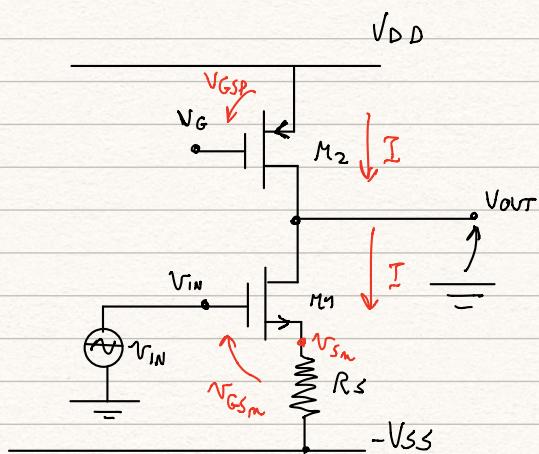


STADIO SOURCE A MASSA CON CARICO ATTIVO

E STADI DIFFERENZIALI



(A) POLARIZZAZIONE

$$VG_{SP} = VG - V_{DD} \rightarrow I = -ID = -k_p (VG_{SP} - V_{TP})^2$$

$$VS_m = -V_{SS} + IR_S$$

$$VG_S = 0 - VS_m \rightarrow ID_m = k_n (VG_{Sm} - V_{TN})^2 = I$$

Saturazione di M_1 $V_{GD_m} < V_{TN}$

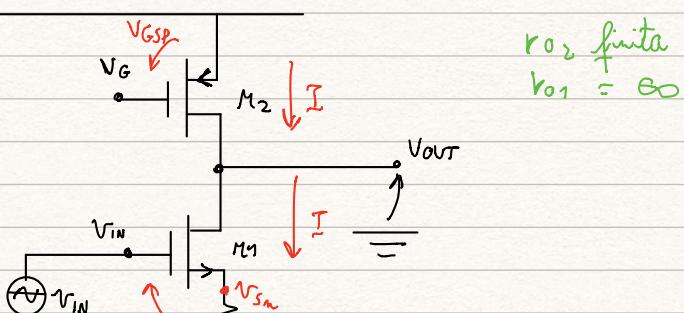
Saturazione di M_2 $V_{GD_p} > V_{TP}$

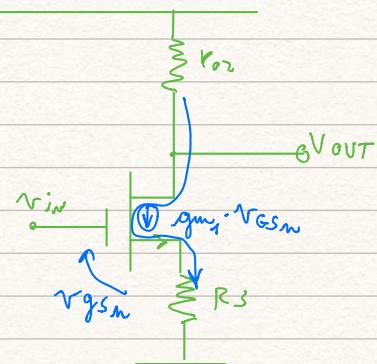
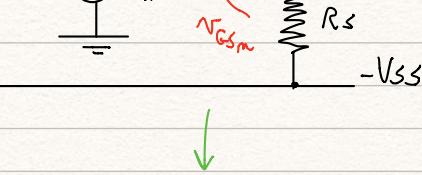
$$VG_{Dm} = VG_m - V_{Dm} = VG_m - V_{OUT} = 0 - V_{OUT}$$

$$VG_{Dp} = VG_p - V_{Dp} = VG - V_{OUT} > V_{TP}$$

$$\left. \begin{array}{l} \text{① } V_{OUT} > V_{TN} \\ \text{② } V_{OUT} < VG - V_{TP} \end{array} \right\} -V_{TN} < V_{OUT} < VG - V_{TP}$$

(B) ANALISI SU SEGNALE: V_{DD}

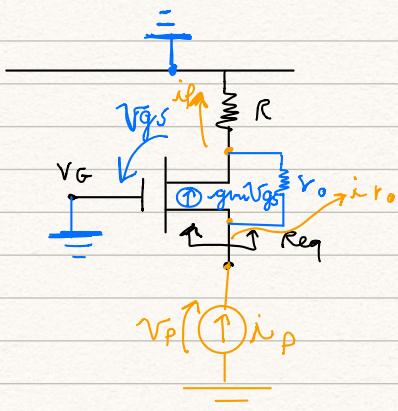




$$V_{OUT} = -g_{m1} \sqrt{g_{SM}} V_{D2}$$

$$V_{out} = \frac{-g_m V_o Z}{1 + g_m R_s} V_{in}$$

$$G \stackrel{\Delta}{=} \frac{V_{OUT}}{V_{IN}} = - \frac{g_{m1} r_o2}{1 + g_{m1} R_3}$$



