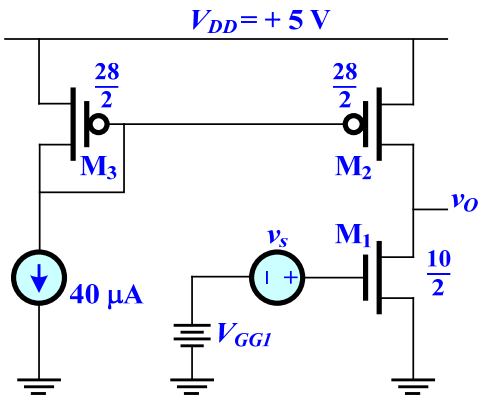
ELECTRÓNICA BÁSICA

Amplificadores Básicos
Problemas

Problema 1(a)

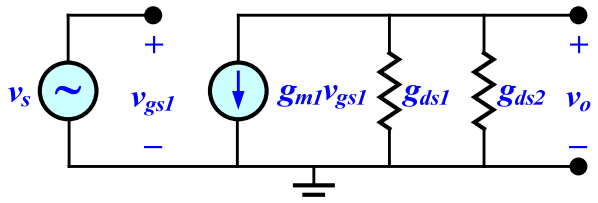
- Transistores saturados. $I_{D1} = I_{DP2} = I_{DP3} = I_{REF} = 40\ \mu\text{A}$



* Dimensiones de puerta en µm

Problema 1(a)

- Circuito equivalente de pequeña señal.



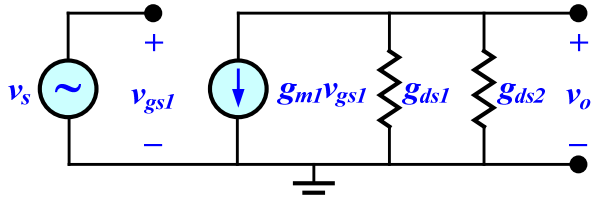
$$g_{m1} = \sqrt{2K_n' \frac{W_1}{L_1} I_{D1}} = 211.6 \frac{\mu\text{A}}{\text{V}}$$

$$g_{ds1} = \lambda_n I_{D1} = 0.4 \frac{\mu\text{A}}{\text{V}} \qquad g_{ds2} = \lambda_p I_{DP2} = 0.8 \frac{\mu\text{A}}{\text{V}}$$

ResPrB.III-3

Problema 1(a)

- Ganancia de tensión y resistencia de salida



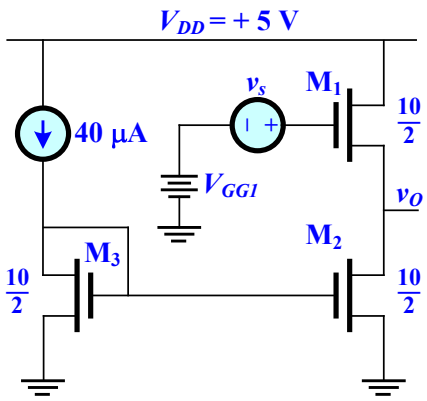
$$A_v = \frac{v_o}{v_s} = \frac{-g_{m1}}{g_{ds1} + g_{ds2}} = -176.3$$

$$R_{out} = \frac{1}{g_{ds1} + g_{ds2}} = 833\ \text{K}\Omega$$

ResPrB.III-4

Problema 1(b)

- Transistores saturados. $I_{D1} = I_{D2} = I_{D3} = I_{REF} = 40\ \mu\text{A}$

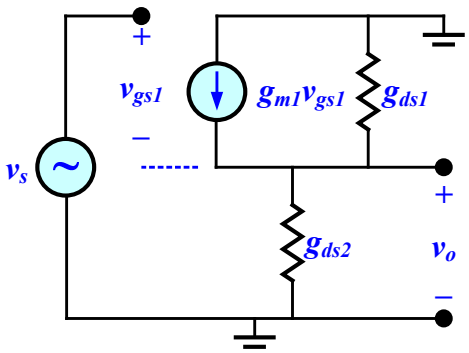


∗ Dimensiones de puerta en μm

ResPrB.III-5

Problema 1(b)

- Circuito equivalente de pequeña señal.



