Electronics II Final Solution 2018/6/15

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#1

$$I_1 = \frac{10 - V_{GS4}}{R_1} = K_{n3}\left(V_{GS4} - V_{TN}\right)^2$$

$$10 - V_{GS4} = (0.1)(80)\left(V_{GS4} - 0.8\right)^2$$

$$10 - V_{GS4} = 8\left(V_{GS4}^2 - 1.6V_{GS4} + 0.64\right)$$

$$8V_{GS4}^2 - 11.8V_{GS4} - 4.88 = 0$$

$$V_{GS4} = \frac{11.8 \pm \sqrt{(11.8)^2 + 4(8)(4.88)}}{2(8)} = 1.81 \text{ V}$$

$$I_1 = I_Q = \frac{10 - 1.81}{80} = 0.102 \text{ mA}$$

$$I_{D1} = I_{D2} = \frac{0.102}{2} = 0.0512 \text{ mA}$$

$$= K_{n1}\left(V_{GS1} - V_{TN}\right)^2$$

$$0.0512 = 0.050\left(V_{GS1} - 0.8\right)^2 \Rightarrow V_{GS1} = 1.81 \text{ V}$$

$$v_{01} = v_{02} = 5 - (0.0512)(40) = 2.95 \text{ V}$$

$$Max\ v_{cm}: V_{DS1}(sat) = V_{GS1} - V_{TN}$$

$$= 1.81 - 0.8 = 1.01 \text{ V}$$

$$v_{cm}(\max) = v_{01} - V_{DS1}(\text{sat}) + V_{GS1}$$

$$= 2.95 - 1.01 + 1.81$$

$$v_{cm}(\max) = 3.75 \text{ V}$$

$$Min\ v_{cm}: V_{DS4}(sat) = V_{GS4} - V_{TN}$$

$$= 1.81 - 0.8 = 1.01 \text{ V}$$

$$v_{cm}(\min) = V_{GS1} + V_{DS4}(\text{sat}) - 5$$

$$= 1.81 + 1.01 - 5$$

$$v_{cm}(\min) = -2.18 \text{ V}$$

$$-2.18 \le v_{cm} \le 3.75 \text{ V}$$

#2

$$r_{\pi 11} = \frac{(120)(0.026)}{0.2} = 15.6\,\text{k}\Omega$$

$$R_E' = R_3 \| r_{\pi 11} = 0.2 \| 15.6 = 0.1975\,\text{k}\Omega$$

$$g_{m11} = \frac{0.2}{0.026} = 7.692\,\text{mA/V}$$

$$r_{o11} = \frac{V_{A11}}{I_{C11}} = \frac{120}{0.2} = 600\,\text{k}\Omega$$

$$R_{C11} = r_{o11}(1 + g_{m11} R_E') = 600[1 + (7.692)(0.1975)] = 1512\,\text{k}\Omega$$

$$R_{C7} = r_{o7} = \frac{V_{A7}}{I_{C7}} = \frac{60}{0.2} = 300\,\text{k}\Omega$$

$$Z = R_{C7} \| R_{C11} = 300 \| 1512 = 250\ \text{k}\Omega$$

$$r_{\pi 8} = \frac{(120)(0.026)}{1} = 3.12\,\text{k}\Omega$$

$$I_{C9} = \frac{1}{120}\left(\frac{120}{121}\right) = 0.008264\,\text{mA}$$

$$r_{\pi 9} = \frac{(120)(0.026)}{0.008264} = 377.5\,\text{k}\Omega$$

$$\text{Now} \quad R_o = R_4 \left\| \frac{r_{\pi 8} + \left(\frac{r_{\pi 9} + Z}{121}\right)}{121} = 5 \right\| \frac{3.12 + \left(\frac{377.5 + 250}{121}\right)}{121} = 5 \| 0.06864$$

$$\text{Or} \quad R_o = 67.7\,\Omega$$

#3

(a)

$$v_1 = v_2 = 0$$

$$I_D = K_n (V_{SG} + V_{TP})^2$$

$$I_D = 6\ \mu\text{A}$$

$$\sqrt{\frac{6}{30}} + 0.4 = V_{SG}$$

$$V_{SG} = 0.847\ \text{V}$$

$$V_S = +0.847\ \text{V}$$

$$v_D = I_D R_D - 3$$

$$= (6)(0.36) - 3 = -0.84\ \text{V}$$

$$V_{SD} = V_S - v_D = 0.847 - (-0.84)$$

$$v_{SD} = 1.69\ \text{V}$$

(b)

$$A_d = \frac{g_m R_D}{2} = \frac{(26.83)(0.36)}{2} \Rightarrow A_d = 4.83$$

$$A_{cm} = \frac{-g_m R_D}{1+2g_m R_Q} = \frac{-(26.83)(0.36)}{1+2(26.83)(4)} = \underline{-0.0448}$$

#4

See Texbook Example 11.15 and Example 11.16, but $\beta = 150$ not 100 in here.

