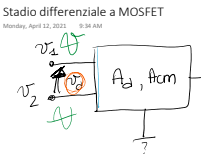
Stadio differenziale a MOSFET

Monday, April 12, 2021 9:34 AM



$v_{out} = A_d (v_2 - v_1) + A_{cm} \left(\frac{v_1 + v_2}{2} \right)$ (1000)

A_d: guadagno differenziale

$A_{cm} = 0$

$v_d = v_2 - v_1$ => SEGNALE DIFFERENZIALE

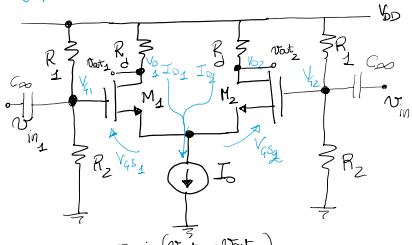
$v_d \sim 100\,\mu V$

$v_{cm} = \frac{v_1 + v_2}{2}$ => SEGNALE DI MODO COMUNE

$v_{cm} = 100\,mV$

A_{cm}: guadagno di modo comune

STADIO DIFFERENZIALE CON GEN. DI CODA IDEALE



stadio differenziale simmetrico $R_{m_1} = R_{m_2} = R_m$

② Polarizzazione

$I_{D_1} = I_{D_2} = \frac{I_o}{2} = k_n (V_{GS} - V_{th})^2$ (hp MOS saturo)

$V_{GS_1} = V_{GS_2} = V_{GS}$

$V_{D_1} = V_{D_2} = V_{DD} - \frac{I_o}{2} R_d$

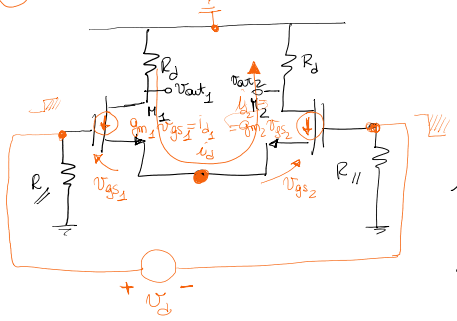
$V_{G_1} = V_{G_2} = \frac{R_2}{R_1 + R_2} V_{DD}$

stadio bilanciato

* DOUBLE - ENDED : $(v_{out_2} - v_{out_1})$

* SINGLE - ENDED : v_{out_1} oppure v_{out_2}

ⓑ ANALISI SU SEGNALE DIFFERENZIALE



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

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

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

$i_{d_1} = -i_{d_2} = i_d$

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

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

$\Downarrow$

$v_{gs} = \frac{v_d}{2}$

$i_d = g_m \frac{v_d}{2}$

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

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

* DOUBLE - ENDED

$v_{out_2} - v_{out_1} = i_d R_d - (-i_d R_d) = 2 i_d R_d = 2 g_m \frac{v_d}{2} R_d = g_m R_d v_d$

$\Downarrow$

GUADAGNO DIFFERENZIALE

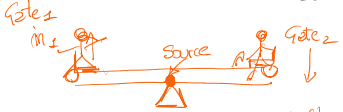
$A_d \triangleq \frac{v_{out_2} - v_{out_1}}{v_d} = g_m R_d$

* SINGLE - ENDED

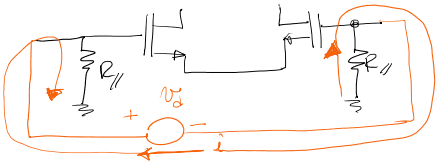
$v_{out_1} = -i_d R_d = -g_m \frac{v_d}{2} R_d$

$v_{out_2} = i_d R_d = g_m \frac{v_d}{2} R_d$

$|A_d|_{single-ended} \triangleq \left| \frac{v_{out_2}}{v_d} \right| = \left| \frac{v_{out_1}}{v_d} \right| = g_m \frac{R_d}{2}$

