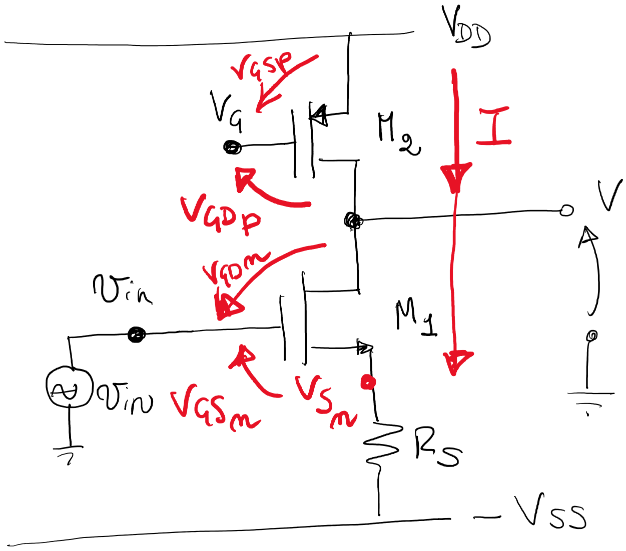
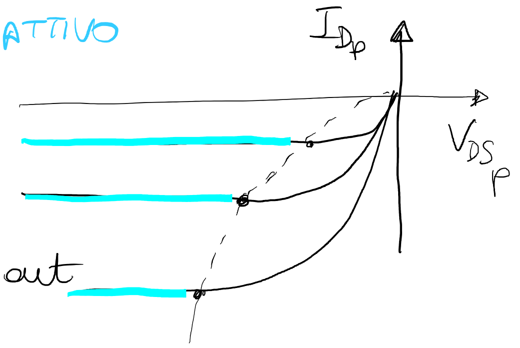
Lezione 10: stadio source a massa con carico attivo e stadi differenziali

mercoledì 22 aprile 2020 10:28

STADIO SOURCE A MASSA CON CARICO ATTIVO





(A) POLARIZZAZIONE

$$V_{GSp} = V_G - V_{DD} \Rightarrow I = -I_D = -k_p\,(V_{GSp} - V_{Tp})^2$$

$$V_{S_m} = -V_{SS} + I R_S$$

$$V_{GS} = 0 - V_{S_m} \Rightarrow I_{D_m} = k_m\,(V_{GS_m} - V_{T_m})^2 = I$$

saturazione di M_1: $V_{GD_m} < V_{T_m}$

saturazione di M_2: $V_{GD_p} > V_{Tp}$

(1) $V_{GD_m} = V_{G_m} - V_{D_m} = V_{G_m} - V_{out} = 0 - V_{out} < V_{T_m}$

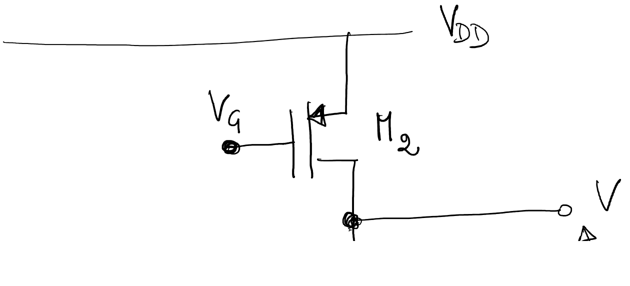
(2) $V_{GD_p} = V_{G_p} - V_{D_p} = V_G - V_{out} > V_{Tp}$

(1) $V_{out} > -V_{T_m}$

(2) $V_{out} < V_G - V_{Tp}$

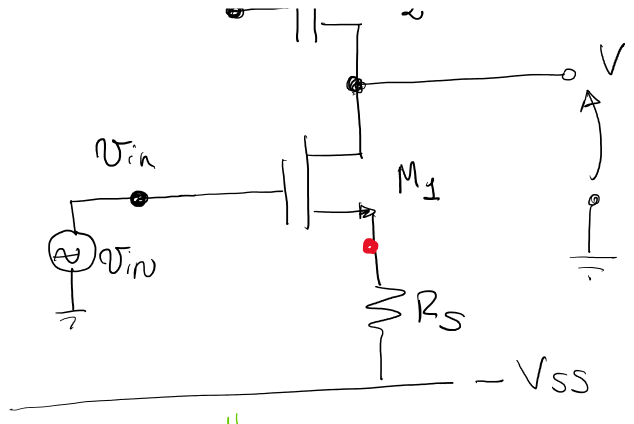
$$\boxed{-V_{T_m} < V_{out} < V_G - V_{Tp}}$$

