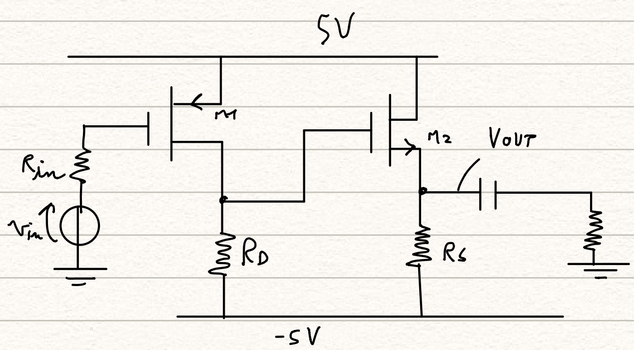
ESERCITAZIONE SUGLI AMPLIFICATORI A TRANSISTOR

es. 1 : TdE 10 Maggio 2013



Dati:

$\frac{1}{2}\mu_n C_{ox} = 100\mu A/V^2$

$|K_p| = 100\mu A/V^2$

$R_L = 10k\Omega$

$C = 47nF$

$r_0 = \infty$

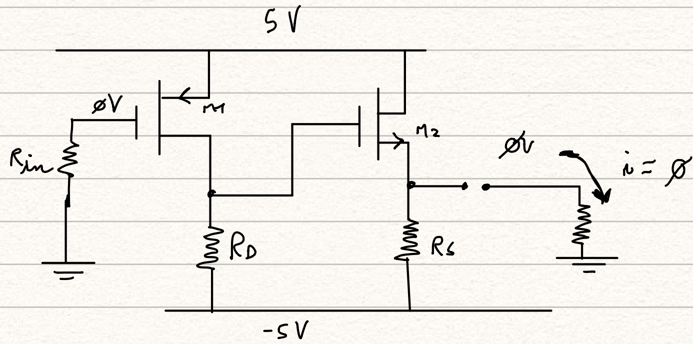
$V_{Tn} = |V_{Tp}| = 1V$

$R_{in} = 50\Omega$

$R_D = 3k\Omega$

$R_S = 900\Omega$

A) Calcolare la polarizzazione del circuito e dimensionare $\left(\frac{W}{L}\right)_2$ per avere $I_{D_{M_2}} = 2mA$



$V_{GS_{M_1}} = -5V < V_{Tp}$ PMOS ACCESO

HP. PMOS IN SATURAZIONE

$I_D = K_p(V_{GS}-V_T)^2 = -100\mu A/V^2 \; (-5V+1V)^2 = -1{,}6mA$

$V_{RD} = I_D \cdot R_D = -1{,}6mA \cdot 3k\Omega = -4{,}8V$

$V_{GM_2} = -5V - (-4{,}8V) = -0{,}2V$

$V_{SM_2} = -5V + I_{DM_2} \cdot R_S = -5 + 2mA \cdot 0{,}9k\Omega = -5V + 1{,}8V = -3{,}2V$

M_2 È IN SATURAZIONE (non ho neanche bisogno di ipotesi)

$I_{DM_2} = K_n(V_{GS}-V_T)^2 = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)_{M_2}(V_{GS}-V_T)^2$

