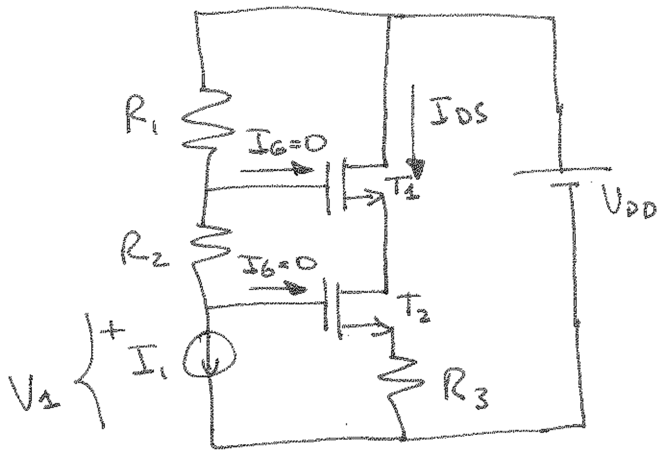
Solución ejercicio Refuerzo MOS:

a) Circuito en DC:



$V_1 = V_{DD} - I_1 (R_1 + R_2) = 8'2\,V$

MALLA G-S T_2

$V_1 = V_{GS_2} + I_{DS} R_3$

sup. T_2 SATURACIÓN

$I_{DS} = \frac{K}{2} \frac{W}{L}_2 (V_{GS_2} - V_T)^2$

$\Rightarrow V_1 = V_{GS_2} + \frac{K}{2} \frac{W}{L}_2 R_3 (V_{GS_2} - V_T)^2 \Rightarrow 8'2 = V_{GS_2} + 0'2 (V_{GS_2} - 1)^2 \Rightarrow$

$\Rightarrow 0'2 V_{GS_2}^2 + 0'6 V_{GS_2} - 8 = 0 \left\{ \begin{array}{l} 5V \\ -8V \end{array} \right.$ como $V_{GS} > V_T \Rightarrow V_{GS} = 5V$

$\Rightarrow I_{DS} = 3'2\,mA$

SUP. SATURACIÓN T_1

$I_{DS} = \frac{K}{2} \frac{W}{L}_1 (V_{GS_1} - V_T)^2 \Rightarrow V_{GS_1} = 3'83\,V$

calculamos V_{DS_1} y V_{DS_2} para comprobar las suposiciones:

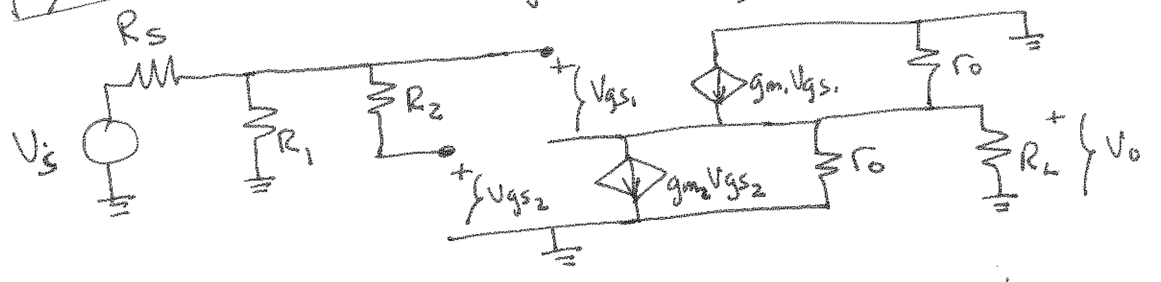
$V_{DS_1} = I_1 \cdot R_1 + V_{GS_1} = 5'03\,V$ $\quad V_{DS_1} > V_{GS_1} - V_T$ ✓

$V_{DS_2} = V_{DD} - I_1 R_1 - V_{GS_1} - I_{DS} R_3 = 6'77\,V$ $\quad V_{DS_2} > V_{GS_2} - V_T$ ✓

$g_{m_1} = \sqrt{2K \frac{W}{L}_1 I_{DS}} = 2'26\,mA/V$ $\quad r_{o_1} = r_{o_2} = r_o = \frac{V_A}{I_{DS}} = 15'6\,K\Omega$