(B) ANALISI SU SEGNALE

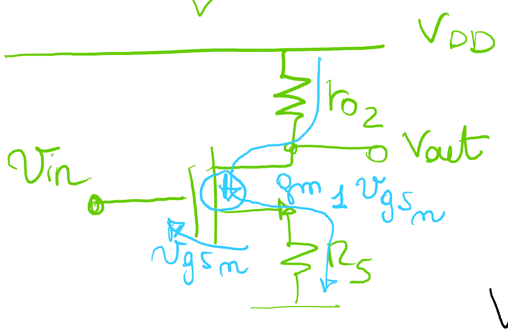


r_{o_2} finita

$r_{o_1} = \infty$



$$r_{o_1} = \infty$$



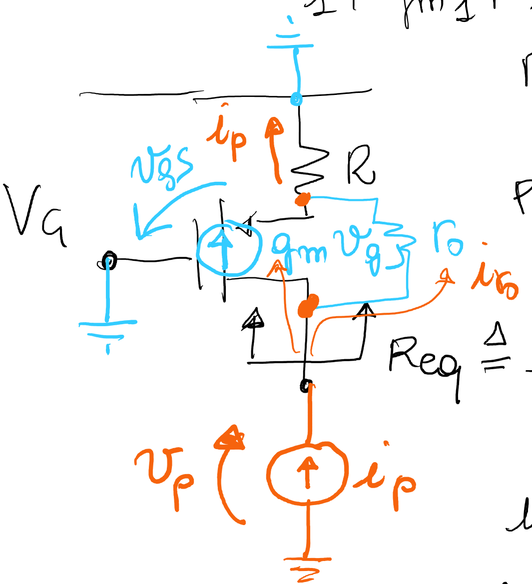
$$V_{out} = -g_{m_1} v_{gs_m} r_{o_2}$$

$$v_{gs_m} = \frac{1/g_{m_1}}{1/g_{m_1} + R_S} v_{in}$$

$$V_{out} = \frac{-g_{m_1} r_{o2}}{1 + g_{m_1} R_S} v_{in}$$

$$G \triangleq \frac{V_{out}}{V_{in}} = -\frac{g_{m_1} r_{o2}}{1 + g_{m_1} R_S}$$

RESISTENZA EQUIVALENTE VISTA DAL DRAIN IN PRESENZA DI r_o



$$R_{eq} \triangleq \frac{v_p}{i_p} = (r_o + R)\left(1 + g_m r_o // R\right)$$

$$i_p = g_m v_{gs} + i_{r_o}$$

$$v_s = -v_{gs} = i_p R$$

$$\hookrightarrow v_{gs} = -i_p R$$

$$i_{r_o} = \frac{v_p - v_s}{r_o} = \frac{v_p - i_p R}{r_o}$$

$$i_p = g_m(-i_p R) + \frac{v_p}{r_o} - \frac{i_p R}{r_o}$$

$$i_p = g_m(-i_p R) + \frac{v_p}{r_o} - \frac{i_p R}{r_o}$$

$$v_p = r_o i_p \left[1 + g_m R + \frac{R}{r_o}\right]$$

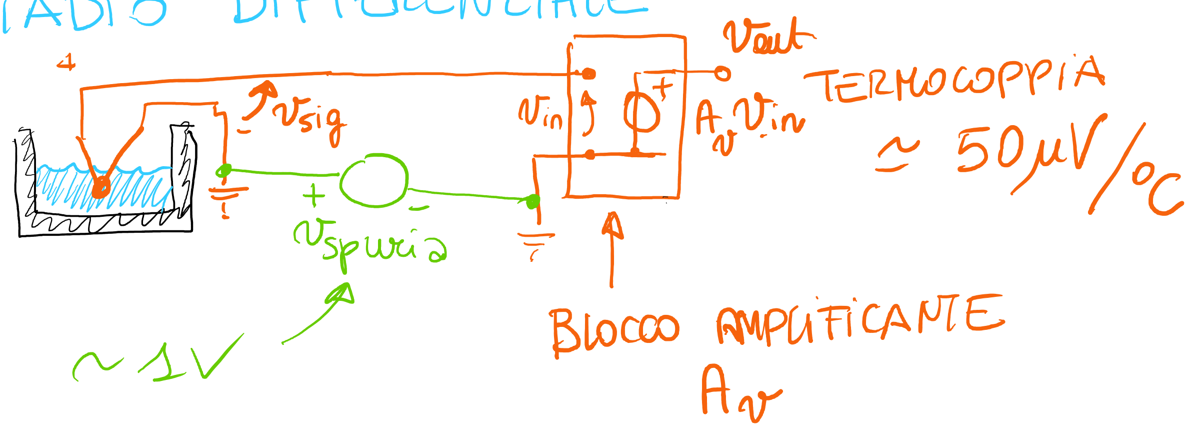
$$R_{eq} = \frac{v_p}{i_p} = r_o + g_m R r_o + R =$$

$$= (r_o + R)\left[1 + g_m \frac{r_o R}{r_o + R}\right] =$$

$$= (r_o + R)\left[1 + g_m \, r_o \| R\right]$$

($r_o \| R$)

