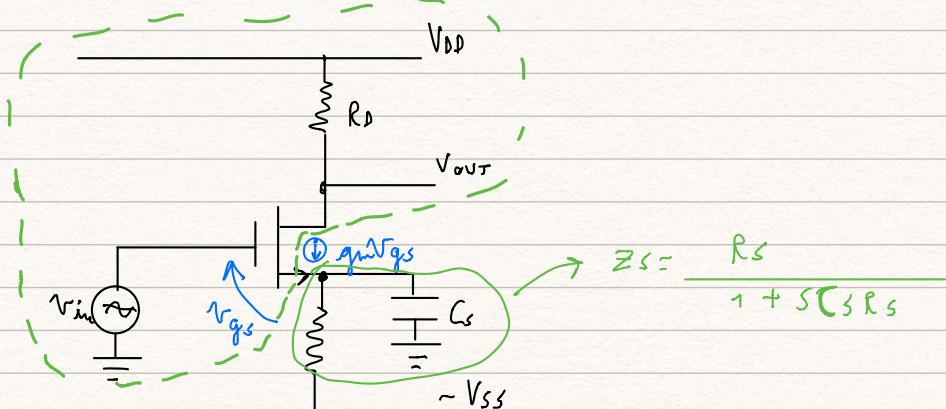
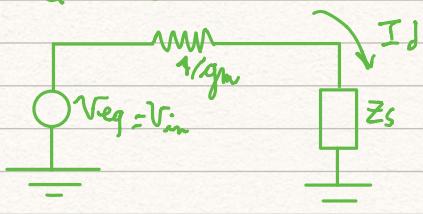


DIMENSIONAMENTO DELLA CAPACITÀ DI BYPASS (nello studio con degenerazione di source)



$$V_{in} = V_{qs} + i_d Z_s$$

EQ. THEVENIN



$$i_d = \frac{V_{in}}{1/g_m + \frac{R_s}{1 + S C_s R_s}}$$

$$V_{out}(s) = -i_d R_d - V_{in}(s) \frac{R_d}{1/g_m + \frac{R_s}{1 + S C_s R_s}}$$

FUNZIONE DI TRASFERIMENTO

$$T(s) \triangleq \frac{V_{out}(s)}{V_{in}(s)} = - \frac{R_d}{1/g_m + \frac{R_s}{1 + S C_s R_s}} = \frac{-g_m R_d (1 + S C_s R_s)}{1 + S C_s R_s + g_m R_s} = \frac{-g_m R_d (1 + S C_s R_s)}{(1 + g_m R_s) \left(1 + \frac{S C_s R_s}{1 + g_m R_s}\right)}$$

$$\approx \frac{-g_m R_d}{1 + g_m R_s} \quad \boxed{\frac{1 + S C_s R_s}{1 + S C_s (R_s / (1/g_m))}}$$

TERMINI IN S

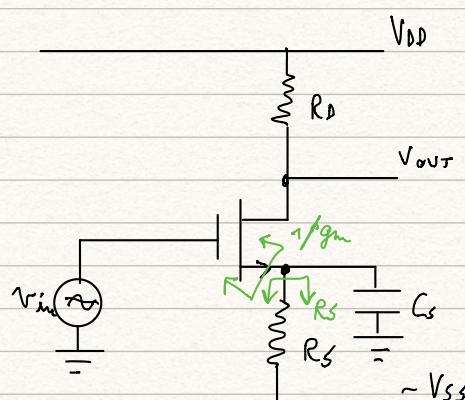
TRASFERIMENTO IN DC

- POLO: $\tau_p = C_s (R_s || 1/g_m)$
- ZERO: $\tau_z = C_s R_s$

Salvo la funzione di trasferimento per input zero

• $T(0)$ trasferimento in DC

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



$V_{in}(s) \neq 0$ se e solo se $i_d(s) = 0$

$$i_d = g_m V_{qs}(s) \quad g_m \neq 0 \rightarrow V_{qs}(s) = 0$$

$$Z_{eq}(s) = \frac{R_s}{1 + S C_s R_s} \xrightarrow{1 + S C_s R_s \gg 1} \infty$$