$I_{D M_2} = 2mA$

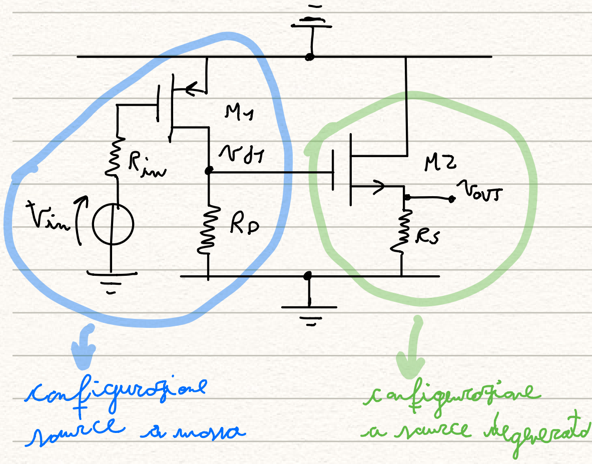
$\left(\frac{W}{L}\right)_N = 5$

$g_{mM_1} = \frac{2I_D}{V_{GS}-V_T} = \frac{2(-1{,}6mA)}{-5V+1V} = +0{,}8\,mA/V$

$g_{mM_2} = 2I_D \; = 2 \cdot 2mA \; = 2mA/V$

$$\overline{V_{GS}-V_T} \qquad \overline{+3V-1V}$$

b) $\frac{V_{OUT}}{V_{in}}$ a bassa frequenza (C circuito aperto)



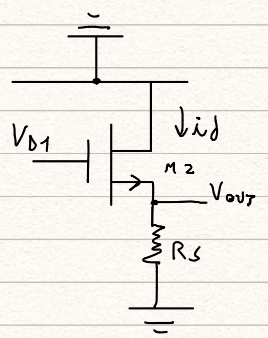
$$\frac{V_{OUT}}{V_{IN}} = \frac{V_{d1}}{V_{IN}} = \frac{V_{OUT}}{V_{d1}}$$

$$V_{gM1} = V_{IN} \longrightarrow V_{gs\,M1} = V_{IN}$$

$$i_d = g_m V_{gs} \longrightarrow i_{dM1} = g_{m1} V_{in}$$

$$V_{d1} = -i_{dM_1} R_d = -g_{m1} R_d V_{IN}$$

$$\frac{V_{d1}}{V_{IN}} = -g_{m1} R_D$$



$$\begin{cases} i_d = g_m V_{gs} \\ V_S = i_d R_S \end{cases}$$

$$V_S = V_G \cdot \frac{R_S}{R_S + 1/g_m} = V_g \frac{g_m R_S}{1 + g_m R_S}$$

$$\frac{V_{OUT}}{V_{d1}} = \frac{g_m R_S}{1 + g_m R_S}$$

c) Determinare le singolarità introdotte da C in $\frac{V_{OUT}}{V_{IN}}$

$$\left.\frac{V_{OUT}}{V_{IN}}\right|_{BF} = -1{,}54$$

$$\left.\frac{V_{OUT}}{V_{IN}}\right|_{AF} = -g_{m1} R_D \cdot \left(\frac{g_{m2} \, R_S // R_L}{1 + g_{m2} R_S // R_L} \right) = -1{,}49$$

(C corto circuito)

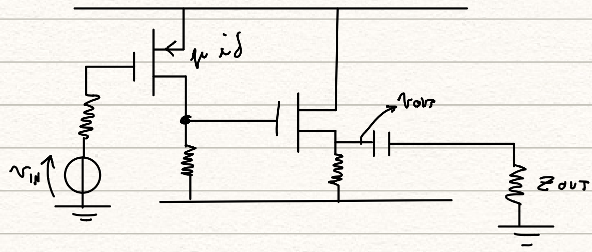
POLO: $\tau_P = C \cdot R_{eq}$

$$R_{eq} = R_L + (R_S // 1/g_{m2})$$

$\tau_P = 485$ ps

$$f_P = \frac{1}{2\pi\tau_P} = 328\ \text{Hz}$$

ZERO:



$v_{IN} \neq 0 \rightarrow v_{gM2} \neq 0$

$v_{OUT} = i_d \cdot Z_{out}$

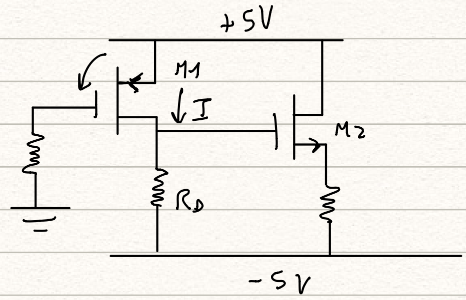
$v_{OUT} = 0 \rightarrow Z_{OUT} = 0$

$Z_{OUT} = R_S // \left(\frac{1}{sC} + R_L\right)$

$\frac{1}{sC} + R_L = 0 \qquad s = -\frac{1}{R_L \cdot C}$

$\tau_z = C \cdot R_L = 470\ \mu s \qquad f_z = 339\ \text{Hz}$

D) Determinare R_{DMAX} per garantire M_1, M_2 in saturazione in polarizzazione



M_2 è SEMPRE IN SATURAZIONE

$V_{GS} = -5V$

I_{DM1}, con M_1 in SAT

$I_{DM1} = K_p(V_{GS} - V_T)^2 = -1{,}6\ mA$

$I = -I_{DM1} = +1{,}6\ mA$

$V_D < 1\ V$

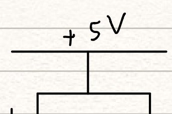
$V_D = -5V + I R_D$

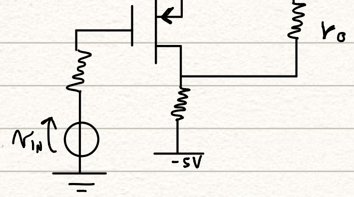
$-5V + I R_D < 1V$

$R_D < 3{,}75\ k\Omega$

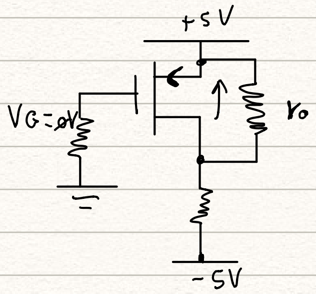
$R_{DMAX} = 3{,}75\ k\Omega$

E) Calcolare polarizzazione e $\frac{v_1}{v_{IN}}$ considerando solo il I stadio e r_0 di M_1 pari a $30\ k\Omega$





① POLARIZZAZIONE



$V_{GS} = -5V$

hp M1 in SAT.

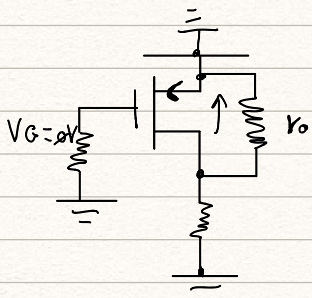
$I_D = K_p (V_{GS} - V_T)^2 = -1{,}6\,mA$

$-I_D + \frac{5V - V_D}{r_o} = \frac{V_D + 5V}{r_o} \longrightarrow V_D = 0{,}273V$

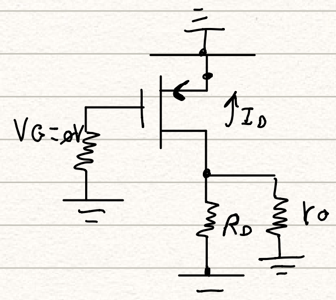
$I_{r_o} = \frac{5V - 0{,}273V}{r_o} = 0{,}157\,mA$

$g_m = \frac{2 I_D}{V_{ov}} = +0{,}8 \frac{mA}{V}$

$\frac{v_{d1}}{v_{IN}}$



eq.

