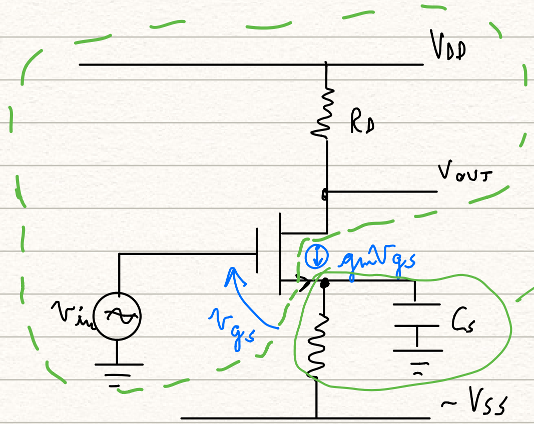
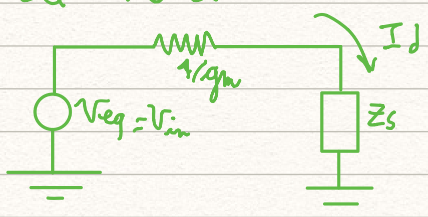
DIMENSIONAMENTO DELLA CAPACITÀ DI BYPASS (nello stadio con degenerazione di source)



$Z_S = \frac{R_S}{1 + sC_SR_S}$

$v_{in} = v_{gs} + i_d Z_S$

EQ. THEVENIN



$$i_d = \frac{v_{in}}{1/g_m + \frac{R_S}{1+sC_SR_S}}$$

$$V_{OUT}(s) = -i_dR_d = -V_{in}(s)\,\frac{R_d}{1/g_m + \frac{R_S}{1+sC_SR_S}}$$

FUNZIONE DI TRASFERIMENTO

$$T(s) \triangleq \frac{V_{OUT}(s)}{V_{in}(s)} = -\frac{R_d}{1/g_m + \frac{R_S}{1+sC_SR_S}} = \frac{-g_mR_d(1+sC_SR_S)}{1+sC_SR_S+g_mR_S} = \frac{-g_mR_d(1+sC_SR_S)}{(1+g_mR_S)\left(1+\frac{sC_SR_S}{1+g_mR_S}\right)} =$$

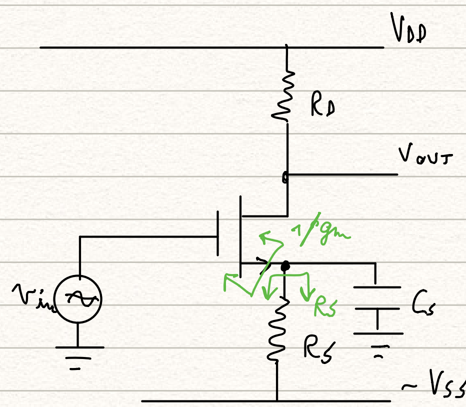
$$= \underbrace{\frac{-g_mR_d}{1+g_mR_S}}_{\text{TRASFERIMENTO IN DC}} \; \underbrace{\frac{1+sC_SR_S}{1+sC_S(R_S//(1/g_m))}}_{\text{TERMINE IN S}}$$

