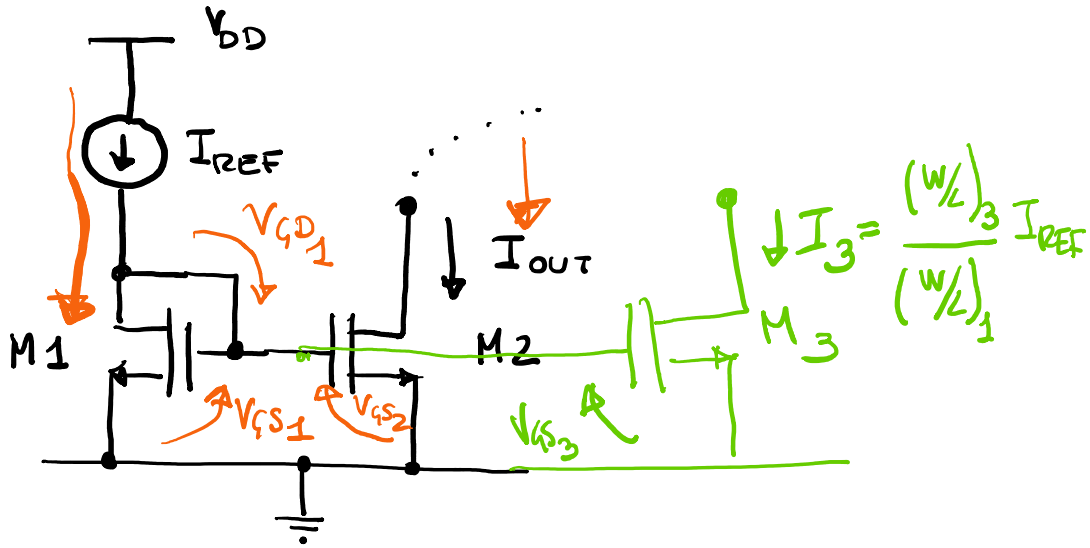
Lezione 11: Specchi di corrente e stadio differenziale con carico a specchio

lunedì 27 aprile 2020 10:21

SPECCHIO DI CORRENTE (CURRENT MIRROR)

nMOS



M_1 è sicuramente saturo $V_{GD_1} = 0$

$$I_{REF} = k_{n_1} (V_{GS_1} - V_{Tn})^2 \Rightarrow (V_{GS_1} - V_{Tn})^2 = \frac{I_{REF}}{k_{n_1}}$$

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

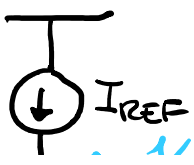
Hp M_2 sia saturo

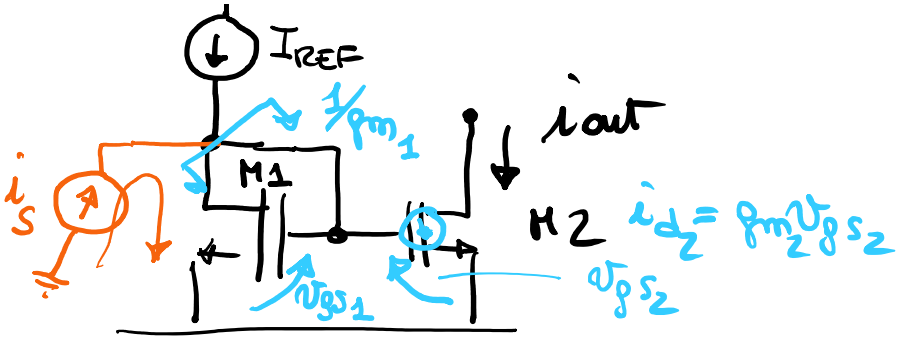
$$I_{out} = k_{n_2} (V_{GS_2} - V_{Tn})^2 = k_{n_2} (V_{GS_1} - V_{Tn})^2 =$$

