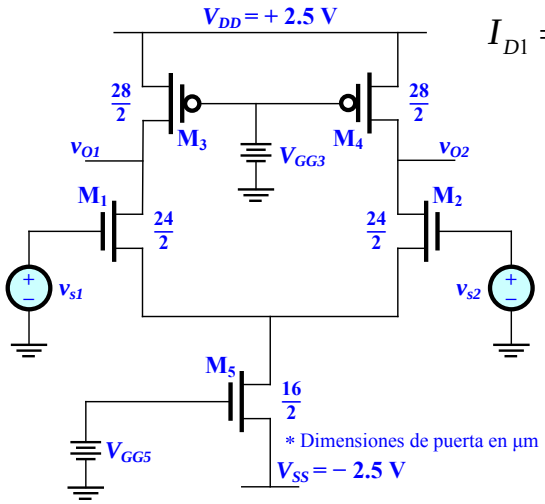
ELECTRÓNICA BÁSICA

Amplificadores Diferenciales
Problemas

Problema 1(a)

- Análisis en *dc*:



$$I_{D1} = 50\ \mu\text{A} \rightarrow I_{D5} = 100\ \mu\text{A}$$

$$V_{GS5} = V_{TON} + \sqrt{\frac{2L_5 I_{D5}}{W_5 K_n'}}$$

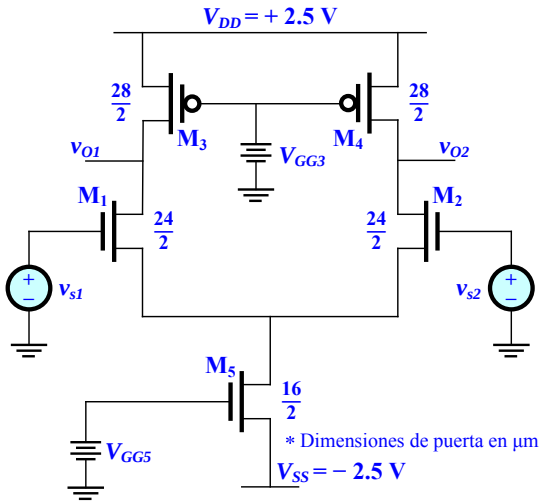
$$= 1.27\ \text{V}$$

$$V_{GG5} = V_{GS5} + V_{SS}$$

$$= -1.23\ \text{V}$$

Problema 1(a)

- Análisis en *ac*:



$$I_{DP3} = I_{D1} = 50\ \mu\text{A}$$
$$I_{DP4} = I_{D2} = 50\ \mu\text{A}$$
$$I_{D5} = 100\ \mu\text{A}$$

$$g_{m1} = 366.6\ \mu\text{A/V}$$
$$g_{ds1} = 0.5\ \mu\text{A/V}$$
$$g_{ds3} = 1\ \mu\text{A/V}$$
$$g_{ds5} = 1\ \mu\text{A/V}$$

ResPrB.IV-3

Problema 1(a)

- Análisis en *ac*:

$$A_{dm} = -\frac{g_{m1}}{g_{ds1} + g_{ds3}} = -244.4$$

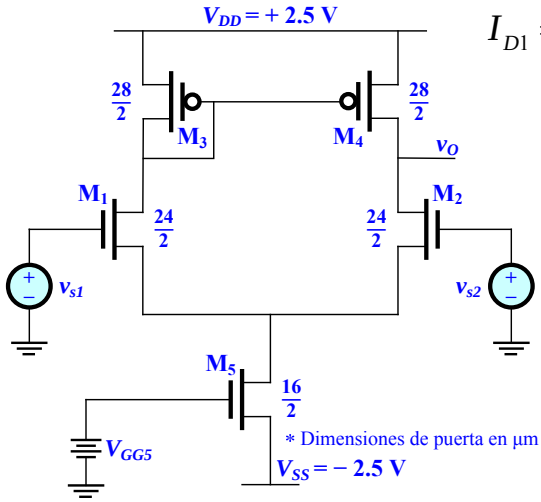
$$A_{cm} = -\frac{g_{m1}}{g_{ds1} + g_{ds3} + \dfrac{2g_{ds3}\left(g_{m1} + g_{ds1}\right)}{g_{ds5}}} = -0.5$$

