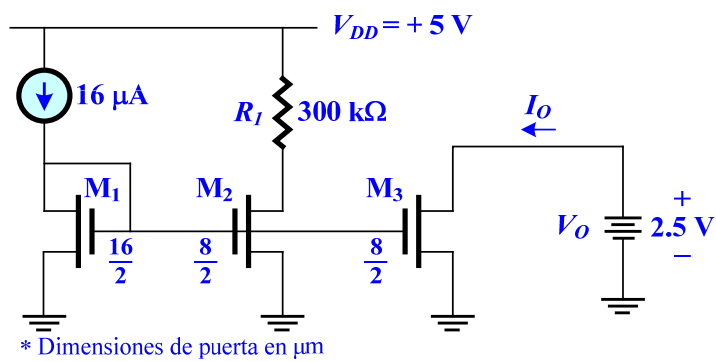

ELECTRÓNICA BÁSICA

Fuentes de Corriente y Tensiones de Referencia Problemas

ResPrB.II-1

Problema 1(a)

- M_1 Sat.

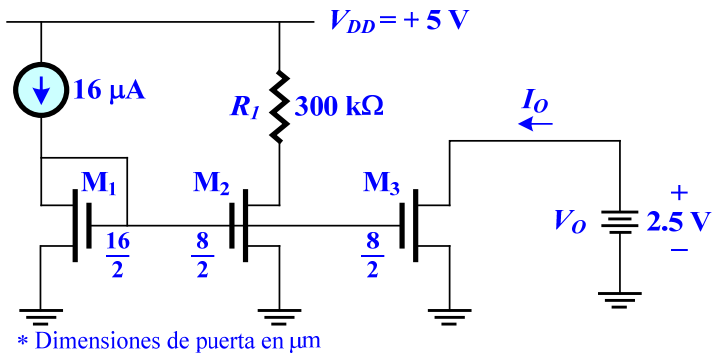


$$V_{GS1} = V_{TON} + \sqrt{\frac{2L_1 I_{D1}}{W_1 K'_n}} = 0.98 \text{ V}$$

ResPrB.II-2

Problema 1(a)

- M_2 Sat.



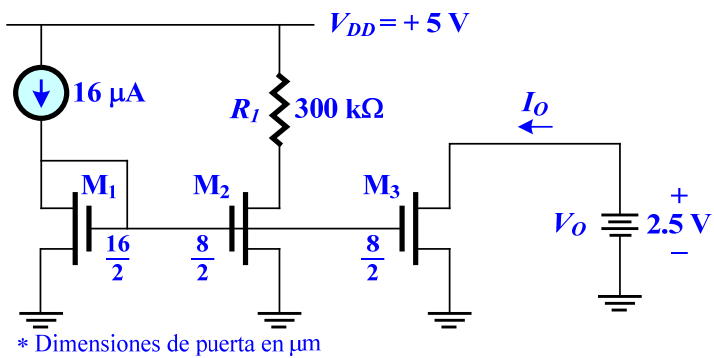
$$I_{D2} = \frac{W_2}{W_1} I_{D1} = 8 \mu\text{A} \rightarrow V_{DS2} = V_{DD} - I_{D2} R_1 = 2.6 \text{ V}$$

$$V_{GS2} = V_{GS1}, \quad V_{GS1} - V_{TON} = 0.18 \text{ V} < V_{DS2} = 2.6 \text{ V}$$

ResPrB.II-3

Problema 1(a)

- M_3 Sat.