• Singolarità di Cs

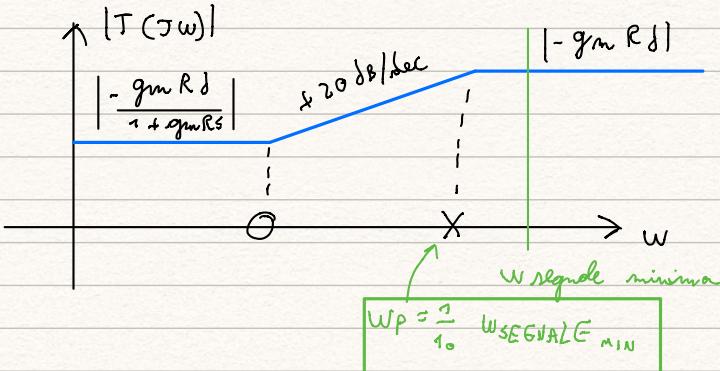
$$S = -\frac{1}{CsRs} = -\frac{1}{C_2}$$

$$\ast \text{ polo } T_p = Cs(R_s/1/g_m)$$

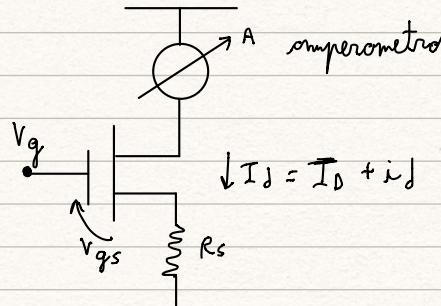
$$\ast \text{ zero } \tau_2 = C_s R_s$$

$$T(\infty) \approx -\frac{g_m R_d}{1+g_m R_s} \quad \frac{Cs R_s}{Cs (R_s/1/g_m)} = -\frac{g_m R_d}{1+g_m R_s} \quad \frac{\cancel{Rs}}{\cancel{R_s}/1/g_m} = \frac{-g_m R_d}{1/g_m + R_s} \quad (\text{argomento})$$

$$= -g_m R_d$$



ERRORE DI LINEARITÀ IN STADIO SOURCE DEGENERATO:



$$I_d = K_m [V_{gs} - V_{Tm}]^2 \approx K_m [V_g - V_s + v_g - v_s - V_{Tm}]^2 = K_m [(V_{gs} - V_{Tm}) + V_{gs}]^2 =$$

$$= K_m [(V_{gs} - V_{Tm}) + v_{gs}]^2 = \boxed{I_D} + \boxed{i_d}$$

$$\begin{cases} i_d = g_m V_{gs} + K_m V_{gs}^2 \\ V_s = i_d R_s \end{cases}$$

$$i_d = g_m (V_g - i_d R_s) + K_m [V_g - i_d R_s]^2$$

$$K_m R_s^2 i_d^2 \sim i_d (1 + g_m R_s + 2 K_m R_s V_g) + g_m V_g + K_m V_g^2 = 0$$

$$a x^2 + b x + c = 0$$

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

2.a

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

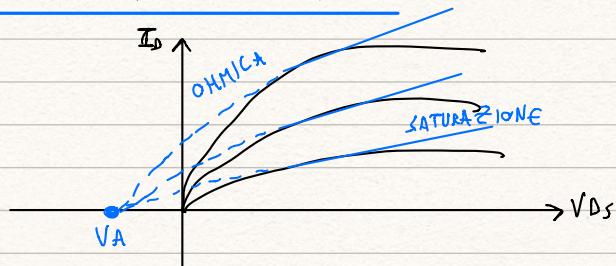
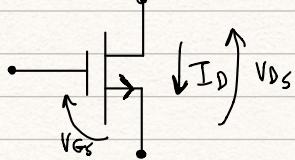
↓
ERRORE DI LINEARITÀ STADIO SOURCE DEGENERATO

$$\epsilon = \frac{k_m V_g^2 / (1 + g_m R_s)^2}{\frac{g_m V_g}{1 + g_m R_s}} = \frac{V_g}{1 + g_m R_s} \cdot \frac{1}{2(V_{GS} - V_{Tm})} \cdot \frac{1}{1 + g_m R_s}$$

