Solution 22 May, 2020, Exam-3, Electronics II, Spring 2020
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#1

2、 參考課本 P.624.

$$A_v \cong \frac{-g_m^2}{\frac{1}{r_{o3} r_{o4}} + \frac{1}{r_{o1} r_{o2}}}$$

$$g_m = 2\sqrt{K_n \cdot I_{DQ}} \qquad I_{DQ} = I_{REF}.$$

$$= 2\sqrt{K_n I_{REF}}$$

$$r_{o3} = r_{o4} = \frac{1}{\lambda_p I_{REF}}$$

$$r_{o1} = r_{o2} = \frac{1}{\lambda_n I_{REF}}$$

$$A_v \cong \frac{-4 K_n I_{REF}}{(\lambda_p^2 + \lambda_n^2) I_{REF}^2} = \frac{-4 K_n}{I_{REF}(\lambda_n^2 + \lambda_p^2)}$$

#2

a.

$$2V_{BE1} = V_{BE3} + I_0 R_E$$

$$V_{BE1} = V_T \ln\left(\frac{I_{REF}}{I_S}\right)$$

$$V_{BE3} = V_T \ln\left(\frac{I_0}{I_S}\right)$$

$$2V_T \ln\left(\frac{I_{REF}}{I_S}\right) - V_T \ln\left(\frac{I_0}{I_S}\right) = I_0 R_E$$

$$V_T\left[\ln\left(\frac{I_{REF}}{I_S}\right)^2 - \ln\left(\frac{I_0}{I_S}\right)\right] = I_0 R_E$$

$$\underline{V_T \ln\left(\frac{I^2{}_{REF}}{I_0 I_S}\right) = I_0 R_E}$$

b.

$$V_{BE} = 0.7 \text{ V at 1 mA} \Rightarrow 10^{-3} = I_S \exp\left(\frac{0.7}{0.026}\right) \text{ or } I_S = 2.03\times 10^{-15} \text{ A}$$

$$V_{BE} \text{ at 0.1 mA} \Rightarrow V_{BE} = (0.026)\ln\left(\frac{0.1\times 10^{-3}}{2.03\times 10^{-15}}\right) = 0.640 \text{ V}$$

Since $I_0 = I_{REF}$, then $V_{BE} = I_0 R_E \Rightarrow R_E = \dfrac{0.640}{0.1}$ or $\underline{R_E = 6.4 \text{ k}\Omega}$

#3

$$I_{REF} = \left(\frac{80}{2}\right)(25)(V_{SG1} - 1.2)^2 = \left(\frac{80}{2}\right)(4)(V_{SG3} - 1.2)^2$$

$$V_{SG1} + 2V_{SG3} = 10 \Rightarrow V_{SG3} = \frac{10 - V_{SG1}}{2}$$

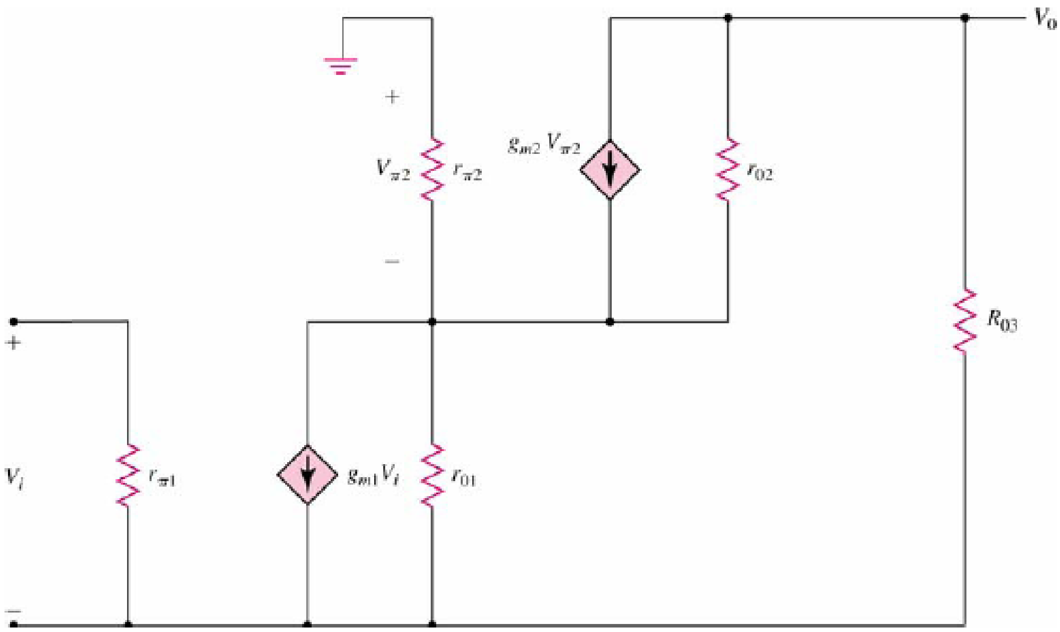
$$\text{Then } \sqrt{\frac{25}{4}}(V_{SG1} - 1.2) = \frac{10 - V_{SG1}}{2} - 1.2$$

