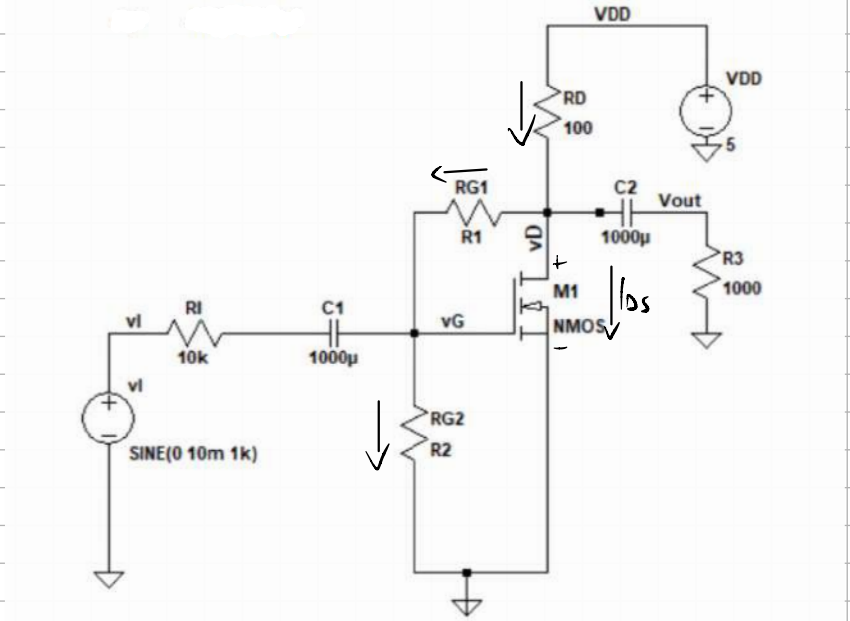
2

NUMERO DI MATRICOLA: 1188356



2.1

$R_{G1} = R_{G2} = 1188356\ \Omega$

APCO TUTTI I CONDENSATORI

$$V_{GS} = V_{DS} - R_{G1} I_G$$

$$= V_{DS} - \frac{R_{G1}}{R_{G2}} V_{GS}$$

$$= V_{DS}/2 \longrightarrow V_{DS} = 2 V_{GS}$$

$$I_D = I_{DS} + I_G = I_{DS} + \frac{V_{GS}}{R_{G2}}$$

$$I_G = \frac{V_{GS}}{R_{G2}}$$

$$V_{DD} = R_D I_D + V_{DS} = R_D I_{DS} + 2 V_{GS}$$

$$= R_D \left(I_{DS} + \frac{V_{GS}}{R_{G2}} \right) + 2 V_{GS}$$

IPOTIZZO TRANSISTOR SATURO

$$I_{DS} = \frac{k_n}{2} (V_{GS} - V_{TN})^2$$

$$\rightarrow 20 V_{GS}^2 - 38 V_{GS} + 15 = 0$$

V_{GS} < 1.34 OK

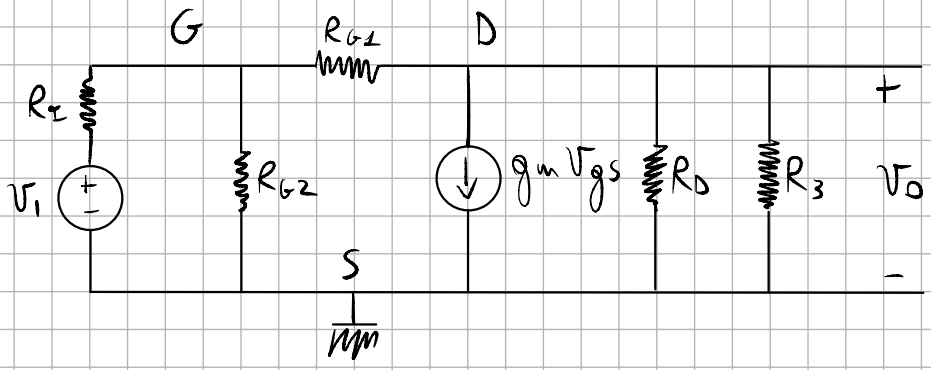
0.55 $\longrightarrow$ NO PERCHÉ $V_{GS} - V_{TN} < 0$

$V_{GS} = 1.34\ V$ $V_{DS} = 2.68\ V$

$I_{DS} = 23.12\ mA$

2.2 $g_m = \frac{2 I_{DS}}{V_{OV}} = 0.136$ $r_o = \infty$

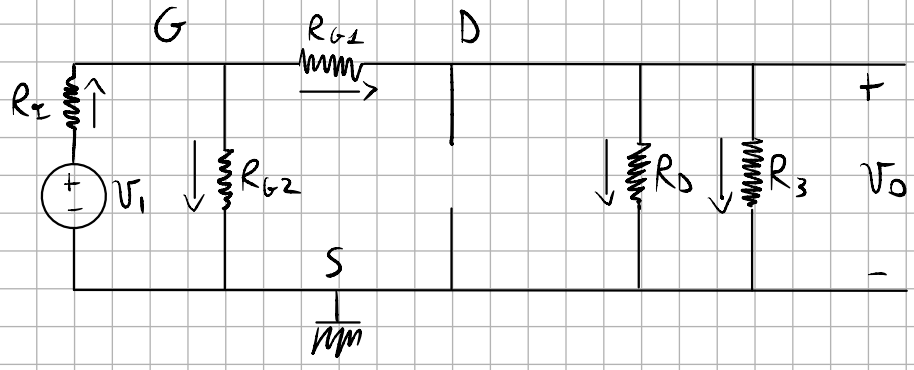
2.3



QUESTA RAPPRESENTAZIONE È A SOURCE COMUNE

MI CALCOLO V_O IN FUNZIONE DI V_I CON LA SOVRAPPOSIZIONE DEGLI EFFETTI

SPENGO $g_m V_{gs}$



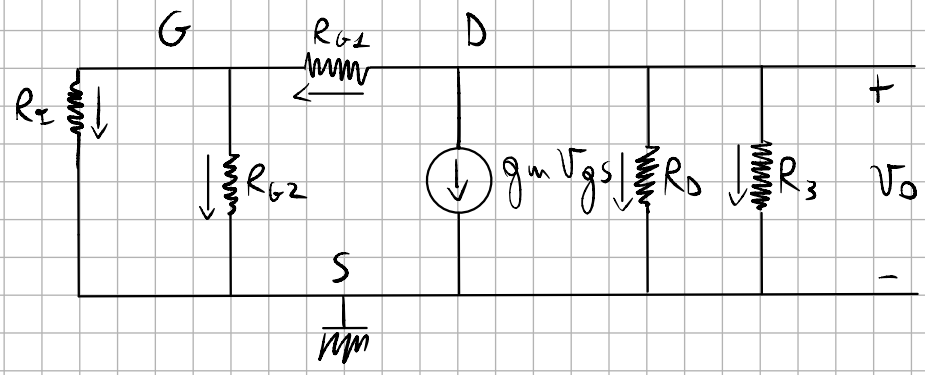
$R_D // R_3 = 90.90\ \Omega$ $R_{G2} // (R_{G1} + R_D // R_3) = 594.200\ \Omega$

$V_{gs1} = \frac{V_I}{R_I + R_{G2} // (R_{G1} + R_D // R_3)}$ $R_{G2} // (R_{G1} + R_D // R_3) = 0.98\ V_I$

$I_{R_{G1}, R_D // R_3} = \frac{V_{gs1}}{R_{G1} + R_D // R_3} = 8.27 \cdot 10^{-7}\ V_I$

$V_{O1} = I_{R_{G1}, R_D // R_3} \cdot R_D // R_3 = 7.52 \cdot 10^{-5}\ V_I$

SPENGO V_I



$R_{G2} // R_I = 9916\ \Omega$ $\quad R_D // R_3 // R_{G1} + (R_I // R_{G2}) = 90.90\ \Omega$

$V_{O2} = -g_m V_{gs} \left[R_D // R_3 // R_{G1} + (R_I // R_{G2}) \right] = -12.36\ V_{gs}$

$$I_{R_{G1}, R_{G2} // R_I} = \frac{V_{O2}}{R_{G1} + (R_{G2} // R_I)} = -1.03 \cdot 10^{-5}\ V_{gs}$$

$V_{gs2} = I_{R_{G1}, R_{G2} // R_I} \cdot R_{G2} // R_I = -0.10\ V_{gs}$

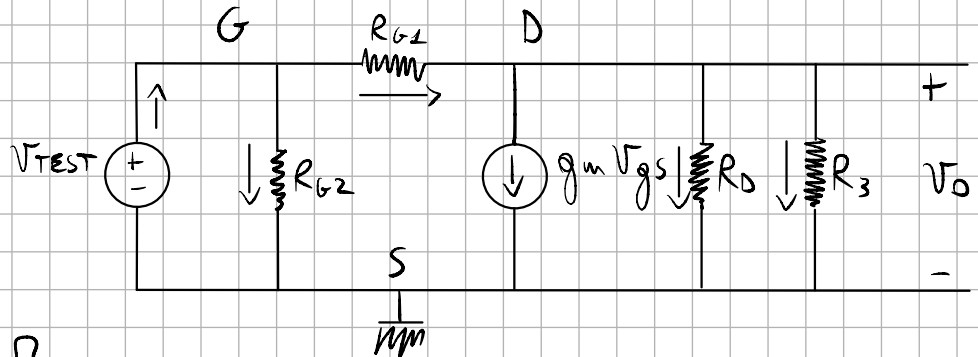
UNISCO LE DUE PARTI

$V_{gs} = V_{gs1} + V_{gs2} = 0.98\ V_I - 0.10\ V_{gs} = 0.89\ V_I$

$V_O = V_{O1} + V_{O2} = 7.52 \cdot 10^{-5}\ V_I - 12.36 (0.89\ V_I) = -11.03\ V_I$