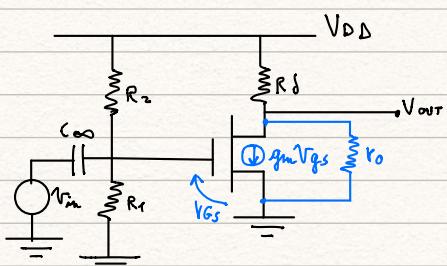
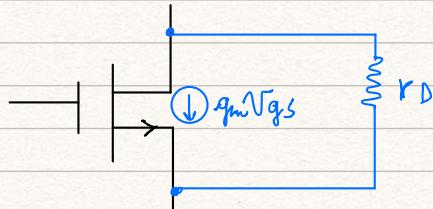
$\underbrace{V_g}_{V_{GS}}$

EFFETTO DELLA MODULAZIONE DELLA LUNGHEZZA DI CANALE SUGLI AMPLIFICATORI:

STADI AMPLIFICATORI:



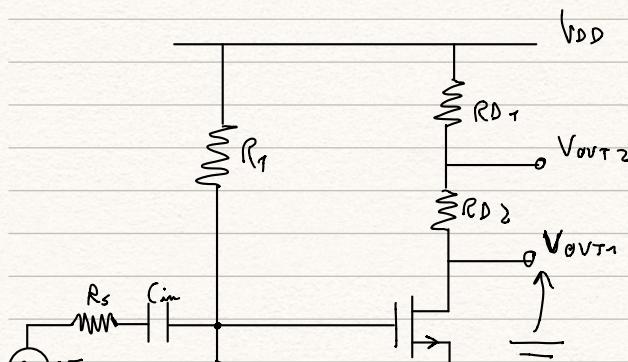
$$r_o = \frac{|V_A|}{I_D}$$



$$i_d = g_m V_{GS} = g_m V_{in}$$

$$V_{out} = -i_d R_d / r_o = -g_m R_d / r_o V_{in} \rightarrow \frac{V_{out}}{V_{in}} = -g_m R_d / r_o$$

esercizio: Andare amplificatore NMOS in configurazione source comune (source a molla)



$$V_{Tm} = 0.5 V$$

$$V_{DD} = +5 V$$

$$-V_{SS} = -5 V$$

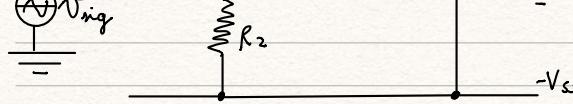
$$k_m = 1/2 \mu_n C_{ox} \frac{W}{L} = 1 \text{ mA/V}^2$$

$$R_2 = 150 \text{ k}\Omega$$

$$R_1 = 850 \text{ k}\Omega$$

$$R_{D1} = 2 \text{ k}\Omega$$

$$R_{D2} = 4 \text{ k}\Omega$$



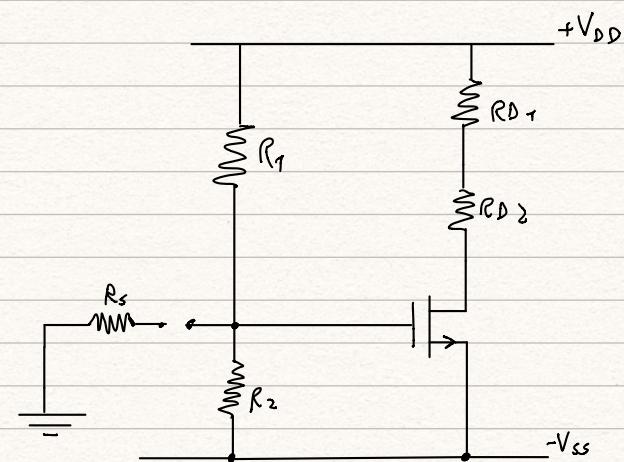
$R_S = 200\Omega$

- 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 50 kHz

A) POLARIZZAZIONE

- 1: Scegliere i generatori di segnale
- 2: i condensatori sono circuiti aperti
- 3: HP che il mos sia saturato
✓ verificato!

