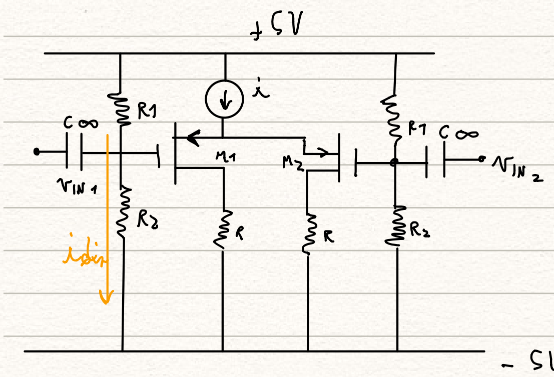
ESERCITAZIONE STADI DIFFERENZIALI

esercizio 1



(A) GEN. DI CODA IDEALE

$|V_{TP}| = 1V$

$K_P = -\frac{1}{2} \mu_P C_{ox} \left(\frac{W}{L}\right)_P = -50 \mu A/V^2$

$R_1 = R_2 = 100 \ K\Omega$

$R = 10 \ K\Omega$

$I = 400 \mu A$

A) POLARIZZAZIONE

1 spengo i generatori forzanti
2 capacità circuiti aperti
3 MOS $\underline{\underline{HP}}$ saturi

$$V_{G1} = V_{G2} = -5V + \frac{R_1}{R_1+R_2} \left(5V - (-5V)\right)] = -5V + 5V = 0 \ V \quad 1/2$$

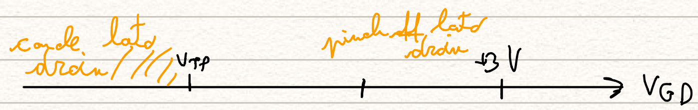
$$I_{P\,mos} = -I_D = |K_P| \left(V_{GS} - V_{TP}\right)^2 \longrightarrow V_{GS} = -\sqrt{\frac{-I_D}{K_P}} + V_{TP} = 3V$$

$I_{P\,mos} = \frac{I}{2} = 200 \mu A$ per la simmetria dello stadio e poiché $V_{GS1} = V_{GS2}$

$$\Delta V_R = I_{P\,mos} R = 200\mu A \cdot 10 K\Omega = 2V$$

$$\hookrightarrow V_{D1} = V_{D2} = -5V + \Delta V_R = -5V + 2V = -3V$$

$$V_{GD1} = V_{GD2} = V_G - V_D = 0 - (-3V) = +3V$$



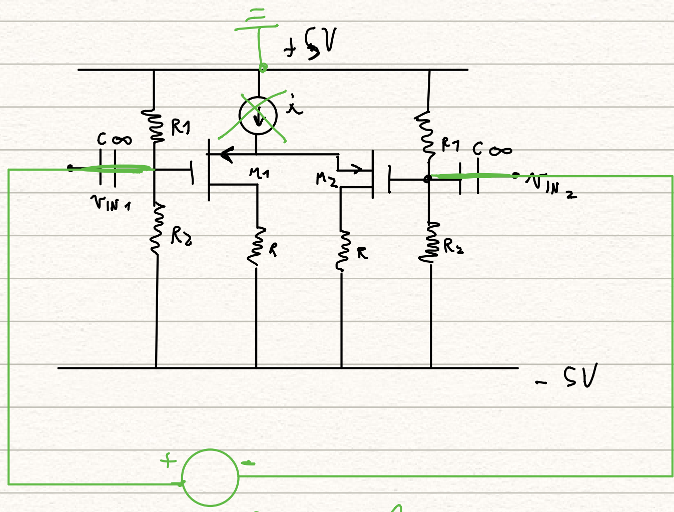
$$I_{div} = \frac{5V - (-5V)}{R_1 + R_2} = \frac{10V}{200 K\Omega} = 50 \mu A$$

$$g_m = 2 \underset{<0}{K_P} \left(\underset{<0}{V_{GS_P}} - V_{TP}\right) = \frac{2 I_D}{V_{ov}} = \frac{-400 \mu A}{-2V} = 200 \mu A/V = 0{,}2 \ mS$$

$$g_m = \frac{\overset{<0}{I_D}}{\underbrace{V_{GS} - V_{TP}}_{V_{ov}} \ {<0}} > 0 !!$$

V_{ov} tensione di overdrive

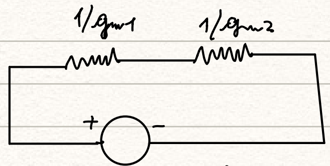
B) COMPORTAMENTO SU SEGNALE DIFFERENZIALE



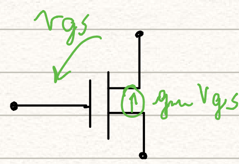
$v_{diff} = v_{IN_1} - v_{IN_2}$

$R_1 // R_2 = R_{//}$

1) Eq. thevenin dai SOURCE



$v_{eq} = v_{diff}$



$$i = \frac{v_{eq}}{1/g_{m1} + 1/g_m} = \frac{v_{diff}}{2/g_m} = g_m \frac{v_{diff}}{2} \qquad g_{m1} = g_{m2}$$

$v_{o1} = -iR$

$v_{o2} = iR$

USCITA DOUBLE ENDED

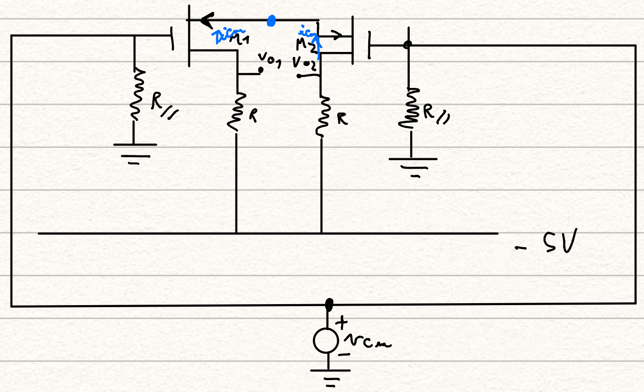
$$v_{OUT_{DE}} \triangleq v_{o2} - v_{o1} = iR - (-iR) = 2iR$$

?