$A_V = -11.03$

$$R_{IN} = \frac{V_{TEST}}{I_{TEST}}$$



$R_D // R_3 = 90.90\ \Omega$

$$\begin{cases} I_{TEST} = \dfrac{V_{TEST}}{R_{G2}} + \dfrac{V_{TEST} - V_0}{R_{G1}} \\ I_{RG1} = \dfrac{V_{TEST} - V_0}{R_{G1}} \\ g_m V_{TEST} = I_{RG1} - \dfrac{V_0}{R_D \| R_3} \end{cases}$$

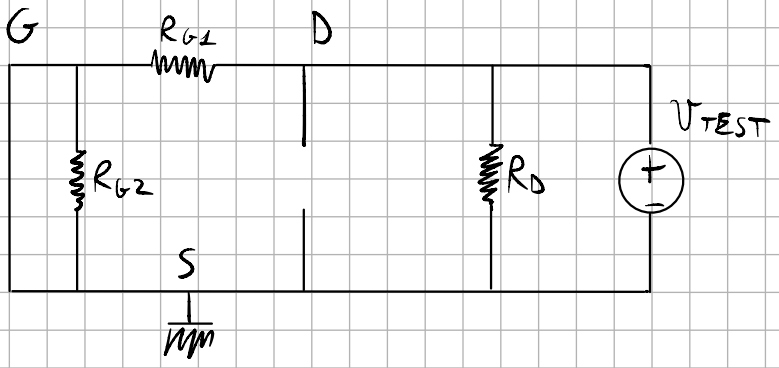
$$g_m V_{TEST} = \frac{V_{TEST} - V_0}{R_{G1}} - \frac{V_0}{R_D \| R_3} = \frac{V_{TEST}}{R_{G1}} - V_0 \left(\frac{1}{R_{G1}} + \frac{1}{R_D \| R_3} \right) =$$

$$V_0 = \left(\frac{V_{TEST}}{R_{G1}} - g_m V_{TEST} \right) \cdot \frac{1}{\left(\frac{1}{R_{G2}} + \frac{1}{R_D \| R_3} \right)}$$

$$= V_{TEST} \frac{\left(\frac{1}{R_{G1}} - g_m \right)}{\left(\frac{1}{R_{G2}} + \frac{1}{R_D \| R_3} \right)} = -12.36\, V_{TEST}$$

$$I_{TEST} = \frac{V_{TEST}}{R_{G2}} + \frac{V_{TEST} + 12.36\, V_{TEST}}{R_{G1}} = \frac{(R_{G1} + 13.36\, R_{G2})}{R_{G1} \cdot R_{G2}} V_{TEST}$$

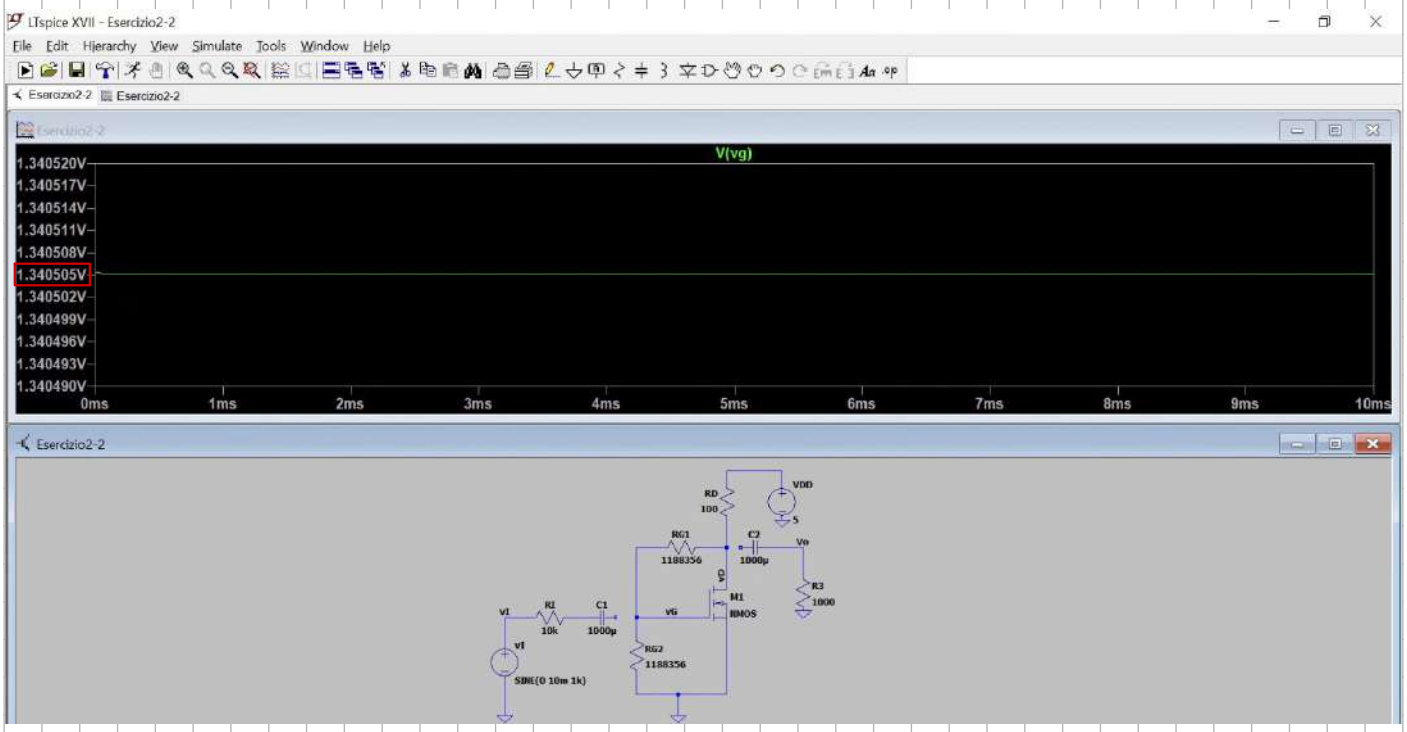
$$R_{IN} = \frac{V_{TEST}}{I_{TEST}} = \frac{R_{G1} \cdot R_{G2}}{(R_{G1} + 13.36\, R_{G2})} = 82755\ \Omega$$