STADIO DIFFERENZIALE

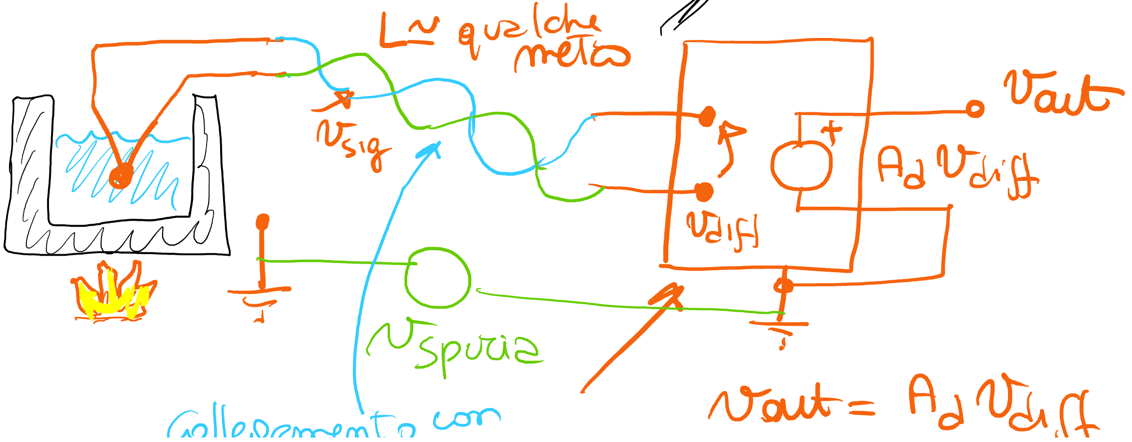


$$v_{out} = A_v v_{in} = A_v v_{sig}$$

$$A_v = 10^3 \Rightarrow v_{sig} = 100\mu V \Rightarrow v_{out} = 100 mV$$

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

$$v_{out} = A_v v_{in} = A_v (v_{sig} + v_{spuria})$$



spuria

Collegamento con cavi twisted pair

BLOCCO AMPLIFICATORE DIFFERENZIALE

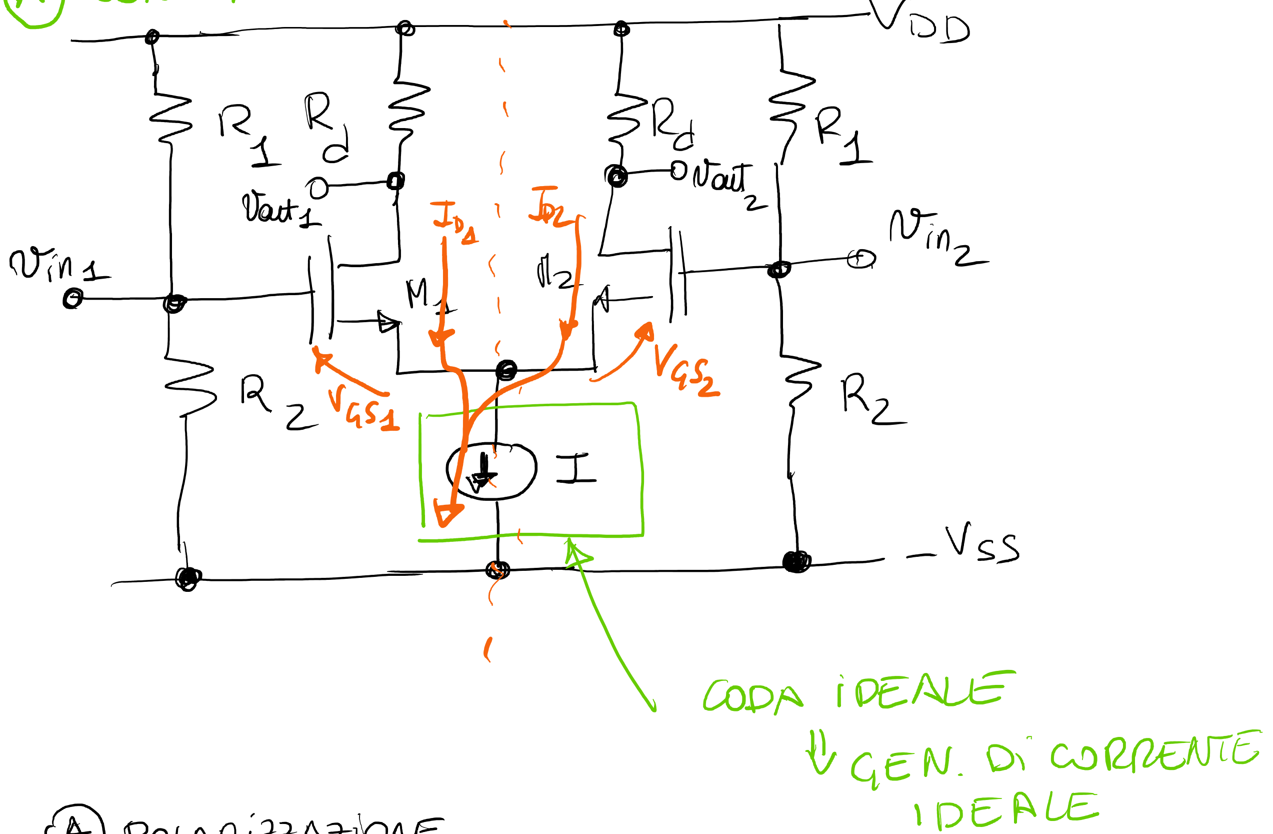
$v_{out} = A_d v_{diff}$

$v_{diff} = v_{sig}$

$v_{out} = A_d v_{diff} = A_d v_{sig}$

STADIO DIFFERENZIALE A MOSFET

(A) CON GENERATORE DI CODA IDEALE



(A) POLARIZZAZIONE

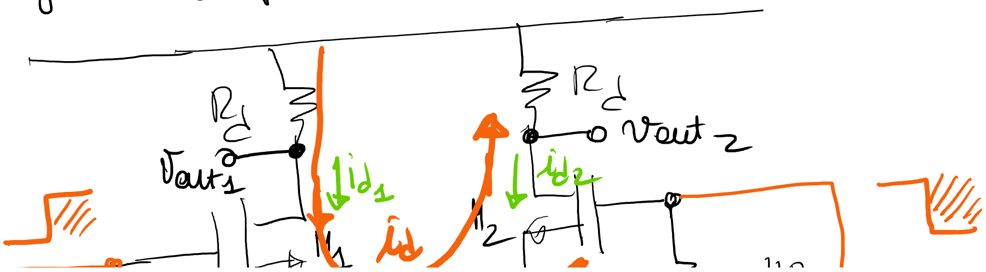
Se lo stadio è simmetrico

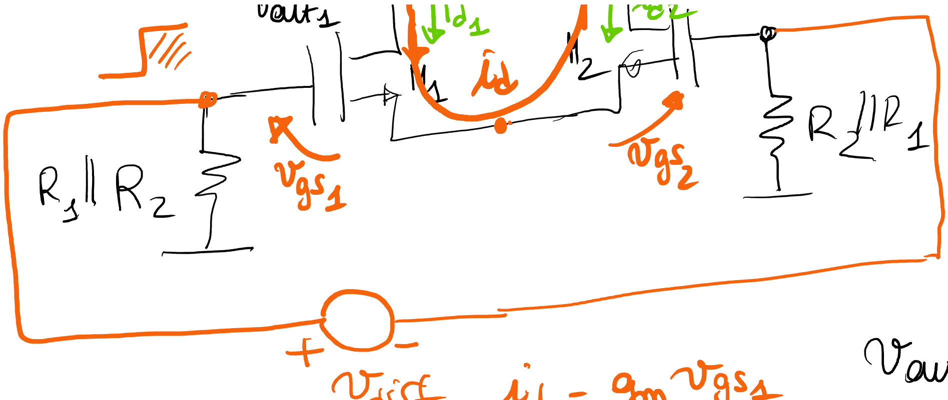
$$V_{GS_1} = V_{GS_2} \Rightarrow I_{D_1} = I_{D_2} = \frac{I}{2}$$

<u>Hp MOS saturi</u> $I_D = k_n (V_{GS} - V_{Tn})^2$

(B) COMPORTAMENTO SU SEGNALE DIFFERENZIALE

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