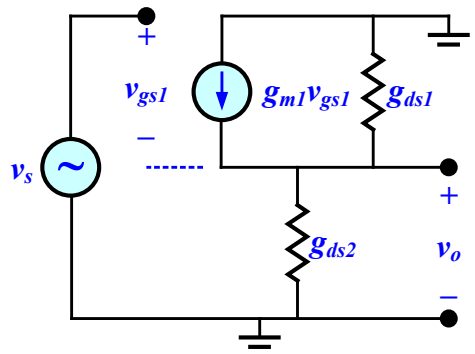
$$g_{m1} = \sqrt{2K_n' \frac{W_1}{L_1} I_{D1}} = 211.6 \frac{\mu\text{A}}{\text{V}}$$

$$g_{ds2} = g_{ds1} = \lambda_n I_{D1} = 0.4 \frac{\mu\text{A}}{\text{V}}$$

ResPrB.III-6

Problema 1(b)

- Ganancia de tensión y resistencia de salida



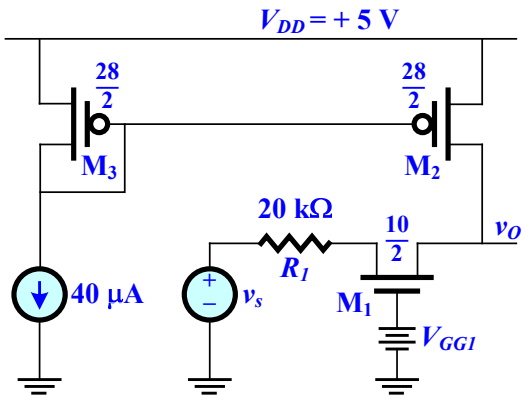
$$A_v = \frac{v_o}{v_s} = \frac{g_{m1}}{g_{m1} + g_{ds1} + g_{ds2}} = 0.99$$

$$R_{out} = \frac{1}{g_{m1} + g_{ds1} + g_{ds2}} = 4.7\ \text{K}\Omega$$

ResPrB.III-7

Problema 2(a)

- Transistores saturados. $I_{D1} = I_{DP2} = I_{DP3} = I_{REF} = 40\ \mu\text{A}$

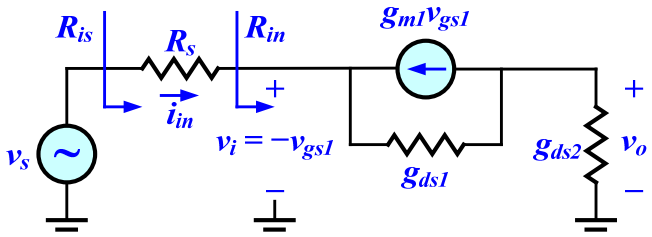


∗ Dimensiones de puerta en µm

ResPrB.III-8

Problema 2(a)

- Circuito equivalente de pequeña señal.

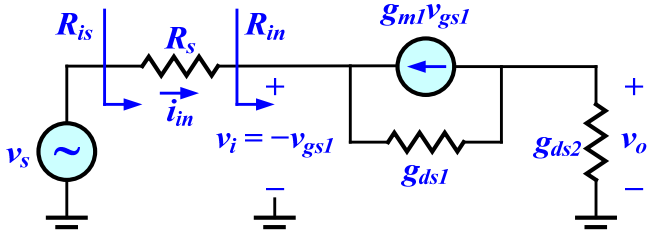


$$g_{m1} = \sqrt{2K_n' \frac{W_1}{L_1} I_{D1}} = 211.6 \frac{\mu\text{A}}{\text{V}}$$

$$g_{ds1} = \lambda_n I_{D1} = 0.4 \frac{\mu\text{A}}{\text{V}} \qquad g_{ds2} = \lambda_p I_{D1} = 0.8 \frac{\mu\text{A}}{\text{V}}$$

Problema 2(a)

- Ganancia de tensión y resistencia de entrada.