RESISTENZA EQUIVALENTE VISTA DAL DRAIN IN PRESENZA DI R_o

$$R_{\text{eq}} \stackrel{\Delta}{=} \frac{V_p}{i_p}$$

$$i_p = g_m \sqrt{g_s} + i_r$$

$$v_s = -\sqrt{g_s} = i_p R$$

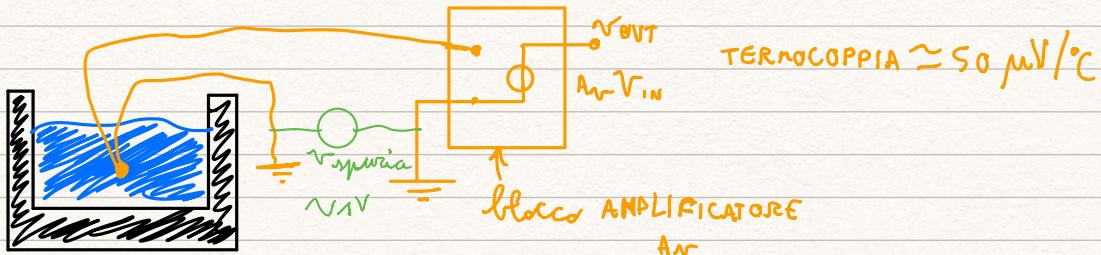
$$i_r = \frac{V_p - V_s}{R_s} = \frac{V_p - i_p R_s}{R_s}$$

$$i_p = g_m \left(-i_p R \right) + \frac{\sqrt{p}}{r_0} - \frac{e_p R_s}{r_0}$$

$$NP = \text{roi} \left[1 + g_m R + \frac{R_s}{r_o} \right]$$

$$R_{eq} = \frac{V_p}{I_p} = r_o + g_m R_{in} + R_s = (r_o + R_s) \left[1 + g_m \frac{r_o R}{r_o + R} \right] = (r_o + R) \left[1 + g_m r_o || R \right]$$