C_S:
- POLO: $\tau_p = C_S(R_S // 1/g_m)$
- ZERO: $\tau_z = C_SR_S$

Calcolo della funzione di trasferimento per ispezione

- $T(0)$ trasferimento in DC

$$T(0) = \frac{-R_d}{1/g_m + R_S} = -\frac{g_mR_d}{1+g_mR_S}$$



$\forall V_{in}(s) \neq 0 \ \exists \bar{s}$ t.c. $V_{OUT}(\bar{s}) = 0$

$V_{OUT}(s) = 0$ se e solo se $i_s(s) = 0$

$i_d = g_m v_{gs}(s)$ $\quad g_m \neq 0 \rightarrow v_{gs}(s) = 0$

$Z_{eq}(\bar{s}) = \frac{R_S}{1+sC_SR_S} \longrightarrow \infty$

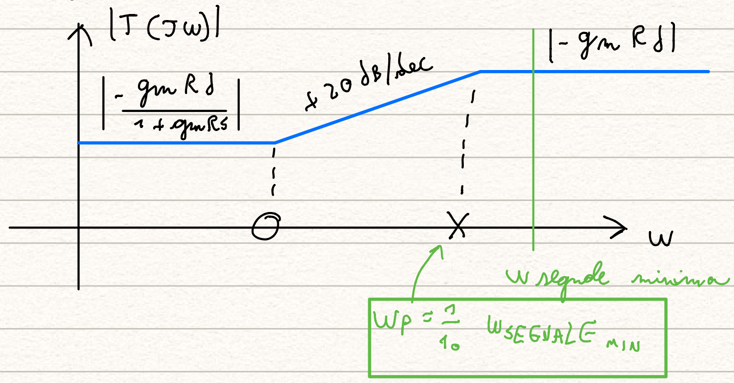
$\hookrightarrow 1 + sC_SR_S = 0$

• Singolarità di C_s $\qquad s = -\frac{1}{C_s R_s} = -\frac{1}{\tau_z}$

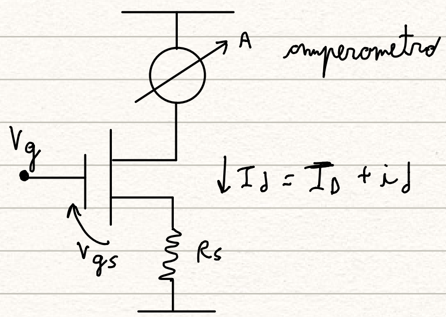
* POLO $\tau_p = C_s \left(R_s // 1/g_m\right)$
* ZERO $\tau_z = C_s R_s$

$$T(\infty) \simeq \frac{-g_m R_d}{1+g_m R_s} \cdot \frac{s C_s R_s}{s C_s (R_s // 1/g_m)} = \frac{-g_m R_d}{1+g_m R_s} \cdot \frac{\cancel{R_s}}{\frac{\cancel{R_s}\, 1/g_m}{1/g_m + R_s}} = \frac{-g_m R_d}{\cancel{1+g_m R_s}} \left(\cancel{1+g_m R_s}\right) =$$

$= -g_m R_d$



ERRORE DI LINEARITÀ IN STADIO SOURCE DEGENERATO:



$$I_d = K_n \left[V_{gs} - V_{Tn}\right]^2 = K_n \left[V_G - V_S + v_g - v_s - V_{Tn}\right]^2 = K_n \left[(V_{GS} - V_{Tn}) + v_{gs}\right]^2 =$$

$$= K_n \left[(V_{GS} - V_{Tn}) + v_{gs}\right]^2 = \underbrace{K_n (V_{GS} - V_{Tn})^2}_{I_D} + \underbrace{2K_n (V_{GS} - V_{Tn}) v_{gs} + K_n v_{gs}^2}_{i_d}$$

$$\begin{cases} i_d = g_m v_{gs} + K_n v_{gs}^2 \\ v_s = i_d R_s \end{cases}$$

$$i_d = g_m (v_g - i_d R_s) + K_n \left[v_g - i_d R_s\right]^2$$

$$\boxed{K_n R_s^2 i_d^2 - i_d \left(1 + g_m R_s + 2K_n R_s v_g\right) + g_m v_g + K_n v_g^2 = 0}$$

$ax^2 + bx + c = 0$

$x = -b \pm \sqrt{b^2 - 4ac}$

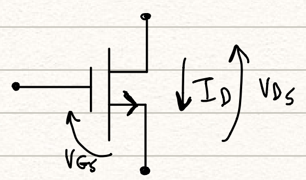
$2a$

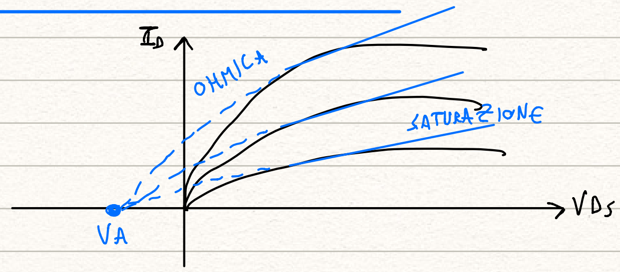
$$(1+x)^{1/2} \simeq 1 + \frac{x}{2} - \frac{1}{2}\frac{x^2}{4} + \dots$$