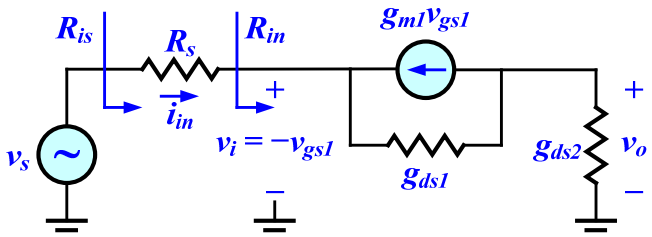


$$A_v = \frac{v_o}{v_i} = \frac{g_{m1} + g_{ds1}}{g_{ds1} + g_{ds2}} = 176.6$$

$$R_{in} = \frac{v_{in}}{i_{in}} = \frac{g_{ds1} + g_{ds2}}{(g_{m1} + g_{ds1}) g_{ds2}} = 7\ \text{K}\Omega$$

Problema 2(a)

- Ganancia de tensión y resistencia de entrada.



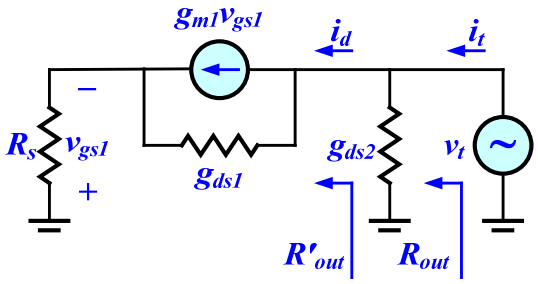
$$A_{vs} = \frac{v_o}{v_s} = \frac{g_{m1} + g_{ds1}}{g_{ds1} + g_{ds2} + g_{ds2}\left(g_{m1} + g_{ds1}\right)R_s} = 46.1$$

$$R_{is} = \frac{v_s}{i_{in}} = R_s + R_{in} = 27\ \mathrm{K\Omega}$$

ResPrB.III-11

Problema 2(a)

- Resistencia de salida



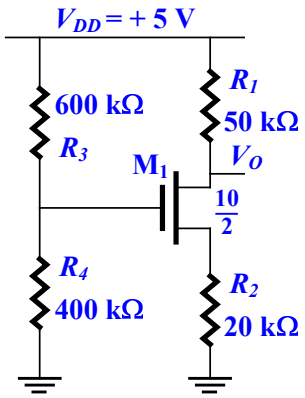
$$R'_{out} = \frac{v_t}{i_d} = g_{ds1}^{-1}\left(1 + g_{m1}R_s\right) + R_s = 13.1\mathrm{M\Omega}$$

$$R_{out} = \frac{v_t}{i_t} = g_{ds2}^{-1} \,||\, R'_{out} = 1.14\ \mathrm{M\Omega}$$

ResPrB.III-12

Problema 2(b)

- Transistor saturado. Análisis en DC.



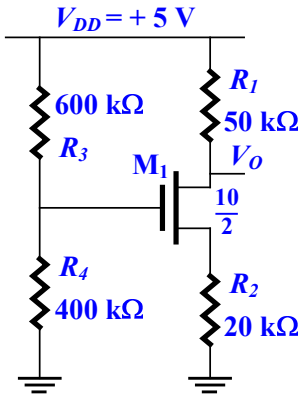
∗ Dimensiones de puerta en μm

$$V_G = \frac{R_4 V_{DD}}{R_3 + R_4} = V_{GS1} + I_{D1} R_2$$

$$I_{D1} = \frac{1}{2}\frac{W_1}{L_1} K_n' \left(V_{GS1} - V_{TON}\right)^2 = \frac{V_{DD} - V_{DS1}}{R_1 + R_2}$$

Problema 2(b)

- Transistor saturado. Análisis en DC.



