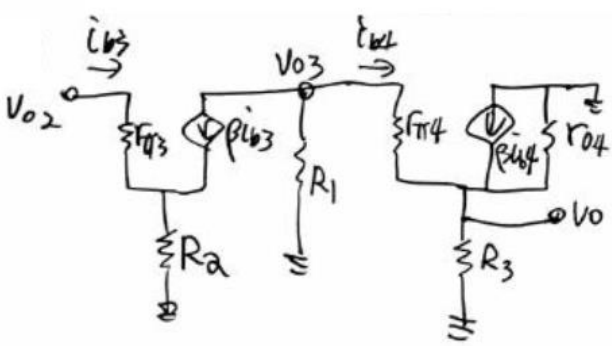
Electronics II, EXAM-4, Solution, 2022/6/17

(1)

(a)



$$v_{o2} = i_{b3}\cdot[r_{\pi 3} + (1+\beta)R_2]$$

$$v_{o3} = -\beta i_{b3}[R_1 // ((r_{\pi 4} + (1+\beta)(R_3 // r_{o4}))]$$

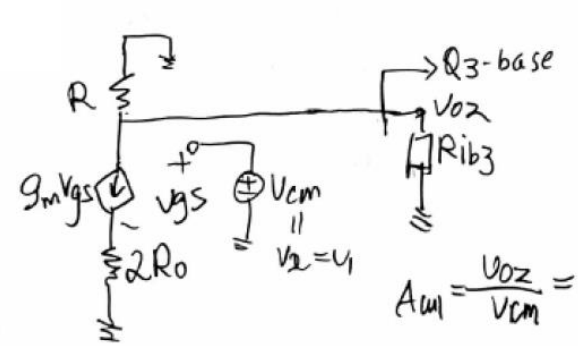
$$v_{o3} = i_{b4}[r_{\pi 4} + (1+\beta)(R_3 // r_{o4})]$$

$$v_o = (1+\beta) i_{b4}\cdot(R_3 // r_{o4})$$

$$\frac{v_o}{v_{o2}} = \frac{v_{o3}}{v_{o2}}\cdot\frac{v_o}{v_{o3}}$$

$$= \frac{-\beta[R_1 // (r_{\pi 4} + (1+\beta)(R_3 // r_{o4})]}{r_{\pi 3} + (1+\beta)R_2} \times \frac{(1+\beta)(R_3 // r_{o4})}{r_{\pi 4} + (1+\beta)(R_3 // r_{o4})}$$

(b)



$$v_{cm} = v_{gs} + g_m v_{gs}\cdot 2R_o$$

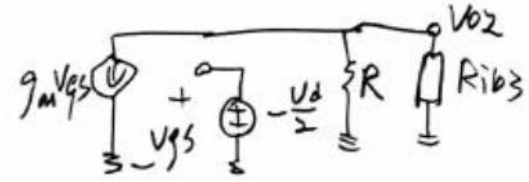
$$v_{gs} = \frac{v_{cm}}{1+2g_m R_o}$$

$$v_{o2} = -g_m v_{gs}[R // (r_{\pi 3} + (1+\beta)R_2)]$$

$$A_{cm} = \frac{v_{o2}}{v_{cm}} = \frac{-g_m[R // (r_{\pi 3} + (1+\beta)R_2)]}{1+2g_m R_o}$$

(c)

$$A_d = \frac{v_{b2}}{v_d}$$



$$v_{o2} = \frac{1}{2} g_m v_d \cdot (R // R_{ib3})$$

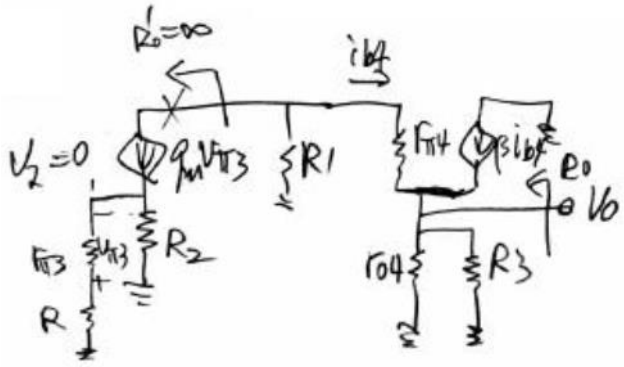
$$A_d = \frac{1}{2} g_m (R // R_{ib3})$$