$i_{d_1} = g_m v_{gs_1}$

$i_{d_2} = g_m v_{gs_2}$

$v_{gs_1} = + v_{diff}/2$

$v_{gs_2} = - v_{diff}/2$

$$i_d = \frac{v_{diff}}{1/g_{m_1} + 1/g_{m_2}}$$

$g_{m_1} = g_{m_2} = g_m$ (stadio simmetrico)

$v_{out_{diff}} \triangleq v_{out_1} - v_{out_2} =$

$= - i_d R_d - (i_d R_d) =$

$= -2\, i_d R_d =$

$$= -2 \frac{R_d}{1/g_{m_1} + 1/g_{m_2}} v_{diff}$$

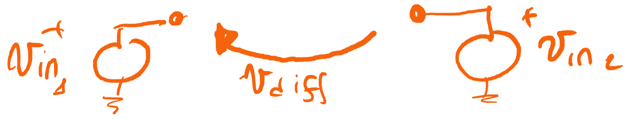
⇓

$$G_{diff} \triangleq \frac{v_{out\,diff}}{v_{diff}} = - \frac{2 R_d}{2/g_m} = - g_m R_d$$

* double ended

v_{diff} segnale differenziale in ingresso

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

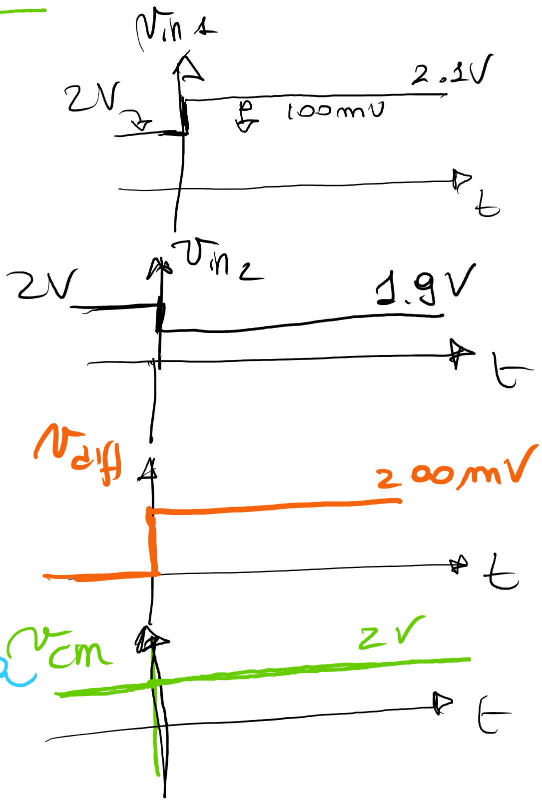


v_{cm} segnale di modo comune in ingresso

$$v_{cm} \triangleq \frac{v_{in_1} + v_{in_2}}{2}$$

$v_{in_1} = 2V + 100mV\, 1(t)$

$v_{in_2} = 2V - 100\,mV\, 1(t)$



$v_{out_{diff}} \triangleq v_{o_1} - v_{o_2}$

(prelevo una uscita double - ended)