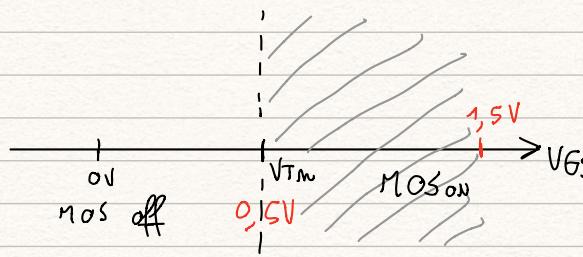
CIRCUITO PER LA POLARIZZAZIONE



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

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

$$V_{GS} = \frac{R_2}{R_1 + R_2} [V_{DD} - (-V_{ss})] = 1,5V \geq V_{Tm} \quad \text{OK} \quad \text{mos ON}$$

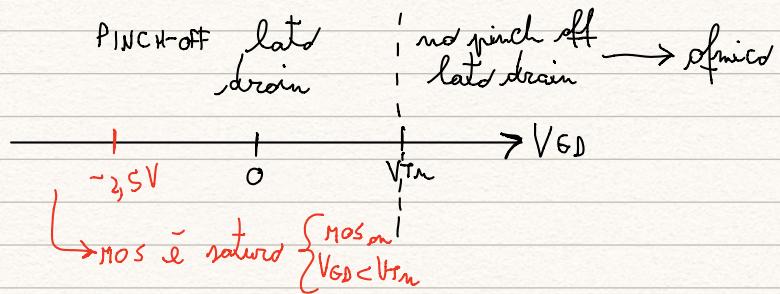


Sotto l'ipotesi che il mos sia saturato

$$I_D = k_m (V_{GS} - V_{Tm})^2 = 1mA/\mu F \quad (1,5V - 0,5V)^2 = V_{DD} - I_D (R_{d1} + R_{d2}) = 5V - 1mA \cdot (2k + 4k) = -1V$$