$$= \frac{k_{n2}}{k_{n1}} I_{REF} = \frac{\cancel{\frac{1}{2}\mu_n C_{ox}} \left(\frac{W}{L}\right)_2}{\cancel{\frac{1}{2}\mu_n C_{ox}} \left(\frac{W}{L}\right)_1} I_{REF} =$$

$$= \frac{(W/L)_2}{(W/L)_1} I_{REF}$$

su segnale





i_s corrente di segnale (piccolo)

$$v_{gs_1} = i_s \frac{1}{g_{m_1}}$$

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

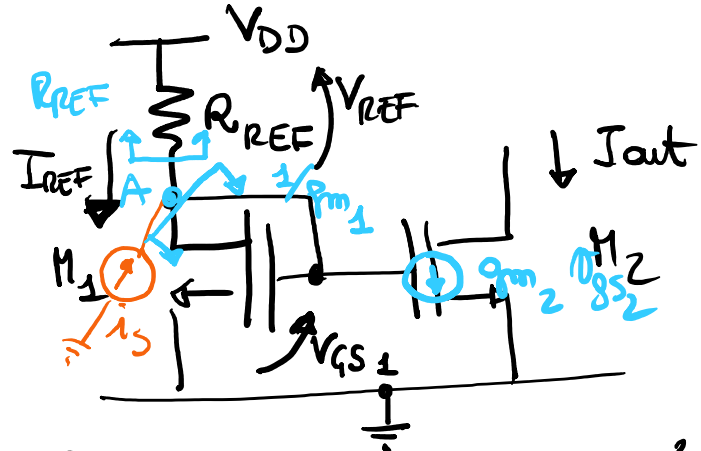
$$i_{out} = g_{m_2} v_{gs_2} - g_{m_2} v_{gs_1} = \frac{g_{m_2}}{g_{m_1}} i_s =$$

$$= \frac{2 k_{n_2} (V_{GS_2} - V_{Tn})}{2 k_{n_1} (V_{GS_1} - V_{Tn})} i_s =$$

$$= \frac{k_{n_2}}{k_{n_1}} i_s = \frac{\cancel{\frac{1}{2}} \cancel{\mu_n C_{ox}} (W/L)_2}{\cancel{\frac{1}{2}} \cancel{\mu_n C_{ox}} (W/L)_1} i_s =$$

$V_{GS_2} = V_{GS_1}$

$$= \frac{(W/L)_2}{(W/L)_1} i_s$$



corr. di segnale in uscita

$$\begin{cases} I_{REF} = k_{n_1} (V_{GS_1} - V_{Tn})^2 \\ V_{out} = I_{out} R \end{cases}$$

$$i_{M_1} = g_{m_1} v_{gs_1}$$

$$\begin{cases} V_{DD} = I_{REF} R_{REF} + V_{GS_1} \end{cases}$$

$i_{M_1} = g_{m_1} v_{gs_1}$

su segnale:

modo A partizione di corrente

$$i_{M_1} = \frac{R_{REF}}{R_{REF} + 1/g_{m_1}} i_S$$

$v_{gs_2} = v_{gs_1}$

$$i_{out} = g_{m_2} v_{gs_2} = g_{m_2} v_{gs_1} = g_{m_2} \frac{i_{M_1}}{g_{m_1}} =$$