∗ Dimensiones de puerta en μm

$$V_{GS1}^2 - \frac{7.96}{5.6} V_{GS1} + \frac{1.584}{5.6} = 0$$

$$V_{GS1} = 1.18 \text{ V}$$

$$I_{D1} = 40.85\ \mu\text{A}$$

$$V_{DS1} = 2.14 \text{ V}$$

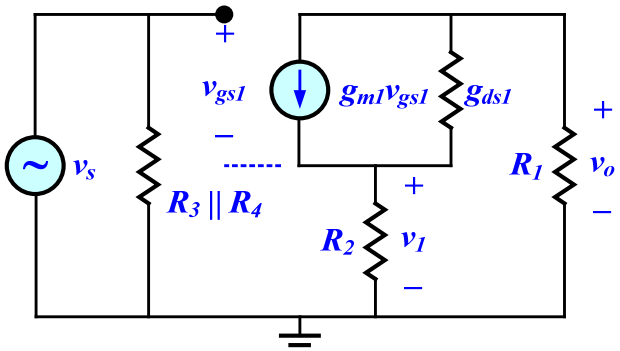
$$V_{G1} = 2 \text{ V}$$

$$V_{D1} = V_O = 2.95 \text{ V}$$

$$V_{S1} = 0.81 \text{ V}$$

Problema 2(b)

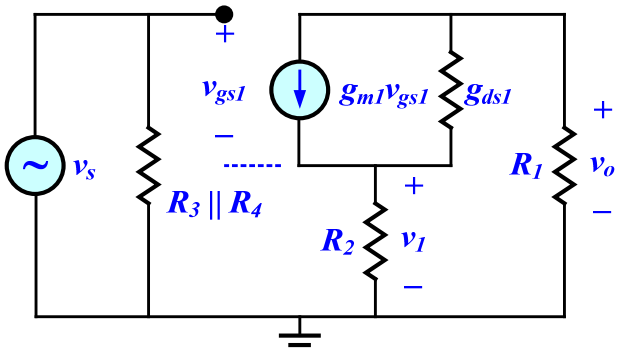
- Circuito equivalente de pequeña señal.



$$g_{m1} = \sqrt{2K_n' \frac{W_1}{L_1} I_{D1}} = 213.9 \frac{\mu\text{A}}{\text{V}} \qquad g_{ds1} = \lambda_n I_{D1} = 0.41 \frac{\mu\text{A}}{\text{V}}$$

Problema 2(b)

- Ganancia de tensión.



$$v_{gs1} = v_s - v_1$$

$$v_1 = -\frac{v_o}{R_1} R_2$$

$$g_{m1} v_{gs1} + g_{ds1}\left(v_o - v_1\right) + \frac{v_o}{R_1} = 0$$

Problema 2(b)

- Ganancia de tensión.

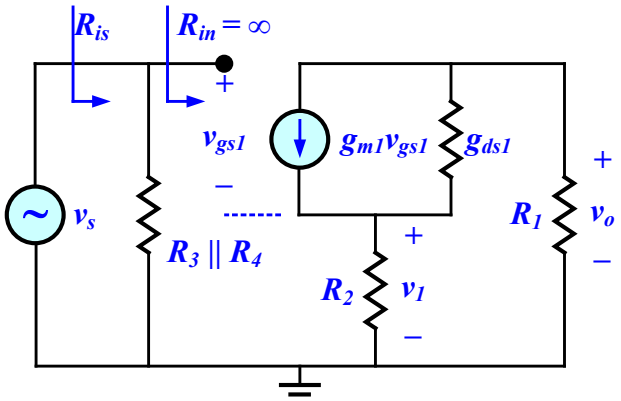
$$g_{m1}\left(v_s+\frac{R_2}{R_1}v_o\right)+g_{ds1}\left(v_o+\frac{R_2}{R_1}v_o\right)+\frac{v_o}{R_1}=0$$

$$g_{m1}R_1v_s+\left(g_{m1}R_2+g_{ds1}R_1+g_{ds1}R_2+1\right)v_o=0$$

$$A_v=\frac{v_o}{v_s}=-\frac{g_{m1}R_1}{g_{m1}R_2+g_{ds1}\left(R_1+R_2\right)+1}=-2$$