$$3V_{SG1} = 6.8 \Rightarrow V_{SG1} = 2.27 \text{ V}$$

$$I_{REF} = \left(\frac{80}{2}\right)(25)(2.267 - 1.2)^2 \Rightarrow \underline{I_{REF} = I_O = 1.14 \text{ mA}}$$

$$V_{SD2}(\text{sat}) = V_{SG2} + V_{TP} = 2.27 - 1.2 \Rightarrow \underline{V_{SD2}(\text{sat}) = 1.07 \text{ V}}$$

#4



(1) $$g_{m1}V_i = \frac{V_{\pi 2}}{r_{\pi 2}} + \frac{V_{\pi 2}}{r_{o1}} + g_{m2}V_{\pi 2} + \frac{V_O - (-V_{\pi 2})}{r_{o2}}$$

(2) $$\frac{V_O}{R_{O3}} + \frac{V_O - (-V_{\pi 2})}{r_{o2}} + g_{m2}V_{\pi 2} = 0$$

(1) $$g_{m1}V_i = V_{\pi 2}\left(\frac{1}{r_{\pi 2}} + \frac{1}{r_{o1}} + g_{m2} + \frac{1}{r_{o2}}\right) + \frac{V_O}{r_{o2}}$$

(2) $$V_O\left(\frac{1}{R_{O3}} + \frac{1}{r_{o2}}\right) + V_{\pi 2}\left(\frac{1}{r_{o2}} + g_{m2}\right) = 0$$

$$g_m >> \frac{1}{r_o}$$

(1) $$g_{m1}V_i = V_{\pi 2}\left(\frac{1+\beta}{r_{\pi 2}}\right) + \frac{V_O}{r_{o2}}$$

(2) $$V_O\left(\frac{1}{R_{O3}} + \frac{1}{r_{o2}}\right) + V_{\pi 2}\cdot g_{m2} = 0$$

(3) $$V_{\pi 2} = -\frac{V_O}{g_{m2}}\left(\frac{1}{R_{O3}} + \frac{1}{r_{o2}}\right)$$

Then

(1) $$g_{m1}V_i = -\frac{V_O}{g_{m2}}\left(\frac{1}{R_{O3}} + \frac{1}{r_{o2}}\right)\left(\frac{1+\beta}{r_{\pi 2}}\right) + \frac{V_O}{r_{o2}}$$

$$= -V_O\left(\frac{1}{R_{O3}} + \frac{1}{r_{o2}}\right)\left(\frac{1+\beta}{\beta}\right) + \frac{V_O}{r_{o2}}$$

$$\approx -\frac{V_O}{R_{O3}}\left(\frac{1+\beta}{\beta}\right)$$

$$\frac{V_O}{V_i} = -g_{m1}R_{O3}\left(\frac{\beta}{1+\beta}\right)$$

From Equation (10.20) $R_{O3} \approx \beta r_{O3}$

So

$$A_v = \frac{V_O}{V_i} = \frac{-g_{m1}r_{o3}\beta^2}{1+\beta} \qquad g_m = \frac{0.25}{0.026} = 9.615 \text{ mA/V}$$

$$r_{o3} = \frac{80}{0.25} = 320 \text{ K}$$

$$A_v = \frac{-(9.615)(320)(120)^2}{121} = -366{,}165$$