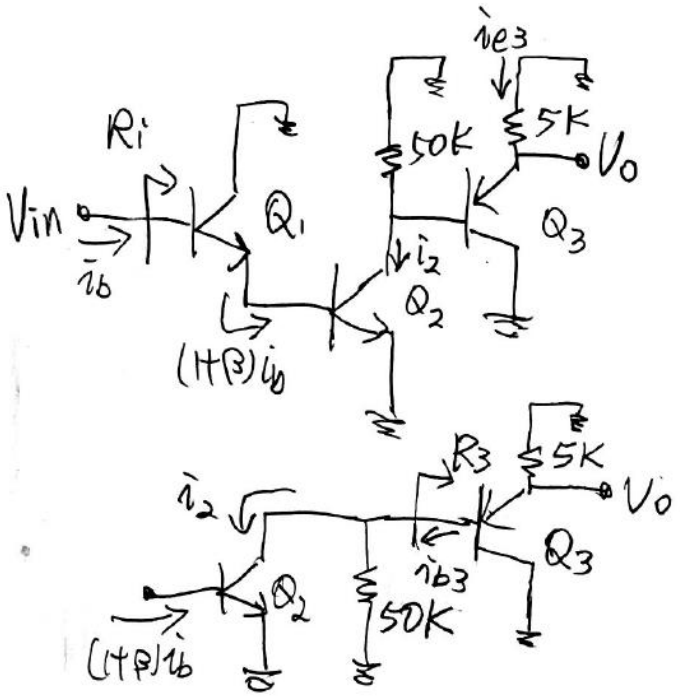
$$r_{\pi 1} = \frac{(100)(0.026)}{(0.5/100)} = \frac{(100)^2 (0.026)}{0.5} = 520\ \text{k}\Omega$$

$$R_i = 520 + (101)(5.2) \Rightarrow \underline{R_i \cong 1.05\ \text{M}\Omega}$$

$$R_0 = 5 \left\| \frac{r_{\pi 3} + 50}{101}, \quad r_{\pi 3} = \frac{(100)(0.026)}{1} = 2.6\ \text{k}\Omega \right.$$

$$R_0 = 5 \left\| \frac{2.6 + 50}{101} = 5 \right\| 0.521 \Rightarrow \underline{R_0 = 0.472\ \text{k}\Omega}$$

(c)



$V_o = -i_{e3} \times 5$

$V_{in} = i_b \times R_i$

$R_3 = r_{\pi 3} + (1+\beta) \times 5$

$= 2.6 + 5 \times 101 = 507.6\ (\text{K})$

$i_2 = \beta(1+\beta) i_b$

$i_{b3} = \frac{50}{50+R_3} \times i_2$, $i_{e3} = (1+\beta) i_{b3}$

$V_o = -5(1+\beta) \cdot \frac{50}{50+R_3} \times \beta(1+\beta) i_b$

$$A_V = \frac{V_o}{V_{in}} \approx \frac{-5 \times 100 \times 101^2 \times 50}{R_i \times (50 + R_3)}$$

$$= -\frac{2550 \times 10^5}{1.05 \times 10^3 \times 557.6}$$

$$\approx -\frac{2550}{5.855} = -435.5$$

#3

$$I_1 = I_3 = 400\ \mu\text{A}$$

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

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

We have

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

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

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

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

#4

$$I_1 = \frac{24 - V_{GS4}}{R_1} = k_n \left(V_{GS4} - V_{Th}\right)^2$$

$$24 - V_{GS4} = (55)(0.2)\left(V_{GS4} - 2\right)^2$$

$$24 - V_{GS4} = 11\left(V_{GS4}^2 - 4V_{GS4} + 4\right)$$

$$11V_{GS4}^2 - 43V_{GS4} + 20 = 0$$

$$V_{GS4} = \frac{43 \pm \sqrt{(43)^2 - 4(11)(20)}}{2(11)} = 3.37 \text{ V}$$

$$I_1 = \frac{24 - 3.37}{55} = 0.375 \text{ mA} = I_Q$$

$$v_{02} = 12 - \left(\frac{0.375}{2}\right)(40) = 4.5 \text{ V}$$

$$\frac{v_{02} - V_{GS3}}{R_5} = I_{D3} = k_n \left(V_{GS3} - V_{Th}\right)^2$$

$$4.5 - V_{GS3} = (0.2)(6)\left(V_{GS3}^2 - 4V_{GS3} + 4\right)$$

$$1.2V_{GS3}^2 - 3.8V_{GS3} + 0.3 = 0$$

$$V_{GS3} = \frac{3.8 \pm \sqrt{(3.8)^2 - 4(1.2)(0.3)}}{2(1.2)} = 3.09 \text{ V}$$

$$I_{D3} = \frac{4.5 - 3.09}{6} = 0.235 \text{ mA}$$

$$g_{m2} = 2\sqrt{K_n I_{D2}} = 2\sqrt{(0.2)\left(\frac{0.375}{2}\right)}$$

$$= 0.387 \text{ mA/V}$$

$$A_{d1} = \frac{1}{2} g_{m2} R_D = \frac{1}{2}(0.387)(40) \Rightarrow A_{d1} = 7.74$$

$$A_2 = \frac{-g_{m3} R_{D2}}{1 + g_{m3} R_5}$$

$$g_{m3} = 2\sqrt{K_n I_{D3}} = 2\sqrt{(0.2)(0.235)}$$

$$= 0.434 \text{ mA/V}$$

$$A_2 = \frac{-(0.434)(4)}{1 + (0.434)(6)} = -0.482$$

$$\text{So } A_d = A_{d1} \cdot A_2 = (7.74)(-0.482) \Rightarrow \underline{A_d = -3.73}$$