$$v_{o1} = A_{dm}\left(v_{s1} - v_{s2}\right)/2 + A_{cm}\left(v_{s1} + v_{s2}\right)/2$$
$$v_{o2} = -A_{dm}\left(v_{s1} - v_{s2}\right)/2 + A_{cm}\left(v_{s1} + v_{s2}\right)/2$$
$$v_{o1} = -122.2\left(v_{s1} - v_{s2}\right) - 0.25\left(v_{s1} + v_{s2}\right)$$
$$v_{o2} = 122.2\left(v_{s1} - v_{s2}\right) - 0.25\left(v_{s1} + v_{s2}\right)$$

ResPrB.IV-4

Problema 1(b)

- Análisis en *dc*:



$$I_{D1} = 50\ \mu\text{A} \rightarrow I_{D5} = 100\ \mu\text{A}$$

$$V_{GS5} = V_{TON} + \sqrt{\frac{2L_5 I_{D5}}{W_5 K_n'}}$$

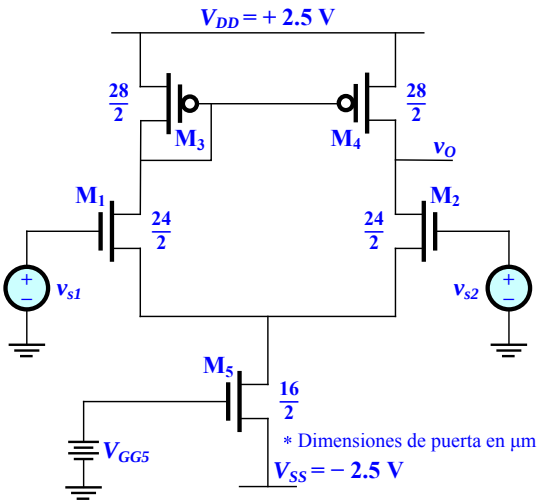
$$= 1.27\ \text{V}$$

$$V_{GG5} = V_{GS5} + V_{SS}$$

$$= -1.23\ \text{V}$$

Problema 1(b)

- Análisis en *ac*:



$$I_{DP3} = I_{D1} = 50\ \mu\text{A}$$

$$I_{DP4} = I_{D2} = 50\ \mu\text{A}$$

$$I_{D5} = 100\ \mu\text{A}$$

$$g_{m2} = 366.6\ \mu\text{A/V}$$

$$g_{ds2} = 0.5\ \mu\text{A/V}$$

$$g_{m4} = 245.3\ \mu\text{A/V}$$

$$g_{ds4} = 1\ \mu\text{A/V}$$

$$g_{ds5} = 1\ \mu\text{A/V}$$

Problema 1(b)

- Análisis en *ac*:

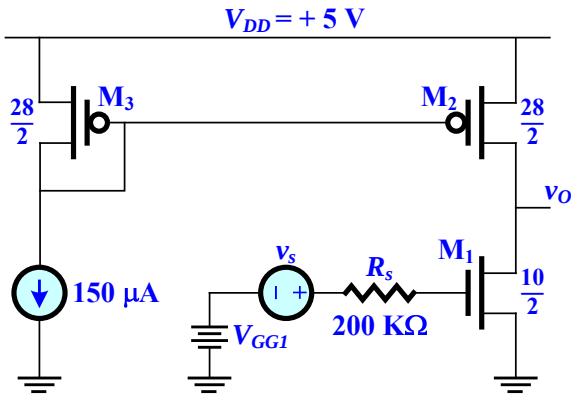
$$A_{dm} = \frac{g_{m2}}{g_{ds2} + g_{ds4}} = 244.4$$

$$A_{cm} = \frac{-g_{ds5} g_{ds2}}{2 g_{m4} \left(g_{ds2} + g_{ds4} \right)} = -0.68 \cdot 10^{-3}$$

$$v_{out} = A_{dm} \left(v_{i1} - v_{i2} \right) + A_{cm} \frac{\left(v_{i1} + v_{i2} \right)}{2} =$$
$$= 244.4 \cdot \left(v_{i1} - v_{i2} \right) - 0.34 \cdot 10^{-3} \cdot \left(v_{i1} + v_{i2} \right)$$