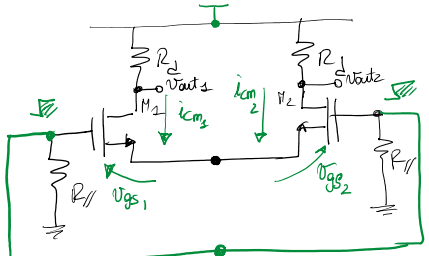


RESISTENZA DI INGRESSO DIFFERENZIALE



$R_{in_{diff}} = R_{//} + R_{//} = 2 R_{//} = 2 (R_1 // R_2)$

ⓒ guadagno di modo comune



$i_{cm_1} + i_{cm_2} = 0$

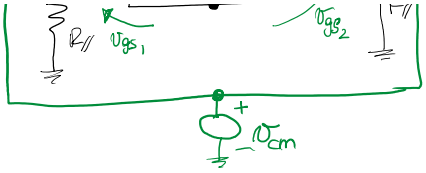
$v_{gs_1} = v_{gs_2}$

$i_{cm_1} = i_{cm_2}$

$\Downarrow$

$i_{cm_1} = i_{cm_2} = 0$!!

* SINGLE - ENDED



$\Rightarrow i_{cm_1} = i_{cm_2} = 0$!!

* SINGLE-ENDED

$$A_{cm} \triangleq \frac{v_{out_1}}{v_{cm}} = \frac{v_{out_2}}{v_{cm}} = 0$$

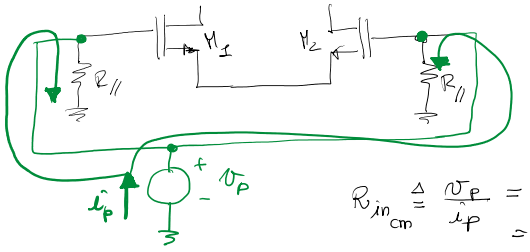
* DOUBLE-ENDED

$$A_{cm} \triangleq \frac{\frac{v_{out_1} + v_{out_2}}{2}}{v_{cm}} = 0$$

COMMON-MODE REJECTION RATIO
(rapporto di reiezione del modo comune)

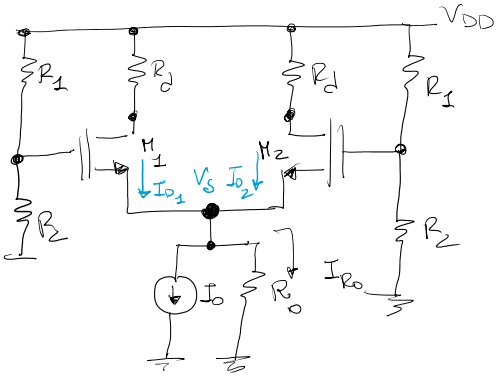
$$CMRR \triangleq \left| \frac{A_d}{A_{cm}} \right| = \infty$$

Resistenza di ingresso di modo comune



$$R_{in_{cm}} \triangleq \frac{v_p}{i_p} = R_{//} \,/\!/\, R_{//} = \frac{R_1 /\!/ R_2}{2}$$

STADIO DIFFERENZIALE CON CODA NON IDEALE



$$I_{D_1} = k_n (V_{GS_1} - V_{Tn})^2$$
$$I_{D_2} = k_n (V_{GS} - V_{Tn})^2$$
$$I_{D_1} + I_{D_2} = I_o + I_{R_o}$$

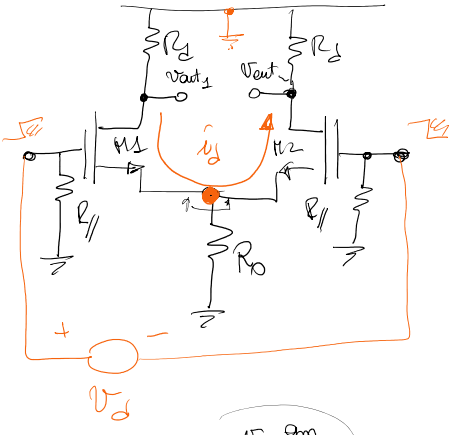
$$I_{R_o} = \frac{V_S}{R_o}$$

Se fosse presente solo R_o:

$$\begin{cases} I_D = k_n (V_{GS} - V_{Tn})^2 \\ V_S = 2 I_D R_o \end{cases}$$

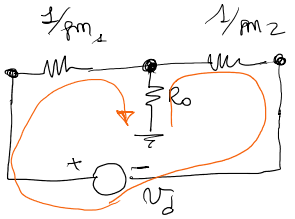
$$I_D = I_{D_1} = I_{D_2}$$
$$V_{GS} = V_{GS_1} = V_{GS_2}$$