LO STADIO DIFFERENZIALE

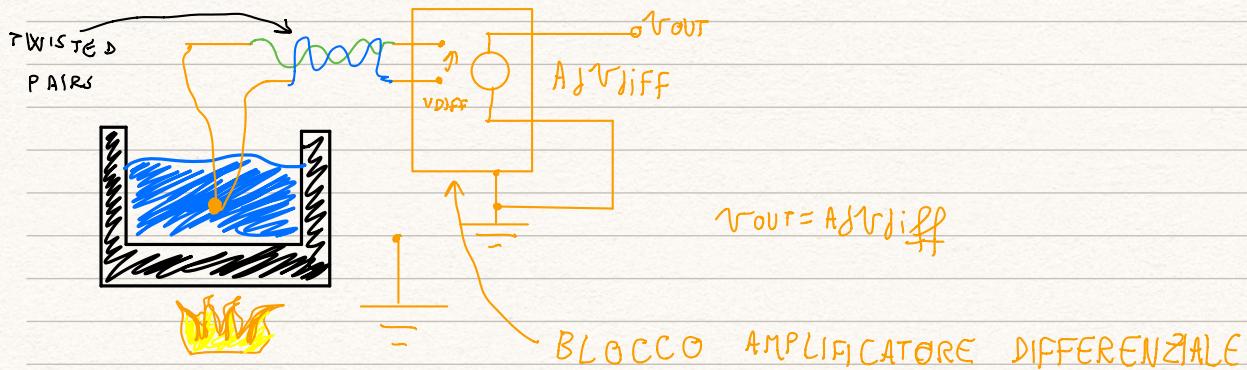


$$V_{out} = Av V_{in} = Av \cdot V_{sig}$$

$$Av = 10^3 \rightarrow V_{sig} = 100 \mu V \rightarrow V_{out}$$

$$V_{in} = V_{sig} + V_{spuria}$$

$$V_{out} = Av V_{in} = Av (V_{sig} + V_{spuria})$$

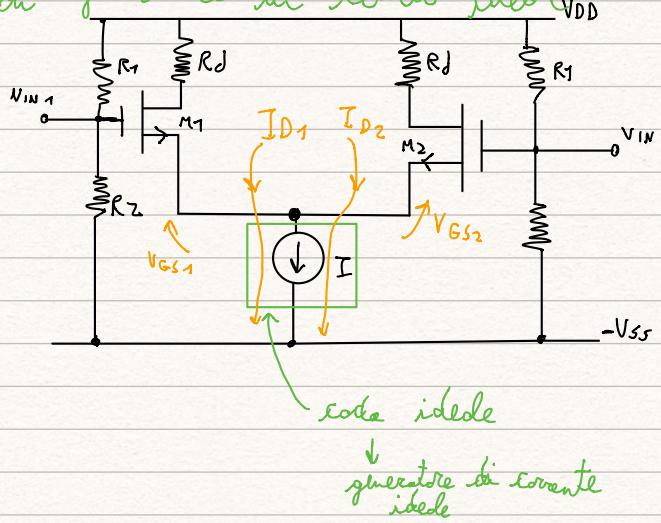


$$V_{diff} = V_{sig}$$

$$V_{out} = AV_{diff} = AV_{sig}$$

STADIO DIFFERENZIALE A MOSFET

(A) con generatore di coda ideale



(A) POLARIZZAZIONE

Se lo stadio è simmetrico

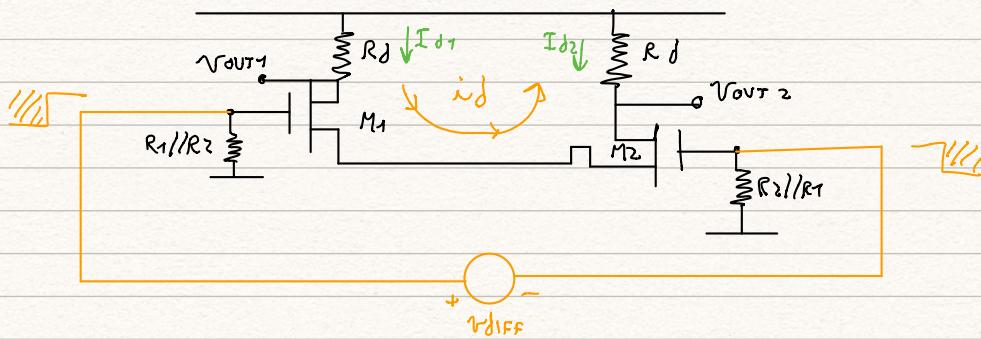
$$V_{GS1} = V_{GS2} \rightarrow I_{D1} = I_{D2} = \frac{I}{2}$$

HP: Mos natura

$$I_D = k_m (V_{GS} - V_{trn})^2$$

(B) COMPORTAMENTO SU SEGNALI DIFFERENZIALI

Segnale differenziale di ingresso va a sbilanciare i gate (segnale applicato tra i gate)



$$\begin{aligned} i_{d1} &= g_m v_{gs1} \\ i_{d2} &= g_m v_{gs2} \\ V_{out1} &= +v_{diff}/2 \\ V_{out2} &= -v_{diff}/2 \end{aligned}$$

$$i_{d1} = \frac{v_{diff}}{g_{m1}/R_2 + 1/g_{m2}}$$

$$g_{m1} = g_{m2} = g_m \quad (\text{stadio simmetrico})$$

v_{diff} segnale differenziale di ingresso
 $v_{diff} = v_{in1} - v_{in2}$

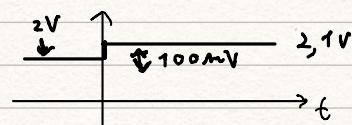


v_{cm} segnale di modo comune

$$v_{cm} \triangleq \frac{v_{in1} + v_{in2}}{2}$$

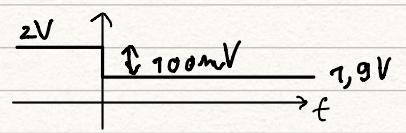
$$v_{in1} = 2V + 100\text{mV} \cdot \gamma(t)$$

$$v_{in2} = 2V - 100\text{mV}\gamma(t)$$



$$v_{out1} - v_{out2} \triangleq v_{out1} \quad (\text{preferiamo uscita ballo-ended})$$

v_{out} single ended



v_{d1}, v_{d2} riferita a massa

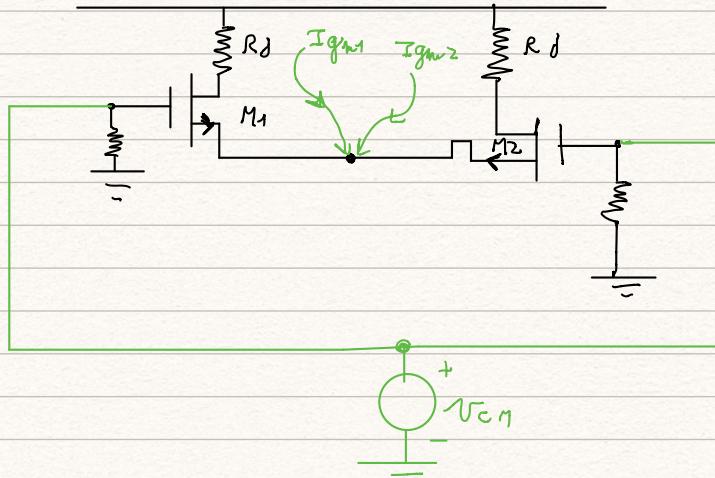
$$v_{out_{av}} \triangleq \frac{v_{out1} + v_{out2}}{2}$$