$$V_{GD} = -3,5V - (-1V) = -3,5V + 1V = -2,5V < V_{Tm}$$

$\Delta V_G - V_D$

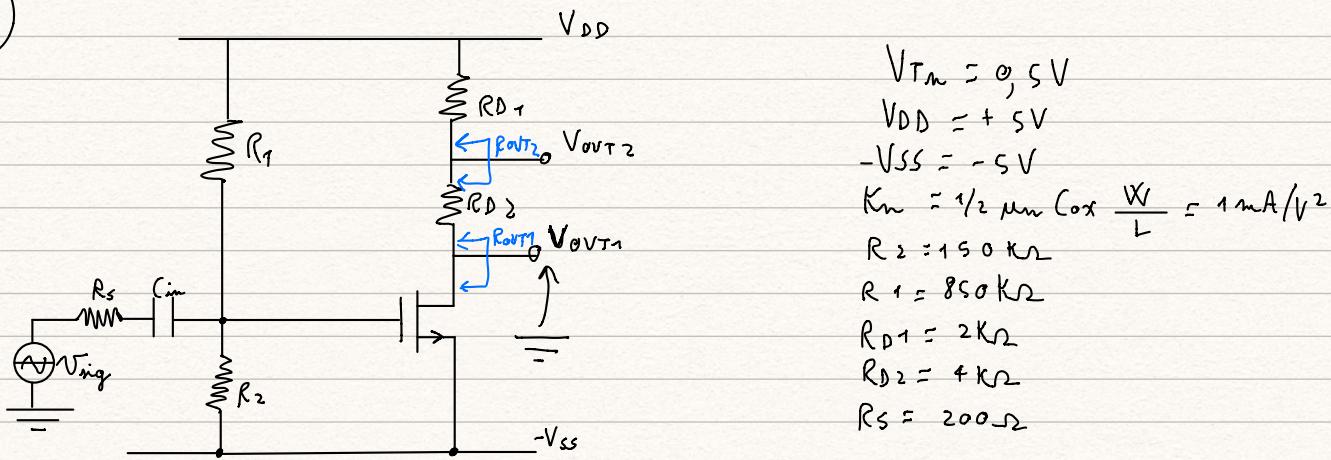


$$I_D = 1 \text{ mA } \text{OK}$$

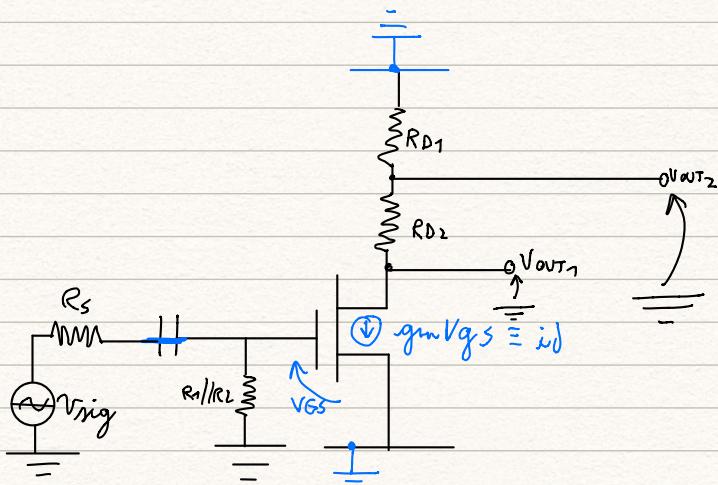
$$\text{transconductance } g_m = 2k_n (V_{GS} - V_{Tm}) \approx 2 \text{ mA/V}^2 (1.5V - 0.5V) \approx 2 \text{ mA/V} = 2 \text{ ms}$$

$$1/g_m = 500 \Omega$$

B)



circuito su rete (piccolo)



$$\sqrt{g_m} = \frac{R_1 // R_2}{R_s + R_1 // R_2} V_{in}$$

$$id = g_m \sqrt{g_m} = g_m \frac{R_1 // R_2}{R_s + R_1 // R_2} V_{in}$$

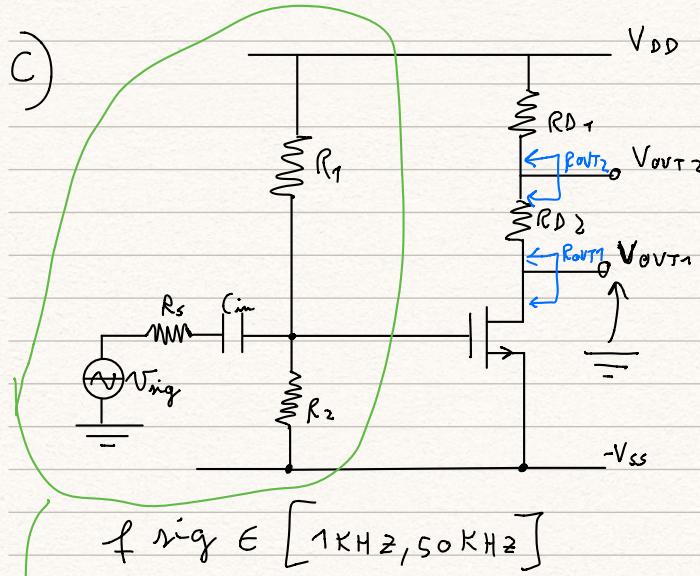
$$V_{out1} = -id(R_{D1} + R_{D2}) \approx -g_m(R_{S1} + R_{D2}) \frac{R_1 // R_2}{R_s + R_1 // R_2} V_{in}$$

$$V_{out} = -g_m(R_{D1} + R_{D2}) \cdot \frac{R_1 // R_2}{R_s + R_1 // R_2} = 22.98$$