Problema 2

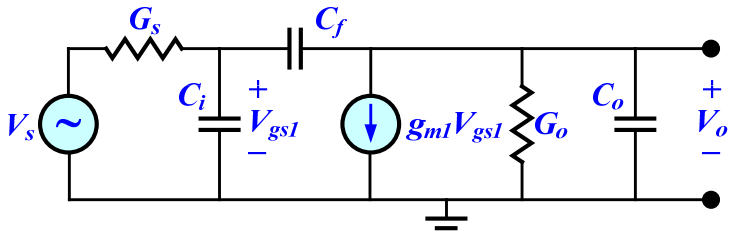
- Amplificador CMOS fuente común:



C_{gs1}	25 fF
C_{gd1}	2 fF
C_{gb1}	0.2 fF
C_{db1}	13 fF
C_{gd2}	5.6 fF
C_{db2}	34.2 fF

Problema 2

- Circuito de pequeña señal en alta frecuencia:



$$g_{m1} = 409.8\ \mu\text{A/V} \quad , \quad R_s = 200\ \text{K}\Omega$$

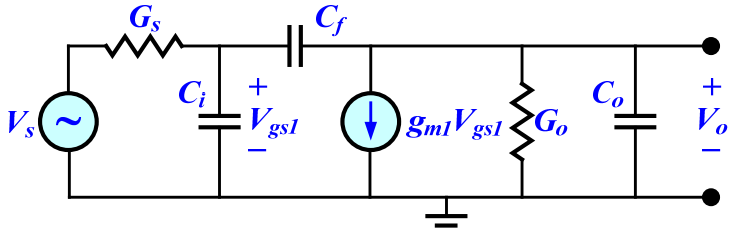
$$G_o = g_{ds1} + g_{ds2} = 4.5\ \mu\text{A/V} \quad \rightarrow \quad R_o = 222\ \text{K}\Omega$$

$$C_i = C_{gs1} + C_{gb1} = 25.2\ \text{fF} \quad , \quad C_f = C_{gd1} = 2\ \text{fF}$$

$$C_o = C_{gd2} + C_{db1} + C_{db2} = 52.8\ \text{fF}$$

Problema 2

- Ganancia de tensión:



$$\frac{V_o(s)}{V_s(s)} = \frac{R_o\left(sC_f - g_{m1}\right)}{b_2 s^2 + b_1 s + 1}$$

$$b_2 = R_s R_o \left(C_i C_o + C_i C_f + C_o C_f\right)$$

$$b_1 = R_s\left(1 + g_{m1} R_o\right) C_f + R_s C_i + R_o\left(C_o + C_f\right)$$

Problema 2

- Modelo completo:

$$\frac{V_o(s)}{V_s(s)} = \frac{R_o\left(sC_f - g_{m1}\right)}{b_2 s^2 + b_1 s + 1}$$

$$z_1 = 204.9 \times 10^9 \text{ rad/seg}$$

$$p_2 = -799 \times 10^6 \text{ rad/seg}$$

$$p_1 = -18.9 \times 10^6 \text{ rad/seg}$$

$$w_c = 18.95 \times 10^6 \text{ rad/seg} \quad \rightarrow \quad f_c = 3 \text{ MHz}$$

ResPrB.IV-11

Problema 2

- Aproximación de polo dominante:

$$p_1 \simeq -\frac{1}{R_s\left(1 + g_{m1}R_o\right)C_f + R_s C_i + R_o\left(C_o + C_f\right)}$$

$$p_2 \simeq -\frac{R_s\left(1 + g_{m1}R_o\right)C_f + R_s C_i + R_o\left(C_o + C_f\right)}{R_s R_o\left(C_i C_o + C_i C_f + C_o C_f\right)}$$