tensione di uscita di modo comune

$$V_{\text{out diff}} = V_{\text{out1}} - V_{\text{out2}} = -(i_{\text{d1}} R_d) - (i_{\text{d2}} R_d) = -2 i_{\text{d}} R_d = -2 \frac{R_d}{1/g_{m1} + 1/g_{m2}} V_{\text{diff}}$$

* in double ended
 $G_{\text{diff}} = -g_{m1} R_d$

(C) Comportamento su segnale di modo comune

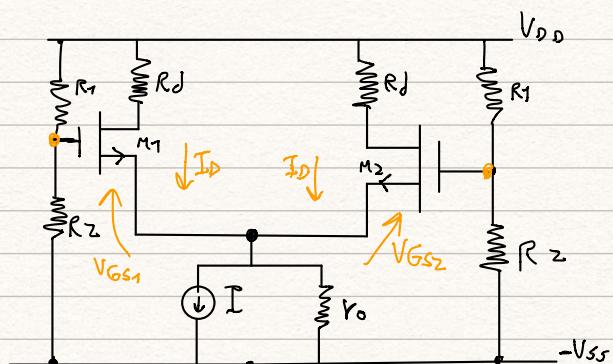


$$\begin{cases} i_{cm1} + i_{cm2} = 0 \\ i_{cm1} = i_{cm2} \end{cases} \rightarrow i_{cm} = 0$$

$$G_{cm} \triangleq \frac{V_{\text{out cm}}}{V_{cm}} = \frac{\frac{V_{\text{out1}} + V_{\text{out2}}}{2}}{V_{cm}} = 0$$

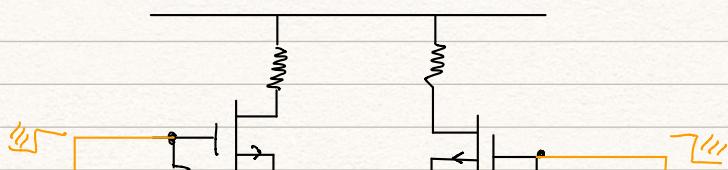
$$\text{CMRR} \triangleq |G_{\text{diff}}|$$

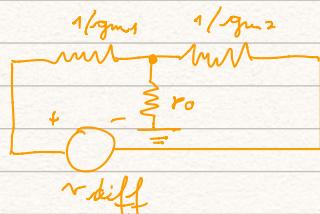
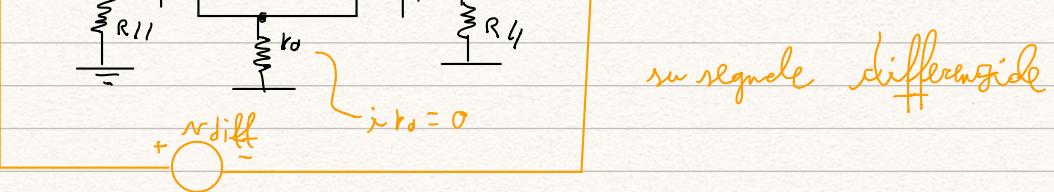
(B) CON GENERATORE DI CODA REALE (NON IDEALE)



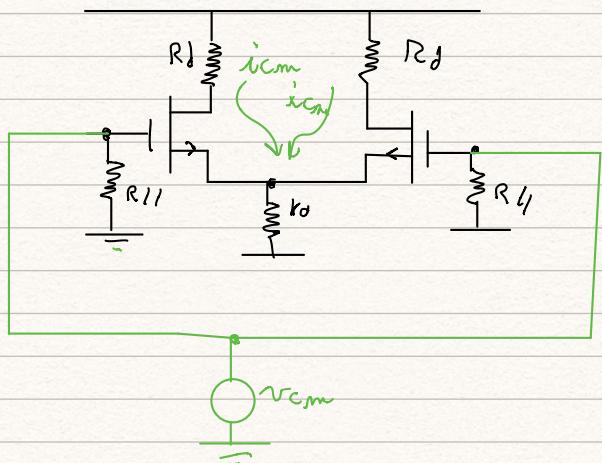
$$\begin{aligned} V_{GS1} &= V_{GS2} = V_{GSN} \\ \begin{cases} I_D = K_n (V_{GSN} - V_{TN})^2 \\ V_{GS} + I_{r_o} \cdot r_o = V_G - (-V_{SS}) \end{cases} \end{aligned}$$