Problema 2(b)

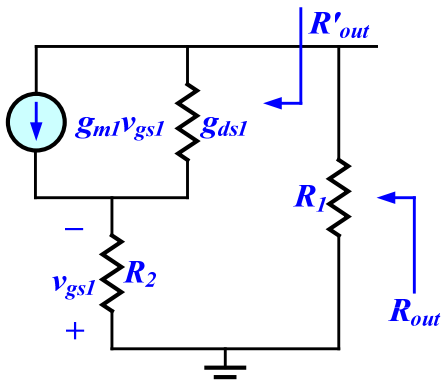
- Resistencia de entrada



$$R_{is}=\left(R_3 \parallel R_4\right) \parallel R_{in}=R_3 \parallel R_4=240\ \mathrm{K\Omega}$$

Problema 2(b)

- Resistencia de salida.



$$R'_{out} = g_{ds1}^{-1}\left(1 + g_{m1}R_2\right) + R_2 = \\ = 12.9\text{M}\Omega$$

$$R_{out} = R_1 \,||\, R'_{out} = 49.8\ \text{K}\Omega$$

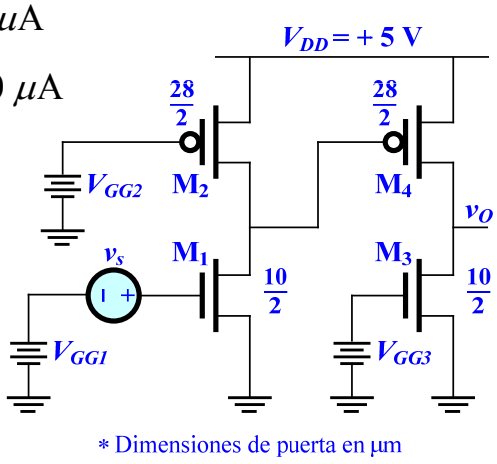
ResPrB.III-19

Problema 3

- Transistores en saturación: M_1 CS, M_4 CS.

$$I_{D1} = I_{DP2} = 40\ \mu\text{A}$$

$$I_{DP4} = I_{D3} = 840\ \mu\text{A}$$

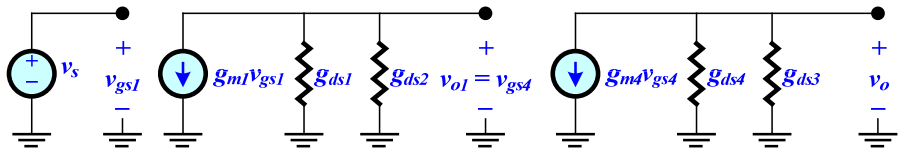


∗ Dimensiones de puerta en μm

ResPrB.III-20

Problema 3

- Circuito equivalente de pequeña señal.



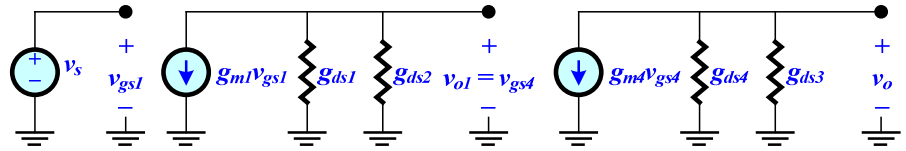
$$g_{m1} = \sqrt{2K_n' \frac{W_1}{L_1} I_{D1}} = 211.6 \frac{\mu A}{V} \qquad g_{ds1} = \lambda_n I_{D1} = 0.4 \frac{\mu A}{V}$$

$$g_{m4} = \sqrt{2K_p' \frac{W_4}{L_4} I_{DP4}} = 1005.6 \frac{\mu A}{V} \qquad g_{ds4} = \lambda_p I_{DP4} = 16.8 \frac{\mu A}{V}$$

$$g_{ds2} = \lambda_p I_{DP2} = 0.8 \frac{\mu A}{V} \qquad g_{ds3} = \lambda_n I_{D3} = 8.4 \frac{\mu A}{V}$$

