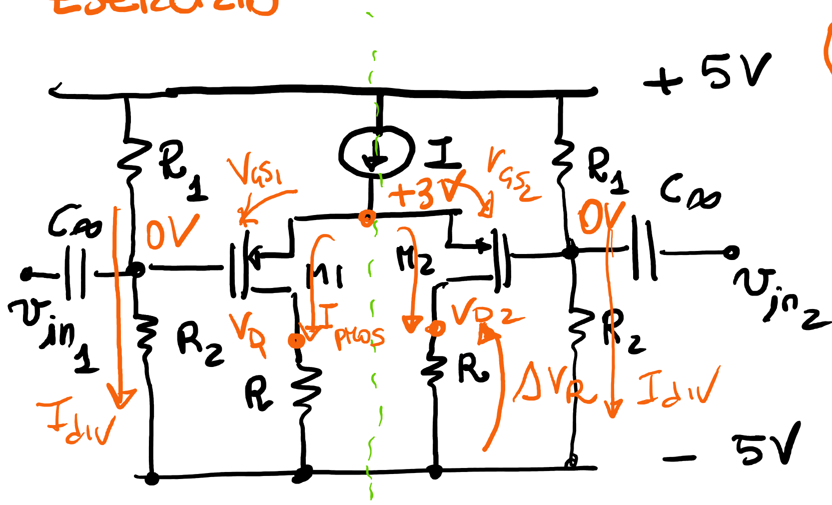
Esercitazione stadi differenziali

mercoledì 6 maggio 2020 10:16

ESERCIZIO



(A) GEN. DI CODA IDEALE

$|V_{Tp}| = 1V$

$k_p = -\frac{1}{2}\mu_p C_{ox}\left(\frac{W}{L}\right)_p = -50\mu A/V^2$

$R_1 = R_2 = 100k$

$R = 10 k\Omega$

$I = 400\mu A$

a) POLARIZZAZIONE

1. spengo gen. forzanti
2. capacità circ. aperti
3. MOS (Hp) SATURI ~~OK~~ verificata

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

$$= -5V + 5V = 0 V$$

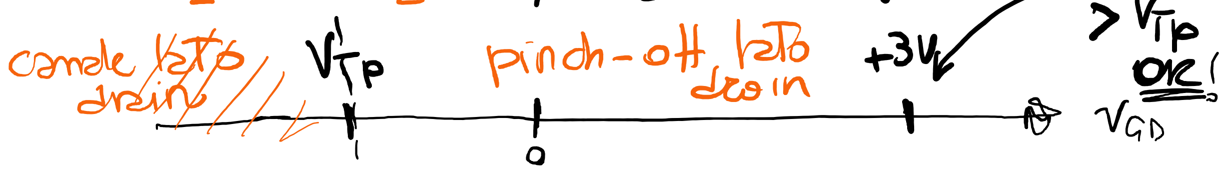
$$I_{pMOS} = -I_D = |k_p| (V_{GS} - V_{Tp})^2 \Rightarrow V_{GS} = -\sqrt{\frac{I_D}{k_p}} + V_{Tp} = -3V$$

$I_{pMOS} = \frac{I}{2} = 200\mu A$ per la simmetria dello stadio e poiché $V_{GS_1} = V_{GS_2}$