v_{out} single ended

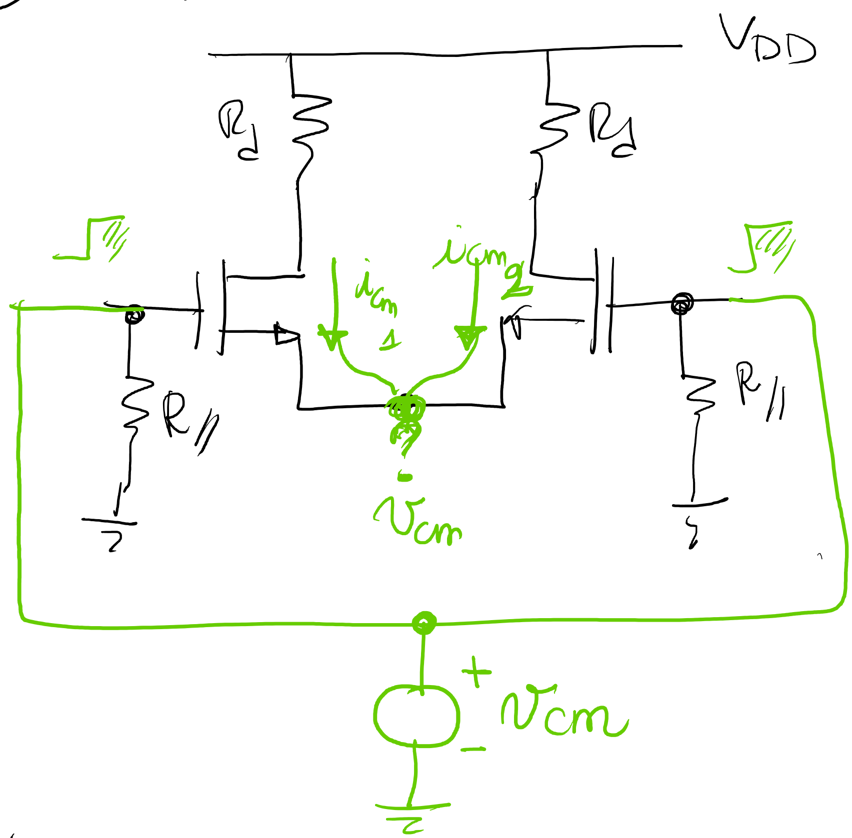
v_{o_1}, v_{o_2} riferita a massa

$$v_{out} \triangleq \frac{v_{out_1} + v_{out_2}}{}$$

$$v_{out_{cm}} \triangleq \frac{v_{out_1} + v_{out_2}}{2}$$

tensione di uscita di modo comune

(c) COMPORTAMENTO SU SEGNALE DI MODO COMUNE



$$i_{cm_1} = g_{m_1} v_{gs_1}$$
$$i_{cm_2} = g_{m_2} v_{gs_2}$$
$$g_{m_1} = g_{m_2} = g_m$$
$$v_{gs_1} = v_{cm} - v_S$$
$$v_{gs_2} = v_{cm} - v_S$$

$$\begin{cases} i_{cm_1} + i_{cm_2} = 0 \\ i_{cm_1} = i_{cm_2} \end{cases} \Rightarrow \boxed{i_{cm} = 0}$$

$$G_{cm} \triangleq \frac{v_{out\,cm}}{v_{cm}} = \frac{\frac{v_{out_1} + v_{out_2}}{2}}{v_{cm}} = 0$$

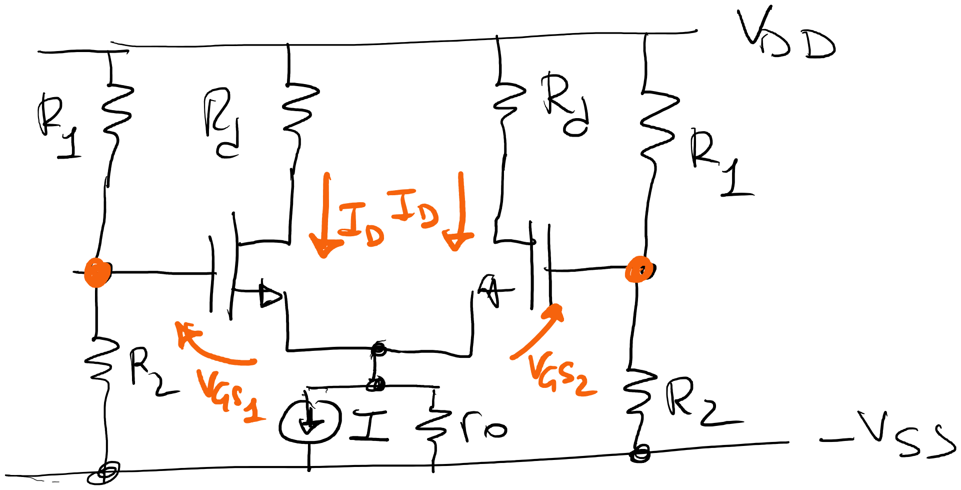
$$CMRR \triangleq \left| \frac{G_{diff}}{G_{cm}} \right|$$