Se stadio simmetrico in regola differenziale non cambia nulla

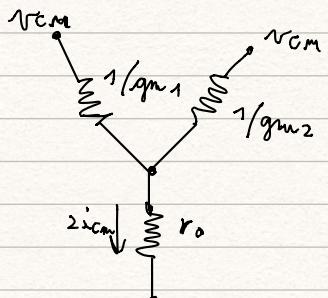




SU SEGNALI DI MODO COMUNE



$$i_{ro} = i_{cm1} + i_{cm2} \xrightarrow{i_{cm1} = i_{cm2}} 2i_{cm}$$



$$2i_{cm} = \frac{V_{cm}}{\frac{1}{2gm} + r_o}$$

$$i_{cm} = V_{cm} \cdot \frac{1}{\frac{1}{2gm} + 2r_o}$$

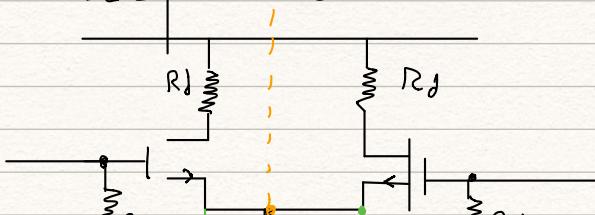
$$\frac{1}{gm_1}, \frac{1}{gm_2}$$

$$V_{out1} =$$

$$G_{cm} \triangleq \frac{\frac{V_{out1} + V_{out2}}{2}}{V_{cm}} = -\frac{R_d}{\frac{1}{2gm} + 2r_o} \quad \text{DOUBLE ENDED}$$

$$G_{cm} \triangleq \frac{V_{out1}}{V_{cm}} = -\frac{R_d}{\frac{1}{gm} + 2r_o} \quad \text{SINGLE ENDED}$$

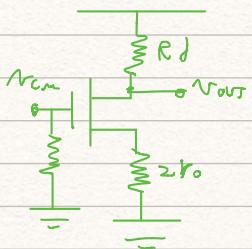
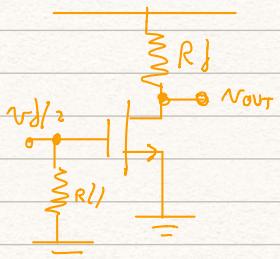
MEZZO CIRCUITO



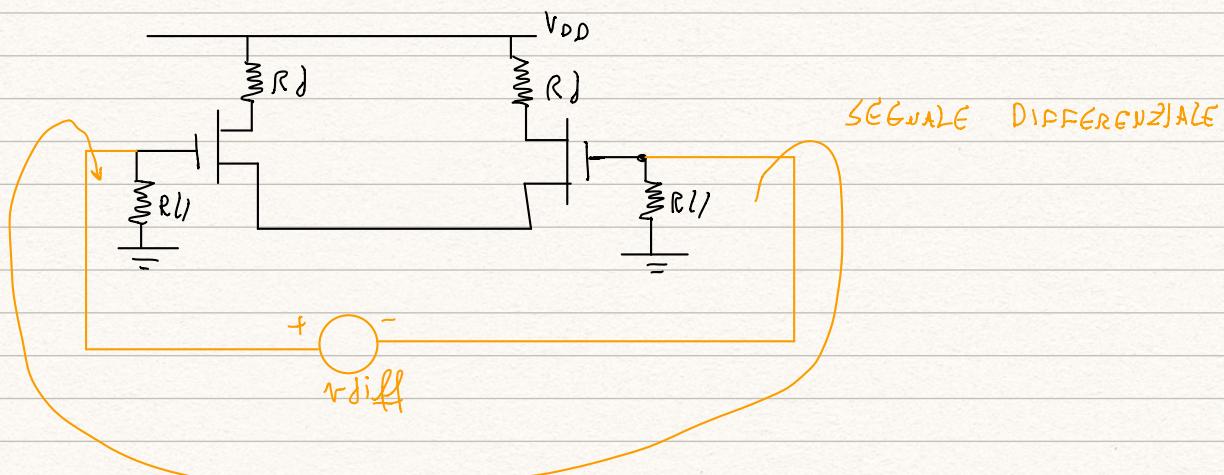


SEGNALE DIFFERENZIALE

V_{SOURCE} fissa in tensione



RESISTENZA DI INGRESSO



$$R_{in\ diff} = R_{11} + R_{11} = 2R_{11}$$