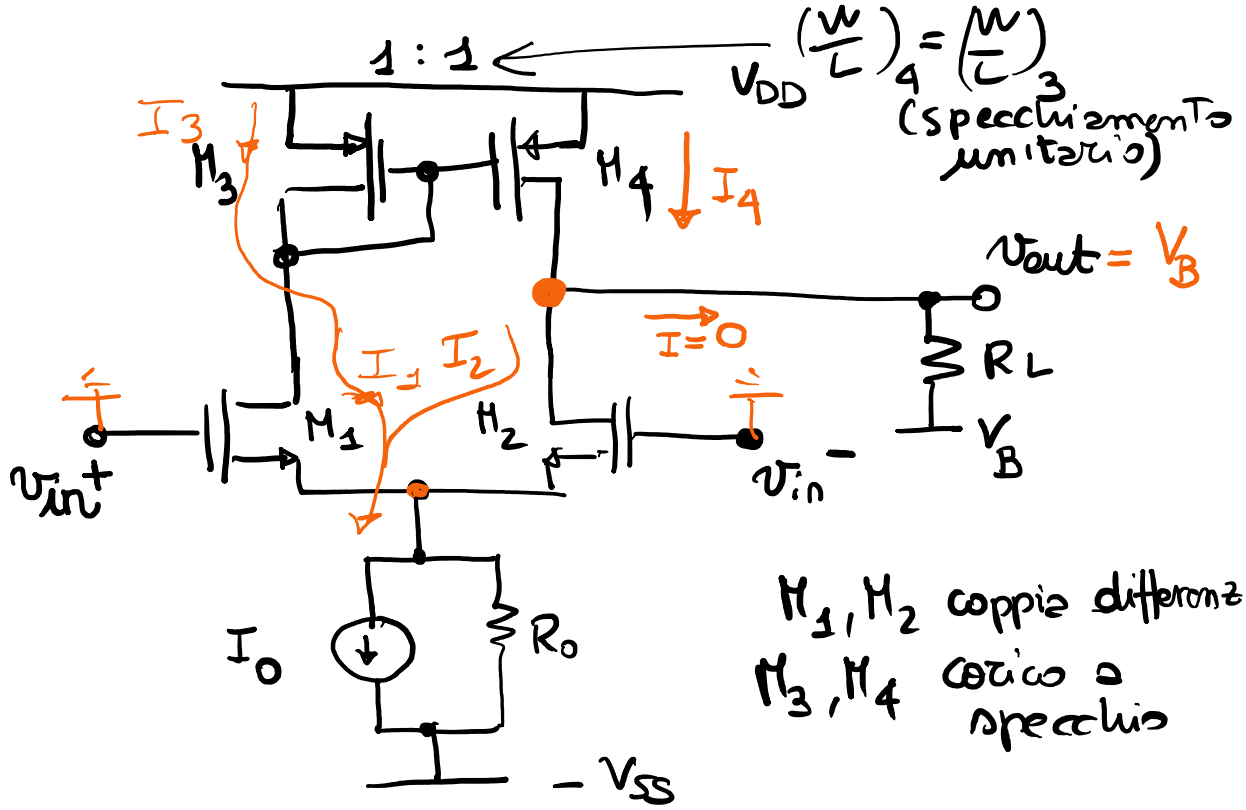
$$= \frac{(W/L)_2}{(W/L)_1} \frac{R_{REF}}{R_{REF} + 1/g_{m_1}} i_S$$

FATTORE DI SPECCHIAMENTO

$$\frac{g_{m2}}{g_{m1}} = \frac{2 k_{n_2} (V_{GS_2} - V_{Tn})}{2 k_{n_1} (V_{GS_1} - V_{Tn})} \overset{V_{GS_1} = V_{GS_2}}{=} \frac{k_{n_2}}{k_{n_1}} =$$

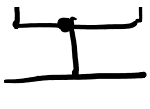
$$= \frac{\frac{1}{2} \mu_n C_{ox} (W/L)_2}{\frac{1}{2} \mu_n C_{ox} (W/L)_1} = \frac{(W/L)_2}{(W/L)_1}$$

STADIO DIFFERENZIALE CON CARICO A SPECCHIO



M_1, M_2 coppia differenz.