Common Mode Rejection Ratio

coda ideale $\Rightarrow$ $CMRR \to \infty$

i_m

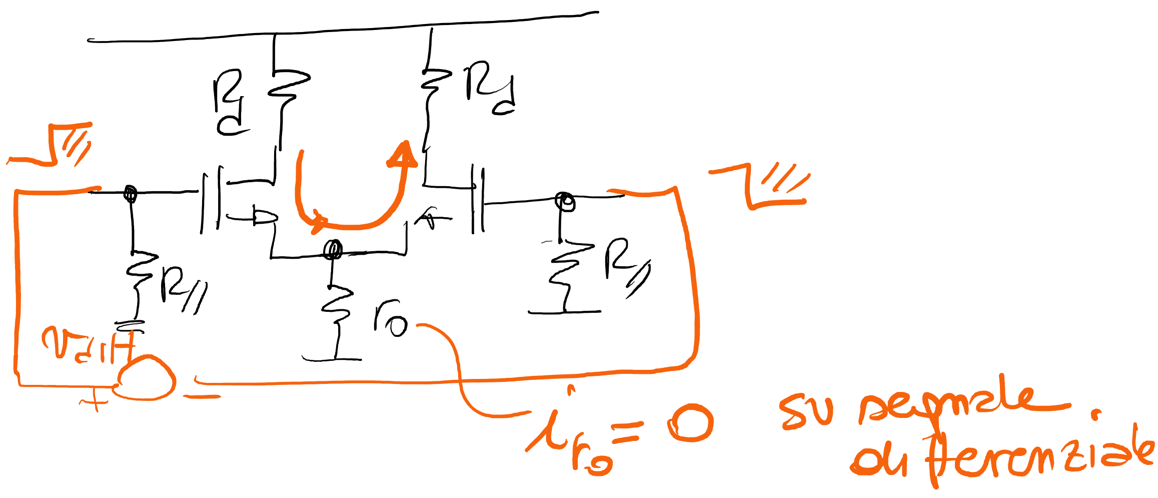
(3) CON GENERATORE DI CODA REALE (NON IDEALE)

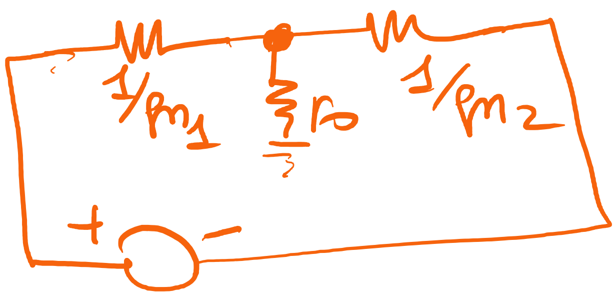


$V_{GS_1} = V_{GS_2} = V_{GS_m}$

$$\begin{cases} I_D = k_m (V_{GS_m} - V_{T_m})^2 \\ V_{GS} + I_{r_o} * r_o = V_G - (-V_{SS}) \end{cases}$$

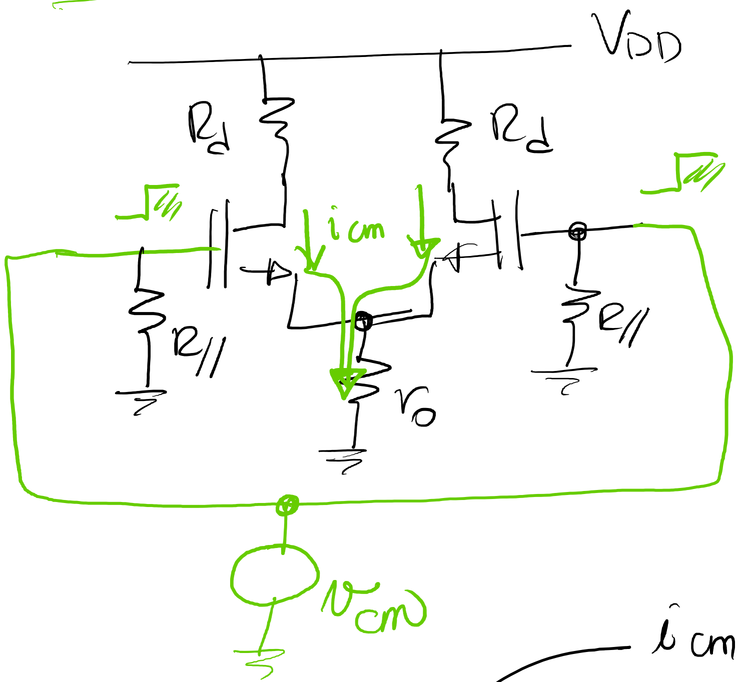
se stadio simmetrico su segnale differenziale non cambia nulla