$\Delta V_R = I_{pMOS} R = 200\mu A * 10k\Omega = 2V$

↳ $V_{D_1} = V_{D_2} = -5V + \Delta V_R = -5V + 2V = -3V$

$V_{GD_1} = V_{GD_2} = V_G - V_D = 0 - (-3V) = +3V > V_{Tp}$ **OK!**



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

v_{div} : $\frac{\quad}{R_1+R_2} = \frac{\quad}{200k\Omega} = \ldots$

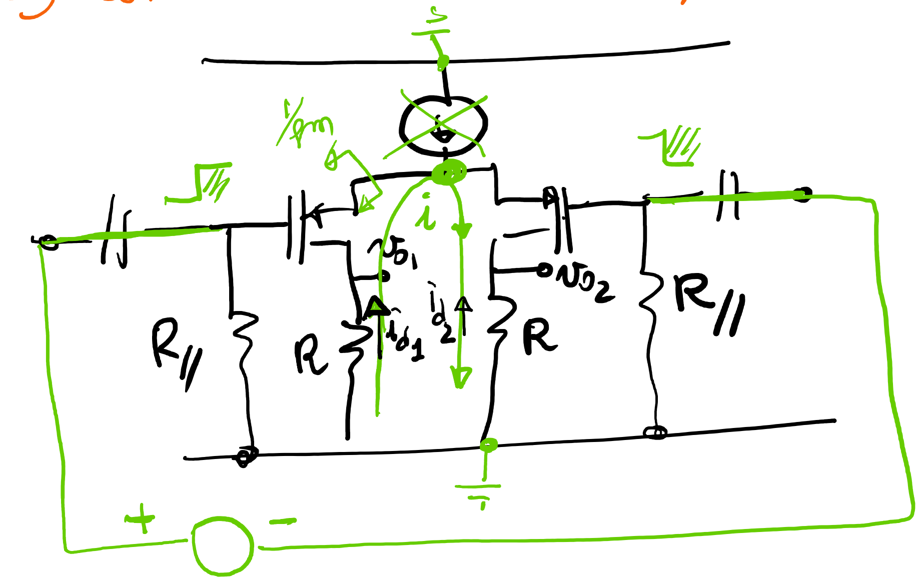
$$g_m = 2k_p\,(V_{GS_p} - V_{Tp}) = \frac{2I_D}{V_{OV}} = -\frac{I/2 \cdot 2}{V_{OV}} = -\frac{400\,\mu A}{-2V} = 200\,\mu A/V = 0.2\,mS$$

($k_p < 0$, $(V_{GS_p}-V_{Tp}) < 0$)

$$g_m = \frac{2I_D}{V_{GS}-V_{Tp}} > 0 \;!!$$

($I_D < 0$; $V_{GS}-V_{Tp} = V_{OV} < 0$ ← tensione di overdrive)

b) COMPORTAMENTO SU SEGNALE DIFFERENZIALE



$R_1 \parallel R_2 = R_{\parallel}$

$i_{d_1} = g_{m_1} v_{gs_1}$

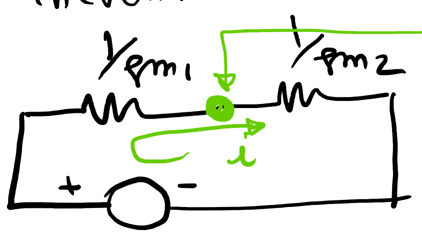
$i_{d_2} = g_{m_2} v_{gs_2}$

$i_{d_1} + i_{d_2} = 0$

$v_{gs_1} - v_{gs_2} = v_{diff}$

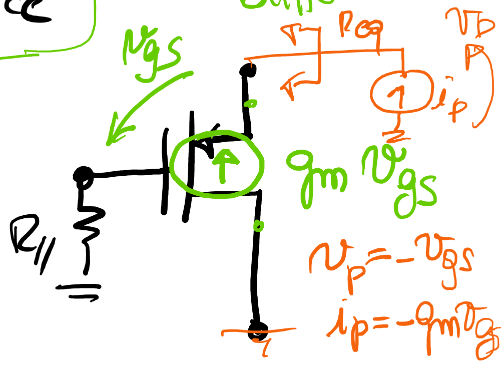
$v_{diff} = v_{in_1} - v_{in_2}$

1. Eq. Thevenin dei source



$v_{eq} = v_{diff}$

non si muove su segnale differenziale!



