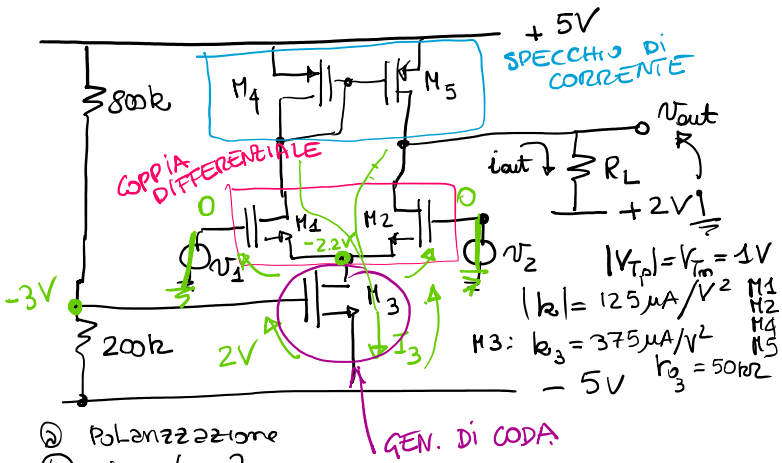
Esercitazione stadi differenziali con carico a specchio

martedì 12 maggio 2020 09:33

ESERCIZIO: STADIO DIFFERENZIALE CON CARICO A SPECCHIO



$|V_{Tp}| = V_{Tn} = 1V$

$|k| = 125\mu A/V^2$ M1 M2 M4 M5

M3: $k_3 = 375\mu A/V^2$, $r_{o_3} = 50k\Omega$

a) Polarizzazione

b) i_{out}/v_d ?

c) i_{out}/v_{cm} ?

a) POLARIZZAZIONE

tip MOS saturi

$$V_{G3} = -5V + \frac{200k}{(200+800)k}\left[5V - (-5V)\right] =$$

$$= -3V$$

Trascuro r_{o_3} (salvo verificare che $I_{r_{o_3}} \ll I_{M_3}$)

$$I_3 = k_3 (V_{GS_3} - V_{Tn})^2 = 375\,\mu A$$

$$I_1 = I_2 = \frac{I_3}{2} = 187.5\,\mu A$$

$$I_1 = I_2 = k_1 (V_{GS} - V_{Tn})^2$$

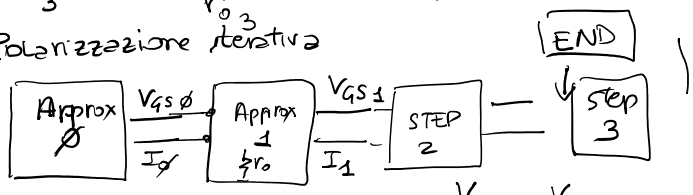
$$\rightarrow V_{GS_1} = V_{GS_2} = V_{GS} =$$

$$= V_{Tn} \pm \sqrt{\frac{I_1}{k_1}} = V_{Tn} + \sqrt{\frac{187.5\mu A}{125\mu A/V^2}} =$$

$$= 2.2\,V$$

$$I_{r_{o_3}} = \frac{-2.2V - (-5V)}{r_{o_3}} = 56\,\mu A\ !!$$

Polarizzazione iterativa



$$\frac{V_{GS_m} - V_{GS_{m-1}}}{V_{GS_m}}$$ piccolo rispetto a 1

$$\Downarrow$$

$$I_1\big|_1 = I_2\big|_1 = \frac{I_3}{2} + \frac{I_{r_{o_3}}}{2} = \frac{375\mu A + 56\mu A}{2} =$$

$$= 215.5\,\mu A$$

$$\Downarrow$$

$$V_{GS}\big|_1 = V_{Tn} \pm \sqrt{\frac{215.5\mu A}{125\mu A/V^2}} = 2.31\,V$$

$$\Downarrow$$

$$V_{DS_3} = -2.31V - (-5V) = 2.7V$$

$$\rightarrow I_{r_{o_3}} = \frac{V_{DS_3}}{r_{o_3}} = 54\,\mu A \quad (56\,\mu A)$$