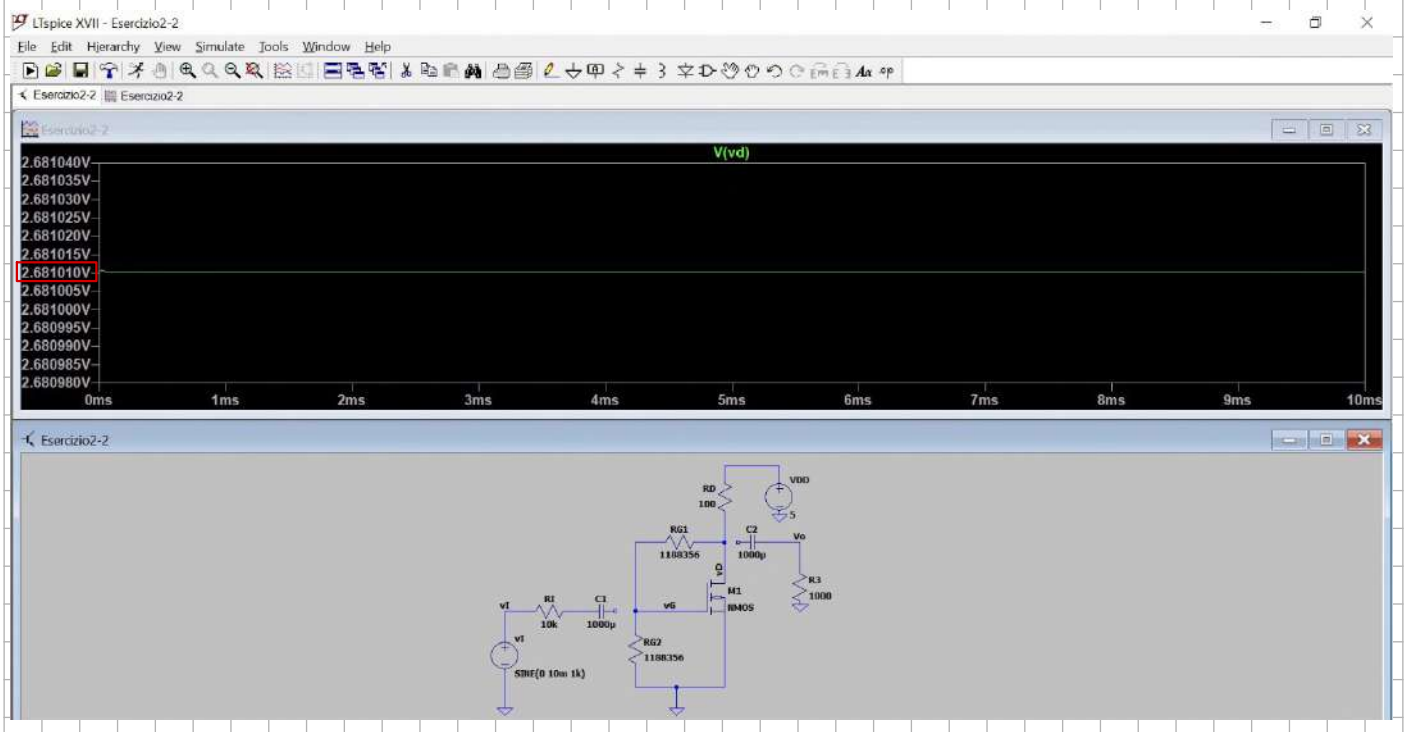
$$R_{OUT} = \frac{V_{TEST}}{I_{TEST}}$$

$$R_{OUT} = R_D \| R_{G1} = 100\ \Omega$$

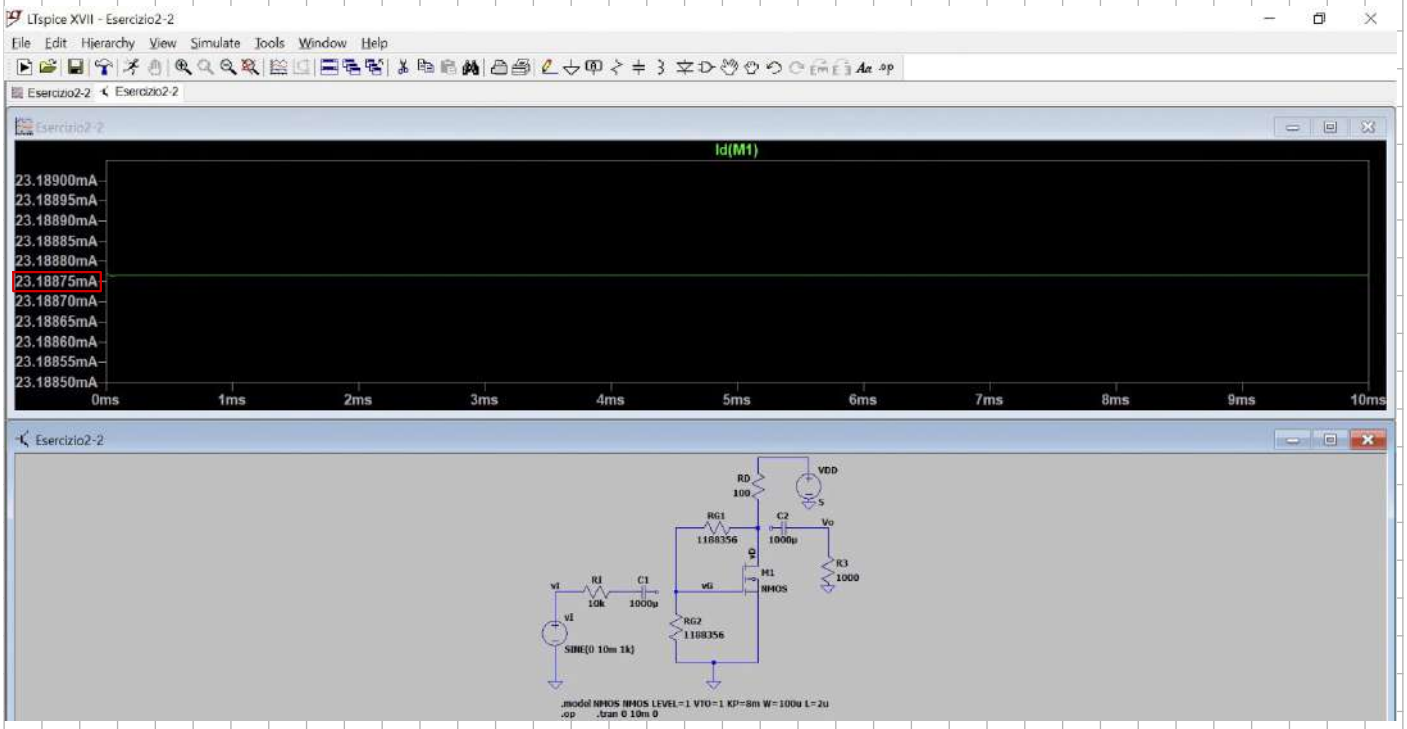
2.4



$V_{GS} = 1,34\ V$

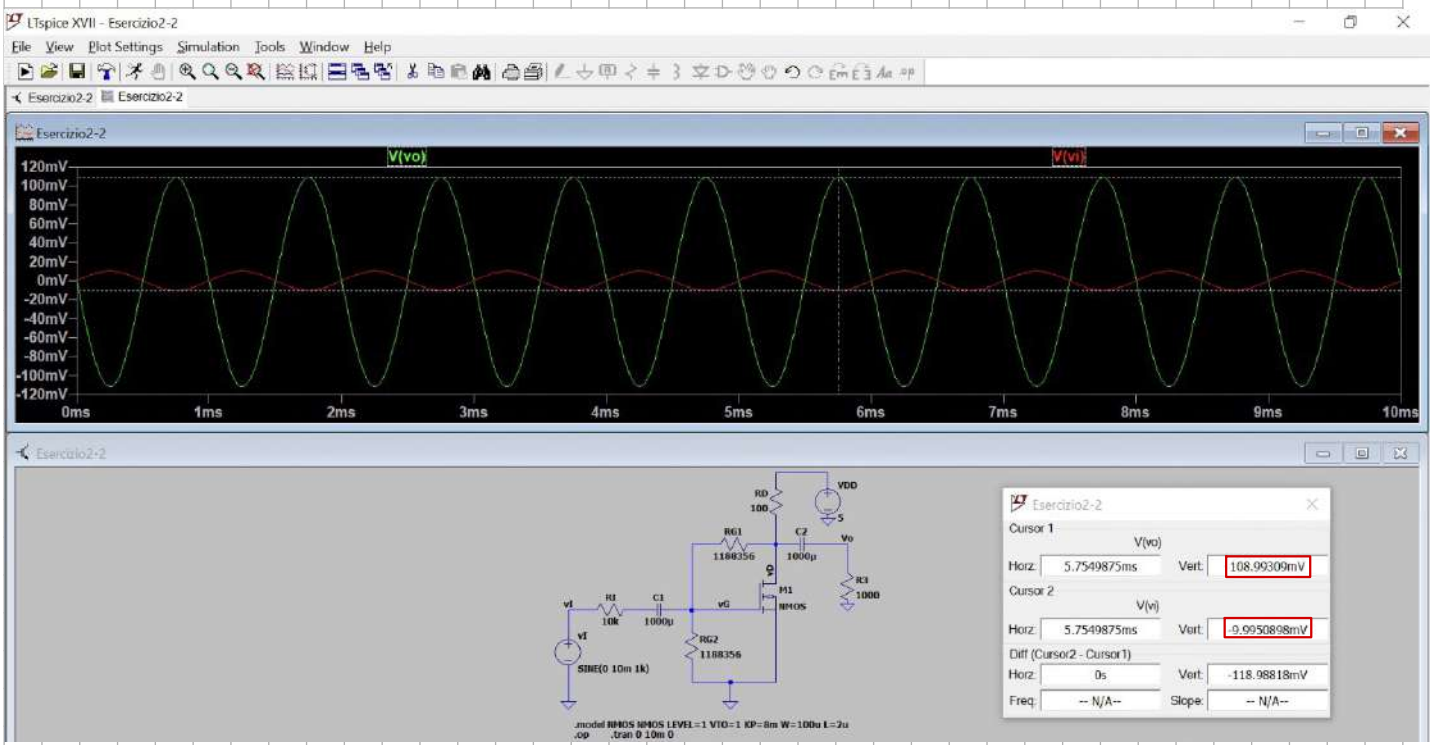


$V_{DS} = 2,68\ V$

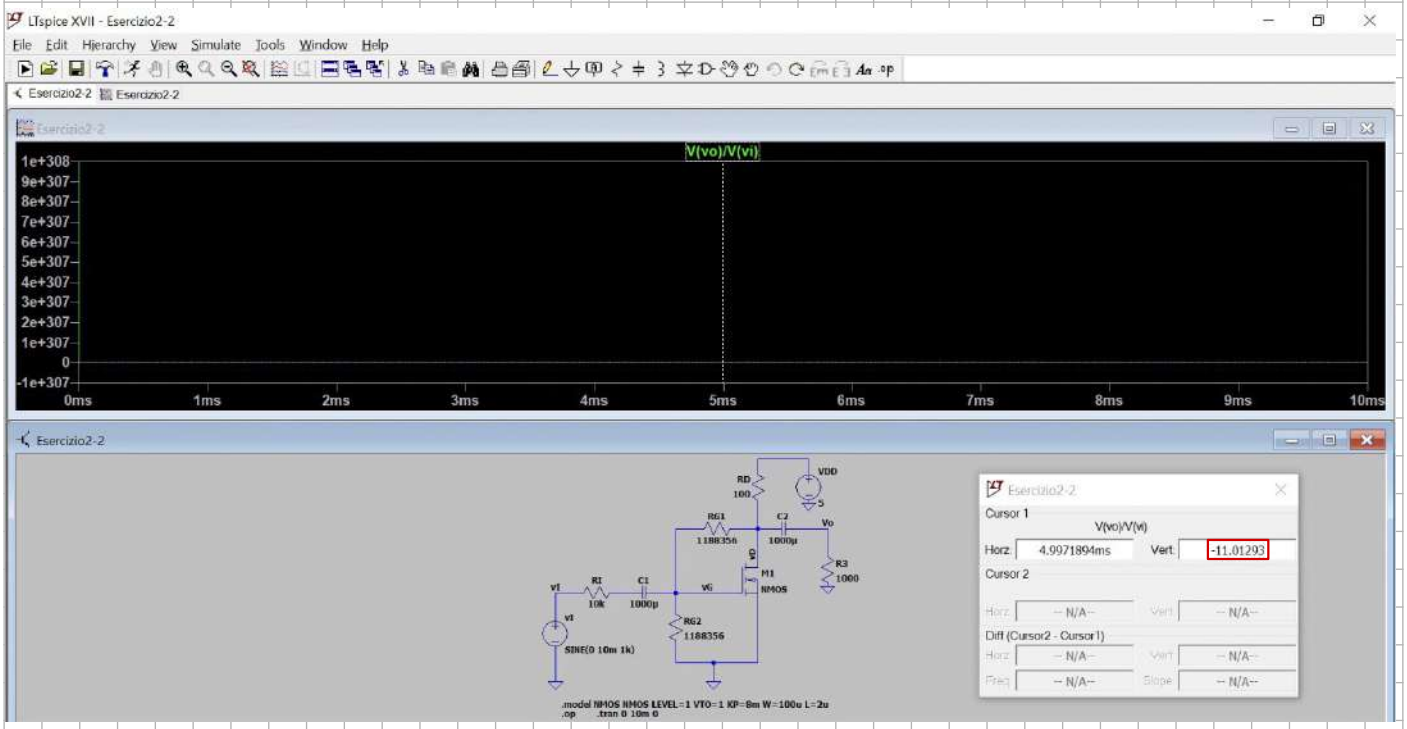


$I_{DS} = 23.12\ mA$

2.5



$$A_V = \frac{V_o}{V_i} = -10.90$$



A_V ANALITICO: -11.03

A_V CON SPICE: -11.02

2.6

$$V_{DS} - |V_{DS\,max}| = V_{GS} - V_{TN} + V_{gs\,max}$$

$$V_{DS} - 11.03\,V_I = V_{GS} - V_{TN} + V_I - R_I I_I$$

$$I_I = 1.65 \cdot 10^{-6} V_I + 9.12 \cdot 10^{-6} V_I = 1.08 \cdot 10^{-5} V_I$$