(b) SEGNALE DIFFERENZIALE



$$\hat{i}_d = \frac{v_d}{1/g_{m_1} + 1/g_{m_2}} = \frac{v_d \, g_m}{2}$$

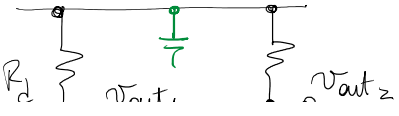
Eq. Thevenin al modo di source



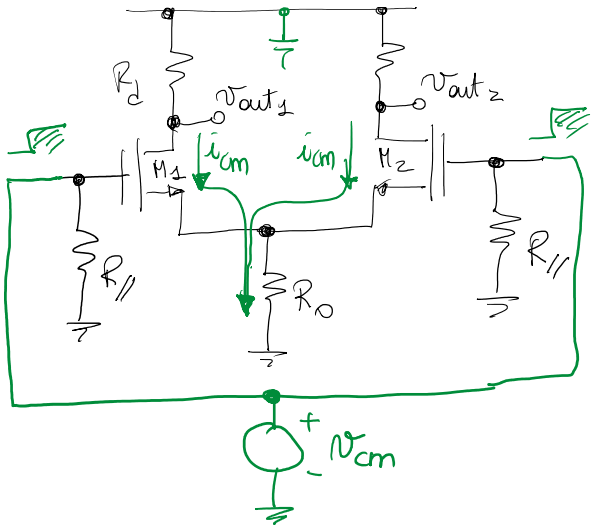
$$A_d \begin{cases} \text{DOUBLE ENDED} = g_m R_D \\ \text{SINGLE ENDED} = \pm g_m \frac{R_D}{2} \end{cases}$$

a seconda dell'uscita

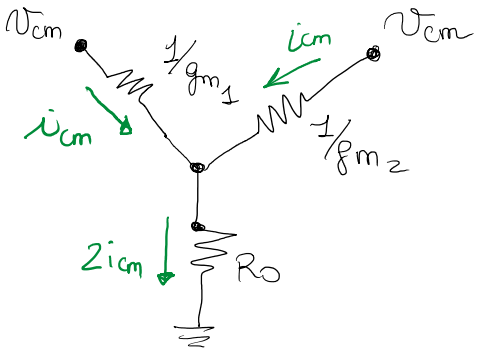
C. segnale di modo comune



Eq. Thevenin al modo di source:



Eq. Thevenin al modo di source:



$$2i_{cm} = \frac{v_{cm}}{\frac{1}{g_m}\frac{1}{2} + R_0} =$$

$$i_{cm} = \frac{1}{2}\,\frac{v_{cm}}{\frac{1}{2g_m} + R_0} = \frac{v_{cm}}{\frac{1}{g_m} + 2R_0}$$

$$v_{out1} = v_{out2} = -i_{cm} R_d =$$

$$= -\frac{R_d}{\frac{1}{g_m} + 2R_0}\, v_{cm}$$

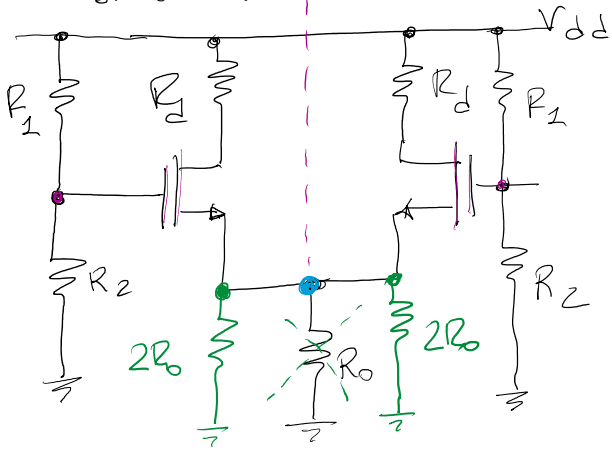
$$A_{cm} \triangleq \frac{(v_{out1} + v_{out2})/2}{v_{cm}} = -\frac{R_d}{\frac{1}{g_m} + 2R_0} = -\frac{g_m R_D}{1 + 2g_m R_0}$$ DOUBLE-ENDED

$$A_{cm} \triangleq \frac{v_{out1}}{v_{cm}} = \frac{v_{out2}}{v_{cm}} = -\frac{g_m R_D}{1 + 2g_m R_0}$$ SINGLE-ENDED