Problema 3

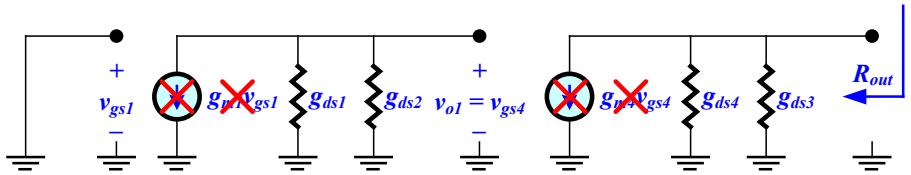
- Ganancia de tensión.



$$A_v = \frac{v_o}{v_s} = \frac{v_o}{v_{o1}} \times \frac{v_{o1}}{v_s} = \frac{-g_{m1}}{g_{ds1} + g_{ds2}} \times \frac{-g_{m4}}{g_{ds4} + g_{ds3}} = 7036.5$$

Problema 3

- Ganancia de tensión.



$$R_{out} = \frac{1}{g_{ds4} + g_{ds3}} = 39.6\ \mathrm{K\Omega}$$

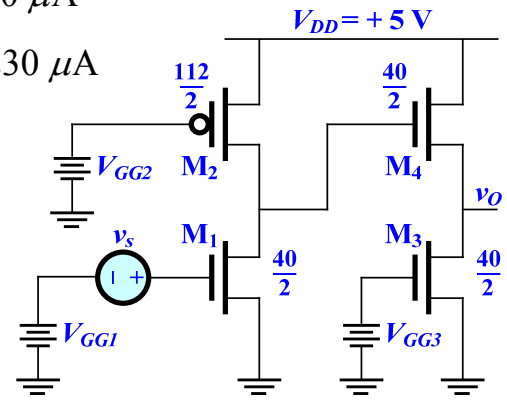
ResPrB.III-23

Problema 4

- Transistores en saturación: M_1 CS, M_4 SF.

$$I_{D1} = I_{DP2} = 40\ \mu\mathrm{A}$$

$$I_{DP4} = I_{D3} = 230\ \mu\mathrm{A}$$

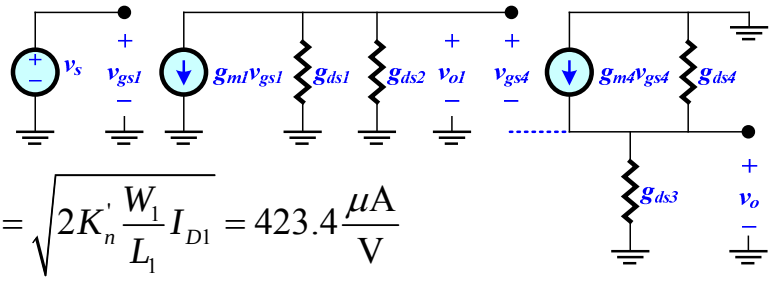


* Dimensiones de puerta en µm

ResPrB.III-24

Problema 4

- Circuito equivalente de pequeña señal.



$$g_{m1} = \sqrt{2K_n' \frac{W_1}{L_1} I_{D1}} = 423.4 \frac{\mu\text{A}}{\text{V}}$$

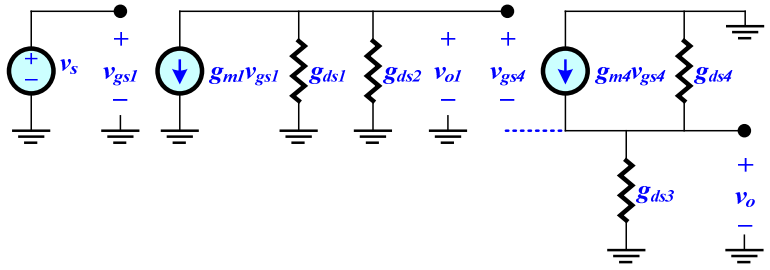
$$g_{ds1} = \lambda_n I_{D1} = 0.4 \frac{\mu\text{A}}{\text{V}} \qquad g_{ds2} = \lambda_p I_{DP2} = 0.8 \frac{\mu\text{A}}{\text{V}}$$

$$g_{m4} = \sqrt{2K_n' \frac{W_4}{L_4} I_{D4}} = 1015 \frac{\mu\text{A}}{\text{V}} \qquad g_{ds3} = g_{ds4} = \lambda_n I_{D4} = 2.3 \frac{\mu\text{A}}{\text{V}}$$