$$V_I = \frac{V_{DS} - V_{GS} + V_{TN}}{\mp A_V + 1 - R_I I_I}$$

$V_I > 0 \longrightarrow V_I = 196$ mV

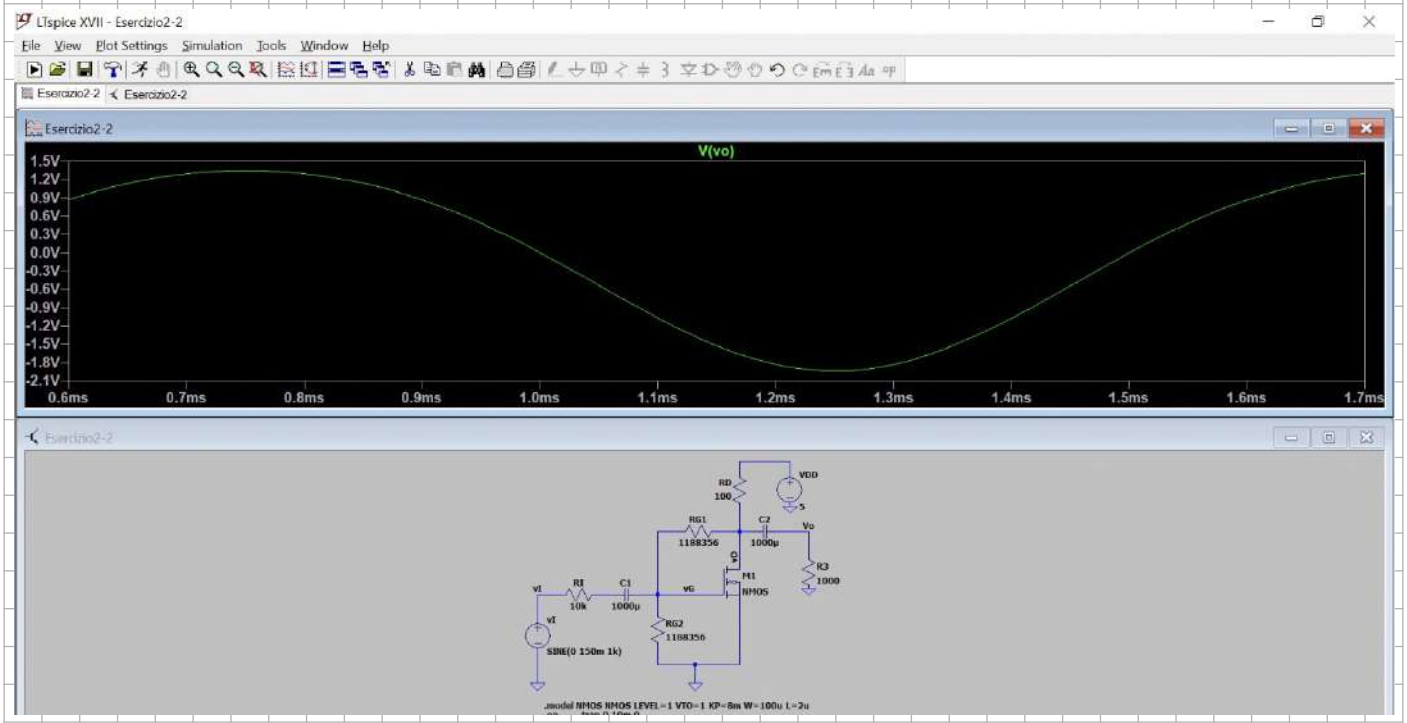
$V_I < 0 \longrightarrow V_I = -230$ mV

TENGO IL VALORE IN MODULO PIÙ STRINGENTE QUINDI:

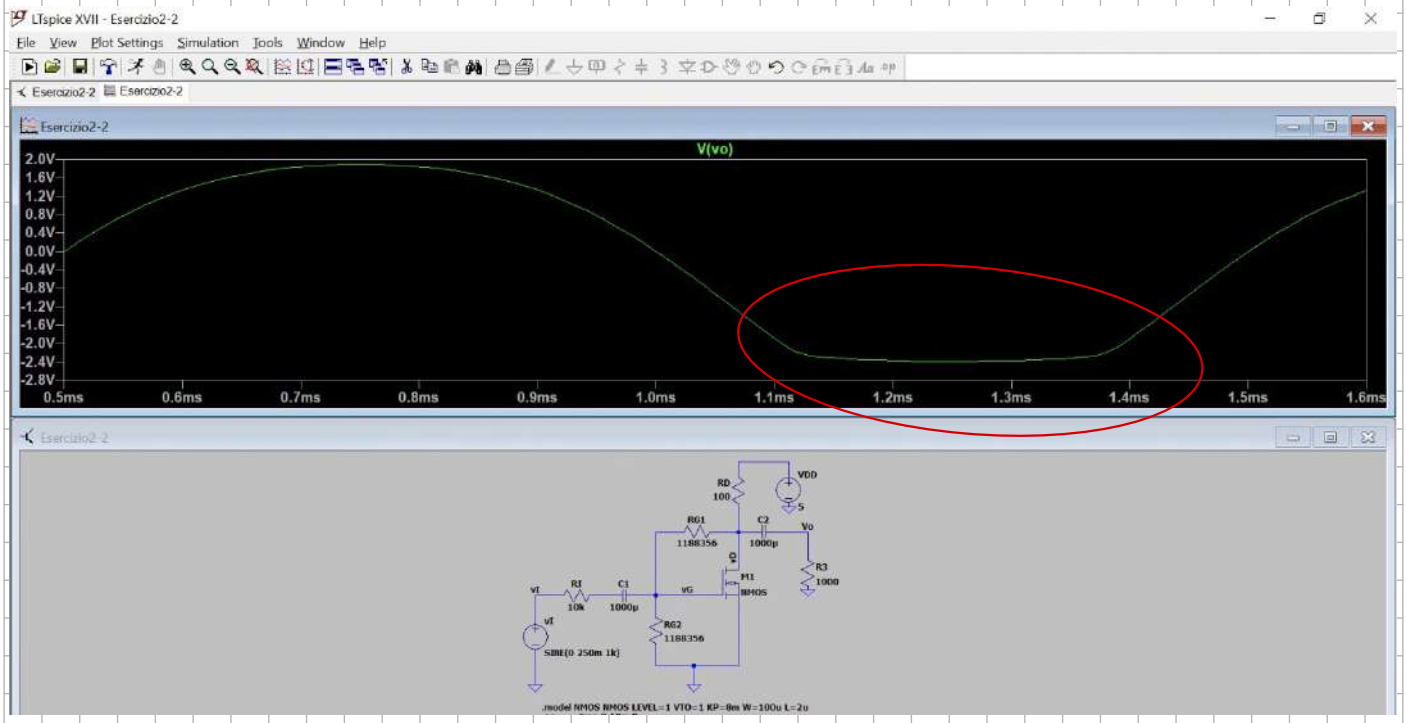
$V_I = 196$ mV

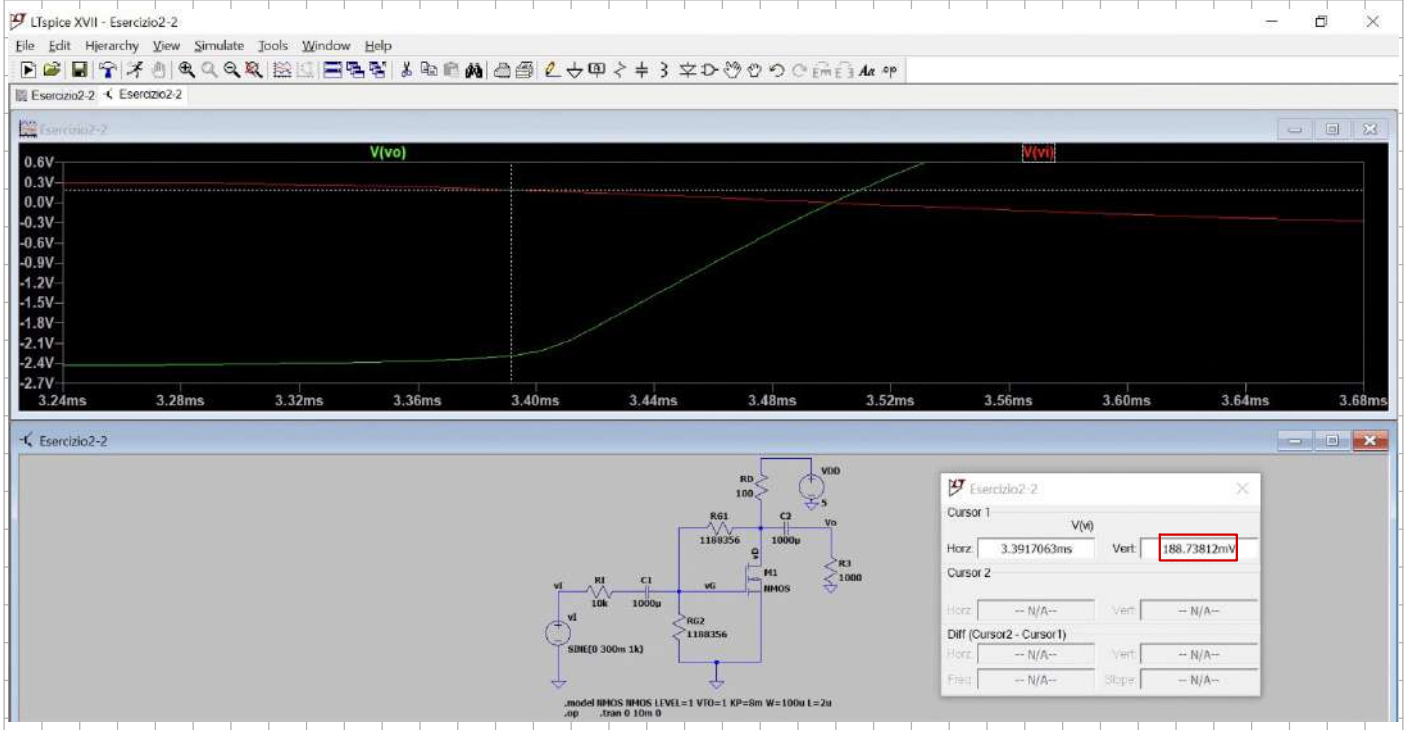
AVENDO UN V_I ABBASTANZA ALTO USEREMO VALORI PIÙ DISTANTI DA V_I LIMITE PER NOTARE MEGLIO LA SATURAZIONE/LINEARITÀ