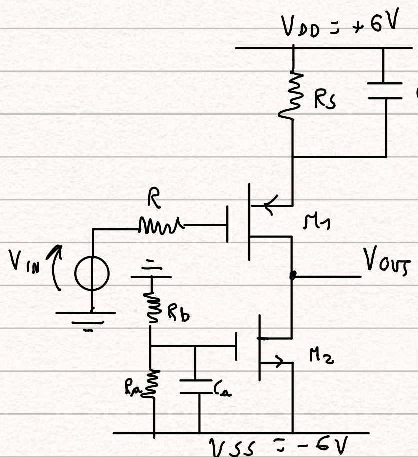


$i_d = v_{gs} \cdot g_m = g_{m1} v_{IN}$

$v_{d1} = -i_d (R_d // r_o)$

$\frac{v_d}{v_{IN}} = -g_m (R_d // R_o) = -2{,}18$

esercizio 2: TDE 9 LUGLIO 2018



$K_N = |K_P| = 0{,}5\,mA/V^2$

$V_{TN} = |V_{TP}| = 1V$

$R_S = 8K\Omega$

$R = 50\Omega$

$R_a = 200K\Omega$

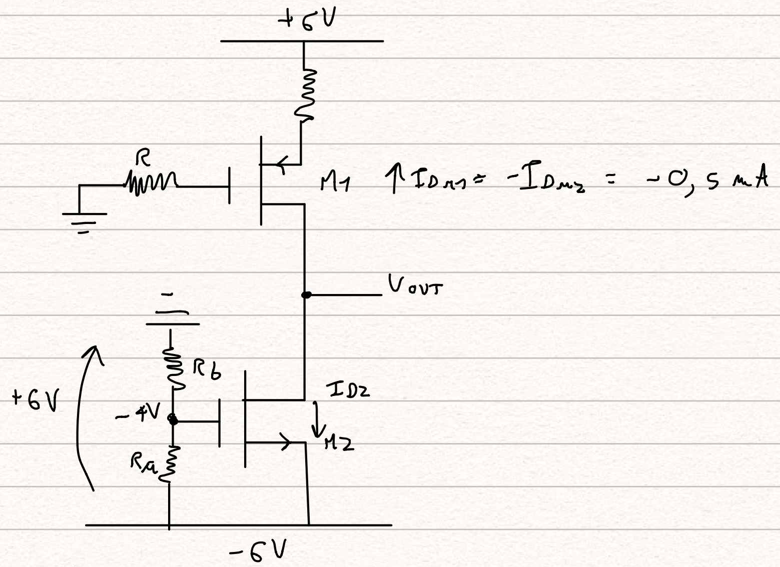
$R_b = 400K\Omega$

$C_a = 10\,\mu F$

$C = 100\,nF$

A) Polarizzazione

Range di tensioni V_{OUT} per il corretto funzionamento del circuito



$$V_{RA} = +6V \frac{R_a}{R_a + R_b} = +2V = V_{GSM2}$$

HP.: M2 in SAT

$$I_{D2} = K_N (V_{GS2} - V_{T2})^2 = 0,5\ mA$$

$$V_S = +6V + I_{DM1} \cdot R_S = 6V - 0,5\ mA \cdot 8k\Omega = +2V$$

$$I_{DM1} = -0,5\ mA$$

HP: M1 sia in saturazione $\qquad V_{GS1} = -1V - 1V = -2V$

$$I_{DM1} = K_P (V_{GS1} - V_{T1})^2$$

$$V_{GS1} = \sqrt{\frac{I_{DM1}}{K_P}} + V_{T1}$$

M2 è in saturazione

$$\underline{V_{OUT} > V_{GM2} - V_{T2}} = -4V - 1V = -5V$$

(Con $V_{OUT} = -5V$
$V_{GDM2} = -4V - (-5V) = +1V = V_T$ pinch off)

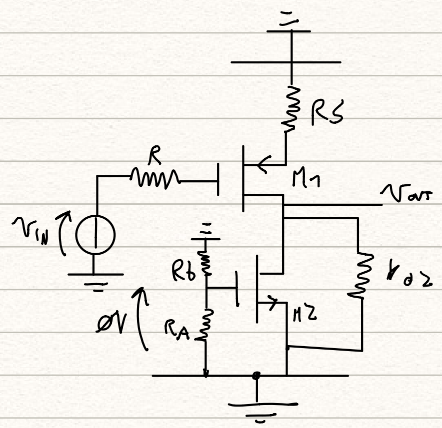
M1 in saturazione se

$$V_{OUT} < V_{GM1} - V_{TP} = 0V - (-1V) = +1V$$

(con $V_{OUT} = 1V$ $\quad V_{GDM1} = \emptyset V - 1V = -1V$ pinch off)