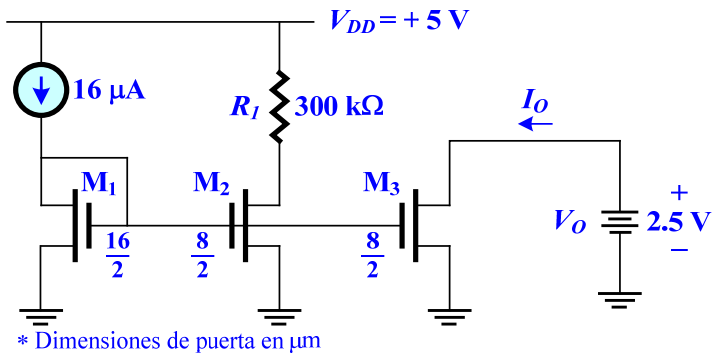
$$V_{GS3} = V_{GS1}, \quad V_{GS1} - V_{TON} = 0.18 \text{ V} < V_{DS2} = 2.5 \text{ V}$$

$$I_O = I_{D3} = \frac{W_3}{W_1} I_{D1} = 8 \mu\text{A}$$

ResPrB.II-4

Problema 1(a)

- M_2 Sat.



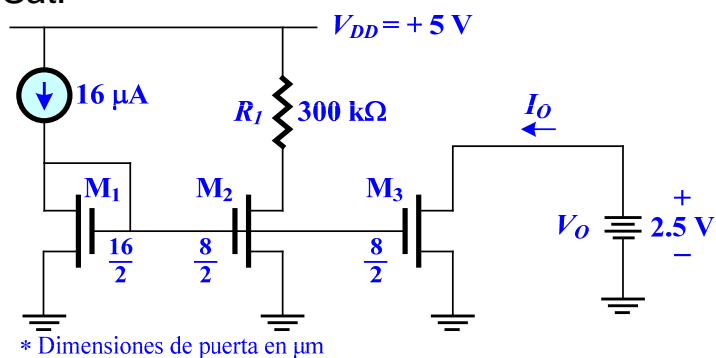
$$I_{D2} = \frac{1}{2} \frac{W_2}{L_2} K'_n (V_{GS2} - V_{TON})^2 (1 + \lambda_n V_{DS2}) = \frac{V_{DD} - V_{DS2}}{R_1}$$

$$V_{DS2} = 2.54 \text{ V} \rightarrow I_{D2} = 8.2 \mu\text{A}$$

ResPrB.II-5

Problema 1(a)

- M_3 Sat.

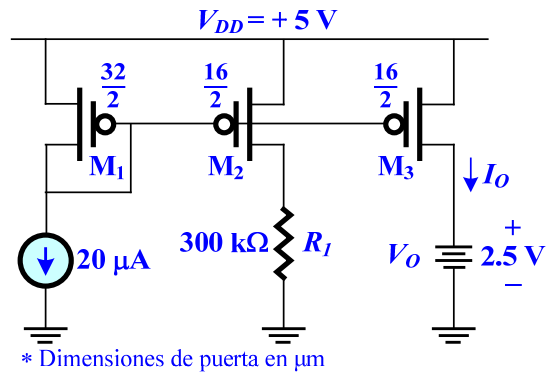


$$I_O = I_{D3} = \frac{1}{2} \frac{W_3}{L_3} K'_n (V_{GS3} - V_{TON})^2 (1 + \lambda_n V_{DS3}) = 8.2 \mu\text{A}$$

ResPrB.II-6

Problema 1(b)

- M_1 Sat.

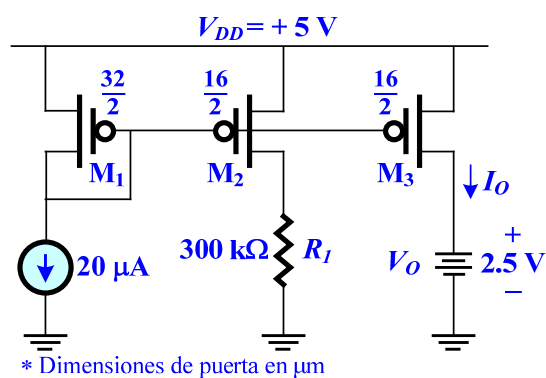


$$I_{DP1} = 20 \mu\text{A} \rightarrow V_{SG1} = |V_{TOP}| + \sqrt{\frac{2L_1 I_{DP1}}{W_1 K'_p}} = 1.14 \text{ V}$$

ResPrB.II-7

Problema 1(b)

- M_2 Sat.