3.6%

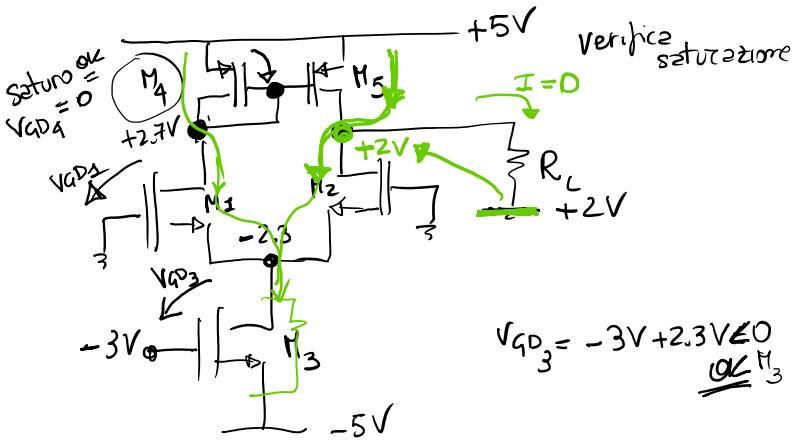
$\hookrightarrow I_{r_{o_3}} = \frac{V_{DS3}}{r_{o_3}} = 54\mu A$ (circa) $\quad 3.6\%$

$\Downarrow$ OVC

$I_{M_3\,TOT} = 375\mu A + 54\mu A$

$I_1 = I_2 = \frac{I_{M_3 TOT}}{2}$

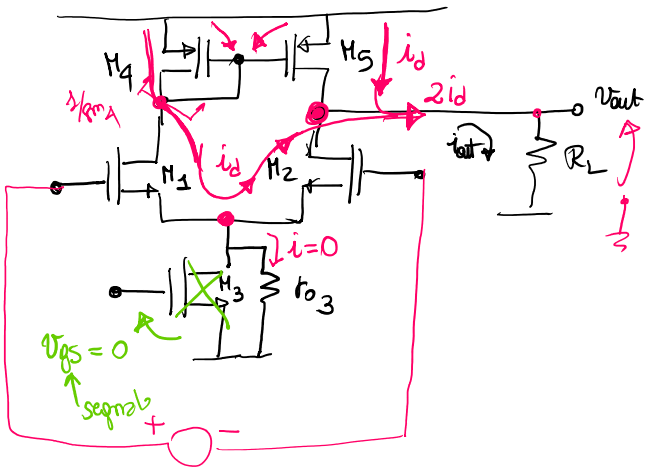
$g_{m_1} = g_{m_2} = 328\,\mu A/V \qquad g_m = 2k(V_{GS} - V_{tn})$

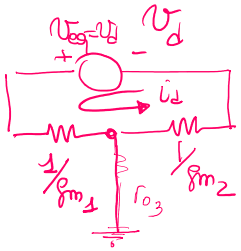


$V_{GD_3} = -3V + 2.3V < 0$ ovc M_3

$V_{GD_1} = -2.7V < 0 < V_{tn}$ ovc M_1

(b) comportamento su segnale differenziale





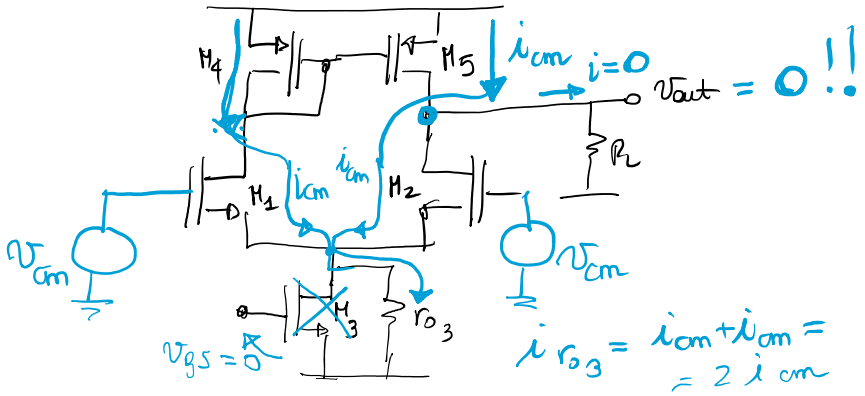
$i_d = \frac{V_d}{1/g_{m_1} + 1/g_{m_2}}$