$V_{OUT} \in [-5V ; +1V]$

b) $\frac{V_{OUT}}{V_{IN}}\Big|_{BF}$ con $r_{oM2} = 65 K\Omega$
($r_{oM1} = \infty$)



$V_{GS_{M2}} = \emptyset \to i_{dM2} = \emptyset$

$V_{gM1} = V_{IN} \longrightarrow V_{gsM1} = V_g \cdot \frac{1/g_{m1}}{1/g_{m1} + RS}$

$i_{dM1} = g_{m1} V_{gs1}$

$i_{dM1} = V_g \frac{g_{m1}}{1+g_{m1}RS} = V_{IN} \cdot \frac{g_{m1}}{1+g_{m1}RS}$

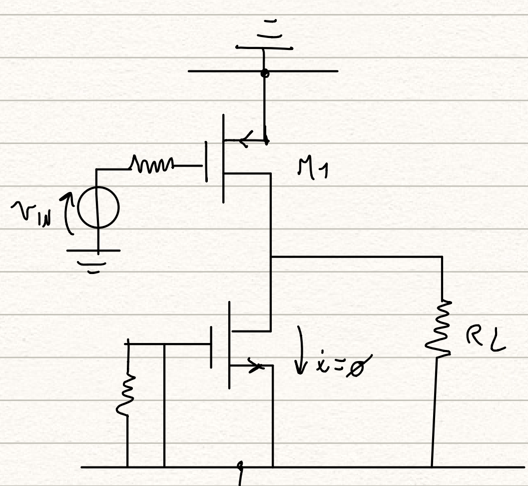
$g_{m2} = \frac{2 I_D}{V_{GS}-V_T} = \frac{-1mA}{-1V} = +1 mA/V$

$V_{OUT} = -I_{dM1} r_{o2}$

$V_{OUT} = -V_{IN} \cdot \frac{g_{m1} \cdot r_{o2}}{1+g_{m1}RS}$

$\frac{V_{OUT}}{V_{IN}} = -\frac{g_{m1} r_{o2}}{1+g_{m1}R_S} = \frac{-1 mA/V \cdot 65 K\Omega}{1+1mA/V \cdot 8K\Omega} = -7,22$

c) $\frac{V_{OUT}}{V_{IN}}\Big|_{AF}$



$V_{GS_{M1}} = V_{IN}$

$i_d = g_{m1} V_{IN}$

$V_{OUT} = -g_{m1} r_{o2} V_{IN}$

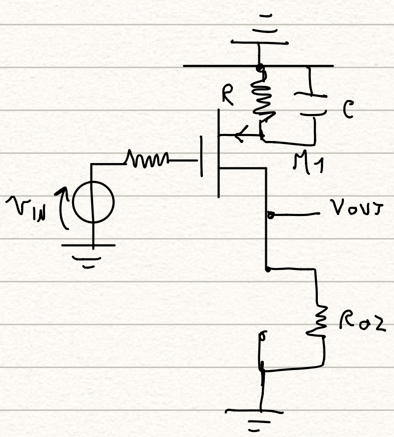
$\frac{V_{OUT}}{V_{IN}}\Big|_{AF} = -g_{m1} r_{o2} = -65$

d) Singolarità nel trasferimento $\frac{V_{OUT}}{V_{IN}}$

Ca non introduce alcuna singolarità

C introduce sia un polo che uno zero

ZERO



$V_{OUT} = -i_d \cdot r_{o2}$

$V_{OUT} = 0$ se $i_d = 0$

$i_d = 0$ se $V_{GS} = 0$ ($i_d = g_m V_{gs}$

$V_{gs} = V_{IN} \cdot \frac{1/g_{m1}}{1/g_{m1} + Z_s}$ dove $Z_s = \frac{1}{sC} \parallel R_s$

