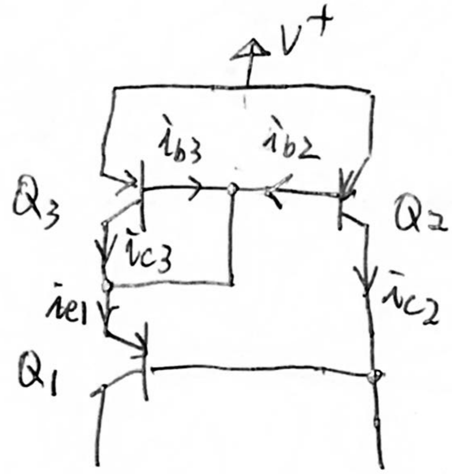
2021 Electronics II
Exam-3. D.C. Chang.
11th June, 2021.

1.



(a) $\because V_{EB3} = V_{EB2}$

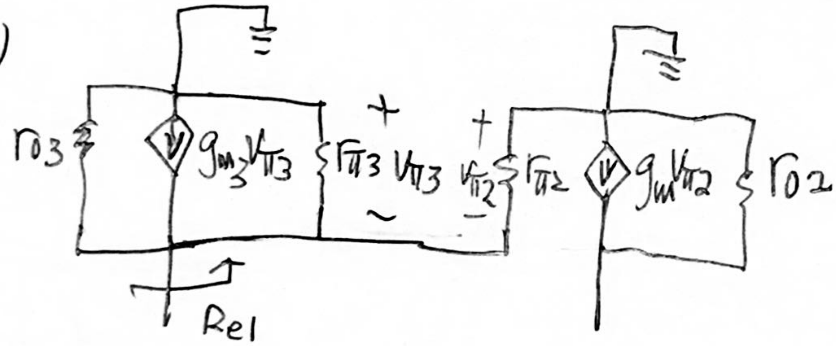
$\therefore i_{c3} = i_{c2}$, $i_{b3} = i_{b2}$

$i_{e1} = i_{c3} + 2 i_{b2}$

$= (\beta+2) i_{b2} = \frac{\beta+2}{\beta} i_{c2}$

when $\beta \to \infty$, $i_{e1} \approx i_{c2}$ #

(b)



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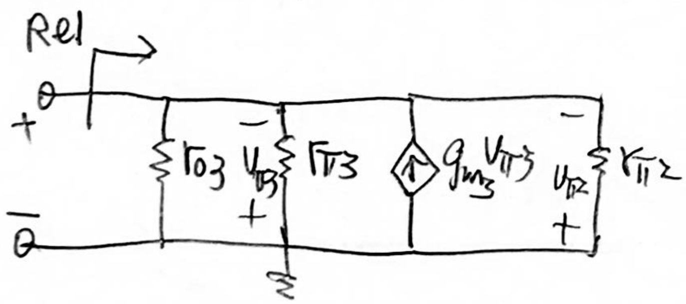
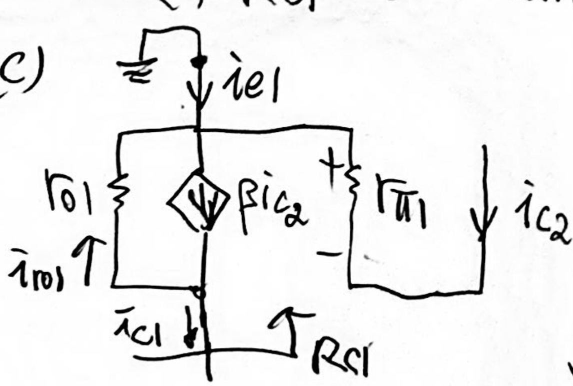


$R_{e1} = r_{o3} \,//\, r_{\pi3} \,//\, r_{\pi2} \,//\, \frac{1}{g_{m3}}$ #

$\because \frac{1}{g_{m3}} \ll r_{\pi2}$, $r_{\pi3} \ll r_{o3}$, $\frac{1}{g_{m3}} \to 0$ (very small)

$\therefore R_{e1} \to 0$ can be treated as virtual ground w.r.t. r_{o1}.

(c)



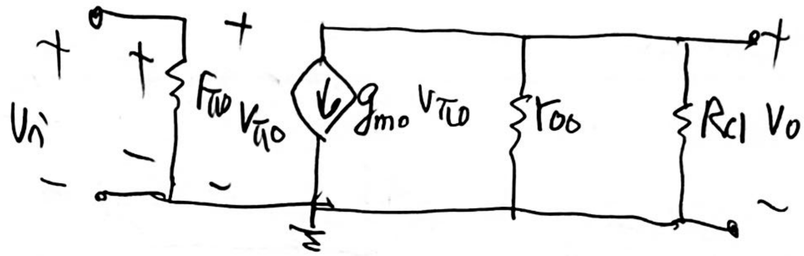
from (a), $i_{e1} = i_{c2}$

$i_{c1} = i_{e1} + i_{c2} = 2 i_{c2}$

$\Rightarrow i_{ro1} = (\beta - 2) i_{c2}$

$\therefore R_{c1} = \frac{-i_{ro1} \cdot r_{o1}}{-i_{c1}} = \frac{\beta-2}{2} r_{o1} \approx \beta r_{o1}/2$ #

