# EELE 5131: SOLUTION TO ASSIGNMENT #2

1) EXTRACTED PARAMETERS FOR $\frac{W}{L} = \frac{10\mu m}{10\mu m}$

$$\left.\frac{g_m}{I_D}\right|_{PEAK} \simeq 25.6$$

$$\boxed{V_{th} = V_G @ 53\% \left.\frac{g_m}{I_D}\right|_{PEAK} = 746\,mV}$$

$$I_S = (I_D @ V_{th}) \times 1.13 = \boxed{116\,nA = I_{SQ}}$$

(NEGLECTING $L_D$ SINCE $L \gg L_D$)

$$n\Big|_{V_S=0,\ V_G=V_{th}} = 1.47$$

→ WILL USE $n \simeq 1.4$ FOR MANUAL CALCULATIONS

- OUTPUT RESISTANCE: USING $V_G = V_{th}$

$$\left.\begin{aligned}\Delta V_{DS} &= 2V - 0.5V \\ \Delta I_D &= 386\,nA - 379\,nA\end{aligned}\right\} \frac{\Delta V_{DS}}{\Delta I_D} = 214\,M\Omega = r_o$$

$$V_A = r_o \times I_D = 81\,V = \frac{L}{\left|\frac{\partial x_D}{\partial V_{DS}}\right|}$$

$$\therefore \left|\frac{\partial x_D}{\partial V_{DS}}\right| = \boxed{0.123\,\frac{\mu m}{V}}$$

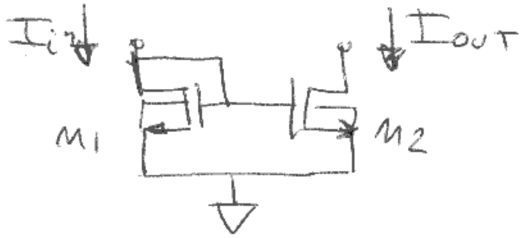
(2)

2) $W = 30\,\mu m$

$L = 2\,\mu m$

$V_{DD} = 2V$

$I_{in} = \begin{cases} 10\,nA \\ 5\,\mu A \\ 100\,\mu A \end{cases}$




a) $V_{S_1} = V_{S_2} = 0$

$$\frac{V_G - V_{th}}{n V_T} = \mathcal{F}(i_f) \qquad I_S = 116\,nA \times \frac{30\,\mu m}{(2\,\mu m - 2 \times 20\,nm)} = 1.78\,\mu A$$

$i_f = ?$

$$I_{in} = I_{sq} \frac{W}{L_{eff}} i_{f_1}$$

$$i_{f_1} = \begin{cases} 0.00563 \\ 2.81 \\ 56.3 \end{cases} \rightarrow \mathcal{F}(i_{f_1}) = \begin{cases} -6.87 \\ -0.097 \\ 7.45 \end{cases}$$

$$\therefore V_{G_1} = V_{D_1} = \begin{cases} 0.498\,V \\ 0.742\,V \\ 1.02\,V \end{cases}$$

$V_{G_1} = V_{th} + n V_T \mathcal{F}(i_{f_1})$

b) $$R = \frac{V_{DD} - V_{G1}}{I_{in}} = \begin{cases} 150.4\,M\Omega \\ 252\,k\Omega \\ 9.8\,k\Omega \end{cases}$$

c) $V_{DS_{SAT_2}} = V_T \left(\sqrt{1+i_{f_2}} + 3\right)$

$$V_{OUT\,MIN} = \begin{cases} 104.\ mV \\ 129\ mV \\ 275\ mV \end{cases}$$

d) $\Delta I$ DUE TO DIFFERENCE IN $V_{DS_1}$ AND $V_{DS_2}$

$$\left.\begin{aligned} V_{DS_1} &= V_{G1} \\ V_{DS_2} &= 2V \end{aligned}\right\} \Rightarrow \Delta I_{1-2} = \frac{2V - V_{G1}}{r_o} = \left(\frac{2V - V_{G1}}{V_A}\right) \times I_D$$

$$V_A = \frac{L}{\left|\frac{\partial x_D}{\partial V_{DS}}\right|} = 15.9\,V$$

$$\Delta I_{1-2} = \begin{cases} 0.94\ nA \\ 0.396\ \mu A \\ 6.16\ \mu A \end{cases}$$

e) $V_G - V_{th} = n V_T F(i_f)$

$$V_{th} = V_G - n V_T F(i_f)$$

$$V_{th} + \Delta V_{th} = V_G - n V_T F(i_f) - n V_T \frac{\partial F(i_f)}{\partial i_f} \Delta i_f$$

$$\Delta V_{th} = -n V_T \frac{\partial F(i_f)}{\partial i_f} \Delta i_f$$

$$|\Delta i_f| = \frac{\Delta V_{th}}{n V_T \frac{\partial F(i_f)}{\partial i_f}} = \frac{\Delta V_{th}}{n V_T} \times 2\left(\sqrt{1+i_f} - 1\right)$$

- ANOTHER APPROACH: RECOGNIZING THAT $V_{th}$ AND $V_G$ HAVE SAME EFFECT ON $i_f$ (WITH OPPOSITE SIGN)

④ $|\Delta I_D| = |i_d| = g_{mg}\,\Delta V_{th} \cong \frac{g_{ms}}{n}\Delta V_{th}$

↑ ACTIVE

$|\Delta I_D| = \frac{2 I_S}{n V_T}\left(\sqrt{1+i_f} - 1\right) = \Delta i_f \times I_S$

(SAME RESULT AS BEFORE)

$$\Delta I_D = \begin{cases} 2.75\,nA \\ 0.93\,\mu A \\ 6.43\,\mu A \end{cases} \qquad \frac{\Delta I_D}{I_D} = \begin{cases} 27.4\% \\ 18.6\% \\ 6.4\% \end{cases}$$

3)

| | PARAMETER | CALCULATED | SIMULATED |
|---|---|---|---|
| 10nA | $V_{in}$ (mV) | 496 | 480.7 |
| | $V_{O,MIN}$ (mV) | 104 | 41.32 (*) |
| | $\Delta I$ (nA) | 0.94 | 0.5 |
| 5μA | $V_{in}$ (mV) | 742 | 767 |
| | $V_{O,MIN}$ (mV) | 129 | 72.7 (*) |
| | $\Delta I$ (nA) | 930 | 124 |
| 100μA | $V_{in}$ (mV) | 1020 | 1022 |
| | $V_{O,MIN}$ (mV) | 275 | 237 (*) |
| | $\Delta I$ (nA) | 6430 | 800 |

COMMENTS: • $V_{in}$ AGREEMENT IS GOOD

(*) • $V_{o,min}$ WAS ESTIMATED IN SIMULATIONS USING THE VALUE OF $V_{DS_{SAT}}$

RESULTS → PRINT → DC OPERATING POINTS

MANUAL CALCULATION IS BETTER

(SEE GRAPH)

(RAZAVI RECOMMENDS: FOR SIMULATIONS LOOK AT GRAPHS, NOT JUST VALUES.)

• $\Delta I$ IN CALCULATIONS IS MORE PESSIMISTIC THAN IN SIMULATIONS. AGREEMENT DEPENDS ON EXTRACTED VALUE OF $\left|\frac{\partial X_D}{\partial V_{DS}}\right|$. IN GENERAL, A PESSIMISTIC VALUE IS SAFER THAN AN OPTIMISTIC ONE.