USCITA SINGLE ENDED

$$v_{OUT}\big|_{SE} \triangleq v_{o1} = -g_m R/2 = -1$$
$$\triangleq v_{o2} = g_m R/2 = 1$$

C) COMPORTAMENTO SU SEGNALE DI MODO COMUNE



$i_{cm} + i_{cm} = 0 \qquad 2 i_{cm} = 0 \rightarrow i_{cm} = 0$

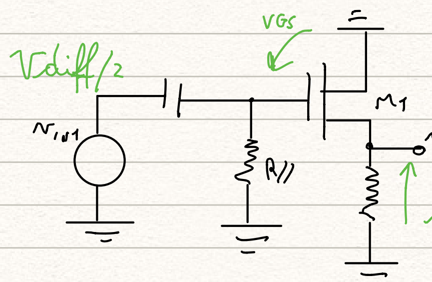
$G_{cm}\big|_{DE} \triangleq \dfrac{v_{o1} + v_{o2}}{2} \dfrac{1}{v_{cm}}$ DOUBLE ENDED

$G_{cm}\big|_{SE} \triangleq \dfrac{v_{o1}}{v_{cm}} = \dfrac{v_{o2}}{v_{cm}}$ SINGLE ENDED

$G_{cm} = 0$!!!

↳ CMRR $\rightarrow \infty$

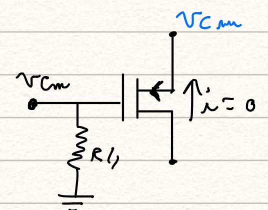
6bis) COMPORTAMENTO DIFFERENZIALE - ANALISI CON MEZZO CIRCUITO



$v_{o1} = -g_m \dfrac{v_{diff}}{2} R$

$g_m v_{GS} = g_m \dfrac{v_{diff}}{2}$

c bis) COMPORTAMENTO SU MODO COMUNE CON MEZZO CIRCUITO



$i = g_m V_{GS}$

$g_m \neq 0$

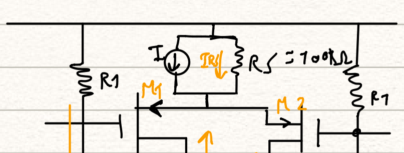
↳ $V_{GS} = 0$

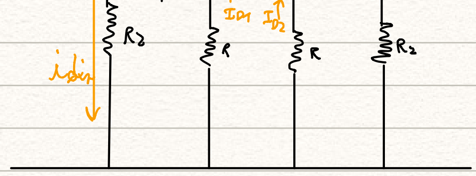
$v_{source} = V_{GATE} = v_{cm}$

B GEN. DI CODA REALE

$R_1 = R_2 = 100 \, k\Omega$

$I = 400 \, \mu A$





$I_{D1} + I_{D2} + I + I_{RS} = 0$

$I_{RS} = \dfrac{V_S - 5V}{R_S}$

$I_{D1} = K_P \left(V_{GS1} - V_{TP} \right)$

$V_{G1} - V_{S1}$

$V_{S1} = V_{S2} = V_S$

approssimando:

$I_{D1} \simeq -I_1$

$I_1 = I_2 \cong \dfrac{I}{2} + \dfrac{5V - V_S}{R_S} \dfrac{1}{2} = 200\mu A + \dfrac{5V - 3V}{100 k\Omega} \dfrac{1}{2} = 210 \mu A$

$10 \mu A \ll 200 \mu A$ OK l'approssimazione è valida

$g_m = 205 \ \mu A/V$ $\quad (V_{GS}) = 3{,}05 V$

SEGNALE DIFFERENZIALE:

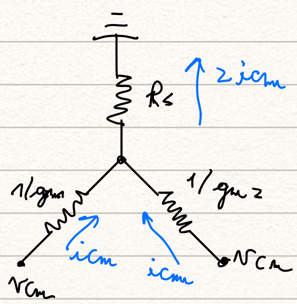
in R_S non scorre corrente se lo stadio è simetrico

↳ $i = v_{diff} / \left(1/g_{m1} + 1/g_{m2} \right) = g_m v_{diff}/2$

NON CAMBIA NULLA

SEGNALE DI MODO COMUNE

eq. thevenin al source



$2 i_{cm} = \dfrac{v_{cm}}{1/g_{m1} \,||\, 1/g_{m2} + R_S}$

$i_{cm} = \dfrac{v_{cm}}{\frac{1}{2} \, 1/g_m + R_S} \cdot \dfrac{1}{2} = \dfrac{v_{cm}}{1/g_m + 2 R_S}$

$$v_{o1} = v_{o2} = -i_{cm} R = -\frac{v_{cm}}{1/g_m + 2R_S} R$$

DOUBLE ENDED $\quad G_{cm} \triangleq \dfrac{\frac{v_{o1}+v_{o2}}{2}}{v_{cm}} = -\dfrac{R}{1/g_m + 2R_S} = -0,05$

SINGLE ENDED $\quad G_{cm} \triangleq \dfrac{v_{o1,2}}{v_{cm}} = -\dfrac{R}{1/g_m + 2R_S} = -0,05$

$$CMRR = \left| \frac{G_{diff}}{G_{cm}} \right| = \frac{2}{0,05} = 40 \longrightarrow 32\,dB$$