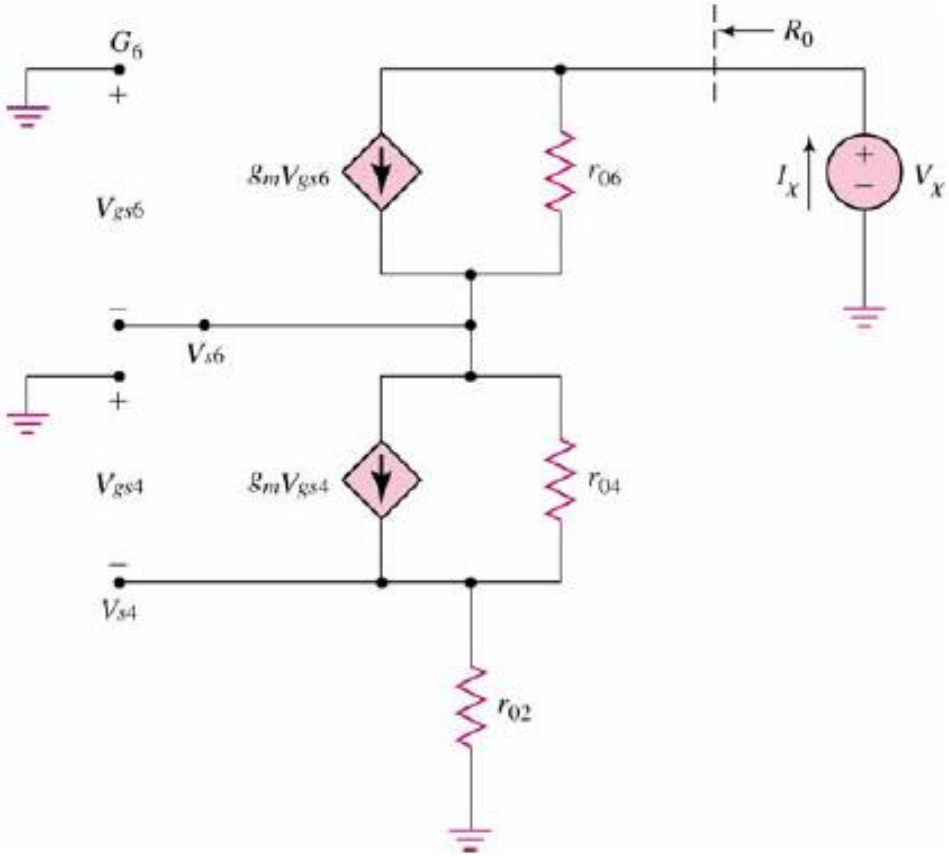
Electronics II Ex3 Solution 2022/5/27

#1



$$V_{gs4} = -I_X r_{02}$$

$$V_{S6} = \left(I_X - g_m V_{gs4}\right) r_{04} + I_X r_{02}$$

$$= \left(I_X + g_m I_X r_{02}\right) r_{04} + I_X r_{02}$$

$$V_{S6} = I_X \left[r_{02} + \left(1 + g_m r_{02}\right) r_{04}\right] = -V_{gs6}$$

$$I_X = g_m V_{gs6} + \frac{V_X - V_{S6}}{r_{06}} = \frac{V_X}{r_{06}} - V_{S6}\left(g_m + \frac{1}{r_{06}}\right)$$

$$I_X = \frac{V_X}{r_{06}} - I_X\left(g_m + \frac{1}{r_{06}}\right)\left[r_{02} + \left(1 + g_m r_{02}\right) r_{04}\right]$$

$$I_X\left\{1 + \left(g_m + \frac{1}{r_{06}}\right)\left[r_{02} + \left(1 + g_m r_{02}\right) r_{04}\right]\right\} = \frac{V_X}{r_{06}}$$

$$\frac{V_X}{I_X} = R_0 = r_{06} + \left(1 + g_m r_{06}\right)\left[r_{02} + \left(1 + g_m r_{02}\right) r_{04}\right]$$

$$I_0 \approx I_{REF} = 0.2\text{ mA} = 0.2\left(V_{GS}-1\right)^2$$

$$V_{GS} = 2\text{ V}$$

$$g_m = 2K_n\left(V_{GS}-V_{TN}\right) = 2(0.2)(2-1) = 0.4\ mA/V$$

$$r_{02} = r_{04} = r_{06} = \frac{1}{\lambda I_0} = \frac{1}{(0.02)(0.2)} = 250\text{ k}\Omega$$

$$R_0 = 250+\left[1+(0.4)(250)\right]\times\left\{250+\left[1+(0.4)(250)\right](250)\right\}$$

$$R_0 = 2575750\text{ k}\Omega \Rightarrow \underline{R_0 = 2.58\times10^9\,\Omega}$$