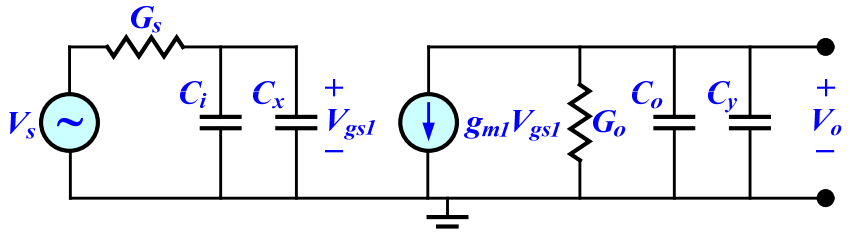
$$p_1 \simeq -18.5 \times 10^6 \text{ rad/seg} \quad \rightarrow \quad f_c = 2.9 \text{ MHz}$$

$$p_2 \simeq -818 \times 10^6 \text{ rad/seg}$$

ResPrB.IV-12

Problema 2

- Aproximación Miller:



$$A_{v0} = \frac{v_o}{v_{gs1}} = -g_{m1}R_o = -90.9$$

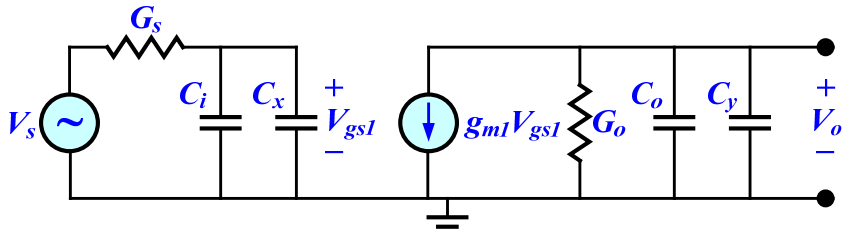
$$C_x \simeq \left(1 - A_{v0}\right)C_f = \left(1 + g_{m1}R_o\right)C_f = 183.9 \text{ fF}$$

$$C_y \simeq \left(1 - \frac{1}{A_{v0}}\right)C_f = \left(1 + \frac{1}{g_{m1}R_o}\right)C_f = 2 \text{ fF}$$

ResPrB.IV-13

Problema 2

- Aproximación Miller:

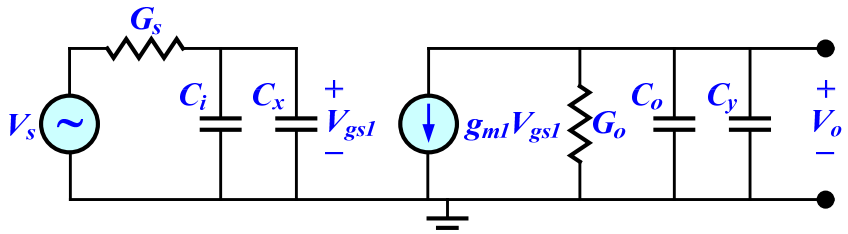


$$\frac{V_o(s)}{V_s(s)} = \frac{-g_{m1}R_o}{\left(1 + R_s\left(C_i + C_x\right)s\right)\left(1 + R_o\left(C_o + C_y\right)s\right)}$$

ResPrB.IV-14

Problema 2

- Aproximación Miller:



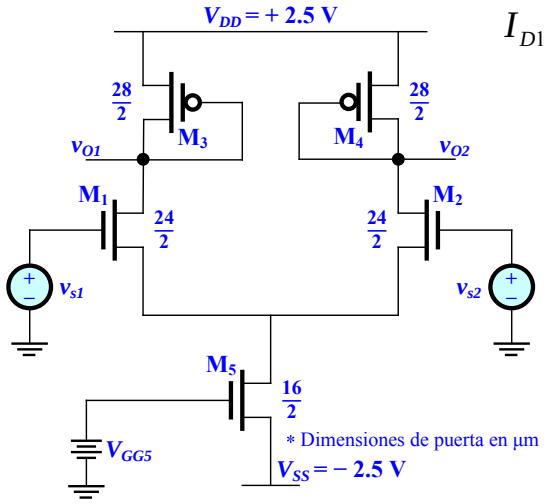
$$p_1 = -\left(R_s C_i + R_s\left(1+g_{m1}R_o\right)C_f\right)^{-1} = -23.9\times10^6 \text{ rad/seg}$$

$$p_2 = -\left(R_o C_o + R_o\left(1+\left(g_{m1}R_o\right)^{-1}\right)C_f\right)^{-1} = -82.1\times10^6 \text{ rad/seg}$$

$$f_c \simeq \left(2\pi\left(R_s C_i + R_s\left(1+g_{m1}R_o\right)C_f\right)\right)^{-1} = 3.8 \text{ MHz}$$