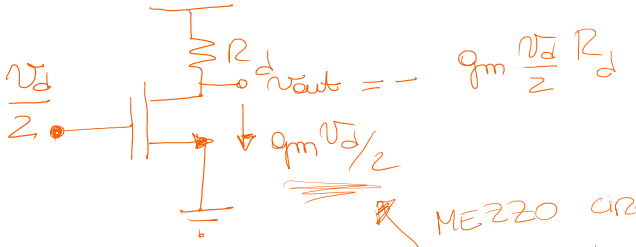
$$CMRR = \left|\frac{A_d}{A_{cm}}\right| = \begin{cases} \dfrac{g_m R_D}{\frac{g_m R_D}{1+2g_m R_0}} = 1 + 2g_m R_0 & \text{DOUBLE ENDED} \\ \dfrac{g_m R_D/2}{g_m R_D/(1+2g_m R_0)} = \dfrac{1+2g_m R_0}{2} & \text{SINGLE ENDED} \end{cases}$$

STADIO DIFFERENZIALE: ANALISI CON IL MEZZO CIRCUITO

stadio simmetrico

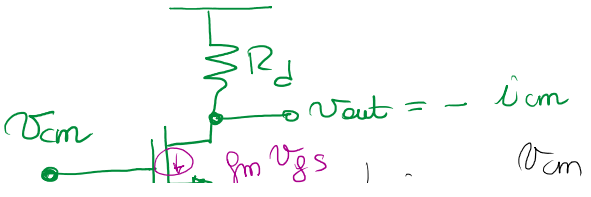


★ su segnale differenziale il nodo di source non si muove in tensione, è come se fosse massa per il segnale

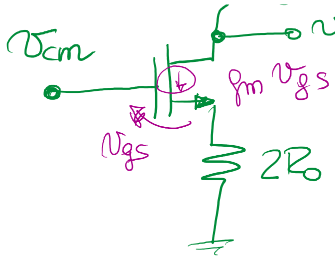


MEZZO CIRCUITO SU SEGNALE DIFFERENZIALE

★ su segnale di modo comune



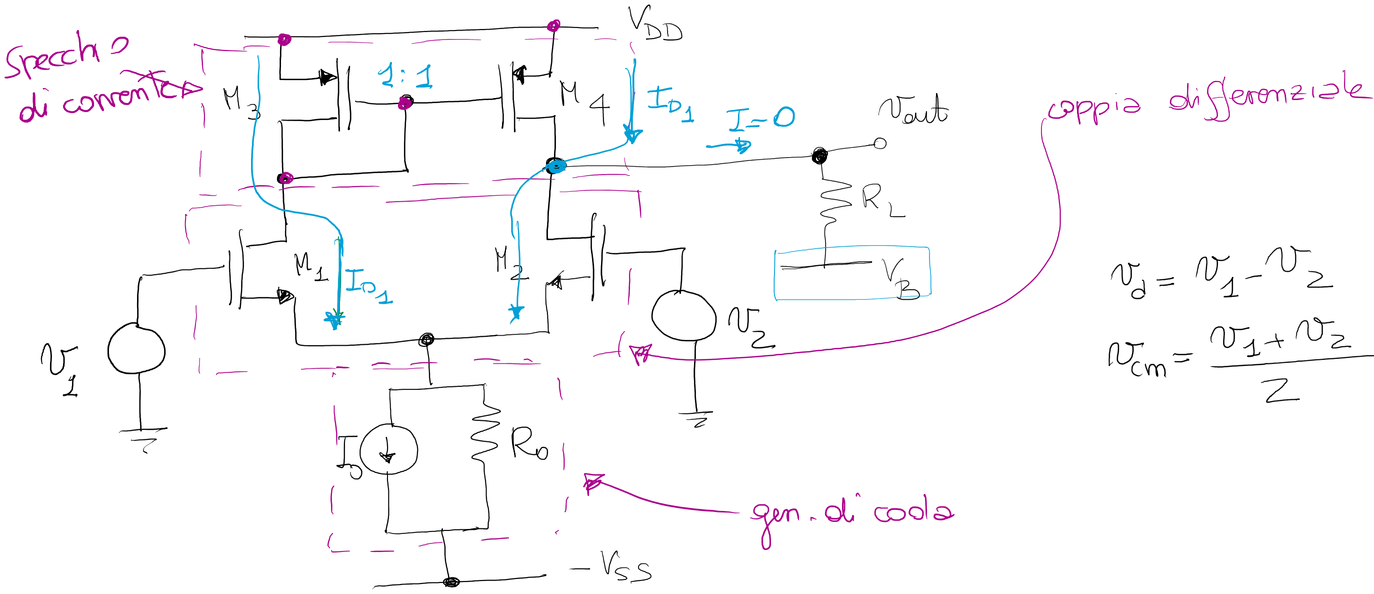
$v_{out} = - \; i_{cm} \; R_d \; - \qquad \frac{1}{g_m} + 2R_o$