PRIMA SIMULAZIONE CON $V_I = 150\ mV$



SECONDA SIMULAZIONE CON $V_I = 250\ mV$





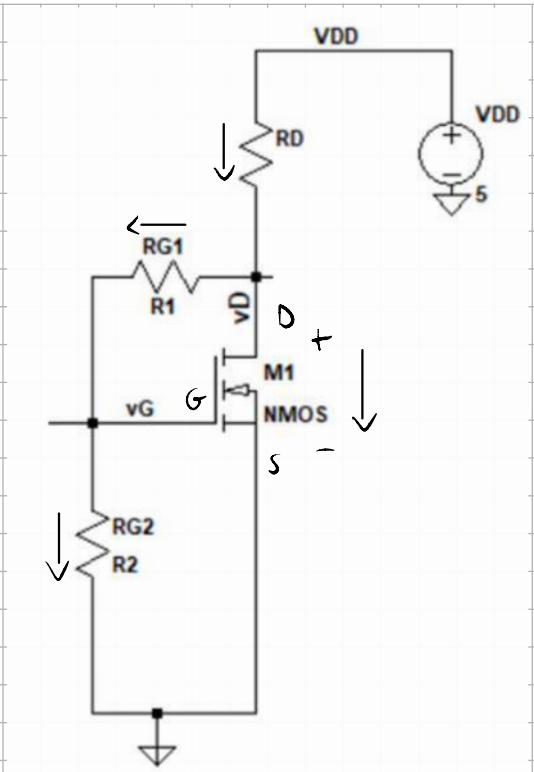
NEL GRAFICO VIENE EVIDENZIATO COME INTORNO AL VALORE TROVATO INIZIA LA SATURAZIONE

3 $W = L = 10\ \mu m$

$k_n' = 8\ mA/V$

$V_{TN} = 1$

$k_n = \frac{W}{L} k_n' = k_n'$



3.1 $I_{DS} = 1\ mA$

$V_{DS} = V_{OV} + 2V = V_{GS} - V_{TN} + 2V$

$I_G = 100\ nA$

IPOTIZZO TRANSISTOR SATURO

$I_{DS} = \frac{k_N}{2}(V_{GS} - V_{TN})^2$

$-1 \cdot 10^{-3} \frac{2}{k_n} = V_{GS}^2 + 1 - 2V_{GS}$

$V_{GS}^2 - 2V_{GS} + \frac{3}{4} = 0$

$V_{GS} <$ 1.5 OK; 0.5 $\longrightarrow$ NO PERCHÈ $V_{GS} - V_{TN} < 0$

$V_{DS} = V_{GS} - V_{TN} + 2V$

$V_{GS} = 1.5\ V \qquad V_{DS} = 2.5\ V$

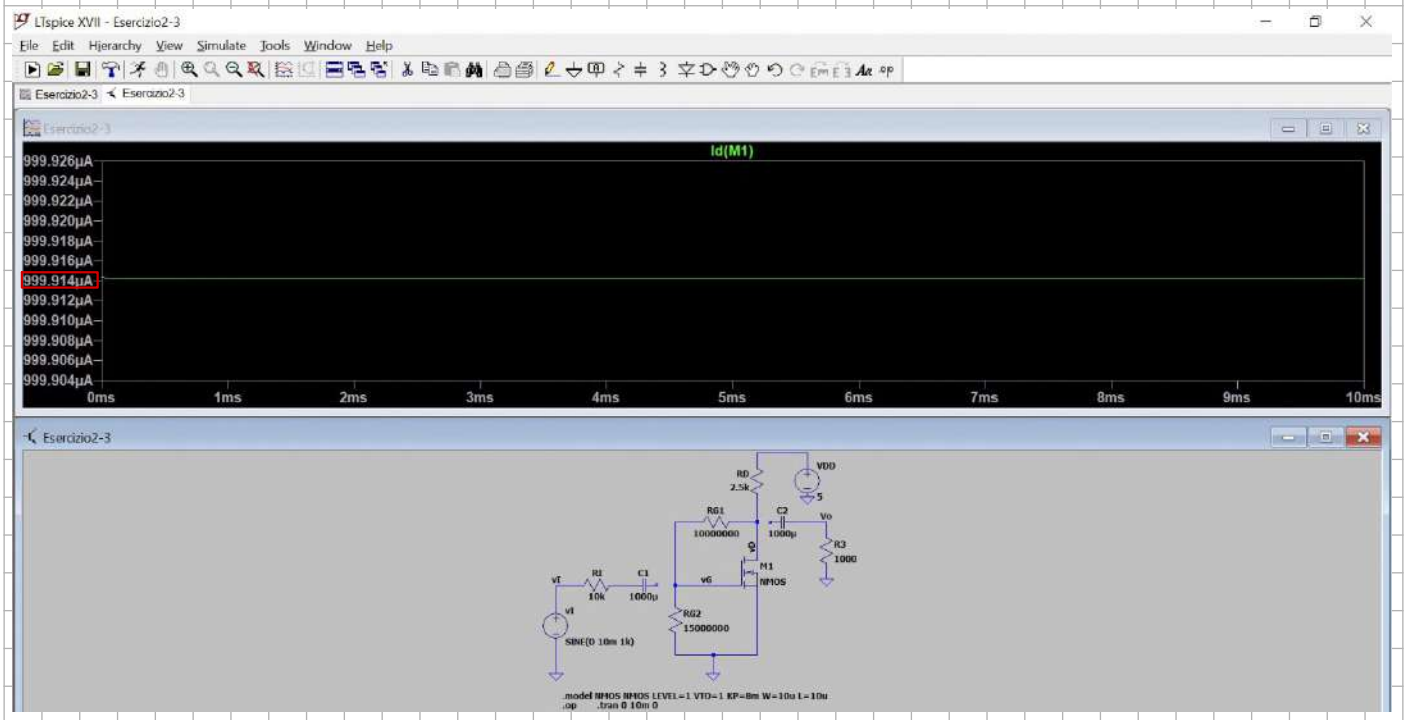
$V_{DS} > V_{GS} - V_{TN} \longrightarrow$ OK IPOTESI SATURAZIONE

$V_{DD} = R_D I_D + V_{DS} \longrightarrow R_D = \frac{V_{DD} - V_{DS}}{I_{DS} + I_G} = 2.5\ k\Omega$

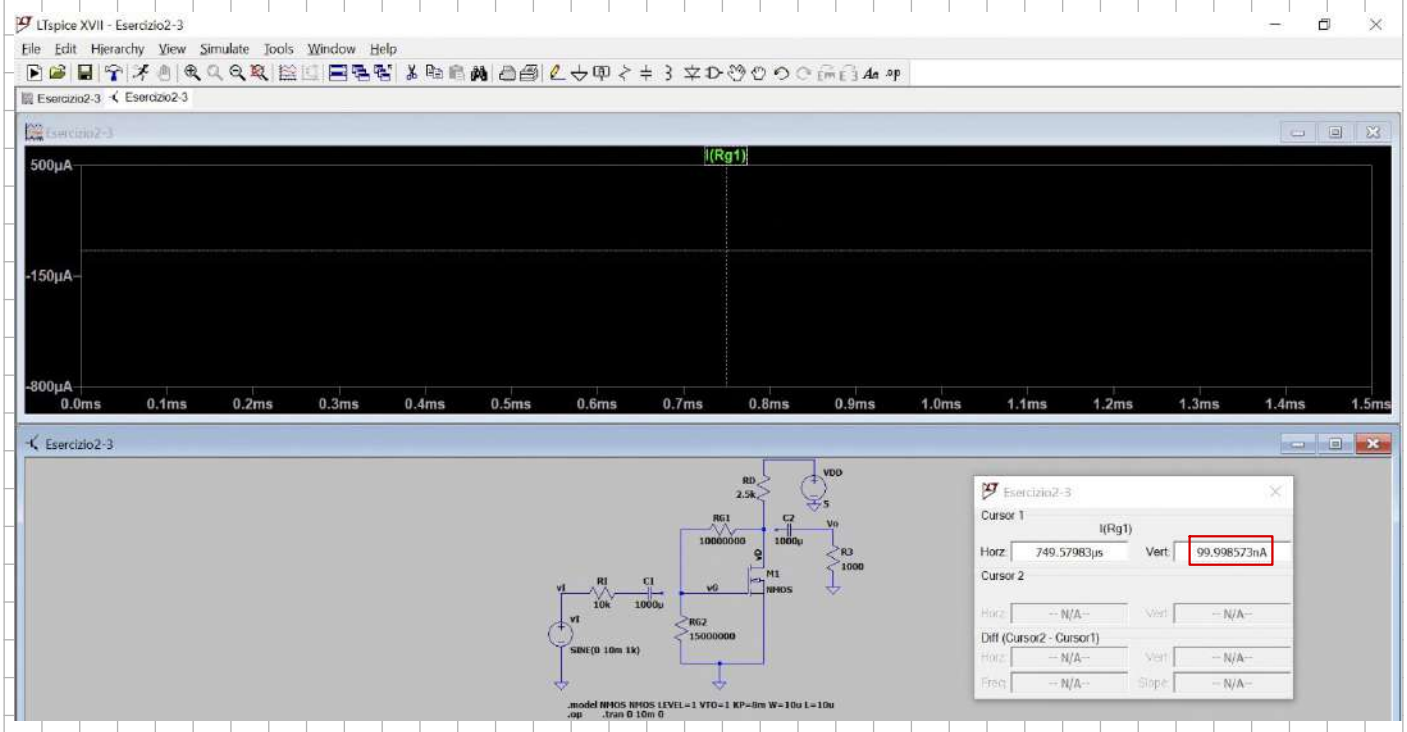
$V_{GS} = V_{DS} - R_{G2} I_G \longrightarrow R_{G2} = \frac{V_{DS} - V_{GS}}{I_G} = 1 \cdot 10^7\ \Omega$