ERRORE DI LINEARITÀ STADIO SOURCE DEGENERATO

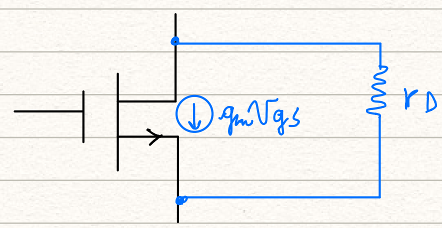
$$\boxed{\varepsilon = \frac{K_n v_g^2/(1+g_m R_S)^2}{\frac{g_m v_g}{1+g_m R_S}} = \underbrace{\frac{v_g}{1+g_m R_S}}_{v_{gs}} \frac{1}{2(V_{GS}-V_{Tn})} \frac{1}{1+g_m R_S}}$$

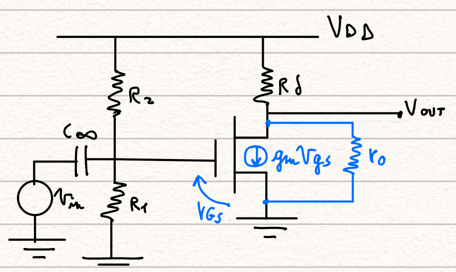
EFFETTO DELLA MODULAZIONE DELLA LUNGHEZZA DI CANALE SUGLI STADI AMPLIFICANTI:





$$r_o = \frac{|V_A|}{I_D}$$

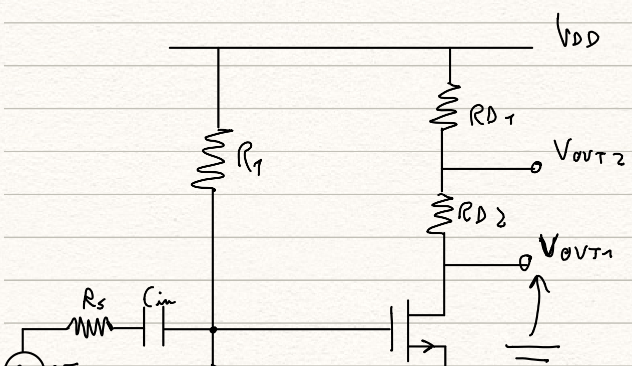




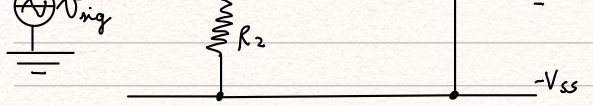
$$i_d = g_m v_{gs} = g_m v_{in}$$

$$v_{out} = -i_d R_d // r_o = -g_m R_d // r_o \; v_{in} \longrightarrow \frac{v_{out}}{v_{in}} = -g_m R_d // r_o$$

esercizio: Analisi amplificatore NMOS in configurazione source comune (source a massa)



$V_{Tn} = 0{,}5\,V$
$V_{DD} = +5\,V$
$-V_{SS} = -5\,V$
$K_n = 1/2\, \mu_n C_{ox} \frac{W}{L} = 1\,mA/V^2$
$R_2 = 150\,k\Omega$
$R_1 = 850\,k\Omega$
$R_{D1} = 2\,k\Omega$
$R_{D2} = 4\,k\Omega$



