HOMEWORK #10

7.24 $g_{m1} = 1mA/V$

$R_o = 400K\Omega$

$V_{tn} = 0.5V$

$V_A' = 5V/\mu m$

$K_n' = 400\mu A/V^2$

$L, W/L, V_{a2}, I$?

$V_{ov} = 0.2V$

$g_{m1} = I/(V_{ov}/2) \Rightarrow I = g_m \cdot \frac{V_{ov}}{2} = 1mA/V \cdot \frac{0.2V}{2}$

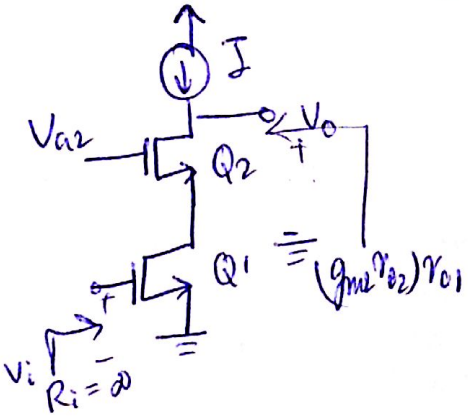
$= 0.1mA$ //

$R_o = (g_{m2} r_{o2}) r_{o1}$

$= \frac{|V_A|^2}{V_{ov}/2\ I_D}$

$\Rightarrow 400K = \frac{|V_A|^2}{0.1 \times 0.1}$ $\Rightarrow |V_A| = 2V \rightarrow V_A$ (NMOS)

$L = \frac{2}{5(\mu m)^{-1}} = 0.4\mu m$ ($\sim 2 \times 0.18\mu m$)



$V_{ov} = V_{GS} - V_t$

$\Rightarrow V_{GS} = V_{ov} + V_t = 0.2 + 0.5 = 0.7V$

$Q_1 \rightarrow$ Saturation (minimum voltage across Q_1 & Q_2 i.e edge of Saturation operation)

$\Rightarrow V_{d1} = 0.2V = V_{S2}$

$\Rightarrow V_{a2} = 0.7 + V_{S2} = 0.7 + 0.2 = 0.9V$ //

$I = \frac{1}{2} k_n' \frac{W}{L} V_{ov}^2 \left(1 + \frac{V_{DS}}{V_A}\right)$

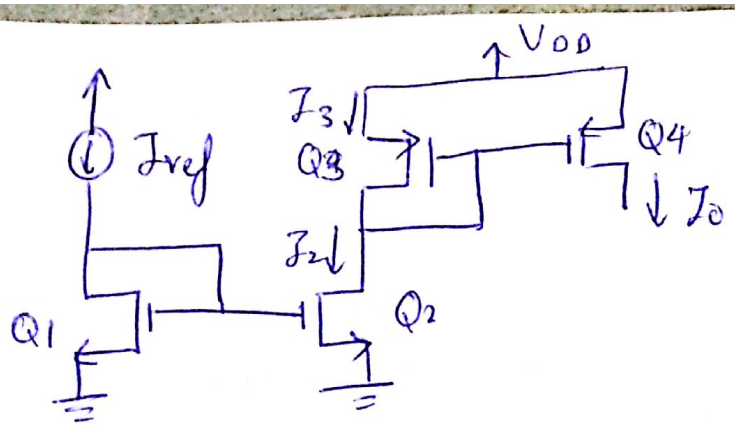
$0.1m = \frac{1}{2} \cancel{400\mu} \frac{200}{2} \left(\frac{W}{L}\right)(0.04)\left(1 + \frac{0.2}{2}\right)$

$\frac{1}{2} = \left(\frac{W}{L}\right)(0.04)(1.1) \Rightarrow \frac{W}{L} = \frac{100}{2.2 \times 4} \simeq 12$ //

$V_o = V_{d2} = V_{DS2} + V_{S2} = 0.2 + 0.2 = 0.4V$ //

($V_{DS2} \hookrightarrow V_{ov}$)