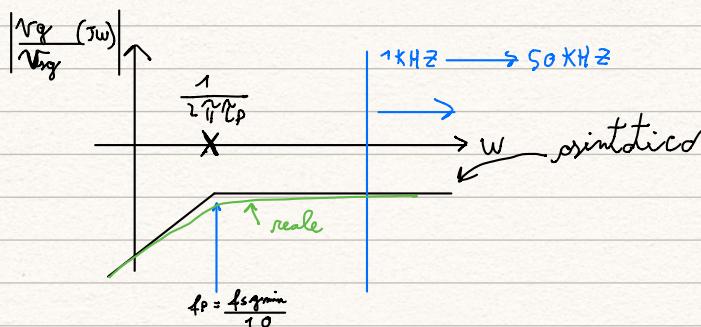
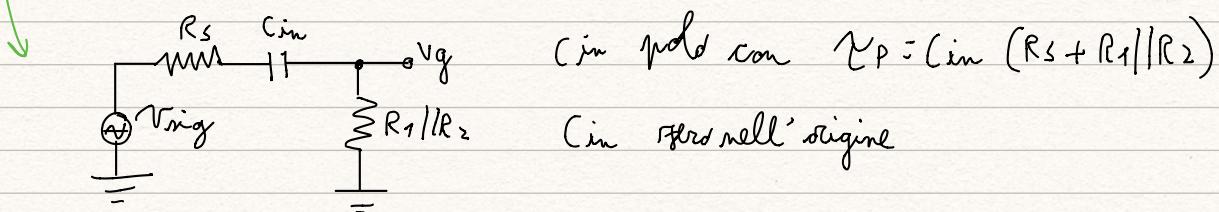
$$\frac{V_{sig}}{R_1 + R_2} \approx -12 \text{ V} \quad \underline{\text{OK}}$$

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

$$V_{out2} = -i_D R_D \rightarrow \frac{V_{out2}}{V_{sig}} = -g_m R_D \frac{R_1 // R_2}{R_S + R_1 // R_2} = -3,99$$



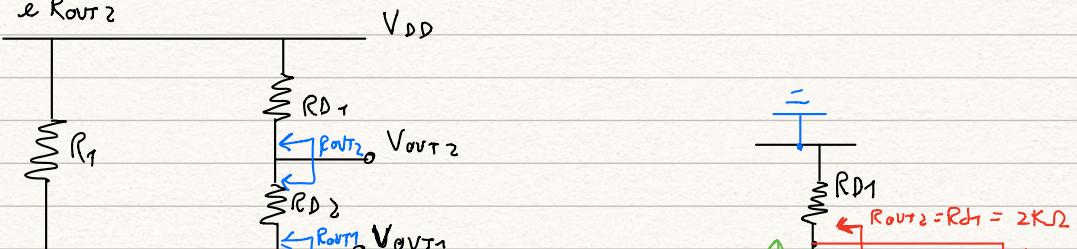
$$\begin{aligned}
 V_{Tm} &= 0,5 \text{ V} \\
 V_{DD} &= +5 \text{ V} \\
 -V_{SS} &= -5 \text{ V} \\
 K_m &= 1/2 \mu \text{m} \text{Cox} \frac{W}{L} = 1 \text{ mA/V}^2 \\
 R_2 &= 150 \text{ k}\Omega \\
 R_1 &= 850 \text{ k}\Omega \\
 R_D1 &= 2 \text{ k}\Omega \\
 R_D2 &= 4 \text{ k}\Omega \\
 R_S &= 200 \text{ }\Omega
 \end{aligned}$$

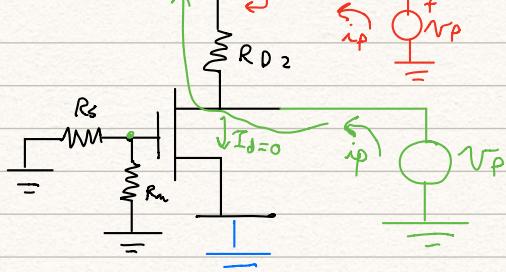
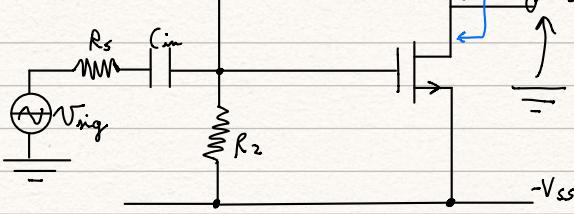