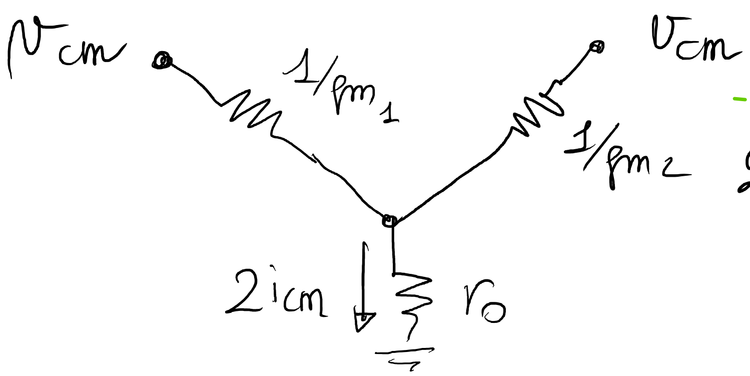
Vdiff

SU SEGNALE DI MODO COMUNE



$i_{cm_1} = i_{cm_2}$

$i_{r_o} = i_{cm_1} + i_{cm_2} = 2 i_{cm}$



$$2 i_{cm} = \frac{v_{cm}}{\frac{1}{2g_m} + r_o}$$

$1/g_{m_1} \,//\, 1/g_{m_2}$

$$i_{cm} = v_{cm} \frac{1}{\frac{1}{g_m} + 2r_o}$$

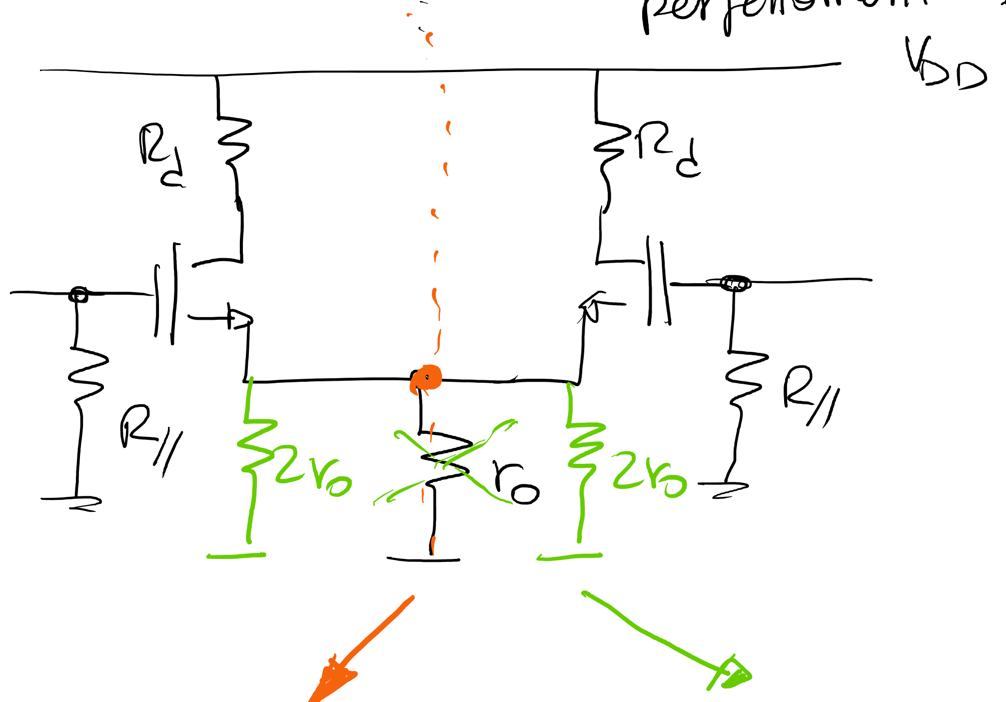
$v_{out_1} = v_{out_2} = -i_{cm} R_d$

$$\Rightarrow G_{cm} \triangleq \frac{\frac{v_{out_1} + v_{out_2}}{2}}{v_{cm}} = -\frac{R_d}{1/g_m + 2r_o} \quad \text{Double ended}$$

$$G_{cm} \triangleq \frac{v_{out_1}}{v_{cm}} = -\frac{R_d}{1/g_m + 2r_o} \quad \text{SINGLE ENDED}$$

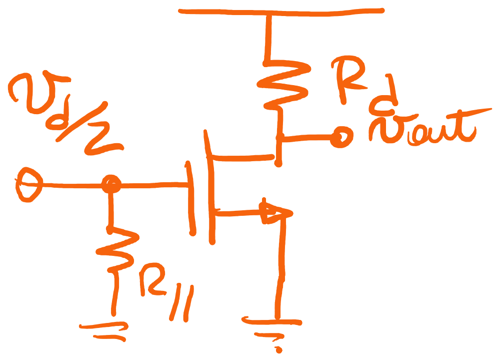
$$G_{cm} \triangleq \frac{v_{out1}}{v_{cm}} = - \frac{R_D}{1/g_m + 2r_o}$$ SINGLE ENDED

MEZZO CIRCUITO (solo se lo stadio è perfettamente simmetrico)