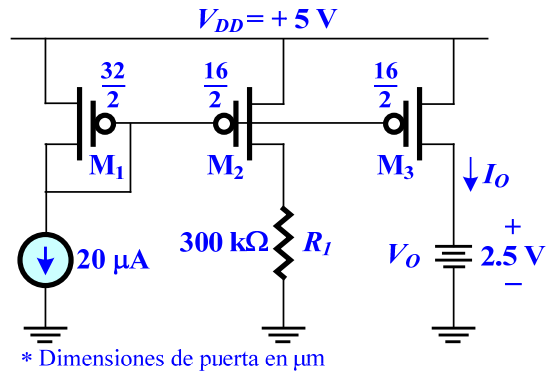
$$I_{DP2} = \frac{W_2}{W_1} I_{DP1} = 10 \mu\text{A} \rightarrow V_{SD2} = V_{DD} - I_{DP2} R_1 = 2 \text{ V}$$

$$V_{SG2} = V_{SG1}, \quad V_{SG2} - |V_{TOP}| = 0.34 \text{ V} < V_{SD2} = 2 \text{ V}$$

ResPrB.II-8

Problema 1(b)

- M_3 Sat.



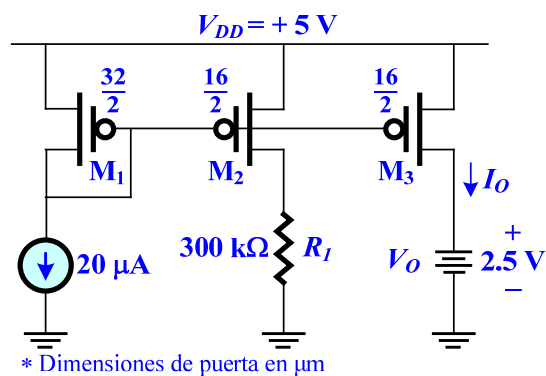
$$V_{SG3} = V_{SG1}, \quad V_{SG3} - |V_{TOP}| = 0.34 \text{ V} < V_{SD3} = 2.5 \text{ V}$$

$$I_O = I_{DP3} = \frac{W_3}{W_1} I_{DP1} = 10 \mu\text{A}$$

ResPrB.II-9

Problema 1(b)

- M_2 Sat.



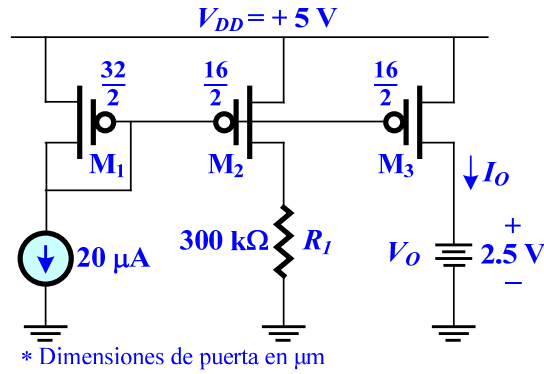
$$I_{DP2} = \frac{1}{2} \frac{W_2}{L_2} K'_p (V_{SG2} - |V_{TOP}|)^2 (1 + \lambda_p V_{SD2}) = \frac{V_{DD} - V_{SD2}}{R_1}$$

$$V_{SD2} = 1.88 \text{ V} \rightarrow I_{D2} = 10.37 \mu\text{A}$$

ResPrB.II-10

Problema 1(b)

- M_3 Sat.