$V_{GS} \to 0$ se $Z_S \to \infty$

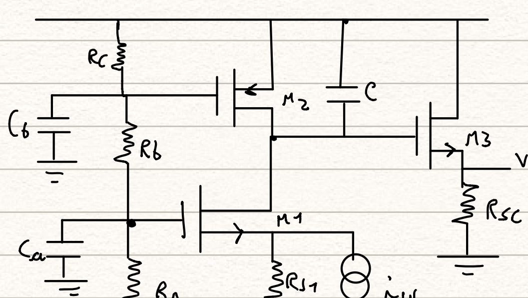
$Z_S = \frac{R_S}{1+sCR_S} \longrightarrow \infty$ $\quad s = -\frac{1}{CR_S}$

$\tau_z = C \cdot R_S =$?

?

$\tau_p : 88,9\ \mu s \longrightarrow F_p = 1,79$ kHz

esercizio 3: TdE 11 settembre 2018



$|K_p| = 1\ mA/V^2$

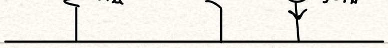
$|V_T| = 1V$

$\frac{1}{2}\mu_n C_{ox} = 100\ \mu A/V^2$

$\left(\frac{W}{L}\right)_3 = 10$

$R_a = 25\ k\Omega$

$R_b = 15\ k\Omega$



$R_C = 20\,\Omega$

$C_a = C_b = 470\,nF$

$R_{S1} = 0{,}5\,k\Omega$

$R_{S2} = 2\,k\Omega$

$C = 2\,pF$

a) Polarizzazione

Determinare $\left(\frac{W}{L}\right)_{M1}$

affinché $|I_D|$ in tutti i MOS sia 1 mA in polarizzazione

$V_{SM1} = 1\,mA \cdot R_{S1} = +0{,}5\,V$

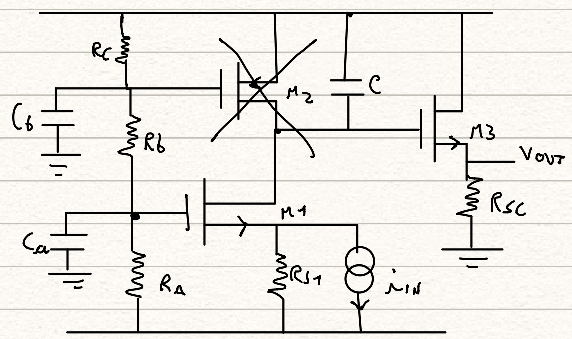
$V_{OUT} = 1\,mA \cdot R_{S2} = +2\,V$

$V_{GM3} = \sqrt{\frac{I_D}{K_3}} + V_S + V_T = 4\,V$

$\left(\frac{W}{L}\right)_{M1} = 10$

b) $\frac{v_{OUT}}{v_{IN}}$ a media f (C_a, C_b corto circuito, C circ. aperto)

considerando $r_{o2} = 100\,k\Omega$



$v_{d1} = -i_{d1} \cdot r_{o2}$

$v_{d1} = -i_{IN} \cdot \frac{R_{S1}}{R_{S1} + 1/g_{m1}} \cdot r_{o2}$

$\frac{v_{d1}}{i_{in}} = \frac{-g_m R_{S1}}{1 + g_m R_{S1}} \cdot r_{o2} = -40\,k\Omega$

$v_{GS\,M2} = \emptyset \rightarrow i_{d\,M2} = \emptyset$

$i_{d\,M1} = i_{IN} \cdot \frac{R_{S1}}{R_{S1} + 1/g_{m1}}$

$\frac{v_{OUT}}{v_{d1}} = \frac{R_{S2}}{R_{S2} + 1/g_{m3}} = + \frac{g_{m3} R_{S2}}{1 + g_{m3} R_{S2}}$

$\frac{v_{OUT}}{i_{IN}} = \frac{-g_{m1} R_{S1}}{1 + g_{m1} R_{S1}} \cdot \frac{g_{m3} R_{S2}}{1 + g_{m3} R_{S2}}$