Problema 3

- Análisis en *dc*:



$$I_{D1} = 50\ \mu\text{A} \rightarrow I_{D5} = 100\ \mu\text{A}$$

$$V_{GS5} = V_{TON} + \sqrt{\frac{2L_5 I_{D5}}{W_5 K_n'}}$$

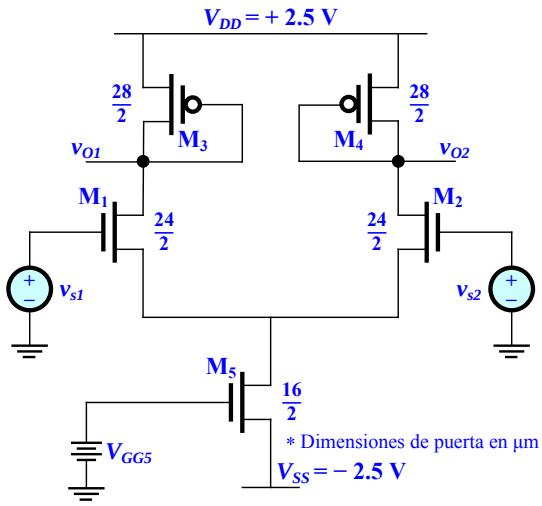
$$= 1.27 \text{ V}$$

$$V_{GG5} = V_{GS5} + V_{SS}$$

$$= -1.23 \text{ V}$$

Problema 3

- Análisis en *dc*:



$$V_{GS1} = V_{GS2} =$$

$$= V_{TON} + \sqrt{\frac{2L_2 I_{D2}}{W_2 K_n'}} =$$

$$= 1.07 \text{ V}$$

$$V_{SG3} = V_{SG4} =$$

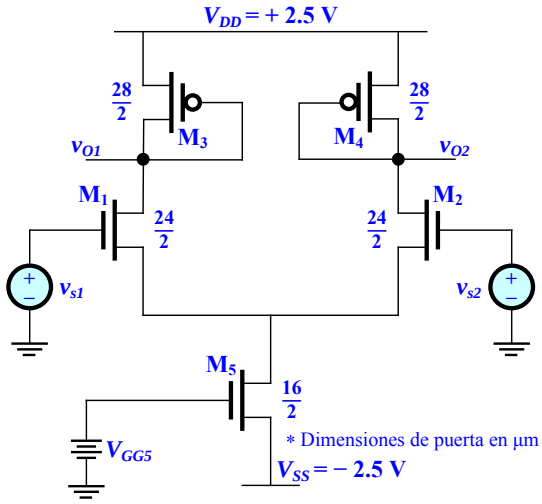
$$= |V_{TOP}| + \sqrt{\frac{2L_4 I_{DP4}}{W_4 K_p'}}$$

$$= 1.3 \text{ V}$$

ResPrB.IV-17

Problema 3

- Análisis en *ac*:



$$I_{DP3} = I_{D1} = 50\ \mu\text{A}$$

$$I_{DP4} = I_{D2} = 50\ \mu\text{A}$$

$$I_{D5} = 100\ \mu\text{A}$$

$$g_{m1} = 366.6\ \mu\text{A/V}$$

$$g_{ds1} = 0.5\ \mu\text{A/V}$$

$$g_{m3} = 245.3\ \mu\text{A/V}$$

$$g_{ds3} = 1\ \mu\text{A/V}$$

$$g_{ds5} = 1\ \mu\text{A/V}$$

ResPrB.IV-18

Problema 3

- Análisis en *ac*:

$$A_{dm} = -\frac{g_{m1}}{g_{ds1} + g_{m3} + g_{ds3}} = -1.48$$

$$A_{cm} = -\frac{g_{m1}}{g_{ds1} + g_{m3} + g_{ds3} + \dfrac{2\left(g_{m3} + g_{ds3}\right)\left(g_{m1} + g_{ds1}\right)}{g_{ds5}}} = -2 \cdot 10^{-3}$$

$$v_{o1} = -0.74\left(v_{s1} - v_{s2}\right) - \left(v_{s1} + v_{s2}\right) \cdot 10^{-3}$$

$$v_{o2} = 0.74\left(v_{s1} - v_{s2}\right) - \left(v_{s1} + v_{s2}\right) \cdot 10^{-3}$$