$v_p = -v_{gs}$

$i_p = -g_m v_{gs}$

$$i = \frac{v_{eq}}{1/g_{m_1} + 1/g_{m_2}} = \frac{v_{diff}}{2/g_m} = g_m \frac{v_{diff}}{2}$$

$g_m = g_{m_1} = g_{m_2}$

$$R_{eq} \triangleq \frac{v_p}{i_p} = \frac{v_p}{+g_m v_p} = 1/g_m$$

$v_{o_1} = -iR$

$v_{o_2} = iR$

USCITA DOUBLE ENDED

USCITA DOUBLE ENDED

$$v_{out_{DE}} \triangleq v_{o_2} - v_{o_1} = iR - (-iR) =$$
$$= 2iR = 2 g_m \frac{v_{diff}}{2} R =$$
$$= g_m v_{diff} R$$

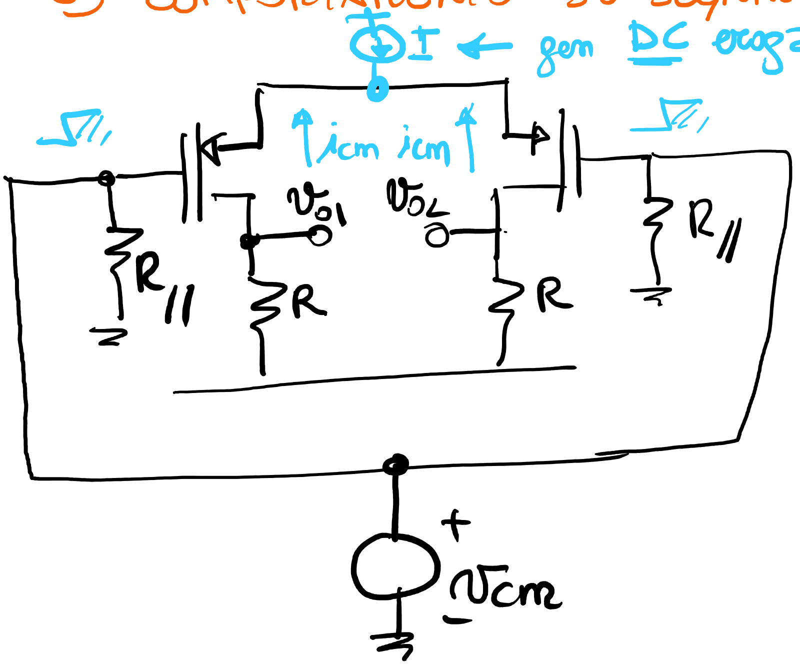
$\hookrightarrow G_{diff}\Big|_{double\ ended} = \dfrac{v_{o_2} - v_{o_1}}{v_{diff}} = g_m R =$
$= 0.2\,mA/V * 10k\Omega =$
$= 2$

USCITA SINGLE ENDED

$$v_{out}\Big|_{SE} \triangleq v_{o_1} = -g_m R/2 = -1$$
$$\triangleq v_{o_2} = g_m R/2 = 1$$

c) COMPORTAMENTO SU SEGNALE DI MODO COMUNE

I ← gen DC eroga su segnale corrente nulla



$i_{cm} + i_{cm} = 0$ $2 i_{cm} = 0 \Rightarrow i_{cm} = 0$

$G_{cm}\Big|_{DE} \triangleq \dfrac{v_{o_1} + v_{o_2}}{2} \dfrac{1}{v_{cm}}$ DOUBLE ENDED

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

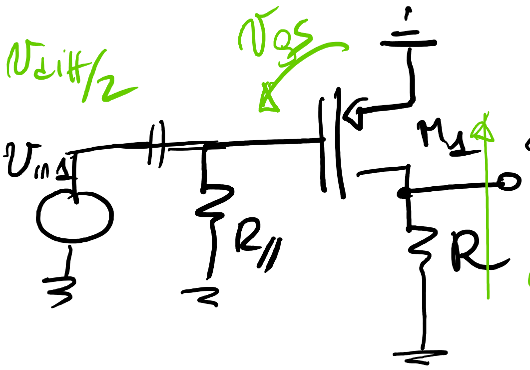
$G_{cm} = 0$!!!