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

MEZZO CIRCUITO SU SEGNALE DI MODO COMUNE

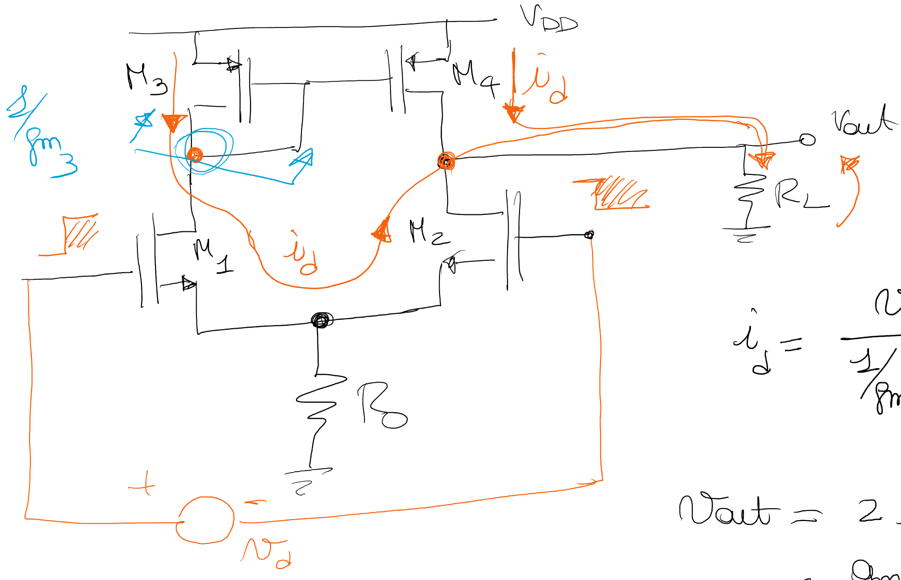
STADIO DIFFERENZIALE CON CARICO A SPECCHIO



$$v_d = v_1 - v_2$$

$$v_{cm} = \frac{v_1 + v_2}{2}$$

(B) COMPORTAMENTO SU SEGNALE DIFFERENZIALE



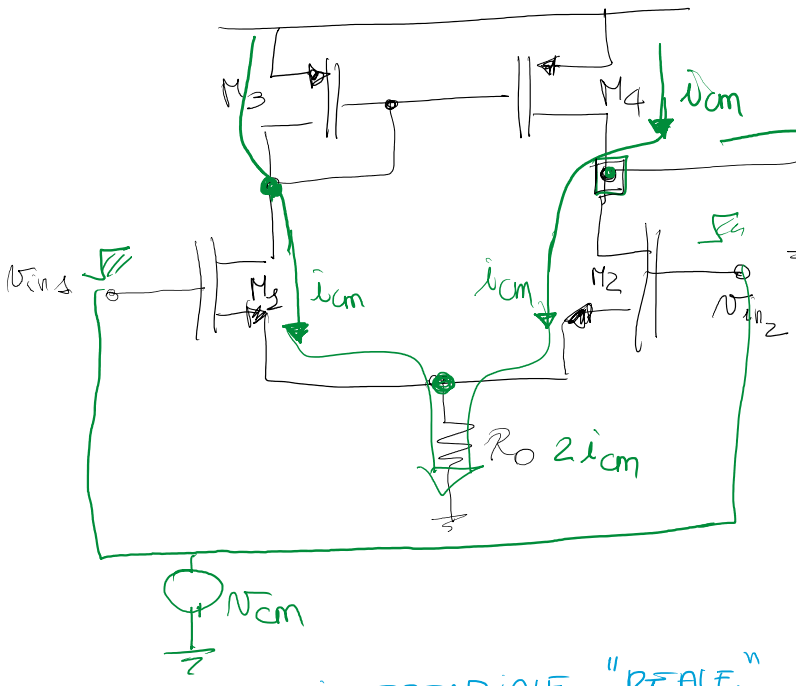
$$i_d = \frac{v_d}{\frac{1}{g_{m_1}} + \frac{1}{g_m}} = g_m \frac{v_d}{2}$$