$V_{DS} = R_{G2} I_G + R_{G1} I_G \longrightarrow R_{G2} = \frac{V_{DS} - R_{G1} I_G}{I_G} = 1.5 \cdot 10^7\ \Omega$

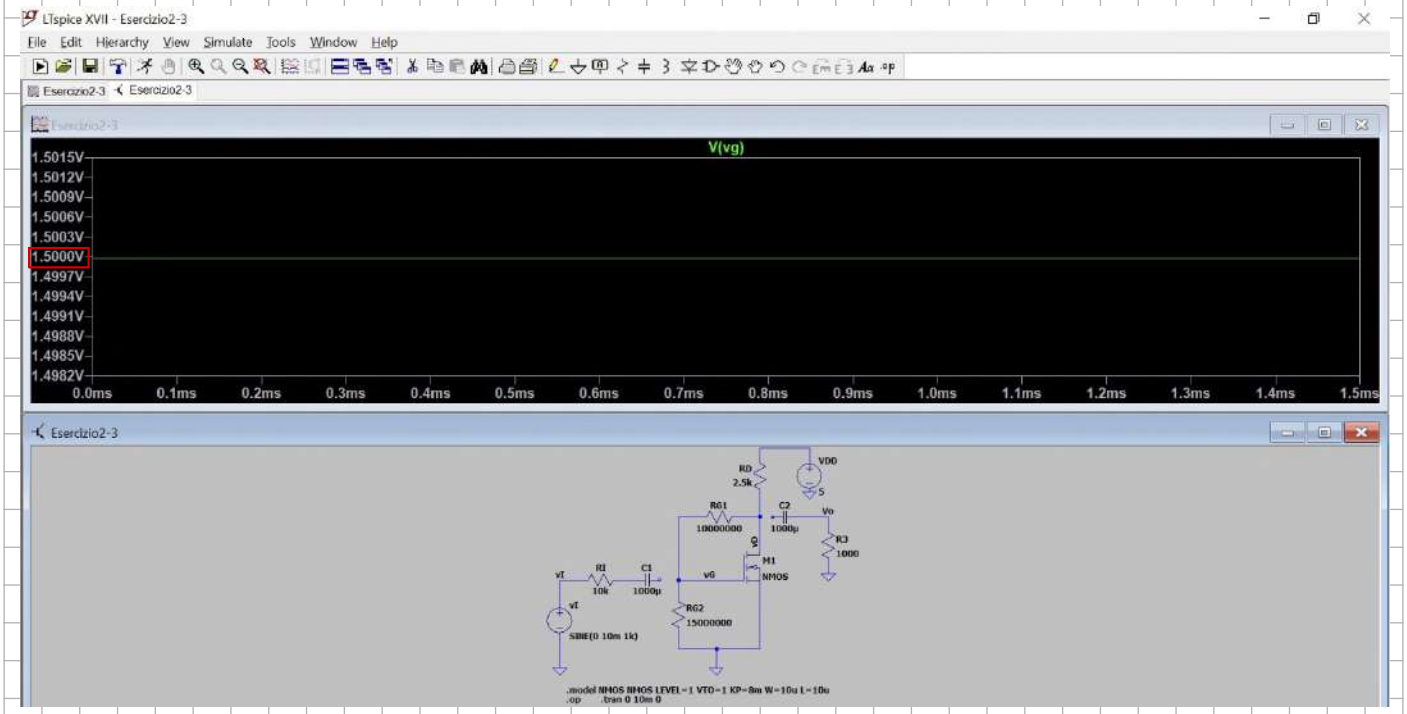
3.2



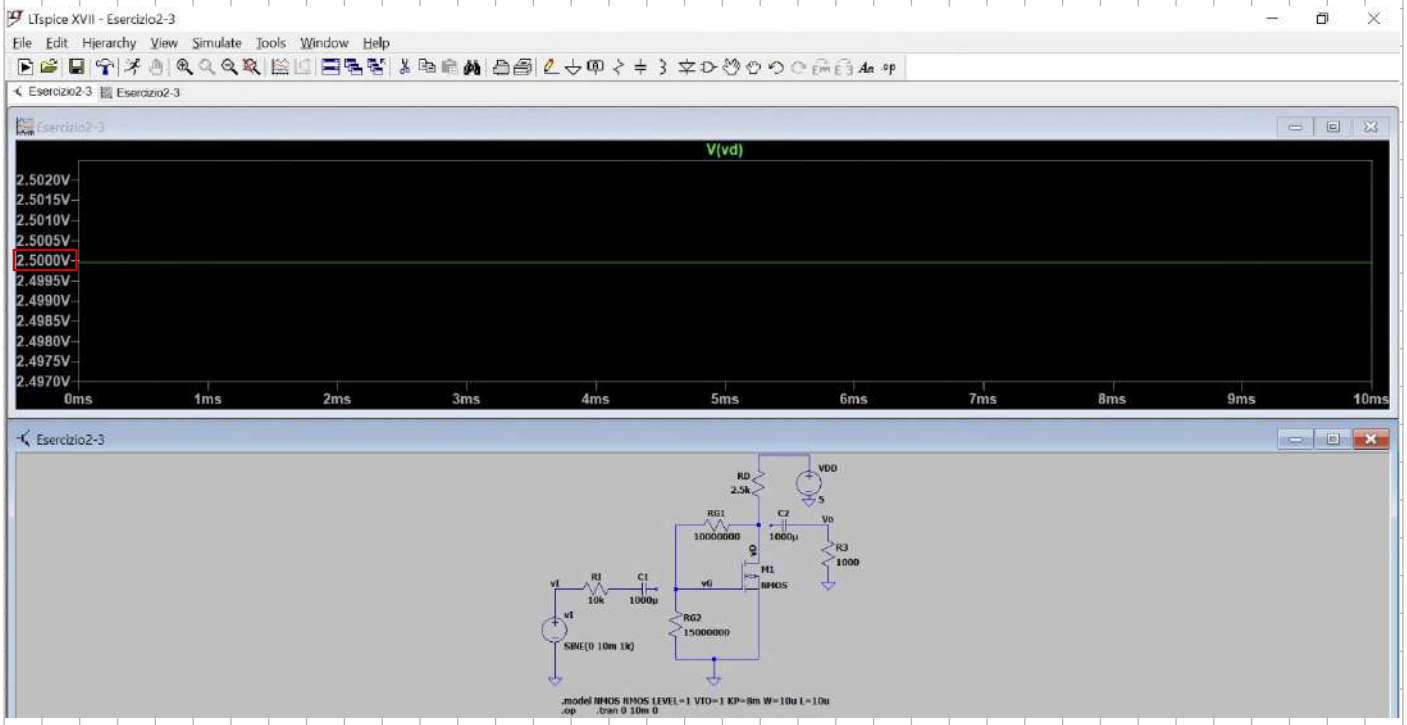
$I_{DS} = 1 \text{ mA}$



$I_G = 100 \text{ nA}$

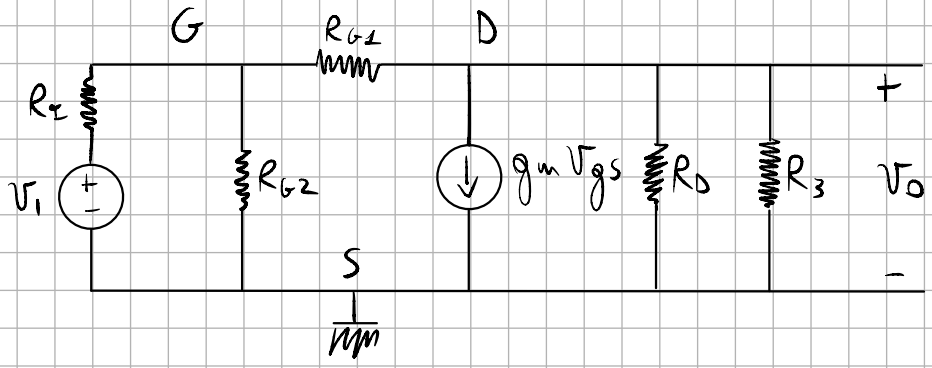


$V_{GS} = 1.5\ V$



$V_{DS} = 2.5\ V$

3.3

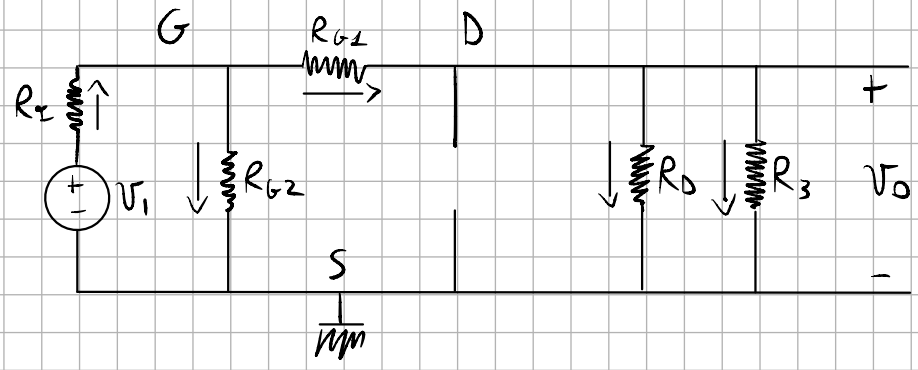


QUESTA RAPPRESENTAZIONE È A SOURCE COMUNE

MI CALCOLO V_O IN FUNZIONE DI V_I CON LA SOVRAPPOSIZIONE DEGLI EFFETTI

$g_m = 4 \cdot 10^{-3}$

SPENGO $g_m V_{gs}$



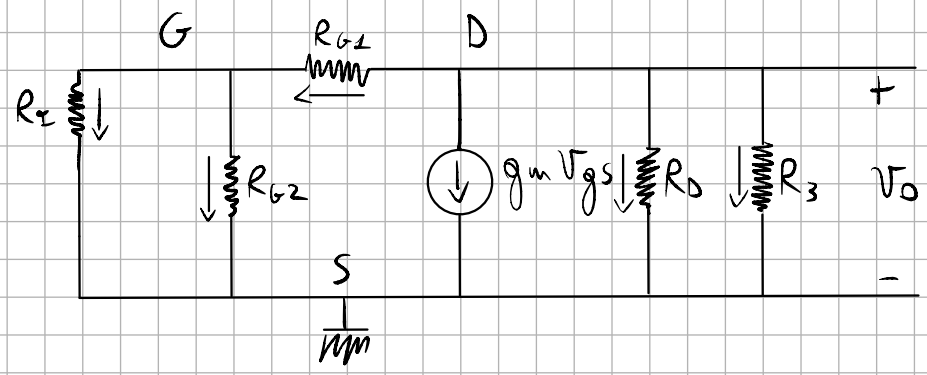
$R_D // R_3 = 714\ \Omega$ $\qquad R_{G2} // (R_{G1} + R_D // R_3) = 6.000257\ \Omega$

$$V_{gs1} = \frac{V_I}{R_L + R_{G2} // (R_{G1} + R_D // R_3)} R_{G2} // (R_{G1} + R_D // R_3) = 0.99\, V_I$$