M_3, M_4 carico a specchio

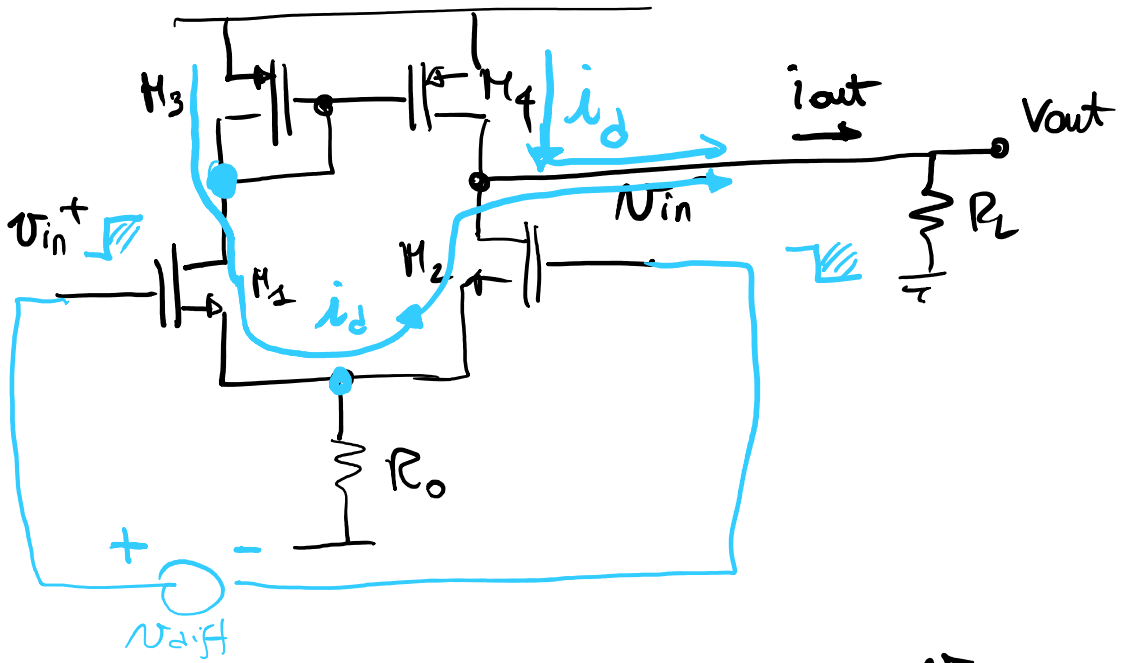


spettro

② POLARIZZAZIONE (—)

$I_3 = I_1 = I_4 = I_2 \Rightarrow I = 0$; $V_{out} = V_B$ devo garantire che M_2 e M_4 siano saturo

ⓑ SEGNALE DIFFERENZIALE



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

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

$$i_{out} = i_d + i_d = 2 i_d$$

$$v_{out} = i_{out} R_L = 2 i_d R_L = 2 g_m \frac{v_{diff}}{2} R_L$$

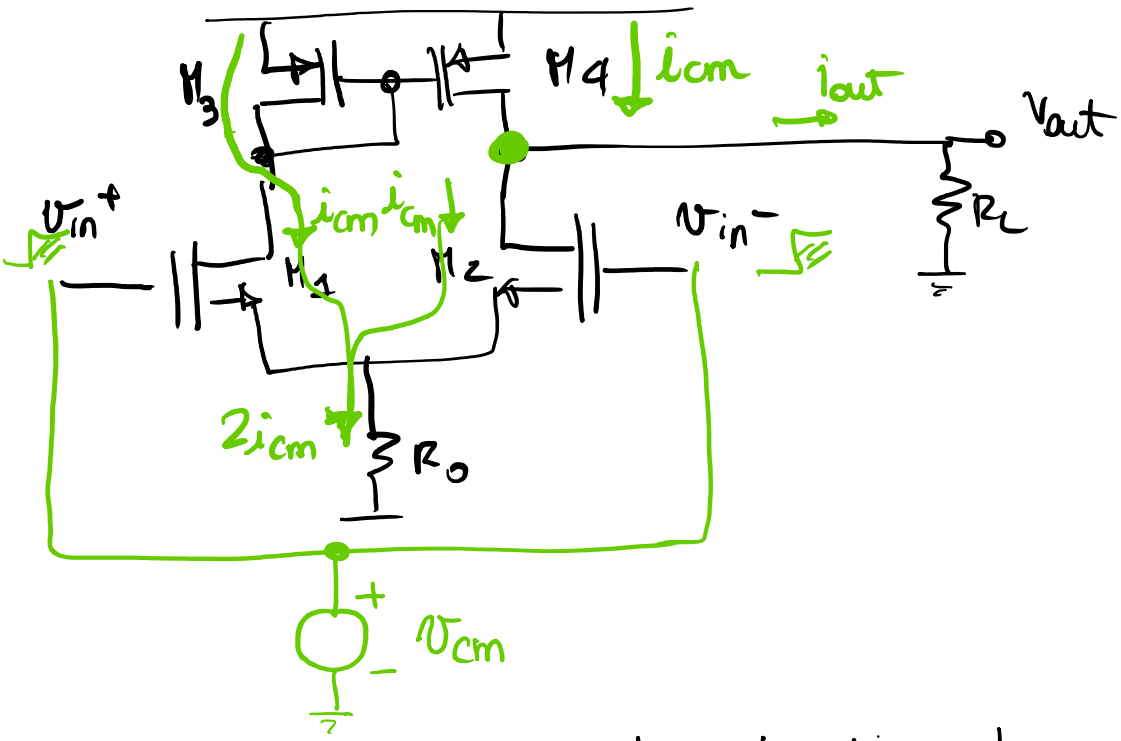
$$\hookrightarrow G_{diff} \triangleq \frac{v_{out}}{v_{diff}} = g_m R_L$$

