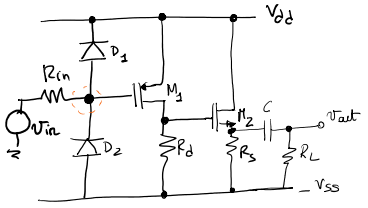
Esercizio 1 quarto appello aa 2014-15 - 12 febbraio 2016

Thursday, April 15, 2021 10:26 AM



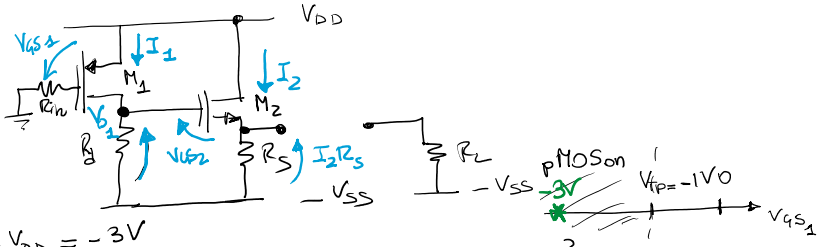
$R_{in} = 100\,k\Omega$ $R_g = 5\,k\Omega$
$R_s = 2\,k\Omega$ $R_L = 4\,k\Omega$
$C = 300\,nF$
$V_{dd} = 3V$ $V_{ss} = 5V$
$k_n = |k_p| = 0.25\,mA/V^2$
$|V_{Tp}| = V_{Tn} = 1V$

a. POLARIZZAZIONE
b. $\frac{v_{out}}{v_{in}}\Big|_{HF}$ $r_o = \infty$
c. $\frac{v_{out}}{v_{in}}\Big|_{HF}$ $r_o = 50\,k\Omega$ è la singolarità del circuito
d. Max guadagno $r_o = \infty$

POLARIZZAZIONE

- spengo i gen. di segnale
- capacità circuiti aperti
- HP MOSFET operanti in saturazione.

D_1 e D_2 sono in polarizzazione inversa



$V_{GS_1} = -V_{DD} = -3V$

$I_1 = |k_p| (V_{GS_1} - V_{Tp})^2 = 0.25\,mA/V^2 (-3V + 1V)^2 = 1mA$

$V_{D_1} = -V_{ss} + I_1 R_d = -5V + 1mA \cdot 5k\Omega = 0V \Rightarrow V_{GD_1} = 0V > V_{Tp}$

M_1 è saturo

$V_{G2} = V_{D_1} \Rightarrow$

$$\begin{cases} I_2 = k_n (V_{GS_2} - V_{Tn})^2 \\ V_{G_2} - (-V_{ss}) = V_{GS_2} + I_2 R_s \end{cases}$$

$5V = V_{GS_2} + k_n (V_{GS_2} - V_{Tn})^2 R_s$

$\hookrightarrow V_{GS_2} = 3V$, altra soluz. non accettabile

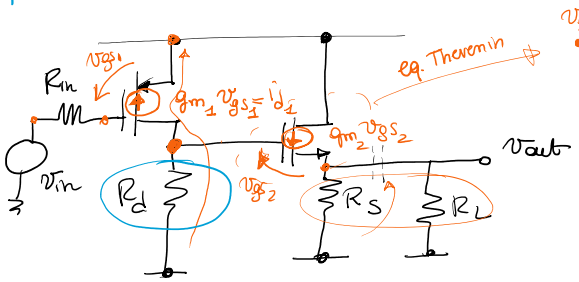
$\Downarrow I_2 = k_n (V_{GS_2} - V_{Tn})^2 = 0.25\,mA/V^2 (3V - 1V)^2 = 1mA$

$V_{GD_2} = 0V - V_{dd} = -3V < V_{Tn}$ saturaz. mMOS ok

$g_{m_1} = 2 k_p (V_{GS_1} - V_{Tp}) = -2 \times 0.25\,mA/V^2 [-3V - (-1V)] = 1\,mS$

$g_{m_2} = 2 k_n (V_{GS_n} - V_{Tn}) = 2 \times 0.25\,mA/V^2 (3V - 1V) = 1\,mS$

b. trasferimento di piccolo segnale ad alta frequenza $\frac{v_{out}}{v_{in}}$



$v_{gs_1} = v_{in}$

$v_{g_2} = v_{d_1} = -i_{d_1} R_d = -g_{m_1} v_{gs_1} R_d$

$i_{d_2} = \frac{v_{g_2}}{1/g_{m_2} + R_s \| R_L}$

$$\begin{cases} i_{d_2} = g_{m_2} v_{gs_2} \\ v_{g_2} = v_{gs_2} + i_{d_2} R_s \| R_L \end{cases}$$

$$i_{d_2} = \frac{v_{gs_2}}{\frac{1}{g_{m_2}} + R_S \| R_L} \qquad \left.\begin{array}{l} v_{g_2} = v_{gs_2} + i_{d_2} R_S \| R_L \end{array}\right\}$$

$$v_{out} = i_{d_2} (R_S \| R_L) = \frac{R_S \| R_L}{\frac{1}{g_{m_2}} + R_S \| R_L} v_{g_2}$$

$$v_{out} = \frac{R_S \| R_L}{\frac{1}{g_{m_2}} + R_S \| R_L} \cdot (-g_{m_1} R_d) v_{in}$$