$R_S = 200\Omega$

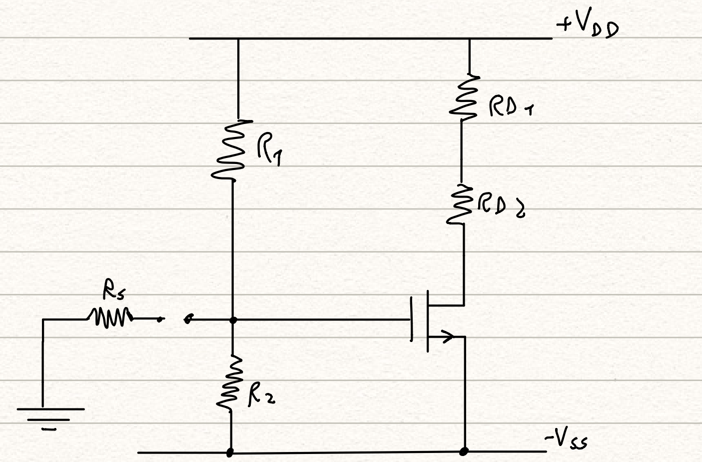
A) Polarizzazione dello stadio
B) Guadagno di piccolo segnale
C) Dimensionamento di C_{in} per amplificare segnali nella banda [1 kHz, 50 kHz]
D) Resistenze R_{OUT1} e R_{OUT2}
E) Errore di linearità se v_s è un segnale sinusoidale di ampiezza 100 mV e frequenza 30 kHz

A) POLARIZZAZIONE

1: spegnere i generatori di segnale
2: i condensatori sono circuiti aperti
3: HP che il mos sia saturo

va verificato!

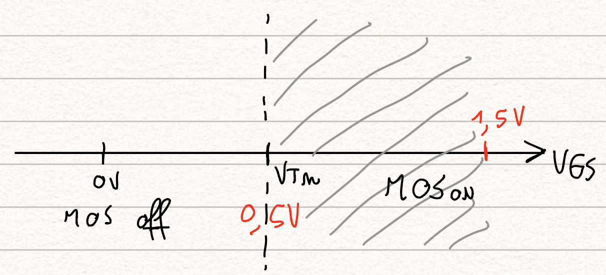
CIRCUITO PER LA POLARIZZAZIONE



$$V_G = -V_{SS} + \frac{R_2}{R_1+R_2}\left[V_{DD}-(-V_{SS})\right] = -5V + \frac{150k}{850k+150k}10V = -5V + 1,5V = -3,5V$$

$$I_{R} = \frac{V_{DD}-(-V_{SS})}{R_1+R_2} = \frac{10V}{1M\Omega} = 10\mu A$$

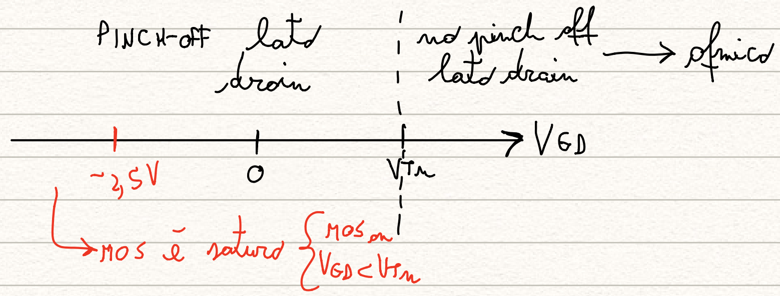
$$V_{GS} = \frac{R_2}{R_1+R_2}\left[V_{DD}-(-V_{SS})\right] = 1,5V \geq V_{Tn}$$ OK mos ON



Sotto l'ipotesi che il mos sia saturo

$$I_D = K_n(V_{GS}-V_{Tn})^2 = 1mA/V^2\,(1,5V-0,5V)^2 = V_{DD}-I_D(R_{d_1}+R_{d_2}) = 5V - 1mA\cdot(2k+4k) = -1V$$

$$\underset{\triangleq V_G - V_D}{V_{GD}} = -3,5V-(-1V) = -3,5V+1V = -2,5V < V_{Tn}$$