☺ G_{diff} $g_m R_L$ pur usando single ended (guadagno un fattore 2 rispetto alle condiz. di carico resistivo!

ⓒ

condiz. di carico resistivo !

⑥ SEGNALE DI MODO COMUNE



bilancio di corrente al nodo di uscita

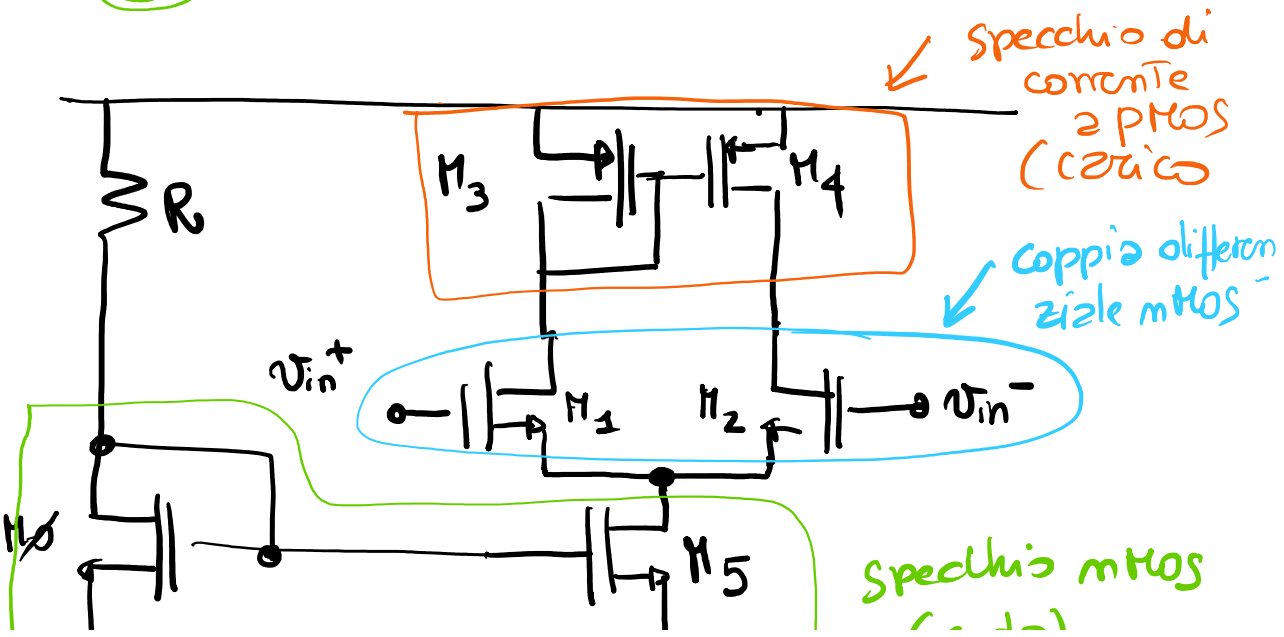
$$i_{cm} = i_{cm} + i_{out} \Rightarrow i_{out} = 0 \; !!$$