$i_{out} = 2\,i_d \Rightarrow V_{out} = 2\,i_d R_L = 2\,\frac{V_d}{2/g_m} R_L$

$G_{diff} = \frac{V_{out}}{V_d} = g_m R_L = 328\,\mu A/V * 10k\Omega = +3.28$

(c) analisi su segnale di modo comune

(c) analisi per segnale di modo comune

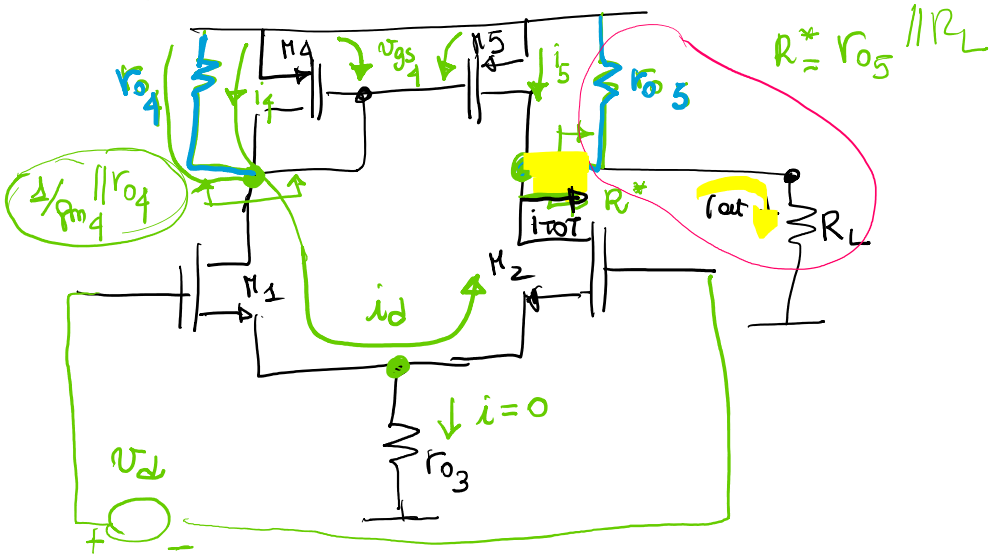


$G_{cm} = 0$!! grazie allo specchio

(d) M_4 e M_5 con r_o $|V_A| = 25\,V$

$$r_{o4} = r_{o5} = \frac{|V_A|}{I_4} = \frac{25\,V}{215.5\,\mu A} = 116\,k\Omega$$

- guadagno differenziale



$$i_5 = i_4$$

$$i_4 \neq i_d \qquad i_d = i_4 + i_{r_{o4}}$$

$$i_4 = \frac{r_{o4}}{1/g_{m4} + r_{o4}}\, i_d$$

partitore di corrente tra $1/g_{m4}$ e r_{o4}

$$v_{gs4} = -i_d \left(1/g_{m4} \| r_{o4}\right)$$

$$v_{gs5} = v_{gs4} \Rightarrow i_{d5} = g_{m5} v_{gs5} = g_{m5} v_{gs4} = g_{m5}\left[-i_d \left(1/g_{m4} \| r_{o4}\right)\right]$$

$$i_5 = -i_{d5}$$

$i_5 = -i_{d5}$

$i_{out} = \dfrac{r_{o5}}{r_{o5} + R_L} i_{TOT}$

$i_5 = i_4$

$i_{TOT} = i_d + i_5 = i_d + i_4 = i_d \left[1 + \dfrac{r_{o4}}{\frac{1}{g_{m4}} + r_{o4}} \right]$