7.50



$$I_2 = \frac{(W/L)_2}{(W/L)_1} I_{ref} = I_3$$

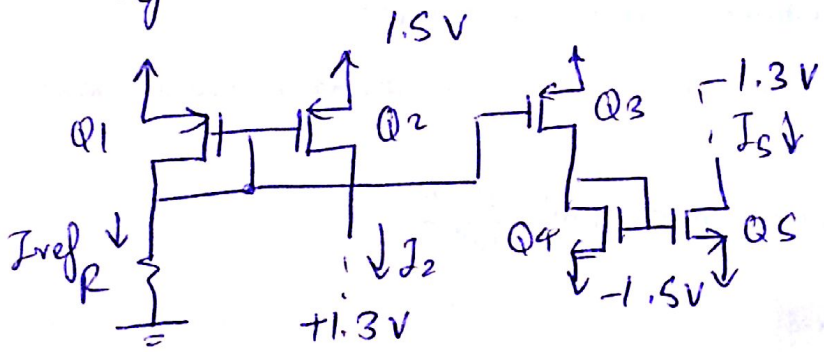
$$I_4 = \frac{(W/L)_4}{(W/L)_3} I_3 \Rightarrow I_0 = \frac{(W/L)_4}{(W/L)_3}\frac{(W/L)_2}{(W/L)_1} I_{ref}$$

7.51 $\mu_n C_{ox} = 200\,\mu A V^{-2}$, $\mu_p C_{ox} = 80\,\mu A V^{-2}$, $|V_{tp}| = 0.6\,V$

$V'_{An} = 10 V/\mu m$, $|V'_{Ap}| = 12 V/\mu m$

$L = 0.8\,\mu m$

$I_{ref} = 20\mu A$, $I_2 = 100\,\mu A$, $I_3 = I_4 = 20\mu A$, $I_5 = 50\,\mu A$



$$I_2 = \frac{(W/L)_2}{(W/L)_1} I_{ref} \Rightarrow \frac{W_2}{W_1} = \frac{I_2}{I_{ref}} = \frac{100\mu}{20\mu} = 5 \quad \ldots (1)$$

$$I_3 = I_4 = \frac{(W/L)_3}{(W/L)_1} I_{ref} \Rightarrow \frac{W_3}{W_1} = \frac{I_3}{I_{ref}} = \frac{20\mu}{20\mu} = 1 \quad \ldots (2)$$

$$I_5 = \frac{W_5}{W_4} I_4 \Rightarrow \frac{W_5}{W_4} = \frac{I_5}{I_4} = \frac{50\mu}{20\mu} = 2.5 \quad \ldots (3)$$

$Q_2 \rightarrow$ Edge of Saturation $V_{SD} = |V_{ov}| = 0.2V$

$\Rightarrow V_{(SG)_2} - |V_{tp}| = 0.2 \Rightarrow V_{SG_2} = 0.8V$

$\Rightarrow V_{G2} = 1.5 - 0.8 = 0.7V = V_{O1}$

$$R = \frac{V_{O1}}{I_{ref}} = \frac{0.7}{20\mu} = \frac{0.35}{10\mu} = \frac{0.35}{10^{-5}} = 0.35 \times 10^5\,\Omega$$

$$= 35\,K\Omega //$$

$I_2 = 100\mu A = \frac{1}{2}\mu_p C_{ox}\frac{W_2}{L_2} V_{ov}^2$ Q2, Q5 ↳ edge of Saturation

$\Rightarrow 100\mu = \frac{1}{2} 80\mu \frac{W_2}{0.2\mu} 0.04$

$\Rightarrow 2.5 = W_2 \frac{0.1}{2} \Rightarrow W_2 = 50\mu m$

$W_2/W_1 = 5 \Rightarrow W_1 = 10\mu m = W_3$

$\Rightarrow V_{DS5} = 0.2V \Rightarrow V_{DS} = V_{GG4} = V_{D4} = 0.2 + 1.5 = 1.23V$

$0.2 = V_{GS5} - 0.6 \Rightarrow V_{GS5} = 0.8 \Rightarrow V_{GS} = V_{GG4} = V_{D4} = -0.7V$

$I_5 = 50\mu A = \frac{1}{2}\mu_n C_{ox}\frac{W_5}{L_5} V_{ov}^2$

$\Rightarrow 50\mu = \frac{1}{2} 200\mu \frac{W_5}{0.8\mu} 0.1 \Rightarrow W_5 = 10\mu m, W_4 = \frac{W_5}{2.5} = 4\mu m$

$r_{o2} = \frac{V_{Ap}}{I_2} = \frac{12 \times 0.8}{100\mu} = 9.6 \times 10^4 = 96K\Omega //$

$r_{o5} = \frac{V_{An}}{I_5} = \frac{10 \times 0.8}{50\mu} = \frac{80}{50\mu} = \frac{16}{100\mu} = 160K\Omega //$

7.59 Textbook for the figure

$V_{E1} = V_{E3} = V_{E4} = 10V$

$V_{B1} = 9.3V = V_{B3} = V_{B4}$

$V_{C1} = V_{B1} = 9.3V$