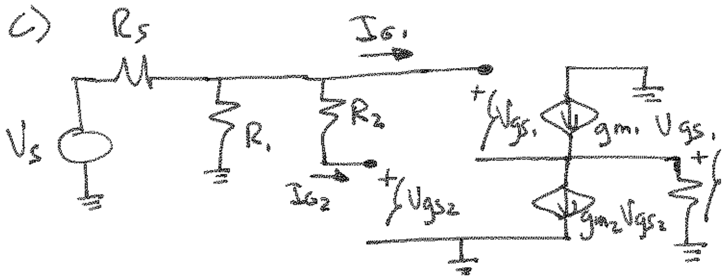
$g_{m_2} = \sqrt{2K \frac{W}{L}_2 I_{DS}} = 1'6\,mA/V$

b) pequeña señal



NOTA: R_L y las dos r_o están en paralelo $\Rightarrow$

c)



$R_L // r_o // r_o = 1'59\ K\Omega = R_{EQ}$

$$\left.\begin{array}{l} I_{G2} = 0 \\ I_{G1} = 0 \end{array}\right\} \Rightarrow I_{G2} R_2 = 0 \Rightarrow V_{gs2} = V_s \frac{R_1}{R_s + R_1}$$

$$V_{gs1} = V_{gs2} - V_o$$

Ley Kirchoff $\Rightarrow g_{m1} V_{gs1} = g_{m2} V_{gs2} + \frac{V_o}{R_{EQ}} \Rightarrow$

$$\Rightarrow g_{m1}\left(V_s \frac{R_1}{R_s+R_1} - V_o\right) = g_{m2} V_s \frac{R_1}{R_s+R_1} + \frac{V_o}{R_{EQ}}$$

$$\Rightarrow (g_{m1} - g_{m2}) \frac{R_1}{R_s+R_1} V_s = \left(g_{m1} + \frac{1}{R_{EQ}}\right) V_o$$

$$\Rightarrow \frac{V_o}{V_s} = \frac{(g_{m1} - g_{m2}) \frac{R_1}{R_s+R_1}}{g_{m1} + \frac{1}{R_{EQ}}} = 0'125$$

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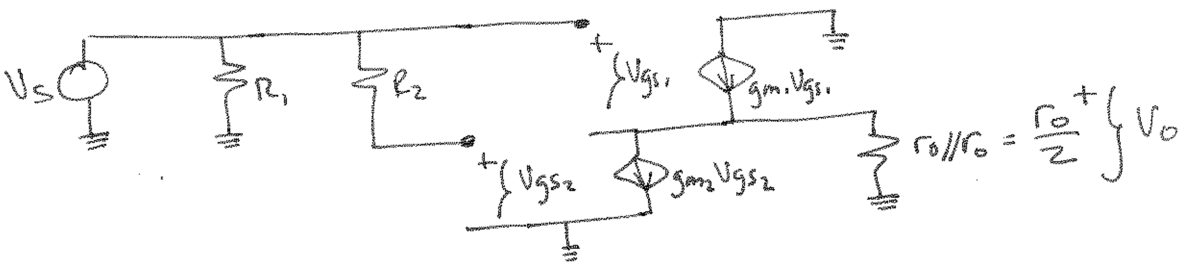
d) Si $R_s = 0$, $R_L = \infty$

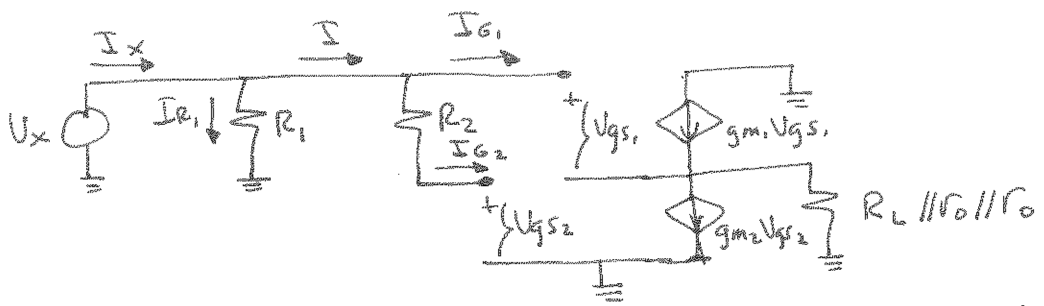


$V_{gs2} = V_s \qquad V_{gs1} = V_s - V_o \qquad g_{m1} V_{gs1} = g_{m2} V_{gs2} + \frac{V_o}{r_o/2}$

$$\Rightarrow g_{m1}(V_s - V_o) = g_{m2} V_s + \frac{2 V_o}{r_o} \Rightarrow (g_{m1} - g_{m2}) V_s = \left(g_{m1} + \frac{2}{r_o}\right) V_o$$