(a)

$$I_1 = \frac{10 - 0.7 - (-10)}{19.3} = 1\,\text{mA}$$

The bias current $I_Q$ is determined from

$$I_Q R_2 = V_T \ln\left(\frac{I_1}{I_Q}\right)$$

$R_2$=$R_3$=59.6Ω

(b) Neglecting base currents,

The collector currents are then

$$I_{C1} = I_{C2} = 0.2\,\text{mA}$$

The dc voltage at the collector of $Q_2$ is

$$V_{O2} = 10 - I_{C2}R_C = 10 - (0.2)(20) = 6\,\text{V}$$

$$I_{R4} = \frac{V_{O2} - 2V_{BE}(\text{on})}{R_4} = \frac{6 - 1.4}{11.5} = 0.4\,\text{mA}$$

$$I_{R6} = I_Q = 0.4\,\text{mA}$$

$$V_{O3} = 10 - I_{R5}R_5 = 10 - (0.4)(5) = 8\,\text{V}$$

$$V_{B6} = V_{O3} - V_{BE}(\text{on}) - I_{R6}R_6 = 8 - 0.7 - (0.4)(16.5) = 0.7\,\text{V}$$

$$I_{R7} = \frac{v_o - (-10)}{R_7} = \frac{10}{5} = 2\,\text{mA}$$

(c)

$R_{i2} = r_{\pi 3} + (1+\beta) r_{\pi 4}$

$r_{\pi 4} = \beta \cdot \frac{V_T}{I_{R4}} = 150 \times \frac{0.026}{0.4} = 9.75\,(\text{K}\Omega)$

$r_{\pi 3} = \beta^2 \cdot \frac{V_T}{I_{R4}} = (150)^2 \times \frac{0.026}{0.4} = 1462.5\,(\text{K}\Omega)$

$R_{i2} = 1462.5 + 151 \times 9.75 = 2934.75\,(\text{K}\Omega)$

$R_{i3} = r_{\pi 5} + (1+\beta)[R_6 + r_{\pi 6} + (1+\beta)R_7]$

$r_{\pi 5} = \beta \frac{V_T}{I_{R6}} = 150 \times \frac{0.026}{0.4} = 9.75\,(\text{K}\Omega)$

$r_{\pi 6} = \beta \cdot \frac{V_T}{I_{R7}} = 150 \times \frac{0.026}{2} = 1.95\,(\text{K}\Omega)$

$R_{i3} = 9.75 + 151 \times (16.5 + 1.95 + 151 \times 5)$

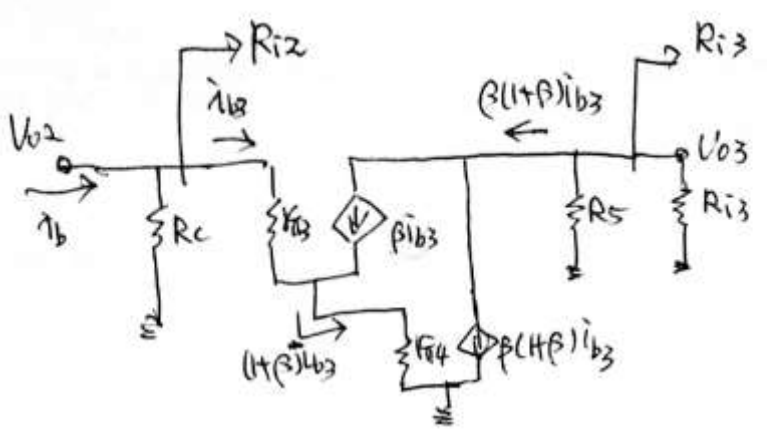
$= 116.8\,\text{M}\Omega$

(d)

$$A_{d1} = \frac{g_m}{2}(R_c // R_{i2})$$

$$g_m = \frac{I_Q}{2V_T} = \frac{0.4}{2 \times 0.026} = 7.7 \ (mA/V)$$

$$A_{d1} = \frac{7.7}{2} \times (20 // 2934.75) = 76.5$$




$$V_{o2} = i_{b3} \cdot (r_{\pi 3} + (1+\beta) r_{\pi 4}) = i_{b3} \cdot R_{i2}$$

$$V_{o3} = \beta(1+\beta) i_{b3} \cdot (R_5 // R_{i3}) \approx \beta(1+\beta) i_{b3} \cdot R_5$$

$$A_2 = \frac{V_{o3}}{V_{o2}} = \frac{\beta(1+\beta) R_5}{R_{i2}} = \frac{150 \times 151 \times 5}{2934.75}$$

$$= 38.6$$