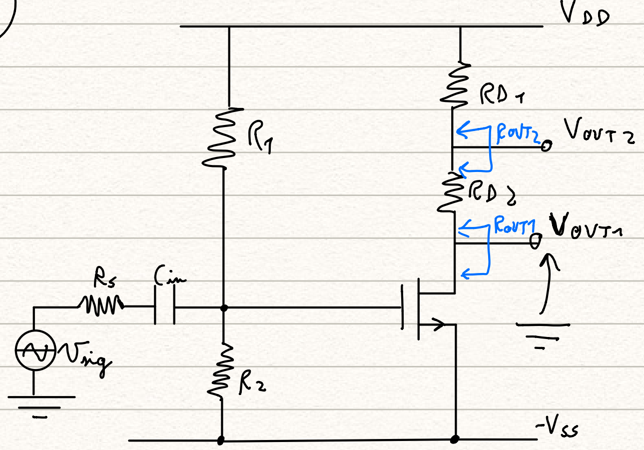


$I_D = 1\,mA$ ok

transconduttanza $g_m = 2K_n (V_{GS} - V_{Tn}) = 2 \cdot 1\,mA/V^2\ (1{,}5V - 0{,}5V) = 2\,mA/V = 2\,mS$

$1/g_m = 500\,\Omega$

B)



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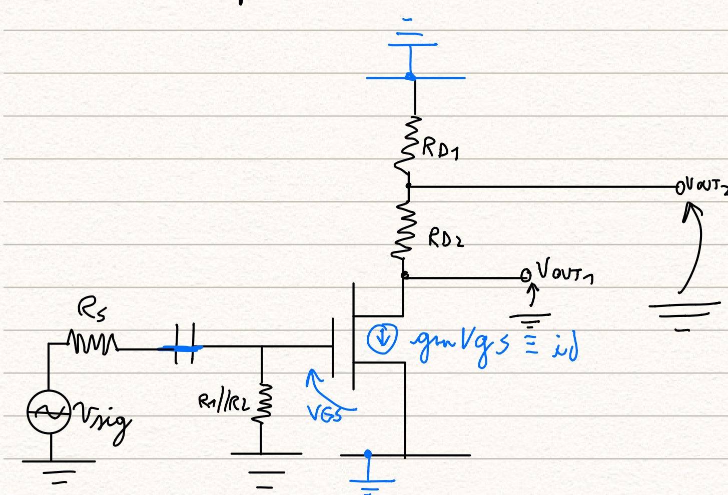
$R_2 = 150\,k\Omega$
$R_1 = 850\,k\Omega$
$R_{D1} = 2\,k\Omega$
$R_{D2} = 4\,k\Omega$
$R_S = 200\,\Omega$

circuito su segnale (piccolo)



$$V_{gs} = \frac{R_1//R_2}{R_S + R_1//R_2} V_{sig}$$

$$i_d = g_m V_{gs} = g_m \frac{R_1//R_2}{R_S + R_1//R_2} V_{sig}$$

$$V_{OUT1} = -i_d (R_{d1} + R_{d2}) = -g_m (R_{d1} + R_{d2}) \frac{R_1//R_2}{R_S + R_1//R_2} V_{sig}$$

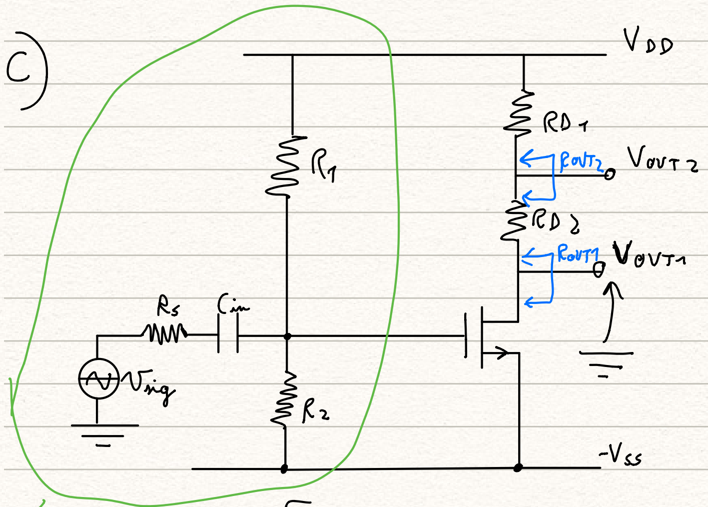
$$\frac{V_{OUT}}{V_{sig}} = -g_m (R_{d1} + R_{d2}) \cdot \underbrace{\frac{R_1//R_2}{\ldots}}_{0{,}998} \simeq -11{,}98$$

$$\frac{\quad}{V_{sig}} \quad \frac{\quad}{R_S+R_1//R_2} \approx -12 \quad \text{OK}$$

$$R_1//R_2 = 150\,K // 850\,k = 127{,}5\ k\Omega$$

$$V_{OUT2} = -i_d R_{d1} \rightarrow \frac{V_{OUT2}}{V_{sig}} = -g_m R_d \frac{R_1//R_2}{R_S+R_1//R_2} = -3{,}99$$