(d)



$$A_v = \frac{V_o}{V_i} = -g_{m0}(r_{00} \| R_{C1})$$

$$g_{m0} = \frac{I_{REF}}{V_T} = \frac{1}{0.026} = 38.46\,(mA/V)$$

$$r_{00} = \frac{V_{AN}}{I_{REF}} = \frac{150}{1} = 150\,(K\Omega)$$

$$R_{C1} = \frac{250}{2} \cdot \frac{V_{AP}}{1} = 125 \times 120 = 15000\,(K\Omega)$$

$$A_v \doteq -38.46 \times \frac{15000 \times 150}{15000 + 150} = -5712 \quad \#$$

2. (a) $\begin{cases} I_{REF} = K_{p1}(V_{SG1} + V_{TP1})^2 = K_{p2}(V_{SG2} + V_{TP2})^2 & \text{— ①} \\ V^+ = V_{SG2} + V_{SG1} + V^- & \text{— ②} \end{cases}$

From ①,

$$\begin{cases} \sqrt{K_{p1}}\,(V_{SG1} + V_{TP1}) = \sqrt{K_{p2}}\,(V_{SG2} + V_{TP2}) \\ V^+ = V_{SG2} + V_{SG1} + V^- \end{cases}$$

Solve for V_{SG2}, then $I_{REF} = K_{p2}(V_{SG2} + V_{TP2})^2$ #

(b) $\begin{cases} V_{SG1} - 1 = 3(V_{SG2} - 1) \\ 6 = V_{SG2} + V_{SG1} \end{cases} \Rightarrow V_{SG2} = 2,\ V_{SG3} = V_{SG2} = 2$

$V_{SD3}(sat) = V_{SG3} + V_{TP} = 1$,

If M_3 remains biased in the saturation region,

$V_{SD3} \geq V_{SD3}(sat) = 1$

$\therefore V_{SD3} = V^+ - V^- - I_O R = 6 - 12 I_O \geq 1$, $I_O \leq \frac{5}{12}\,(mA)$ #

(c) $0.2 = \frac{0.1}{2}\left(\frac{W}{L}\right)_3 \cdot (2-1)^2 = \frac{0.1}{2}\left(\frac{W}{L}\right)_3 \Rightarrow \left(\frac{W}{L}\right)_3 = 4$ #

3. (a) $I_{REF} = \frac{k_n'}{2}\left(\frac{W}{L}\right)_3 (V_{GS3}-1)^2$

$0.1 = \frac{0.08}{2} \times 4 \cdot (V_{GS3}-1)^2$

$V_{GS3} = 1+0.79 = 1.79$

$\because \left(\frac{W}{L}\right)_1 = \left(\frac{W}{L}\right)_2$, for a same I_{REF} current,

$\Rightarrow V_{GS1} = V_{GS2} = V_{GS}$ #

$\therefore V^+ = V_{GS1} + V_{GS2} + V_{GS3} = 2V_{GS} + V_{GS3}$

$V_{GS} = \frac{5-1.79}{2} = 1.605$

$0.1 = \frac{0.08}{2} \cdot \left(\frac{W}{L}\right)_2 (1.605-1)^2$

$\Rightarrow \left(\frac{W}{L}\right)_2 = \left(\frac{W}{L}\right)_1 = \frac{20}{8 \times (0.605)^2} = 6.83$ #

(b) $I_{O1,min} = \frac{k_n'}{2}\left(\frac{W}{L}\right)_4 (V_{GS4}-1)^2 (1+\lambda_4 V_{DS4}(sat))$

$0.5 = \frac{0.08}{2} \left(\frac{W}{L}\right)_4 (0.79)^2 \cdot (1+0.05 \times 0.79)$

$\left(\frac{W}{L}\right)_4 = \frac{1}{0.08 \times (0.79)^2 \times 1.0395} \doteq 19.27$ #

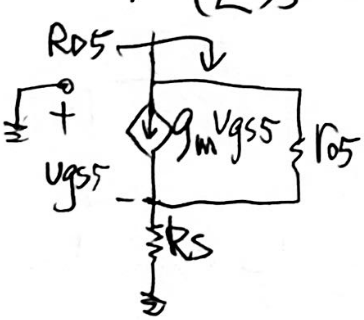
(c) $V_{GS3} = V_{GS5} + I_{O2} \cdot R_S \geq V_{TN} + I_{O2} \cdot R_S$, $\because V_{GS5} \geq V_{TN}$

$1.79 \geq 1 + 0.04 \cdot R_S$, $R_S \leq 19.75 (k\Omega)$ #

(d) $40 = \frac{80}{2}\left(\frac{W}{L}\right)_5 (V_{GS5}-1)^2 (1+\lambda_5 \cdot V_{DS5}(sat))$

$V_{GS5} = V_{GS3} - I_{O2} \cdot R_S = 1.79 - 0.04 \times 10 = 1.39$

$1 = \left(\frac{W}{L}\right)_5 \times (0.39)^2 (1+0.01 \times 0.39)$, $\left(\frac{W}{L}\right)_5 \doteq 6.55$ #



$R_{O5} = R_S + r_{o5}(1+g_m R_S)$

$g_m = 2\sqrt{I_{O2} \cdot K_{n5}} = 2\sqrt{0.04 \times 0.262} = 0.205 (mA/V)$

$r_{o5} = 1/(\lambda_5 \cdot I_{O2}) = 1/(0.01 \times 0.04) = 2500 (k\Omega)$

$R_{O5} = 10 + 2500(1+0.205 \times 10) = 7635 (k\Omega)$ #