$$\frac{1}{2\pi C_{in} (R_S + R_1 // R_2)} \leq \frac{1 \text{ kHz}}{10}$$

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

D) Folded Rout1 e Rout2

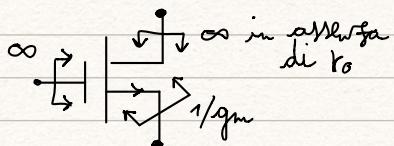




$$R_{II} = R_1 // R_2$$

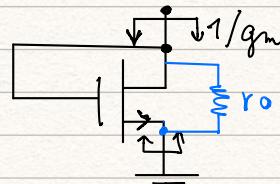
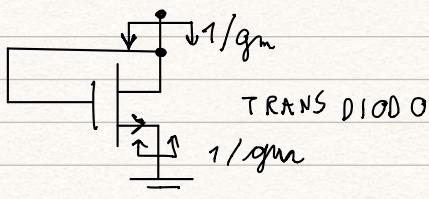
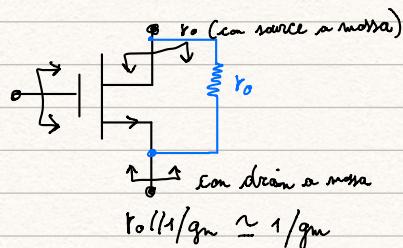
$$R_{OVR_1} \stackrel{\Delta}{=} \frac{V_p}{i_p} = R_{d1} + R_{d2} = 6 \text{ k}\Omega$$

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



RESISTENZE VISTE AI
MOSFET DI UN
TRANSISTOR

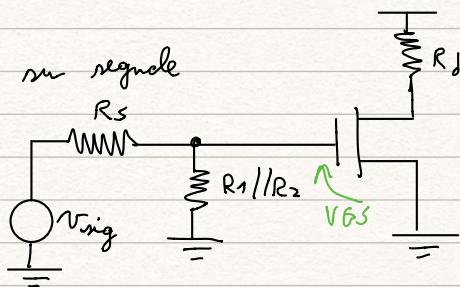
con r_o



E) ERRORE DI LINEARITÀ:

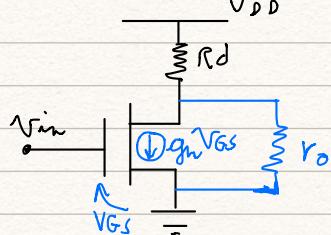
$$V_{sig} = 100 \text{ mV} \sin(2\pi f_{sig} t)$$

$$f_{sig} = 30 \text{ kHz}$$



$$V_{gss} = \frac{R_1 // R_2}{R_s + R_1 // R_2} \quad V_{sig} = \frac{127,5 \text{ k}\Omega}{127,7 \text{ k}\Omega} \cdot 100 \text{ mV}$$

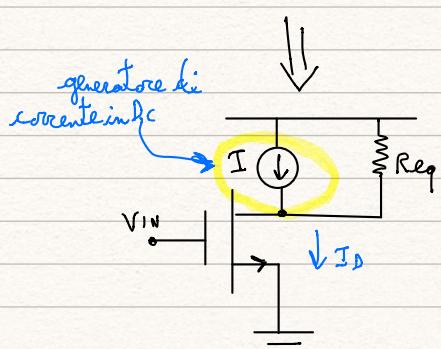
$$\epsilon = \frac{V_{gss}}{2(V_{GS} - V_T)} = \frac{99,8 \text{ mV}}{2(1,5 \text{ V} - 0,5 \text{ V})} \approx 5 \%$$



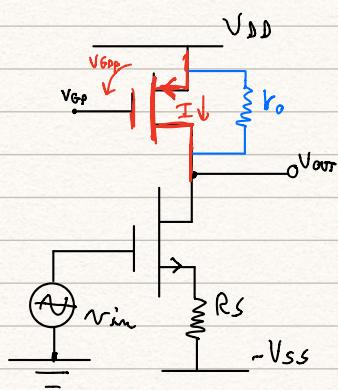
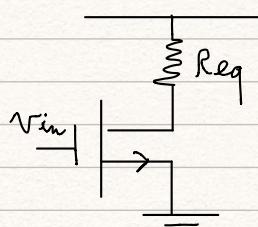
circuito su regole

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

$$G \approx -g_m R_o / R_d$$



- polarizzazione $I_D \approx I$ (req molto grande)
- regole



STADIO A TRANSISTORE CON CARICA ATTIVA