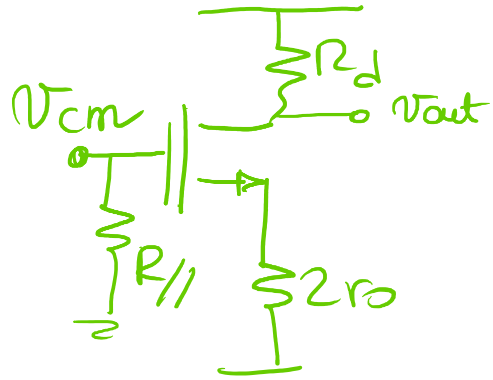
SEGNALE DIFFERENZIALE

V_{source} fissa in tensione

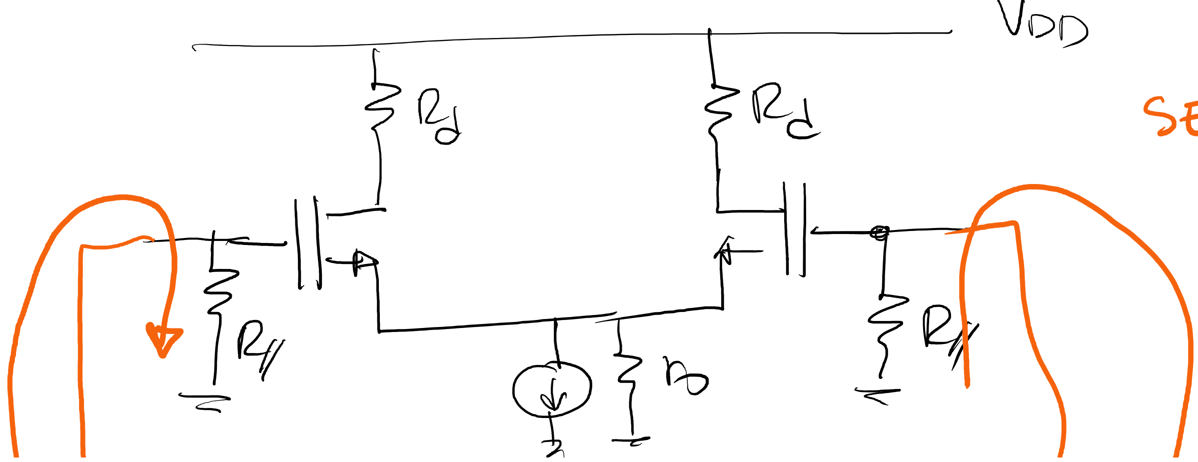


MODO COMUNE

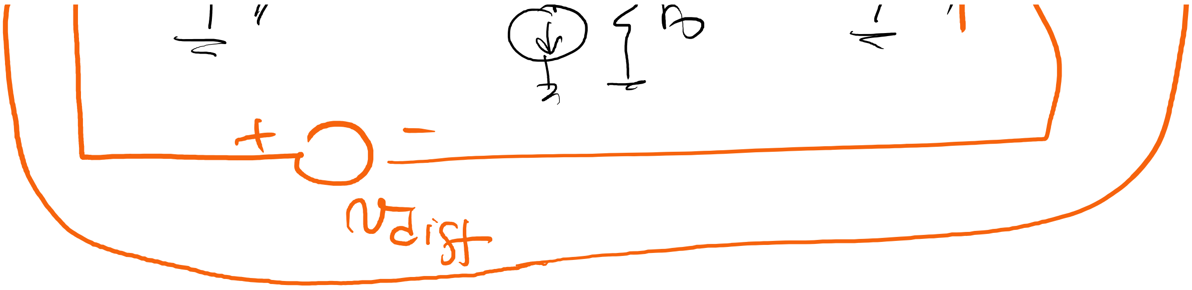
r_o è vista come $2r_o // 2r_o$



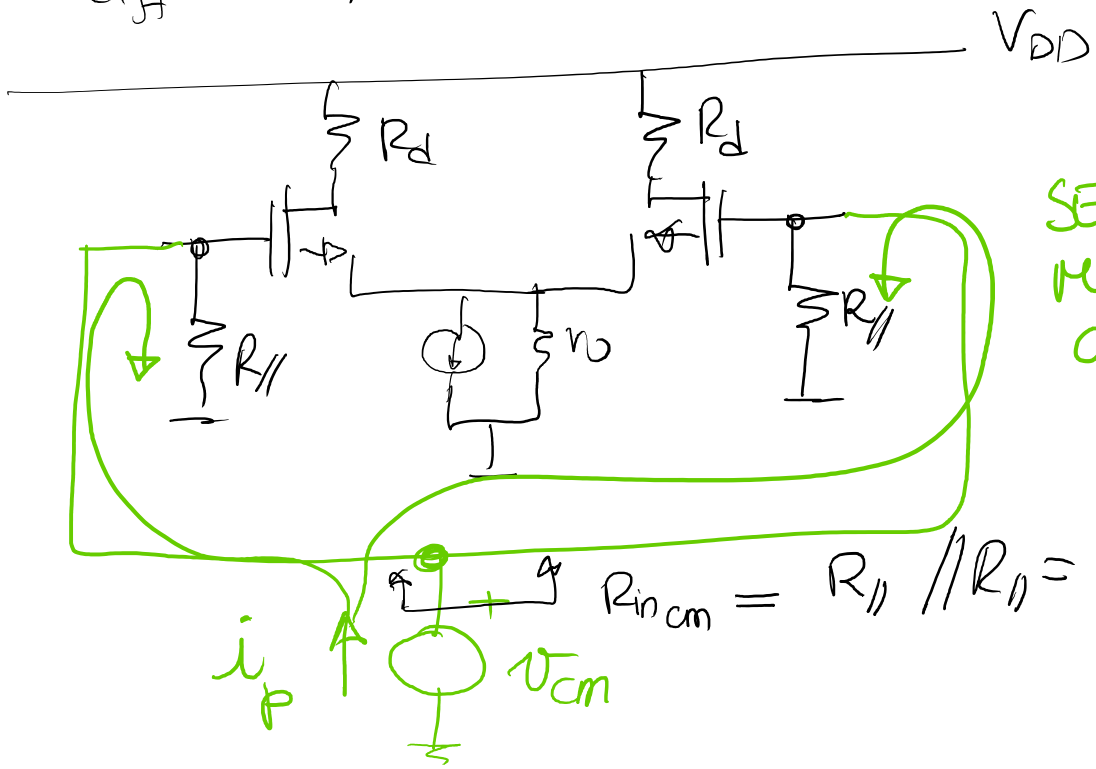
RESISTENZA DI INGRESSO



SEGNALE DIFFERENZ.



$$R_{in\,diff} = R_{//} + R_{//} = 2R_{//}$$



SEGNALE MODO COMUNE

$$R_{in\,cm} = R_{//} \,//\, R_{//} = \frac{R_{//}}{2}$$