$$CMRR = \left|\frac{A_d}{A_{cm}}\right| = \left|\frac{\frac{1}{2}g_m}{\frac{g_m}{1+2g_m R_o}}\right|$$

$$= \frac{1+2g_m R_o}{2}$$

$$CMRR_{dB} = 20 \log_{10}\left(\frac{1+2g_m R_o}{2}\right)$$

(d)



$$R_o = r_{o4} // R_3 // \frac{r_{\pi 4} + R_1}{1+\beta}$$

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(2)

$$I_{B5} = \frac{I_{E5}}{1+\beta} = \frac{I_{B3}+I_{B4}}{1+\beta} = \frac{I_{C3}+I_{C4}}{\beta(1+\beta)}$$

Now $I_{C3} + I_{C4} \approx I_Q$

So $I_{B5} \approx \dfrac{I_Q}{\beta(1+\beta)}$

$$I_{B6} = \frac{I_{E6}}{1+\beta} = \frac{I_{Q1}}{\beta(1+\beta)}$$

For balance, we want $I_{B6} = I_{B5}$

So that $\underline{I_{Q1} = I_Q}$

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(3)

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

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

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

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

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

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

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

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

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

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

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

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

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(4)

4.

(a). 參考課本 Example 11.18

$I_Q = 0.4\,mA$

$I_{C2} = 0.2\,mA \Rightarrow V_{O2} = 10 - I_{C2}\cdot R_C = 6\,V.$

$I_{R4} = \frac{V_{O2} - 2\times 0.7}{R_4} = 0.4\,mA. \approx I_{R5}$

$V_{O3} = 10 - 5\cdot I_{R5} = 8\,V.$

$V_{B6} = 8 - 0.7 - I_Q\cdot R_6 = 8 - 0.7 - 0.4\times 16.5 = 0.7\,V.$

$\Rightarrow V_O = 0.7 - 0.7 = 0\,V.$

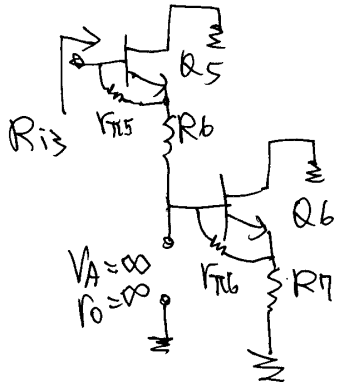
(b) ① $R_{i2} = r_{\pi 3} + (1+\beta) r_{\pi 4}.$

$r_{\pi 4} = \beta\cdot \frac{V_T}{I_{R4}} = 120\cdot \frac{0.026}{0.4} = 7.8\,K\Omega$

$r_{\pi 3} = \beta\cdot \frac{V_T}{I_{R4}/\beta} = (120)\cdot r_{\pi 4} = 936\,K\Omega$

$R_{i2} = 936 + 121\times 7.8 = 1880\,K\Omega$

②



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

$r_{\pi 5} = \beta\cdot \frac{V_T}{I_{R6}} = 120\cdot \frac{0.026}{0.4} = 7.8\,K\Omega$

$I_{R7} = 10/5 = 2\,mA$

$r_{\pi 6} = \beta\cdot \frac{V_T}{I_{R7}} = 120\cdot \frac{0.026}{2} = 1.56\,K\Omega$

$R_{i3} = 7.8 + 121\cdot (16.5 + 1.56 + 121\times 5)$

$= 75.4\,M\Omega.$

③ $A_d = A_{d1}\cdot A_2\cdot A_3$

$A_{d1} = \frac{g_m}{2}\cdot (R_C \| R_{i2}) = \frac{1}{4}\cdot \frac{0.4}{0.026}\cdot (20 \| 1880) = 76.11$

$A_2 = \frac{I_{R4}}{2V_T}\cdot (R_5 \| R_{i3}) = \frac{0.4}{2\times 0.026}\cdot (5 \| 75.4\times 10^3) = 38.46$

$A_3 \approx 1.$

$A_d = 76.11\times 38.46 = 2927$