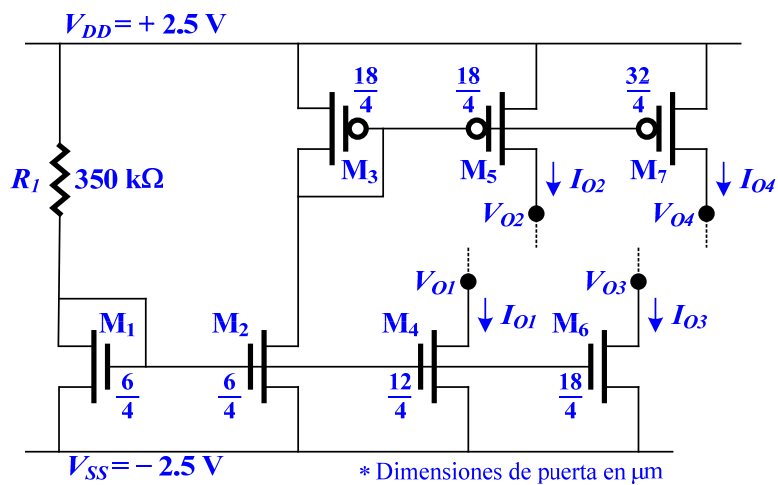


$$I_{DP3} = \frac{1}{2} \frac{W_3}{L_3} K'_p (V_{SG3} - |V_{TOP}|)^2 (1 + \lambda_p V_{SD3}) = 10.5 \mu\text{A}$$

ResPrB.II-11

Problema 2(a)

- MOSFET saturados.



ResPrB.II-12

Problema 2(a)

- M_1 :

$$I_{D1} = \frac{1}{2} \frac{W_1}{L_1} K_n' (V_{GS1} - V_{TON})^2 = \frac{V_{DD} - V_{GS1} - V_{SS}}{R_1}$$

$$V_{GS1} = 1.16 \text{ V} \rightarrow I_{D1} = 10.97 \mu\text{A}$$

- M_2, M_4, M_6 : $V_{GS6} = V_{GS4} = V_{GS2} = V_{GS1} = 1.16 \text{ V}$

$$I_{D2} = \frac{W_2}{W_1} I_{D1} = 10.97 \mu\text{A} \quad I_{D4} = \frac{W_4}{W_1} I_{D1} = 21.94 \mu\text{A}$$

$$I_{D6} = \frac{W_6}{W_1} I_{D1} = 32.91 \mu\text{A}$$

ResPrB.II-13

Problema 2(a)

- M_3, M_5, M_7 :

$$I_{DP3} = I_{D2} = 10.97 \mu\text{A} \rightarrow V_{SG3} = |V_{TOP}| + \sqrt{\frac{2L_3 I_{DP3}}{W_3 K_p'}} = 1.24 \text{ V}$$

$$V_{SG7} = V_{SG5} = V_{SG3} = 1.24 \text{ V}$$

$$I_{DP5} = \frac{W_5}{W_3} I_{DP3} = 10.97 \mu\text{A} \quad I_{DP7} = \frac{W_7}{W_3} I_{DP3} = 19.5 \mu\text{A}$$

- M_2 :

$$V_{DS2} = V_{DD} - V_{SG3} - V_{SS} = 3.76 \text{ V} \rightarrow M_2 \equiv \text{SAT}$$

ResPrB.II-14

Problema 2(b)

- Corrientes de salida:

$$I_{O1} = I_{D4} = 21.94 \mu\text{A} \quad , \quad I_{O2} = I_{DP5} = 10.97 \mu\text{A}$$

$$I_{O3} = I_{D6} = 32.91 \mu\text{A} \quad , \quad I_{O4} = I_{DP7} = 19.5 \mu\text{A}$$

- Resistencias de salida :