ResPrB.III-25

Problema 4

- Ganancia de tensión.

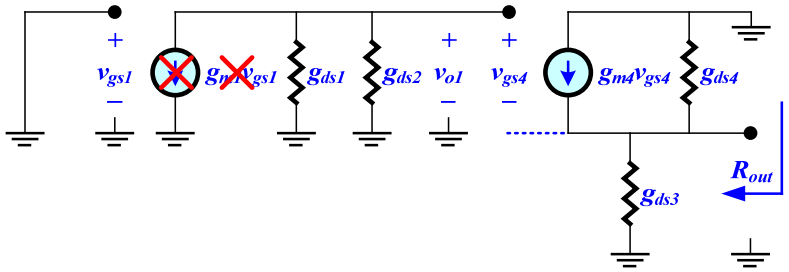


$$A_v = \frac{v_o}{v_s} = \frac{v_o}{v_{o1}} \times \frac{v_{o1}}{v_s} = \frac{-g_{m1}}{g_{ds1} + g_{ds2}} \times \frac{g_{m4}}{g_{m4} + g_{ds4} + g_{ds3}} = -351$$

ResPrB.III-26

Problema 4

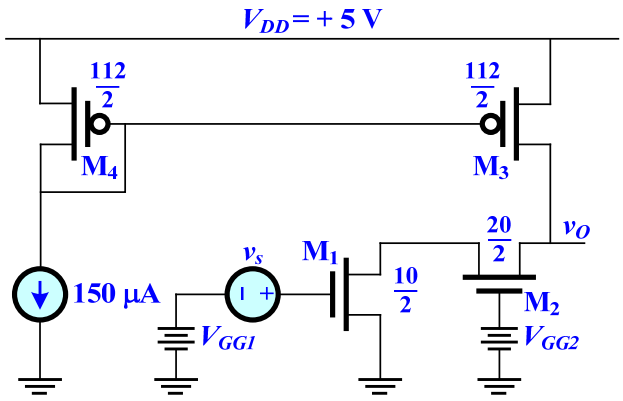
- Resistencia de salida.



$$R_{out} = \frac{1}{g_{m4} + g_{ds4} + g_{ds3}} = 0.98\ \mathrm{K\Omega}$$

Problema 5

- Transistores en saturación: M_1 CS, M_2 CG.

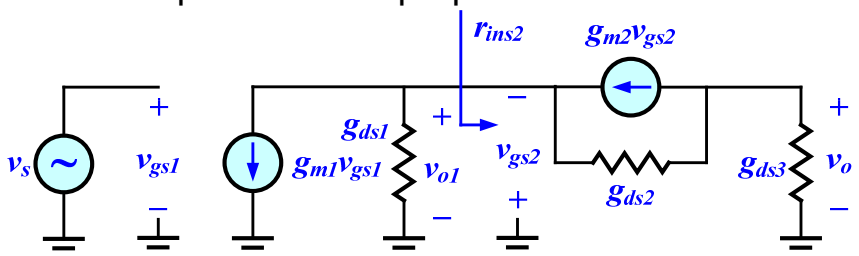


∗ Dimensiones de puerta en µm

$$I_{D1} = I_{D2} = I_{DP3} = 150\ \mu\mathrm{A}$$

Problema 5

- Circuito equivalente de pequeña señal.