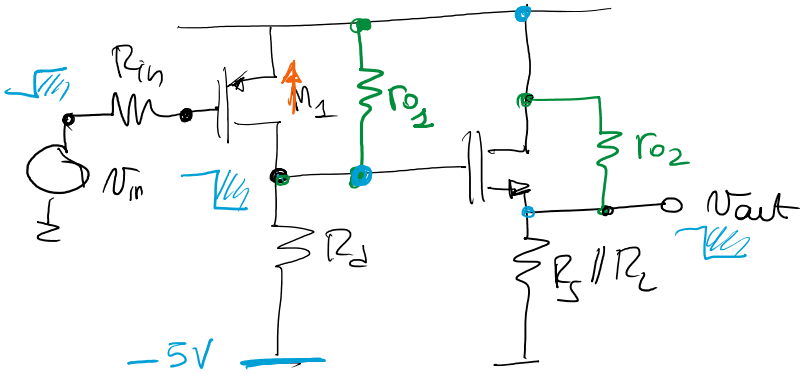
$$\frac{8k\Omega}{6k\Omega} = \frac{8}{6}\,k\Omega = 1.33k$$

$$G\Big|_{HF} = \frac{v_{out}}{v_{in}}\Big|_{HF} = -(g_{m_1} R_d) \frac{R_S \| R_L}{\frac{1}{g_{m_2}} + R_S \| R_L} = -5 \frac{2k\|4k}{1k + 2k\|4k} =$$

$$= -5 \cdot \frac{1.33k}{2.33k} = -\frac{20}{7} = -2.86$$

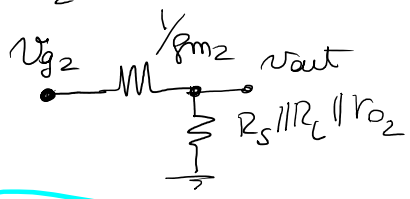
$$\frac{\frac{8}{6}}{\frac{14}{6}} = \frac{4}{7}$$

c. trasferimento con r_o e singolarità introdotte da C



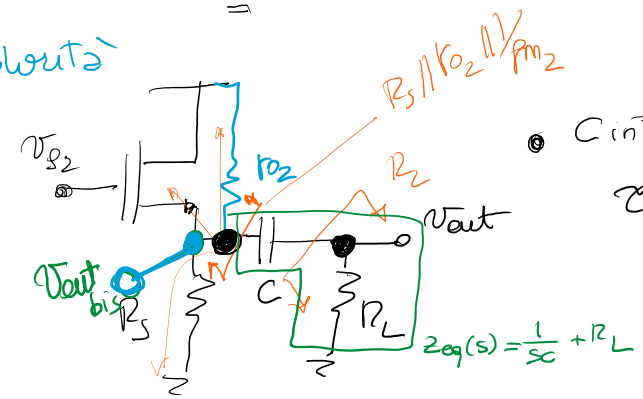
r_{o_1} è in parallelo a R_d

r_{o_2} è in parallelo a $R_S \| R_L$



$$G\Big|_{HF} = \frac{v_{out}}{v_{in}}\Big|_{HF} = \underbrace{-g_{m_1} \cdot (R_d \| r_{o_1})}_{\text{trasferimento source a massa}} \cdot \underbrace{\frac{R_S \| R_L \| r_{o_2}}{\frac{1}{g_{m_2}} + R_S \| R_L \| r_{o_2}}}_{\text{Trasferimento source follower}} =$$

singolarità



- C introduce un polo con

$$\tau_p = C \left[R_L + \underbrace{R_S \| r_{o_2} \| \frac{1}{g_{m_2}}}_{\frac{2}{3}\,k\Omega} \right] \simeq 1.5\,ms$$

$$f_p = \frac{1}{2\pi \tau_p}$$

- C introduce uno zero nell'origine

per $v_{out\,bis}$

polo = il medesimo

zero: $Z_{eq}(s) = \frac{1}{sC} + R_L = 0 \Rightarrow \tau_z = CR_L$

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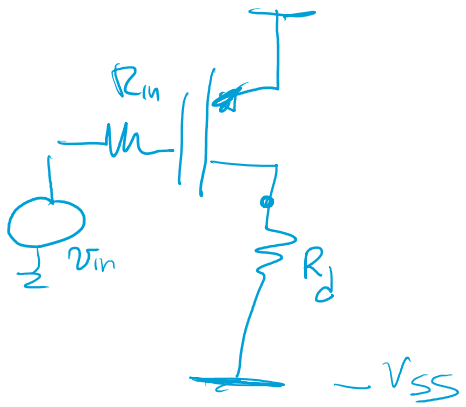
d. Massimo guadagno



cond. limite

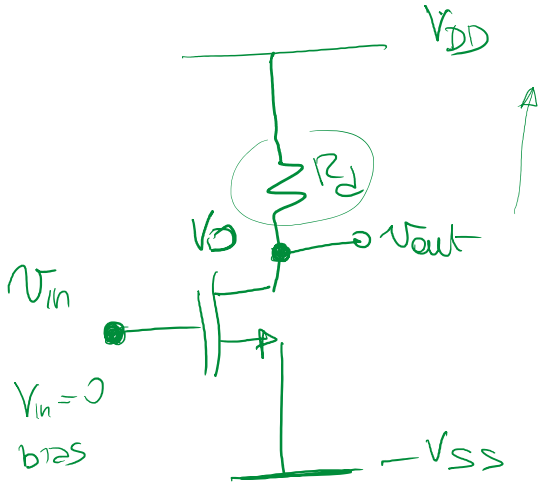
$V_{GD_1} = V_{Tp}$

$V_{G_1} = 0\,V$

$V_{D_1} = -V_{SS} + I_{D_1} R_d$ (I_{D_1} = 1 mA)

$V_{SS} - I_{D_1} R_d = V_{Tp}$

$\rightarrow R_{d\,max} = 6\,k\Omega$



$V_{out_{MAX}} = V_{DD}$

$V_{out_{min}} = -V_{Tn}$ (assumendo $V_L = 0$)

$V_{GD} = V_{Tn}$