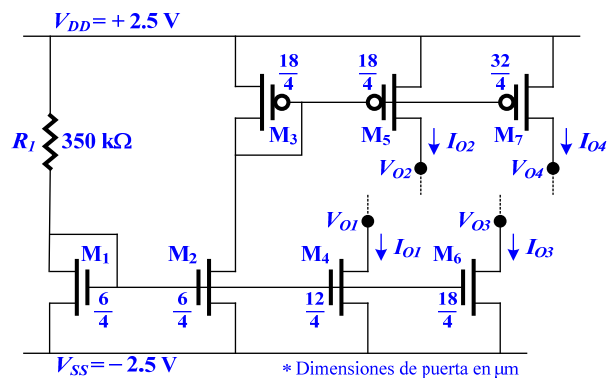
$$R_{O1} = r_{o4} = \frac{1}{\lambda_n I_{D4}} = 11.4 \text{ M}\Omega \quad , \quad R_{O2} = r_{o5} = \frac{1}{\lambda_p I_{DP5}} = 13 \text{ M}\Omega$$

$$R_{O3} = r_{o6} = \frac{1}{\lambda_n I_{D6}} = 7.6 \text{ M}\Omega \quad , \quad R_{O4} = r_{o7} = \frac{1}{\lambda_p I_{DP7}} = 7.3 \text{ M}\Omega$$

ResPrB.II-15

Problema 2(c)

- Rango de tensiones de salida:



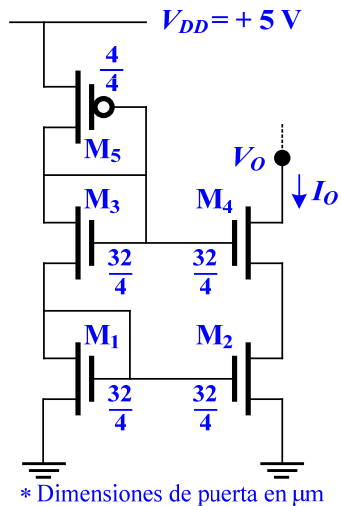
$$V_{O3(\min)} = V_{O1(\min)} = V_{G4} - V_{TON} = V_{GS4} + V_{SS} - V_{TON} = -2.14 \text{ V}$$

$$V_{O2(\max)} = V_{O4(\max)} = V_{G5} + |V_{TOP}| = V_{DD} - V_{SG5} + |V_{TOP}| = 2.16 \text{ V}$$

ResPrB.II-16

Problema 3(f.3.a)

- MOSFET saturados y libres del efecto sustrato.



$$V_{DD} = V_{GS1} + V_{GS3} + V_{SG5}$$

$$I_{D1} = I_{D3} = I_{DP5} = I_{REF}$$

$$V_{GS3} = V_{GS1}$$

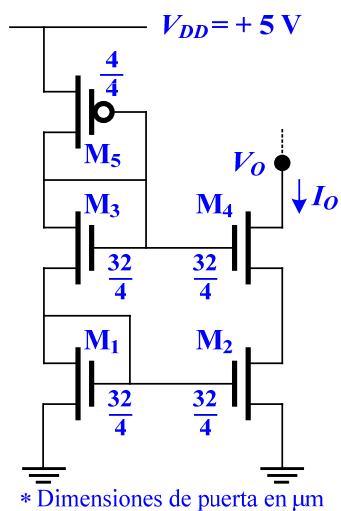
$$V_{GS1} = V_{TON} + \sqrt{\frac{2L_1 I_{REF}}{W_1 K'_n}}$$

$$V_{SG5} = |V_{TOP}| + \sqrt{\frac{2L_5 I_{REF}}{W_5 K'_p}}$$

ResPrB.II-17

Problema 3(f.3.a)

- MOSFET saturados y libres del efecto sustrato.