$\hookrightarrow$ CMRR $\to \infty$

$G_{cm} = 0 \ldots$

↳ $CMRR \to \infty$

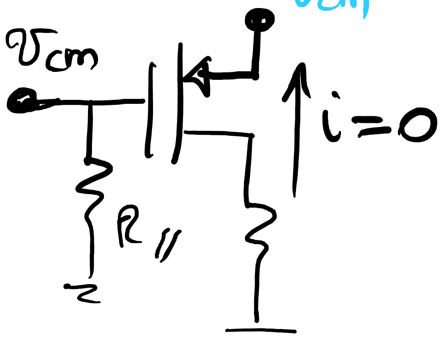
b bis) COMPORTAMENTO DIFFERENZIALE – ANALISI CON MEZZO CIRCUITO



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

$$g_m v_{gs} = g_m \frac{v_{diff}}{2}$$

c bis) COMPORTAMENTO SU MODO COMUNE CON MEZZO CIRCUITO



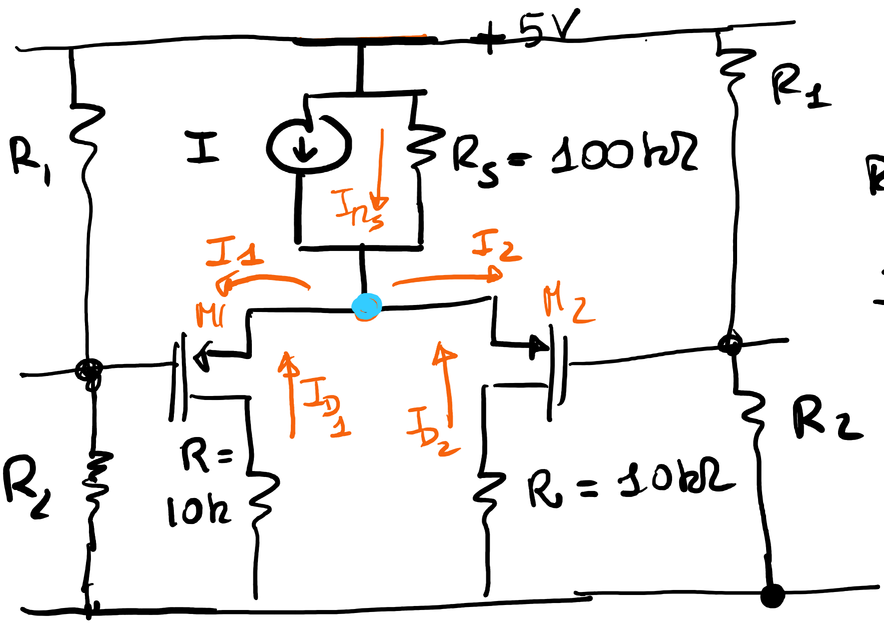
$$i = g_m v_{gs}$$

$g_m \neq 0$

↳ $v_{gs} = 0$

$v_{source} = v_{gate} = v_{cm}$

B) GEN. DI CORR REALE



$R_1 = R_2 = 100k\Omega$

$I = 400\mu A$

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

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$$I_{D_1} + I_{D_2} + I + I_{R_S} = 0$$

$$I_{R_S} = \frac{V_S - 5V}{R_S}$$

$$I_{D_1} = k_p (V_{GS_1} - V_{T_P})^2 \qquad V_{GS_1} = V_{G_1} - V_{S_1}$$

$$V_{S_1} = V_{S_2} = V_S$$

Approssimando

$$I_{D_1} = -I_1$$

uso il valore di V_S calcolato in assenza di R_S

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

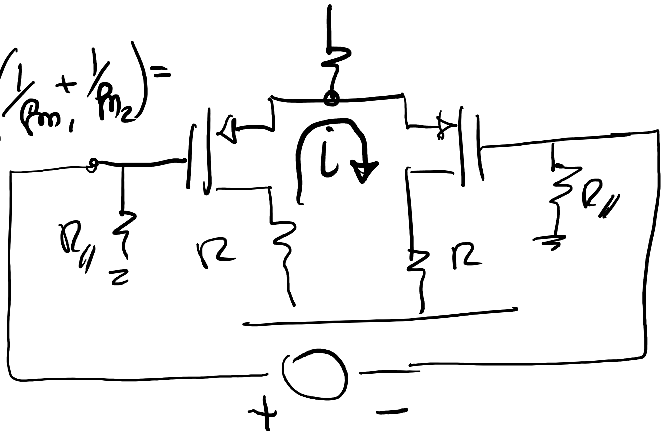
$10\mu A \ll 200\mu A$ ok approx.