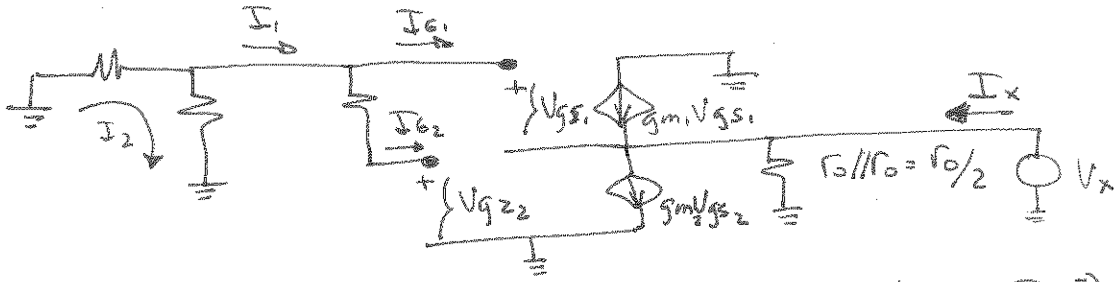
$$\Rightarrow \frac{V_o}{V_s} = \frac{g_{m1} - g_{m2}}{g_{m1} + \frac{2}{r_o}} = 0'276$$

e) R_{IN}:



$I_{G1} = I_{G2} = 0 \Rightarrow I = 0 \Rightarrow I_{R1} = I_x \Rightarrow R_{IN} = \frac{U_x}{I_x} = R_1 = 600\Omega$

R_{OUT}:



$I_{G1} = I_{G2} = 0 \Rightarrow I_1 = 0$ Malla $\rightarrow I_2 = 0 \Rightarrow U_{gs2} = 0 \Rightarrow g_{m2} V_{gs2} = 0$

$V_{gs1} = -V_x \Rightarrow I_x = \frac{V_x}{r_o/2} + g_{m1} V_x \Rightarrow R_{OUT} = \frac{V_x}{I_x} = \left(\frac{2}{r_o} + g_{m1}\right)^{-1} = 419\Omega$

NOTA: se cumple que: $\frac{V_o}{V_s} = \frac{R_{IN}}{R_s + R_{IN}} \frac{V_o}{V_s}(R_s = 0, R_L = \infty) \frac{R_L}{R_{OUT} + R_L}$ (*)

resultados sin incluir efecto Early: $(r_o \rightarrow \infty)$

$\frac{V_o}{V_s} = \frac{(g_{m1} - g_{m2}) \frac{R_1}{R_s + R_1}}{g_{m1} + \frac{1}{R_L}} = 0'130$

$\frac{V_o}{V_s}(R_s = 0, R_L = \infty) = \frac{g_{m1} - g_{m2}}{g_{m1}} = 0'292$

$R_{IN} = R_1 = 600\Omega$

$R_{OUT} = \frac{1}{g_{m1}} = 442\Omega$

} también cumplen (*)

f) para poder aplicar pequeña señal ⇒

⇒ ambos transistores en saturación

T_1: $V_{DS1} = I_1 R_1 + V_{GS1}$ ⇒ $V_{DS1} > V_{GS1} - V_T$ siempre se cumple

T_2: $V_{DS2} = V_{DD} - I_1 R_1 - V_{GS1} - I_{DS} R_3$

No dependen de W/L_1 (I_{DS} es solución de la malla G-S para T_2)

$I_{DS} = \frac{K}{2} \frac{W}{L}_1 (V_{GS1} - V_T)^2$ ⇒ Si $\frac{W}{L}_1 \downarrow$ ⇒ $V_{GS1} \uparrow$ ⇒ $V_{DS2} \downarrow$

límite con triodo ⇒ $V_{DS2} = V_{GS2} - V_T = 4V$ ⇒ $V_{GS1} = 6'6V$

⇒ $\frac{W}{L}_1 = \frac{2 I_{DS}}{K} \frac{1}{(V_{GS1} - V_T)^2} = 10'2$