$$V_{DD} = 2V_{TON} + 2\sqrt{\frac{2L_1 I_{REF}}{W_1 K'_n}} +$$

$$+ |V_{TOP}| + \sqrt{\frac{2L_5 I_{REF}}{W_5 K'_p}}$$

$$I_{REF} = 65 \mu\text{A}$$

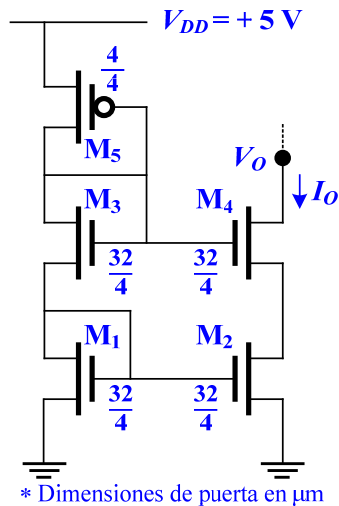
$$V_{GS3} = V_{GS1} = 1.18 \text{ V}$$

$$V_{SG5} = 2.64 \text{ V}$$

ResPrB.II-18

Problema 3(f.3.b)

- MOSFET saturados y libres del efecto sustrato.



$$I_O = I_{D2} = I_{D4} = I_{REF} = 65 \mu\text{A}$$

$$g_{m4} = \sqrt{2K'_n \frac{W}{L} I_{D4}} = 341.3 \frac{\mu\text{A}}{\text{V}}$$

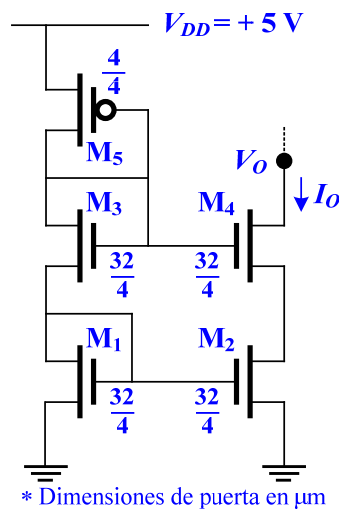
$$r_{o4} = r_{o2} = \frac{1}{\lambda_n I_{D2}} = 3.84 \text{ M}\Omega$$

$$R_o = r_{o4} (1 + g_{m4} r_{o2}) + r_{o2} = 5040 \text{ M}\Omega$$

ResPrB.II-19

Problema 3(f.3.c)

- MOSFET saturados y libres del efecto sustrato.



$$V_{GS4} = V_{GS2} = V_{GS1} = 1.18 \text{ V}$$

$$V_{G4} = V_{GS1} + V_{GS3} = 2.36 \text{ V}$$

$$V_{DS2} = V_{G4} - V_{GS4} = 1.18 \text{ V}$$

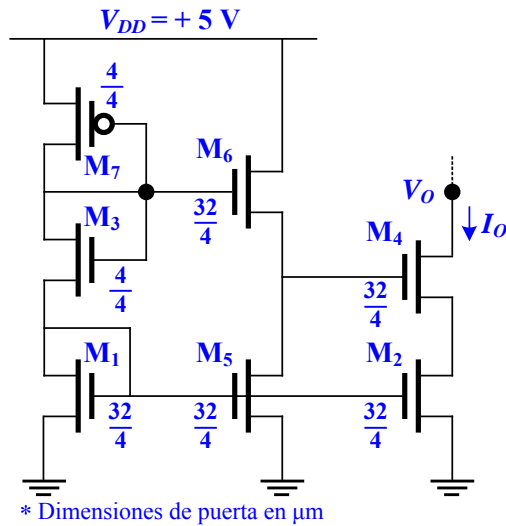
$$V_{GS2} = V_{DS2} = 1.18 \text{ V} \rightarrow M_2 \equiv \text{SAT}$$

$$V_{O(\min)} = V_{G4} - V_{TON} = 1.56 \text{ V}$$

ResPrB.II-20

Problema 3(f.4.a)

- MOSFET saturados y libres del efecto sustrato.