$$g_m = 205\mu A/V \qquad |V_{GS}| = 3.05V$$

SEGNALE DIFFERENZIALE

in R_S non scorre corrente se lo stadio è simmetrico

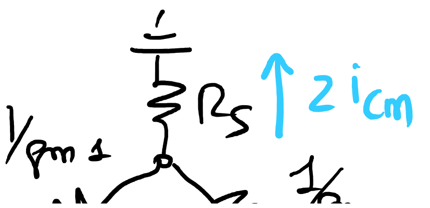
$$\to i = v_{diff} / \left(\frac{1}{g_{m_1}} + \frac{1}{g_{m_2}}\right) = g_m \frac{v_{diff}}{2}$$

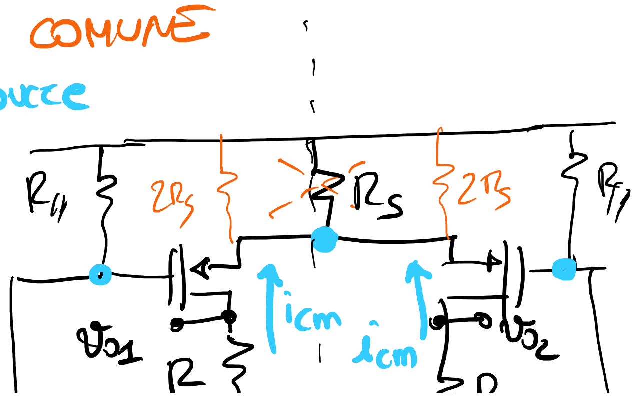


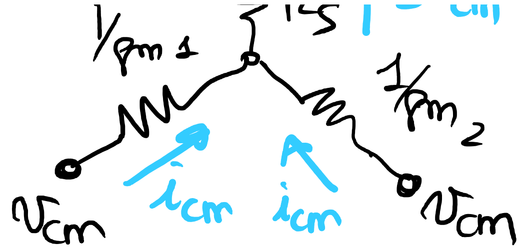
NON CAMBIA NULLA!!

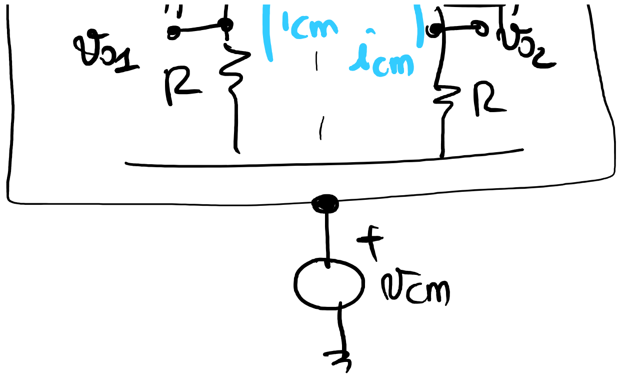
SEGNALE DI MODO COMUNE

Eq. Thevenin al source









$$2 i_{cm} = \frac{v_{cm}}{1/g_{m1} \parallel 1/g_{m2} + R_S}$$

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

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

$\Downarrow$

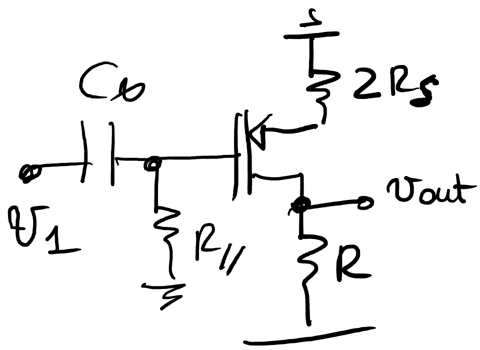
DOUBLE ENDED $$G_{cm} \triangleq \frac{\frac{v_{o1} + v_{o2}}{2}}{v_{cm}} = -\frac{R}{1/g_m + 2R_S} = -0.05$$