$$v_{out} = 2\, i_d\, R_L = 2\, g_m \frac{v_d}{2} R_L = g_m R_L\, v_d$$

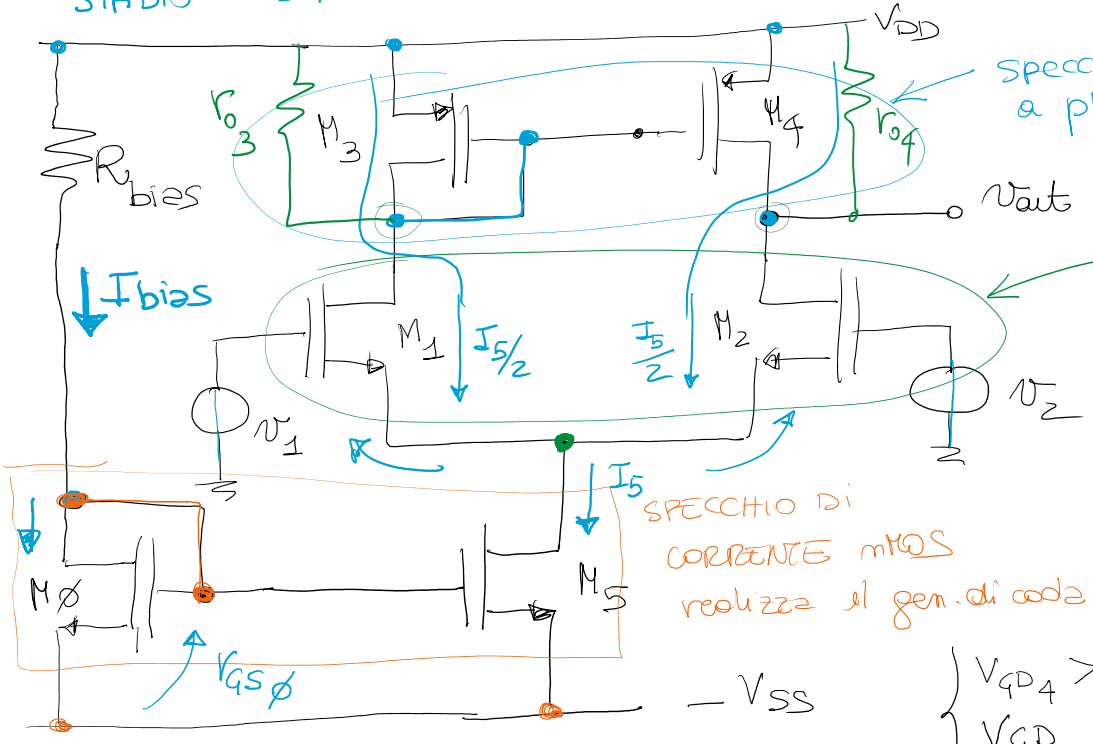
↳ guadagno differenziale

$$\boxed{\frac{v_{out}}{v_d} = g_m R_L}$$

(C) comportamento su segnale di modo comune.



STADIO DIFFERENZIALE "REALE"



$$\begin{cases} V_{GD_4} > V_{Tp} \\ V_{GD_2} < V_{Tn} \end{cases}$$

$$\begin{cases} V_{G4} - V_{out} > V_{Tp} \\ V_{G2} - V_{out} < V_{Tn} \end{cases} \qquad \begin{cases} V_{out} \\ V_{out} > \end{cases}$$

$$V_{G2} - V_{Tn} < V_{out} < V_{G4}$$

$$V_{Tn} = |V_{Tp}| = V_T$$

$$V_{G2} - V_T < V_{out} < V_G$$

coda

corrente
carico
attivo

differen
di
esso

$< V_{G4} - V_{Tp}$

$> V_{G2} - V_{Tn}$

$- V_{Tp}$

$_4 + V_T$