$$V_{DD} = V_{GS1} + V_{GS3} + V_{SG7}$$

$$I_{D1} = I_{D3} = I_{DP7} = I_{REF}$$

$$V_{GS1} = V_{TON} + \sqrt{\frac{2L_1 I_{REF}}{W_1 K'_n}}$$

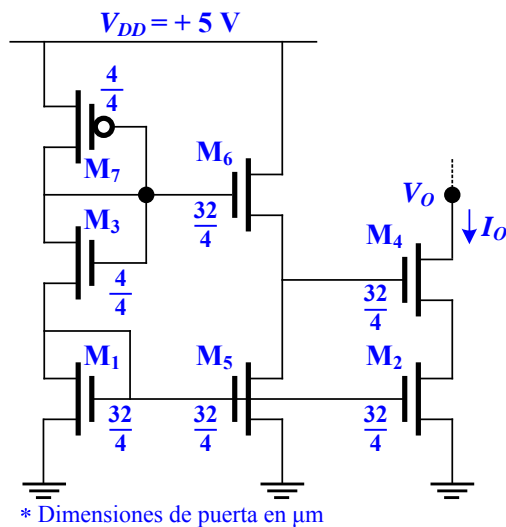
$$V_{GS3} = V_{TON} + \sqrt{\frac{2L_3 I_{REF}}{W_3 K'_n}}$$

$$V_{SG7} = |V_{TOP}| + \sqrt{\frac{2L_7 I_{REF}}{W_7 K'_p}}$$

ResPrB.II-21

Problema 3(f.4.a)

- MOSFET saturados y libres del efecto sustrato.



$$V_{DD} = V_{TON} + \sqrt{\frac{2L_1 I_{REF}}{W_1 K'_n}} +$$

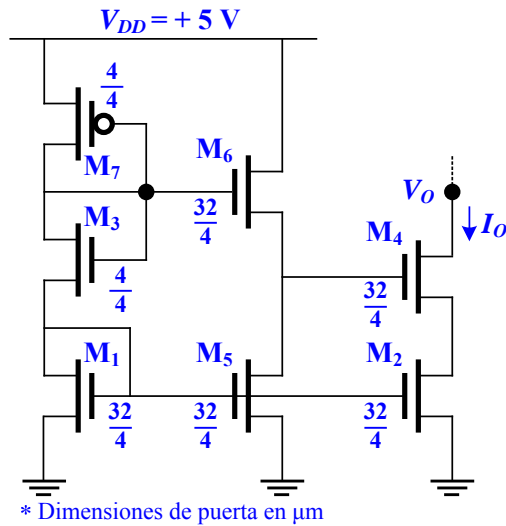
$$+ V_{TON} + \sqrt{\frac{2L_3 I_{REF}}{W_3 K'_n}} +$$

$$+ |V_{TOP}| + \sqrt{\frac{2L_7 I_{REF}}{W_7 K'_p}}$$

ResPrB.II-22

Problema 3(f.4.a)

- MOSFET saturados y libres del efecto sustrato.



$$I_{REF} = 39.75 \mu\text{A}$$

$$V_{GS1} = 1.1 \text{ V}$$

$$V_{GS3} = 1.64 \text{ V}$$

$$V_{SG7} = 2.26 \text{ V}$$

$$I_O = I_{D4} = I_{D2} = 39.75 \mu\text{A}$$

$$I_{D6} = I_{D5} = 39.75 \mu\text{A}$$

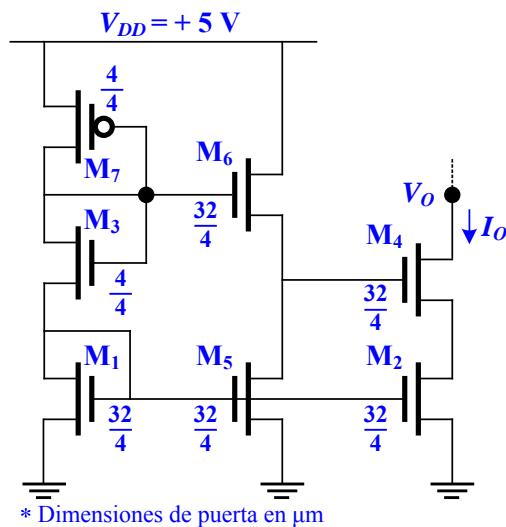
$$V_{GS4} = V_{GS2} = 1.1 \text{ V}$$

$$V_{GS6} = V_{GS5} = 1.1 \text{ V}$$

ResPrB.II-23

Problema 3(f.4.a)