$$I_{RG1,\, R_D // R_3} = \frac{V_{gs1}}{R_{G1} + R_D // R_3} = 9.98 \cdot 10^{-8}\, V_I$$

$$V_{O1} = I_{RG1,\, R_D // R_3} \cdot R_D // R_3 = 7.13 \cdot 10^{-5}\, V_I$$

SPENGO V_I



$R_{G2} // R_I = 9993\ \Omega$ $\quad R_D // R_3 // R_{G1} + (R_I // R_{G2}) = 714\ \Omega$

$V_{O2} = -g_m V_{gs} \left[R_D // R_3 // R_{G1} + (R_I // R_{G2}) \right] = -2.86\, V_{gs}$

$$I_{R_{G1}, R_{G2} // R_I} = \frac{V_{O2}}{R_{G1} + (R_{G2} // R_I)} = -2.85 \cdot 10^{-7} V_{gs}$$

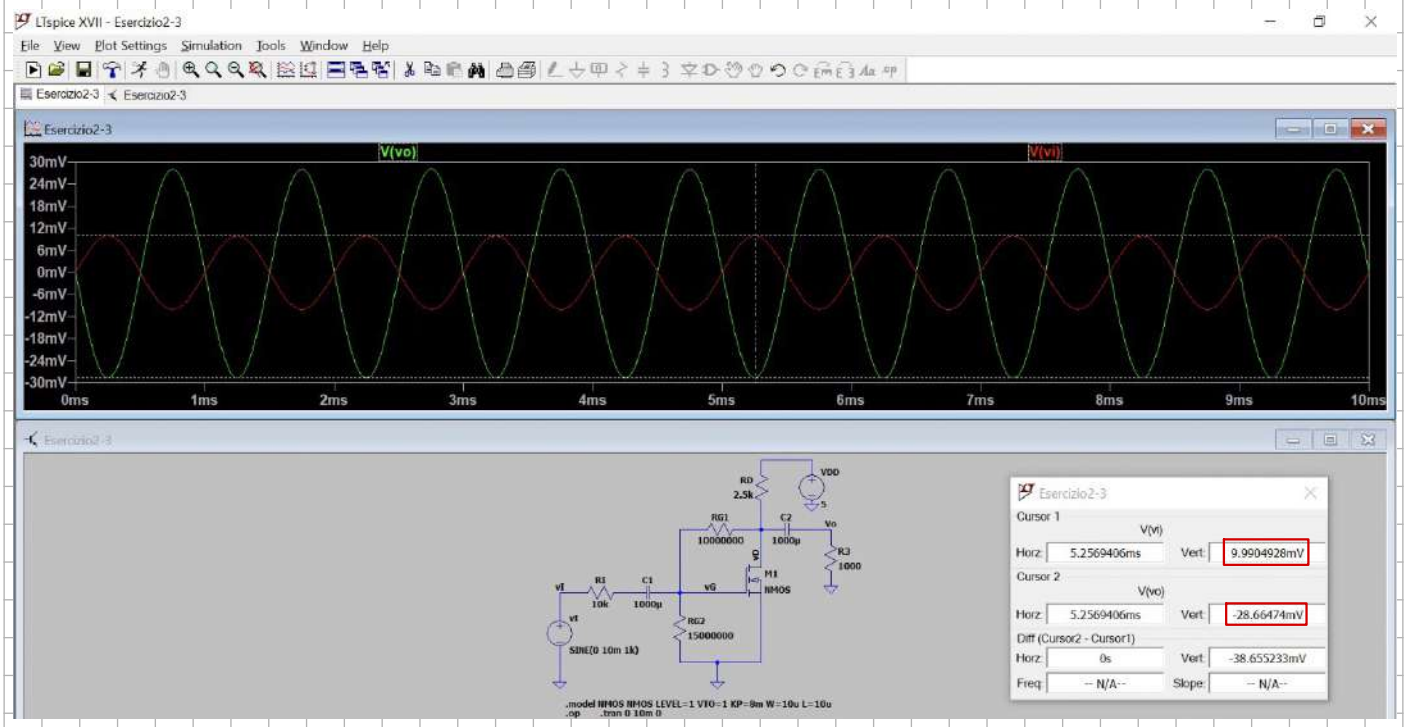
$V_{gs2} = I_{R_{G1}, R_{G2} // R_I} \cdot R_{G2} // R_I = -2.85 \cdot 10^{-3} V_{gs}$

UNISCO LE DUE PARTI

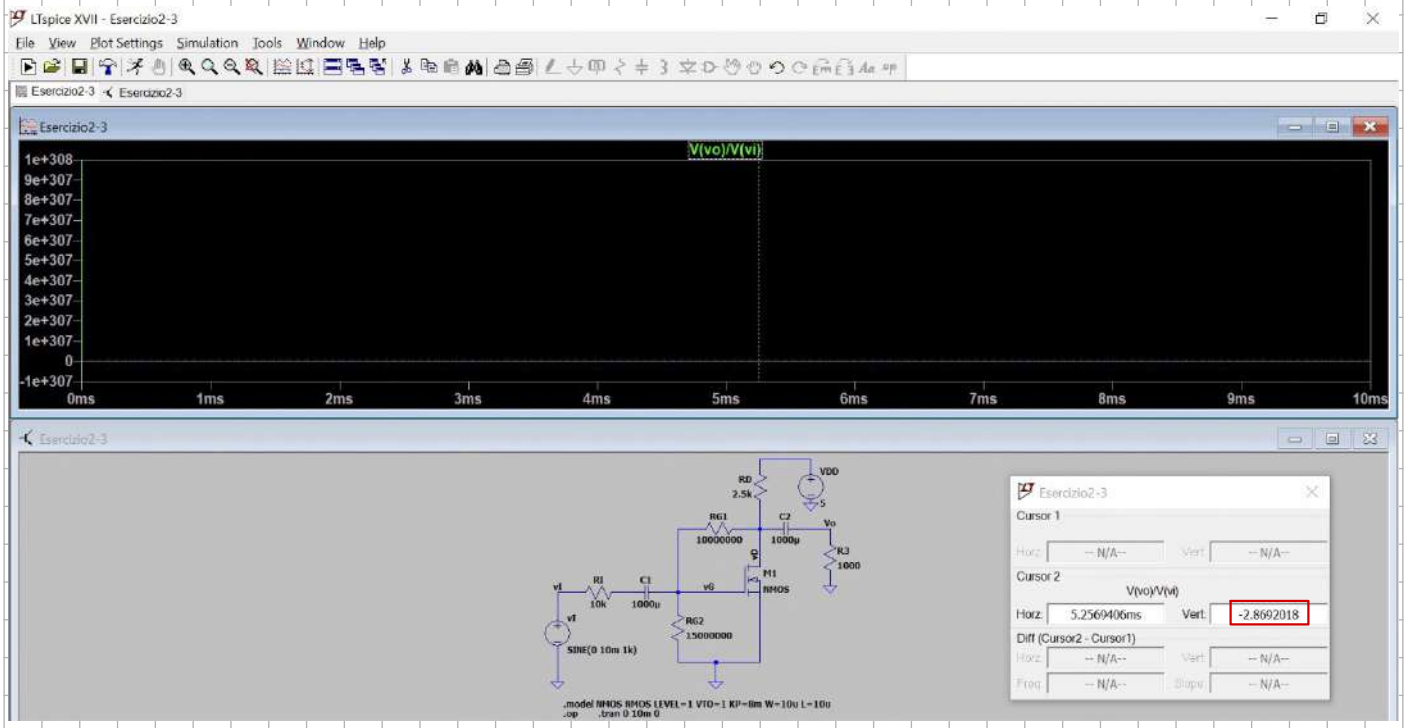
$V_{gs} = V_{gs1} + V_{gs2} = 0.99\, V_I - 2.85 \cdot 10^{-3} V_{gs} = 0.99\, V_I$