$$v_{out}\Big|_{cm} = 0$$

$$\Downarrow$$

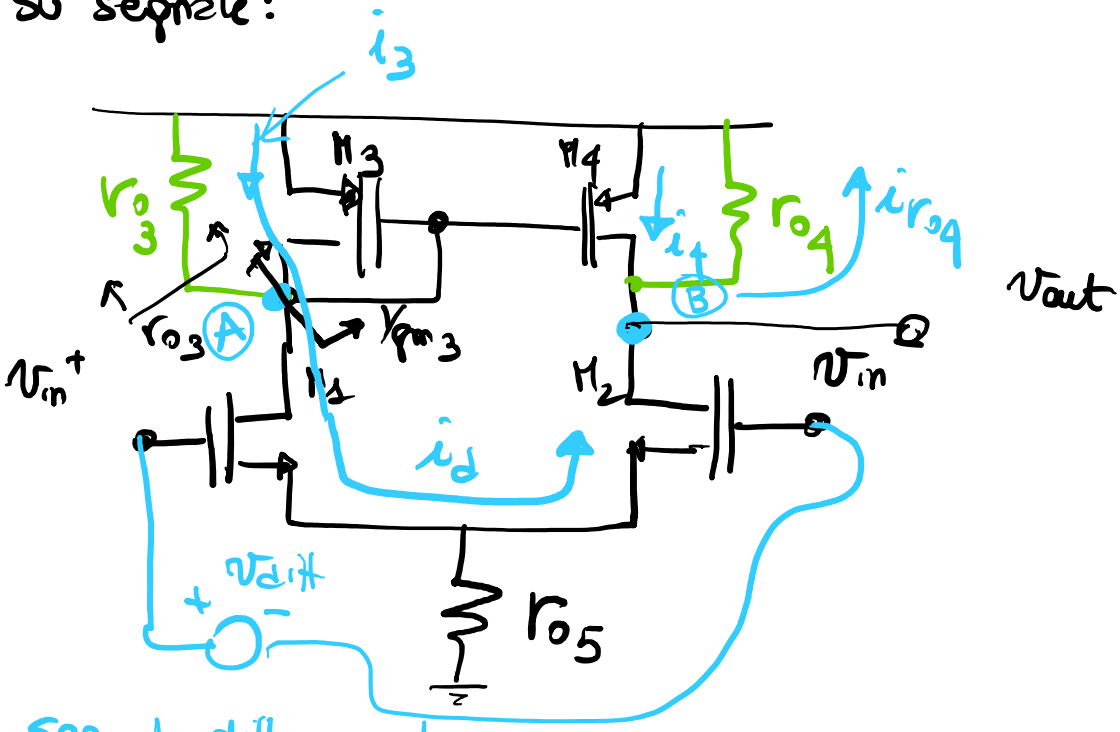
$$G_{cm} = \frac{v_{out}}{v_{cm}} = 0 \Rightarrow CMRR = \left|\frac{G_{diff}}{G_{cm}}\right| = \infty$$

$G_{cm} = 0$ e $CMRR = \infty$!!



specchio nMOS (coda)

su segnale:



Segnale differenziale

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

$$i_3 = \frac{r_{o3}}{r_{o3} + 1/g_{m_3}} i_d$$ (partizione di corrente al nodo (A))

$$i_4 = i_3$$

bilancio di corrente al nodo (B)

$$i_{r_{o4}} = i_4 + i_d =$$

$$= \frac{r_{o3}}{r_{o3} + 1/g_{m_3}} i_d + i_d =$$

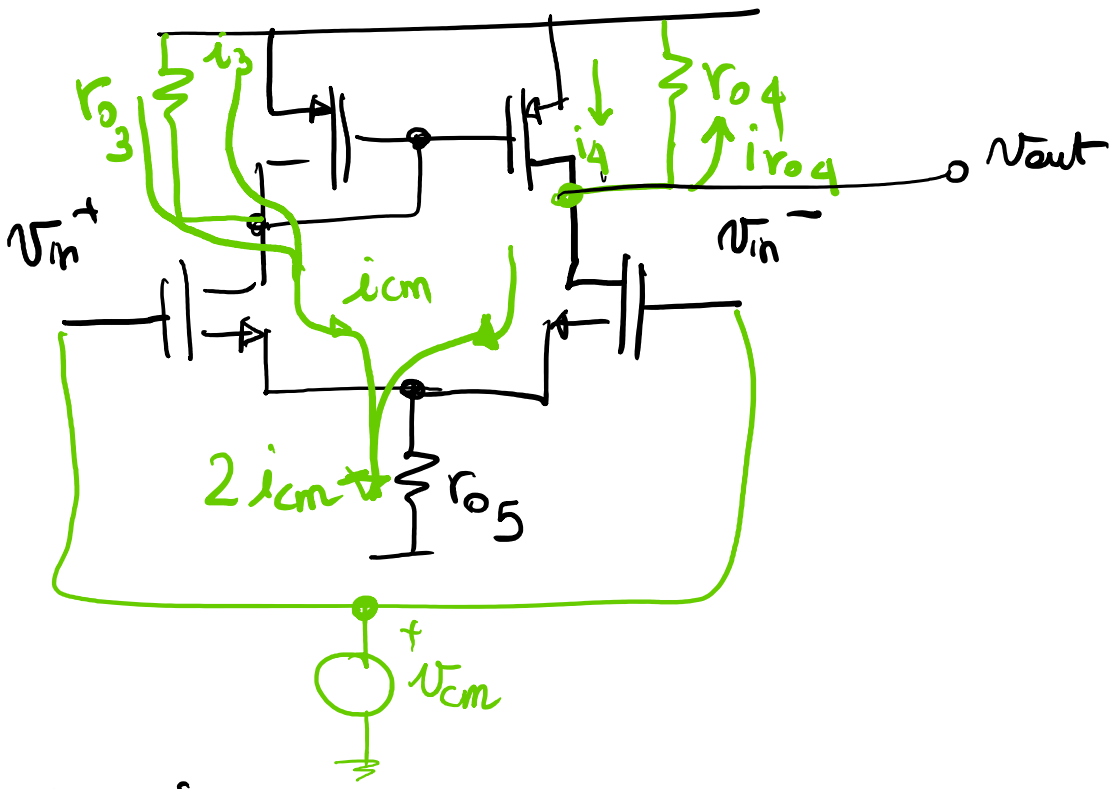
$$= i_d \left[1 + \frac{r_{o3}}{r_{o3} + 1/g_{m_3}} \right]$$

↳ tende a 2 se

↳ tende a 2 se $r_{o3} \to \infty$.

$$V_{out} = i_{r_{o4}} r_{o4}$$

segnale di modo comune



$$i_4 = i_3 = i_{cm} \frac{r_{o3}}{r_{o3} + 1/g_{m3}}$$

bilancio di corrente in uscita:

$$i_4 = i_{cm} + i_{r_{o4}}$$

$$i_{r_{o4}} = i_4 - i_{cm} = i_{cm} \left[\frac{r_{o3}}{r_{o3} + 1/g_{m3}} - 1 \right]$$

↳ 0 se $r_{o3} \to \infty$

$$V_{out} = i_{r_{o4}} * r_{o4}$$

per effetto delle r_o $G_{cm} \neq 0$ anche con carico a specchio