- MOSFET saturados y libres del efecto sustrato.



$$M_6 \equiv \text{SAT} (V_{D6} > V_{G6})$$

$$V_{G6} = V_{GS1} + V_{GS3} = 2.74 \text{ V}$$

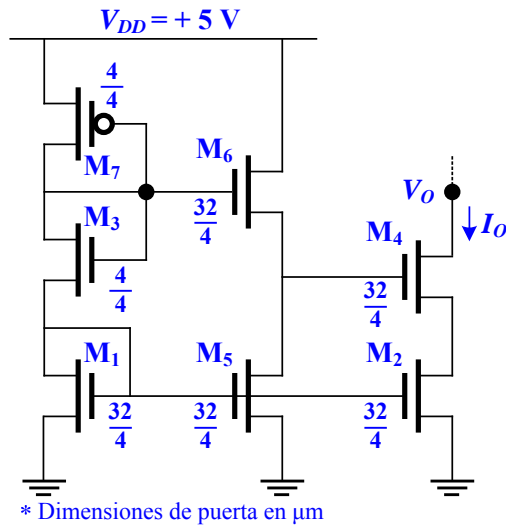
$$V_{G4} = V_{G6} - V_{GS6} = 1.64 \text{ V}$$

$$V_{DS5} = 1.64 \text{ V} \rightarrow M_5 \equiv \text{SAT}$$

ResPrB.II-24

Problema 3(f.4.b)

- MOSFET saturados y libres del efecto sustrato.



$$I_o = 39.75 \mu\text{A}$$

$$g_{m4} = \sqrt{2K'_n \frac{W}{L} I_{D4}}$$

$$= 266.9 \frac{\mu\text{A}}{\text{V}}$$

$$r_{o4} = r_{o2} = \frac{1}{\lambda_n I_{D2}} = 6.29 \text{ M}\Omega$$

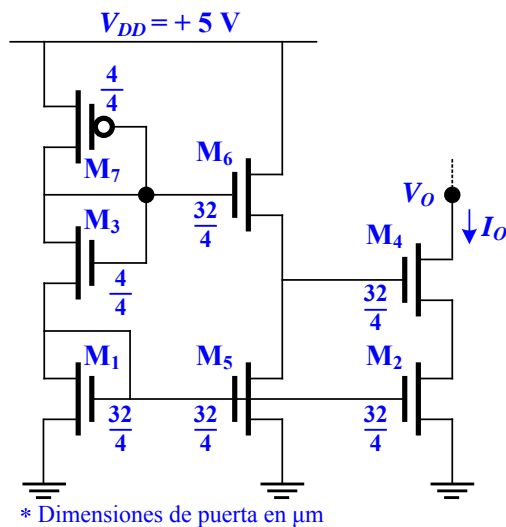
$$R_o = r_{o4} (1 + g_{m4} r_{o2}) + r_{o2}$$

$$= 10.57 \text{ G}\Omega$$

ResPrB.II-25

Problema 3(f.4.c)

- MOSFET saturados y libres del efecto sustrato.



$$V_{G4} = 1.64 \text{ V}$$

$$V_{S4} = V_{G4} - V_{GS4} = 0.54 \text{ V}$$

$$V_{DS2} = 0.54 \text{ V} \rightarrow M_2 \equiv \text{SAT}$$

$$V_{O(\text{min})} = V_{G4} - V_{TON} = 0.84 \text{ V}$$

ResPrB.II-26