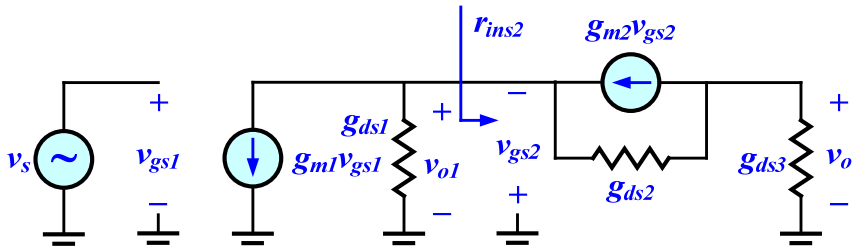
$$g_{m1} = \sqrt{2K_n' \frac{W_1}{L_1} I_{D1}} = 409.8 \frac{\mu\text{A}}{\text{V}} \qquad g_{ds2} = g_{ds1} = \lambda_n I_{D1} = 1.5 \frac{\mu\text{A}}{\text{V}}$$

$$g_{m2} = \sqrt{2K_n' \frac{W_2}{L_2} I_{D2}} = 579.6 \frac{\mu\text{A}}{\text{V}} \qquad g_{ds3} = \lambda_p I_{DP3} = 3 \frac{\mu\text{A}}{\text{V}}$$

ResPrB.III-29

Problema 5

- Ganancia de tensión.



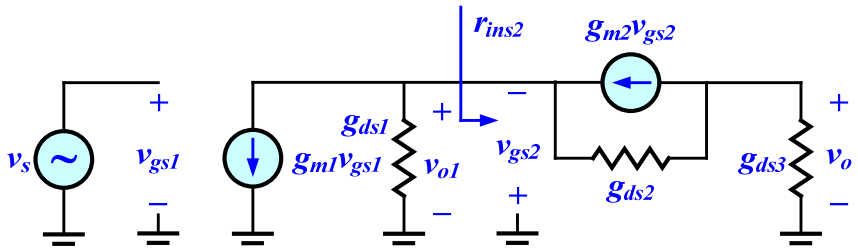
$$r_{ds1} = \frac{1}{g_{ds1}} = \frac{2}{3}\,\text{M}\Omega \qquad r_{ins2} = \frac{g_{ds2} + g_{ds3}}{\left(g_{m2} + g_{ds2}\right) g_{ds3}} = 2.58\,\text{K}\Omega$$

$$A_{v1} = \frac{v_{o1}}{v_s} = -g_{m1}\left(r_{ds1} \,\|\, r_{ins2}\right) = -1.05$$

ResPrB.III-30

Problema 5

- Ganancia de tensión.



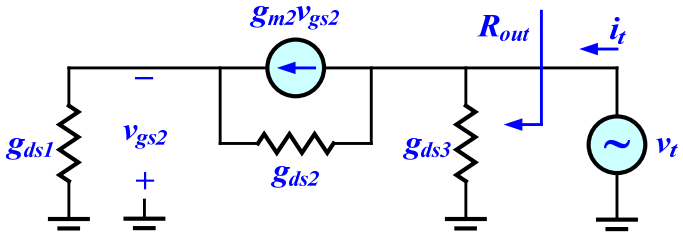
$$A_{v2} = \frac{v_o}{v_{o1}} = \frac{g_{m2} + g_{ds2}}{g_{ds2} + g_{ds3}} = 129.13$$

$$A_v = \frac{v_o}{v_s} = \frac{v_{o1}}{v_s} \times \frac{v_o}{v_{o1}} = -135.6 \qquad A_v = \frac{v_o}{v_s} \simeq -\frac{g_{m1}}{g_{ds3}} = -136.6$$

ResPrB.III-31

Problema 5

- Resistencia de salida.



$$R_o = \left(g_{ds1}^{-1} + g_{ds2}^{-1} + g_{m2}g_{ds1}^{-1}g_{ds2}^{-1}\right) \Big\| \, g_{ds3}^{-1} = 332.9 \text{ K}\Omega$$

$$R_o \simeq g_{ds3}^{-1} = 333.3 \text{ K}\Omega$$

ResPrB.III-32