C)



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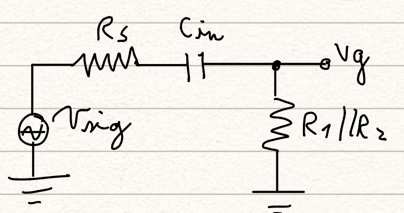
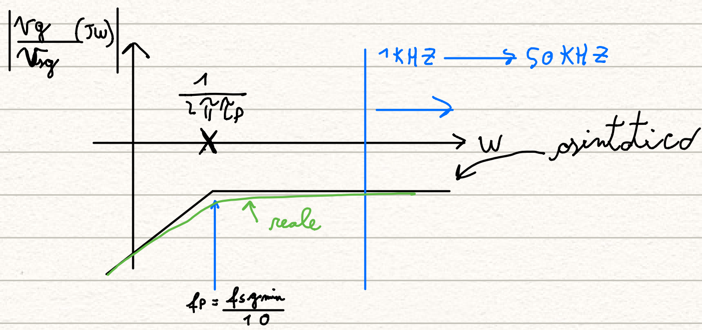
$R_2 = 150\ k\Omega$
$R_1 = 850\ k\Omega$
$R_{D1} = 2\,k\Omega$
$R_{D2} = 4\,k\Omega$
$R_S = 200\,\Omega$

$f_{sig} \in [1\,KHz, 50\,KHz]$



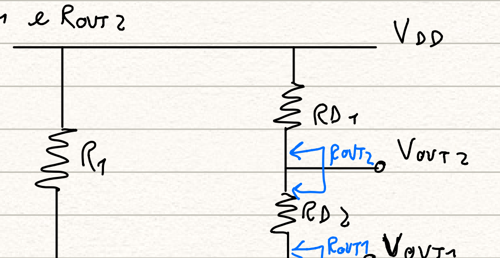
C_{in} polo con $\tau_P = C_{in}\,(R_S + R_1//R_2)$

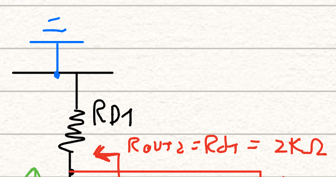
C_{in} zero nell'origine

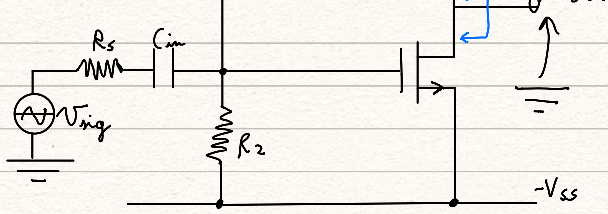


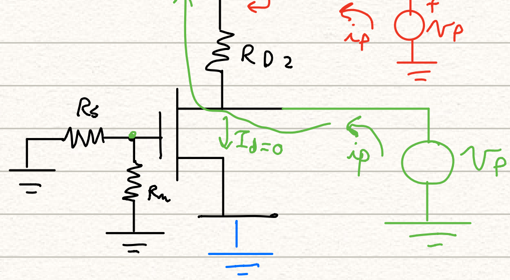
$$\frac{1}{2\pi C_{in}(R_S+R_1//R_2)} \leq \frac{1\,KHZ}{10} \qquad C_{in} \geq \frac{1}{2\pi\,(R_S+R_1//R_2)\cdot 100\,Hz} = 12{,}5\ nF$$