$\rightarrow 2$ per $r_{o4} \to \infty$

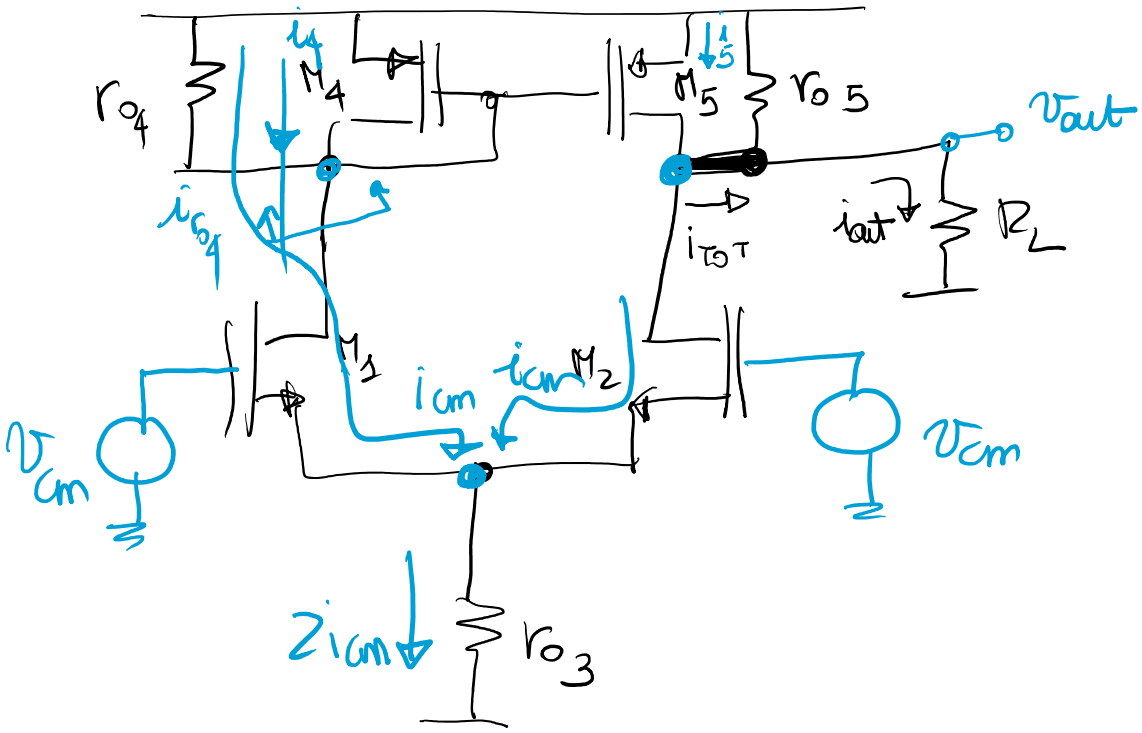
$v_{out} = i_{out} R_L \| r_{o5}$

$$G_{diff} = \frac{v_{out}}{v_d} = \frac{R_L \| r_{o5}}{A v_d} \left[1 + \frac{r_{o4}}{\frac{1}{g_{m4}} + r_{o4}} \right] *$$

$$* \frac{v_d}{\frac{1}{g_{m1}} + \frac{1}{g_{m2}}} =$$

$$= (R_L \| r_{o5}) \left[1 + \frac{r_{o4}}{\frac{1}{g_{m4}} + r_{o4}} \right] \frac{g_m}{2}$$

- modo comune



$$i_5 = i_4 = i_{cm} \frac{r_{o4}}{r_{o4} + \frac{1}{g_{m4}}}$$

$$V_{out} = i_{TOT} * (r_{o5} \| R_L)$$

$$i_{TOT} \neq i_{cm} = i_5$$

$$i_{TOT} = i_5 - i_{cm}$$

$r_{o4} \to \infty \to 1$

$$V_{out} = (r_{o5} \| R_L) \left[i_{cm} \frac{r_{o4}}{r_{o4} + 1/g_{m4}} - i_{cm} \right]$$

$G_{cm} \neq 0$

$$\left.\begin{array}{l} G_{cm} = -2.25\,10^{-3} \\ G_{dif} = 2.98 \end{array}\right\} \quad CMRR = \left| \frac{G_{dif}}{G_{cm}} \right| =$$

$$= 1300 \Rightarrow \sim 60\,dB$$