$V_O = V_{O1} + V_{O2} = 7.13 \cdot 10^{-5} V_I - 2.86 \cdot (0.99\, V_I) = -2.83\, V_I$

$A_V = -2.83$



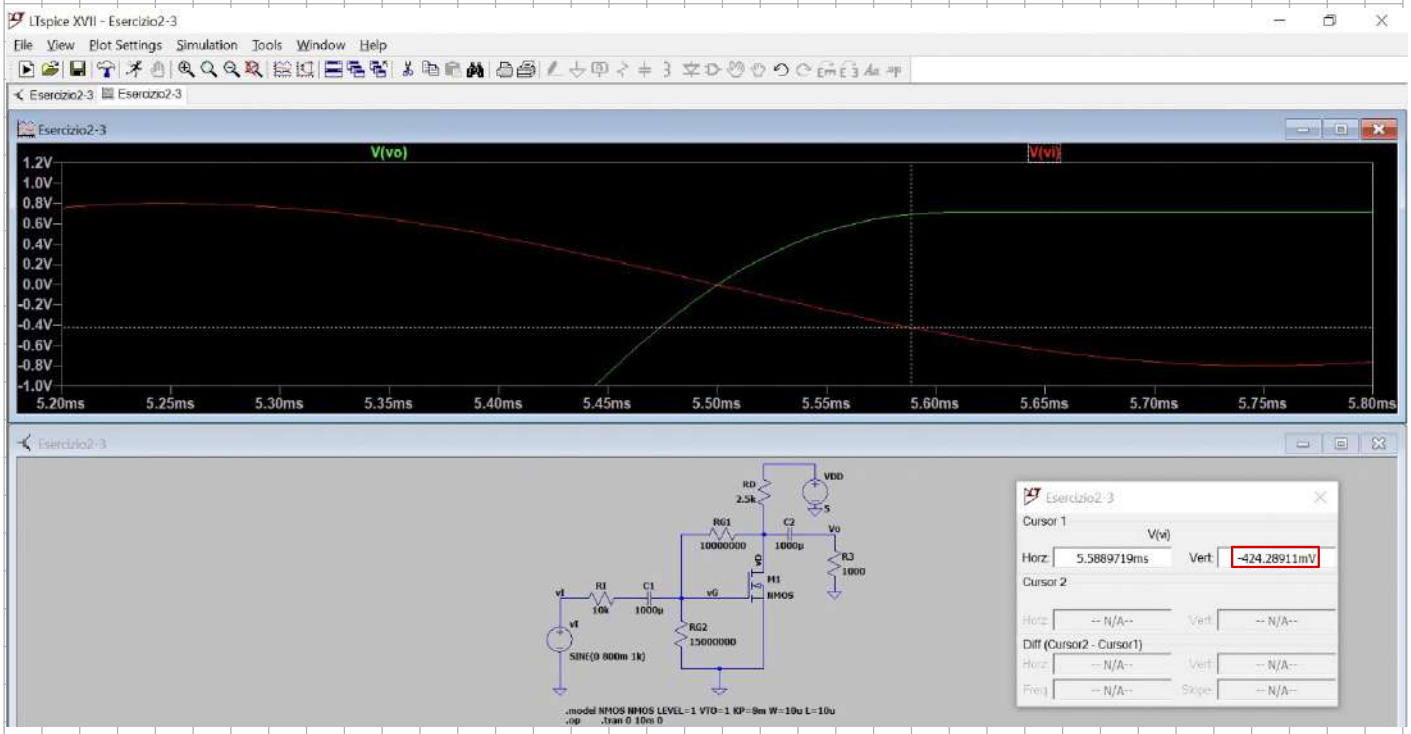
$$A_V = \frac{V_o}{V_i} = -2.86$$



AV ANALITICO: -2.83

AV CON SPICE: -2.86

3.4



IL VALORE DI V_{IN} CERCATO È CIRCA -425 mV

$$V_{DS} - |V_{DS\,max}| = V_{GS} - V_{TN} + V_{gs\,max}$$

$$|A_V v_i| = V_{DS} - V_{GS} + V_{TN} - V_I + R_I I_I$$

$$I_I = 2 \cdot 10^{-7} V_I + 2.83 \cdot 10^{-4} V_I = 2.83 \cdot 10^{-4} V_I$$

$V_I > 0 \longrightarrow V_I = 522$ mV

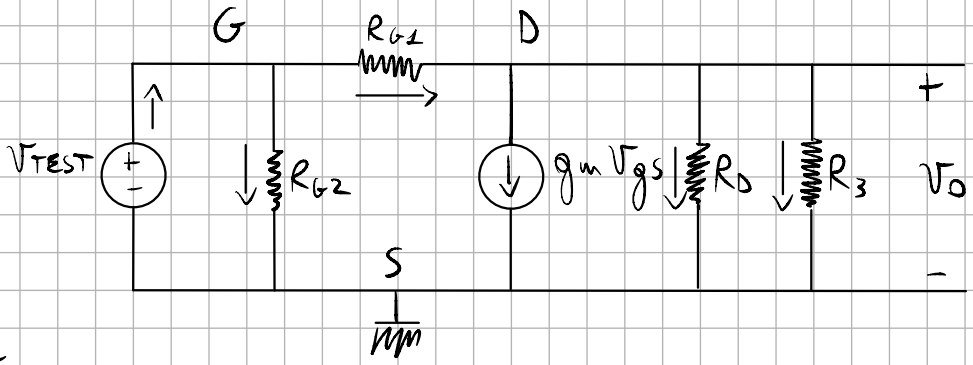
$V_I < 0 \longrightarrow V_I = -429$ mV

TENGO IL VALORE IN MODULO PIÙ STRINGENTE QUINDI:

$V_I = 429$ mV

3.5

$$R_{IN} = \frac{V_{TEST}}{I_{TEST}}$$



$$R_D \| R_3 = 714\ \Omega$$

$$\begin{cases} I_{TEST} = \dfrac{V_{TEST}}{R_{G2}} + \dfrac{V_{TEST} - V_O}{R_{G1}} \\ I_{RG1} = \dfrac{V_{TEST} - V_O}{R_{G1}} \\ g_m V_{TEST} = I_{RG1} - \dfrac{V_O}{R_D \| R_3} \end{cases}$$

$$g_m V_{TEST} = \frac{V_{TEST} - V_O}{R_{G1}} - \frac{V_O}{R_D \| R_3} = \frac{V_{TEST}}{R_{G1}} - V_O \left(\frac{1}{R_{G1}} + \frac{1}{R_D \| R_3} \right) =$$

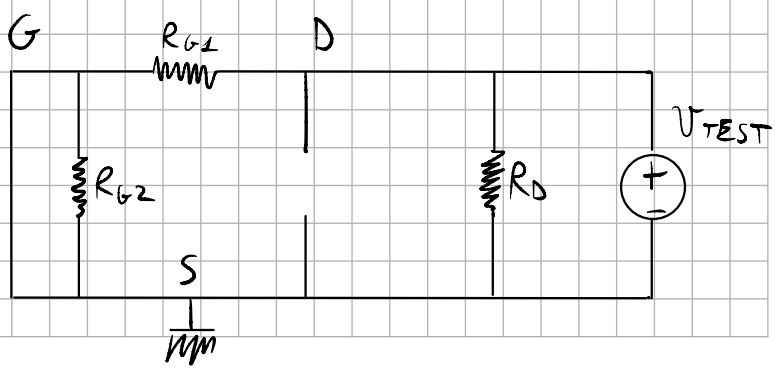
$$V_O = \left(\frac{V_{TEST}}{R_{G1}} - g_m V_{TEST} \right) \cdot \frac{1}{\left(\frac{1}{R_{G1}} + \frac{1}{R_D \| R_3} \right)}$$

$$= V_{TEST} \frac{\left(\frac{1}{R_{G1}} - g_m \right)}{\left(\frac{1}{R_{G1}} + \frac{1}{R_D \| R_3} \right)} = -2.86\ V_{TEST}$$

$$I_{TEST} = \frac{V_{TEST}}{R_{G2}} + \frac{V_{TEST} + 2.86\ V_{TEST}}{R_{G1}} = \frac{(R_{G1} + 3.86\ R_{G2})}{R_{G1} \cdot R_{G2}} V_{TEST}$$

$$R_{IN} = \frac{V_{TEST}}{I_{TEST}} = \frac{R_{G1} \cdot R_{G2}}{(R_{G1} + 3.86\ R_{G2})} = 2.209.231\ \Omega$$

$$R_{OUT} = \frac{V_{TEST}}{I_{TEST}}$$



$$R_{OUT} = R_D \| R_{G1} = 2.5\ k\Omega$$

4

	A_V	R_{IN}	R_{OUT}
CASO 1	-13.51	73'529	100
CASO 2	-11.03	82'755	100
CASO 3	-2.83	2'209'131	2499

COME SI PUÒ NOTARE NEI PRIMI DUE CASI, LE RESISTENZE DI INGRESSO/USCITA NON CAMBIA MOLTO; NON A CASO ANCHE IL GUADAGNO VARIA DI POCO.

NELL'ULTIMO CASO LE RESISTENZE DI INGRESSO E DI USCITA SONO MOLTO PIÙ ALTE E QUESTO LIMITA DRASTICAMENTE IL GUADAGNO.