D) Calcolo R_{OUT1} e R_{OUT2}







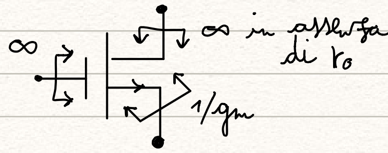


$R// = R_1//R_2$

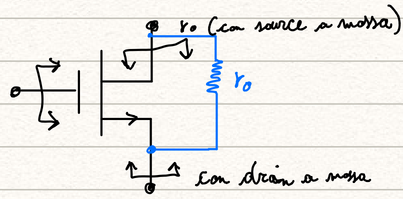
$$R_{OUT_1} \triangleq \frac{v_P}{i_P} = R_{d1} + R_{d2} = 6\,k\Omega$$

$$i_p = \frac{v_p}{R_{d1} + R_{d2}}$$

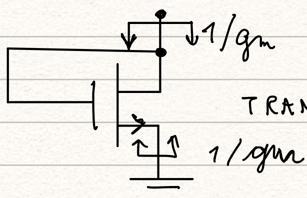
RESISTENZE VISTE AI MORSETTI DI UN TRANSISTOR

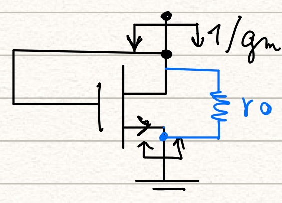


con r_o



$r_o // 1/g_m \simeq 1/g_m$

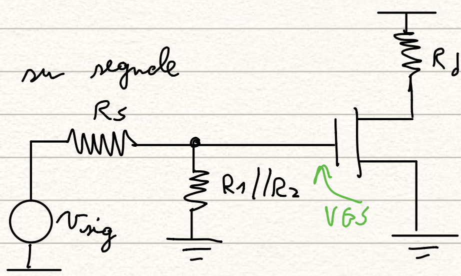




E) ERRORE DI LINEARITÀ:

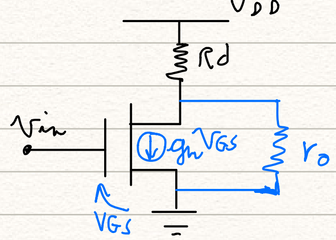
$$v_{sig} = 100\,mV \sin(2\pi f_{sig} t) \qquad f_{sig} = 30\,KHz$$

su segnale



$$v_{gs} = \frac{R_1//R_2}{R_S + R_1//R_2} v_{sig} = \frac{127,5\,k\Omega}{127,7\,k\Omega} \cdot 100\,mV$$

$$\varepsilon = \frac{v_{gs}}{2(V_{GS} - V_T)} = \frac{99,8\,mV}{2(1,5V - 0,5V)} \simeq 5\,\%$$

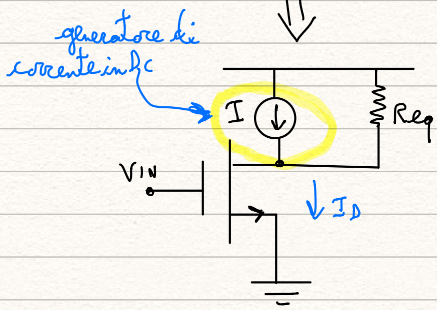


circuito su segnale

$$|G_{max}| = g_m R_o$$

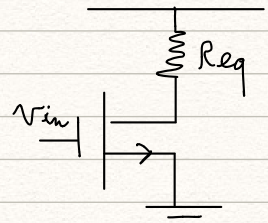
$$G \simeq -g_m\, r_o // R_d$$

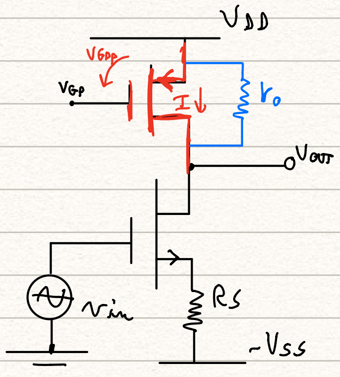
$\Downarrow$



• polarizzazione $I_D \simeq I$ (Req molto grande)

• segnale





STADIO A TRANSISTORE CON CARICO ATTIVO