SINGLE ENDED $$G_{cm} = \frac{v_{o1,2}}{v_{cm}} = -\frac{R}{1/g_m + 2R_S} = \underline{-0.05}$$

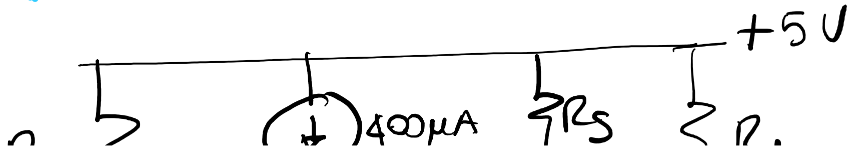
CMRR double ended $$= \left| \frac{G_{diff}}{G_{cm}} \right| = \frac{2}{0.05} = 40 \Rightarrow 32\,dB$$

$$= \frac{g_m \cancel{R}}{\cancel{R}} \left(1/g_m + 2R_S \right) = \underline{1 + 2 g_m R_S}$$

MEZZO CIRCUITO SU SEGNALE DI MODO COMUNE

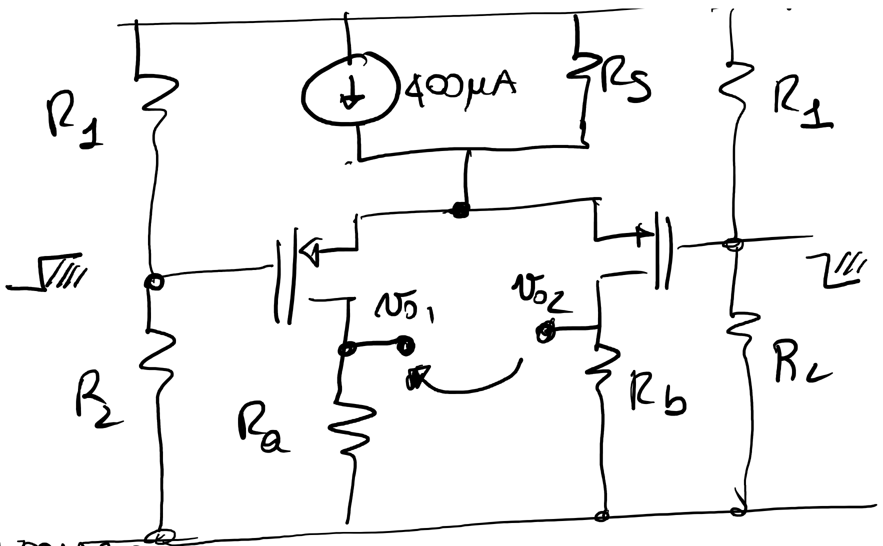


ASIMMETRIA RESISTENZE CARICO



$R_S = 100\,k\Omega$

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



$R_S = 100\,k\Omega$
$R_1 = R_2 = 100\,k\Omega$
$R_a = 10\,k\Omega$
$R_b = 10\,k\Omega + 5\% = 10.5\,k\Omega$
$|V_{Tp}| = 1V$
$|k_p| = 50\,\mu A/V^2$

a) POLARIZZAZIONE in DC $v_{o1} \neq v_{o2}$

b) SEGNALE DIFF.

$$v_{out_{diff}} = v_{o1} - v_{o2} = -i_d R_a - (-i_d R_b) = -\frac{g_m}{2}(R_a + R_b)\, v_{diff}$$

$$\Downarrow$$

$$G_{diff} = -2.1$$

$$|v_{out}|_{cm_d} = \frac{v_{out\,1} + v_{o2}}{2} = 2.62 \cdot 10^{-2}\, v_{diff}$$

c) MODO COMUNE

ingresso modo comune ⇒ uscita anche differenziale

$$v_{out_{diff}}|_{CM} = 2.44 \cdot 10^{-3}\, v_{cm}$$