#2

(a) $$I_{REF} = \left(\frac{k_p'}{2}\right)\left(\frac{W}{L}\right)_1\left(V_{SG1}+V_{TP}\right)^2 = \left(\frac{k_p'}{2}\right)\left(\frac{W}{L}\right)_3\left(V_{SG3}+V_{TP}\right)^2$$

$$V_{SG3} = 3-V_{SG1}$$

$$\sqrt{25}\left(V_{SG1}-0.4\right) = \sqrt{5}\left(3-V_{SG1}-0.4\right)$$

$$3.236V_{SG1} = 3.4944 \Rightarrow V_{SG1} = 1.08\text{ V} \quad \text{and} \quad V_{SG3} = 1.92\text{ V}$$

$$I_{REF} = \left(\frac{60}{2}\right)(25)(1.08-0.4)^2 \Rightarrow I_{REF} = 0.347\text{ mA}$$

$$I_O = \left(\frac{60}{2}\right)(15)(1.08-0.4)^2 \Rightarrow I_O = 0.208\text{ mA}$$

(b) $$V_{SD2}(sat) = V_{SG2}+V_{TP} = 1.08-0.4 = 0.68\text{ V}$$

$$R = \frac{3-0.68}{0.208} = 11.15\,\text{k}\Omega$$

#3

a.

$$I_0 = I_{C1} \text{ and } I_{REF} = I_{C1} + I_{B3} = I_{C1} + \frac{I_{E3}}{1+\beta}$$

$$I_{E3} = I_{B1} + I_{B2} + \frac{V_{BE}}{R_2} = \frac{2I_{C1}}{\beta} + \frac{V_{BE}}{R_2}$$

$$I_{REF} = I_{C1} + \frac{2I_{C1}}{\beta(1+\beta)} + \frac{V_{BE}}{(1+\beta)R_2}$$

$$I_{REF} - \frac{V_{BE}}{(1+\beta)R_2} = I_0\left(1 + \frac{2}{\beta(1+\beta)}\right)$$

$$I_0 = \frac{I_{REF} - \dfrac{V_{BE}}{(1+\beta)R_2}}{\left(1 + \dfrac{2}{\beta(1+\beta)}\right)}$$

$$I_{REF} = (0.70)\left(1 + \frac{2}{(80)(81)}\right) + \frac{0.7}{(81)(10)}$$

$$I_{REF} = 0.700216 + 0.000864$$

$$\underline{I_{REF} = 0.7011 \text{ mA}} = \frac{10 - 2(0.7)}{R_1} \Rightarrow \underline{R_1 = 12.27 \text{ k}\Omega}$$

b.

#4

$$I_{REF} = \left(\frac{50}{2}\right)(15)(V_{SG1} - 0.5)^2 = \left(\frac{50}{2}\right)(3)(V_{SG3} - 0.5)^2$$

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

$$\sqrt{\frac{15}{3}}(V_{SG1} - 0.5) = 10 - V_{SG1} - 0.5$$

$$3.236V_{SG1} = 10.618 \Rightarrow V_{SG1} = 3.28 \text{ V}$$

$$I_{REF} = \left(\frac{50}{2}\right)(15)(3.28 - 0.5)^2 \Rightarrow I_{REF} = 2.90 \text{ mA}$$

$$I_O = I_{REF} = 2.90 \text{ mA}$$

$$V_{SD2}(\text{sat}) = V_{SG2} + V_{TP} = 3.28 - 0.5 \Rightarrow \underline{V_{SD2}(\text{sat}) = 2.78 \text{ V}}$$