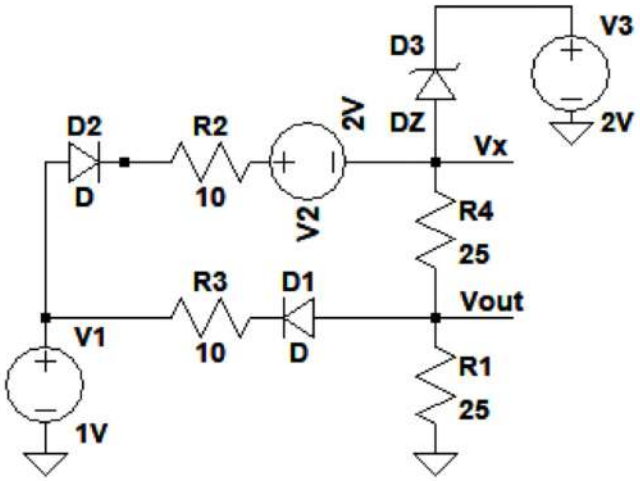
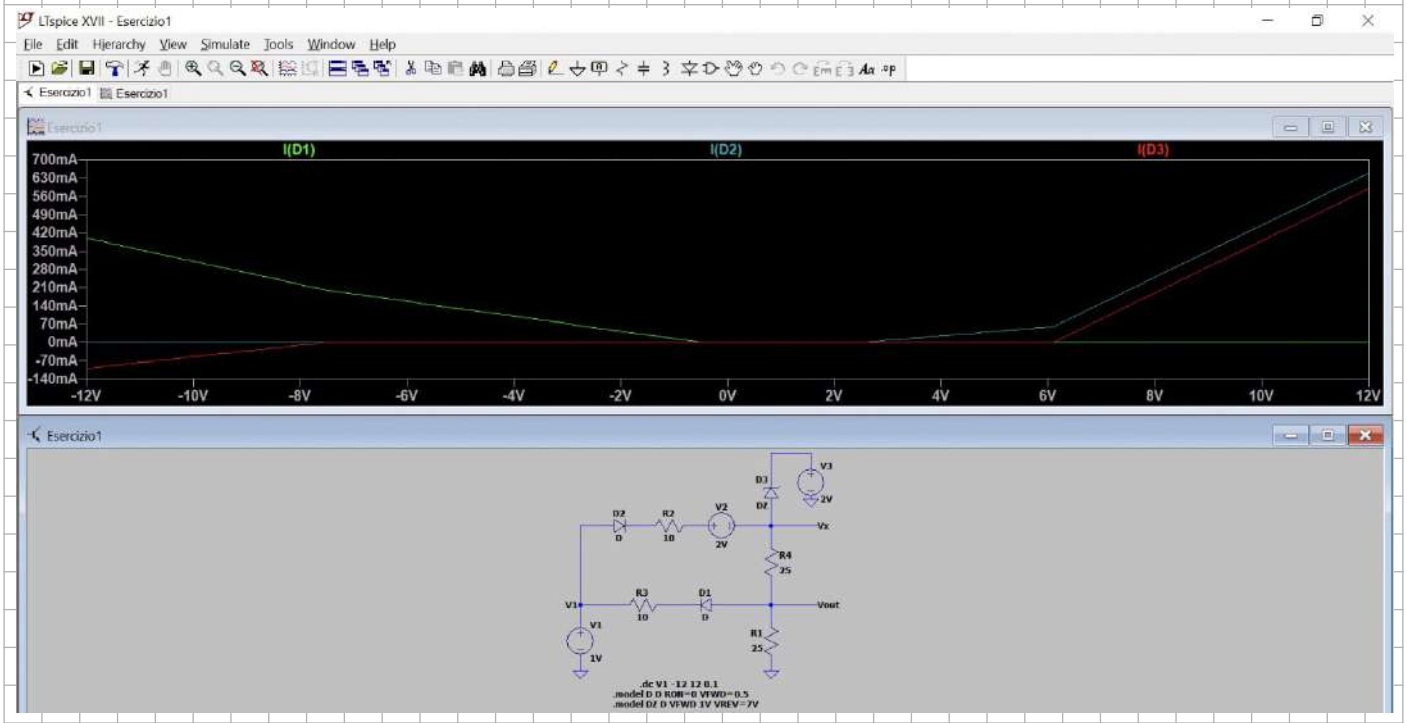
ESERCIZIO 1

A.



SIMULO SUBITO CON SPICE LE CORRENTI NEI DIODI TRA $-12 < V_2 < 12$ PER CAPIRE QUALI CASI PRENDERE IN CONSIDERAZIONE. SE LA CORRENTE È UGUALE A 0 VUOL DIRE CHE IL DIODO È OFF



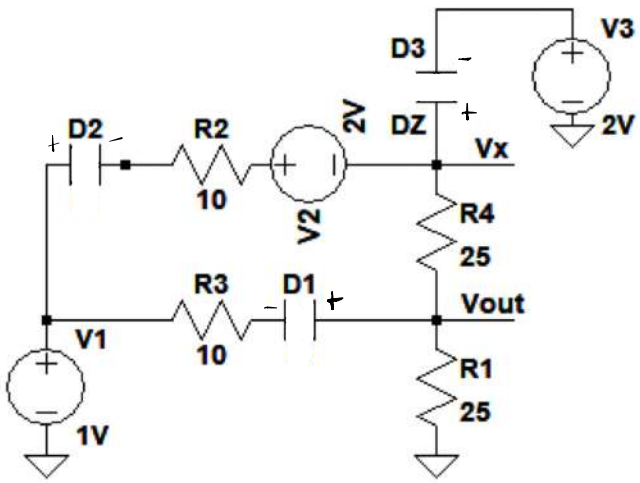
COME SI PUÒ NOTARE I CASI DA PRENDERE IN CONSIDERAZIONE SONO SOLO 5:

1) D_1, D_2, D_3 OFF
2) D_1 ON, D_2 OFF, D_3 IN BLK
3) D_1 ON, D_2 OFF, D_3 OFF
4) D_1 OFF, D_2 ON, D_3 OFF
5) D_1 OFF, D_2 ON, D_3 ON

1) D_1, D_2, D_3 OFF

$V_{OUT} = 0$

$V_X = 0$



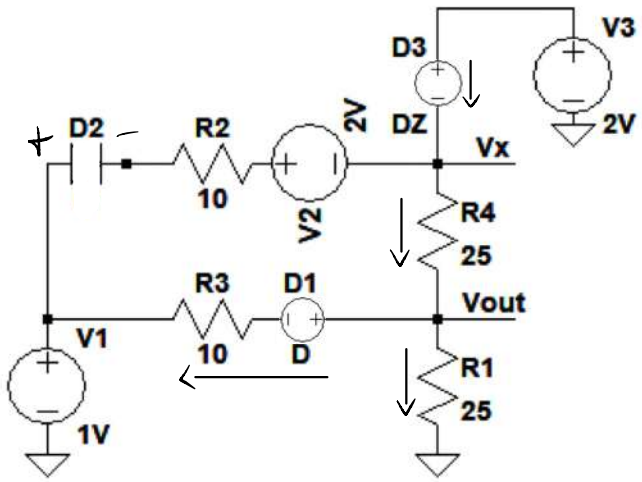
D_1: $0 - V_1 < 0.5 \longrightarrow V_1 > -0.5$

D_2: $V_1 - 2 < 0.5 \longrightarrow V_1 < 2.5$

D_3: $\begin{cases} 0 - 3 < 1 & \text{ok} \\ -7 < 0 - 3 & \text{ok} \end{cases}$

1) PER $\quad -0.5 < V_1 < 2.5$

2) D_1 ON, D_2 OFF, D_3 IN BEK



$V_X = 2 - 7 = -5\ V$

$I_1 = \dfrac{V_{OUT} - 0}{R_1} = \dfrac{V_{OUT}}{R_1}$

$I_4 = \dfrac{V_X - V_{OUT}}{R_4}$

$I_3 = \dfrac{V_{OUT} - V_\gamma - V_1}{R_3}$

$I_1 = I_4 - I_3$

$$\frac{V_{OUT}}{R_1} = \frac{V_X - V_{OUT}}{R_4} - \frac{V_{OUT} - V_\gamma - V_1}{R_3}$$

$$V_{OUT}\left(1 + \frac{R_1}{R_4} + \frac{R_1}{R_3}\right) = \frac{R_1}{R_4} V_X + \frac{R_1}{R_3}\left(V_\gamma + V_1\right)$$

$$V_{OUT} = \frac{5}{9} V_1 - \frac{5}{6}$$

D_1: $I_3 > 0 \longrightarrow \dfrac{V_{OUT} - V_\gamma - V_1}{R_3} > 0 \longrightarrow V_1 < -3$

D_2: $V_1 + 3 < 0.5$

$V_1 < -2.5$

D_3: $I_4 > 0 \longrightarrow \frac{V_X - V_{OUT}}{R_4} > 0 \longrightarrow -5 > \frac{5}{9} V_I - \frac{5}{6}$

$V_I < -7.5$

2) PER $-12 < V_I < -7.5$

3) D_1 ON, D_2 OFF, D_3 OFF

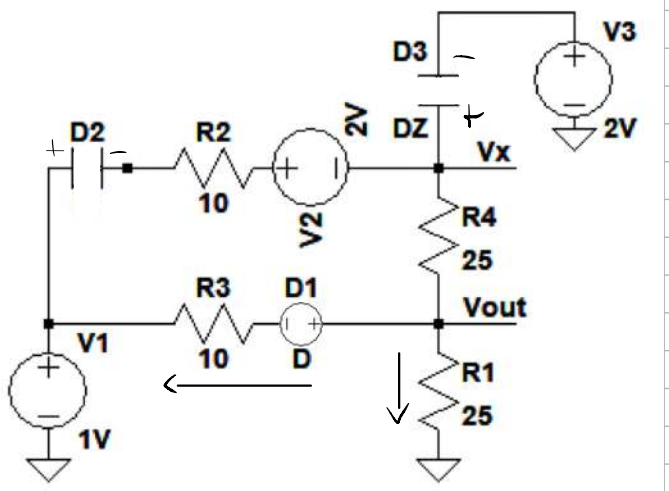
$V_X = V_{OUT}$

$V_{OUT} = V_1 + R_3 I_3 + V_\gamma$

$I_3 = -I_1 = -\frac{V_{OUT}}{R_1}$

$I_1 = \frac{V_{OUT}}{R_1}$

$V_{OUT} = V_1 - R_3 \frac{V_{OUT}}{R_1} + V_\gamma$



$V_{OUT} = \frac{V_1 + V_\gamma}{1 + \frac{R_3}{R_1}} = \frac{5}{7} V_1 + \frac{5}{14} = V_X$

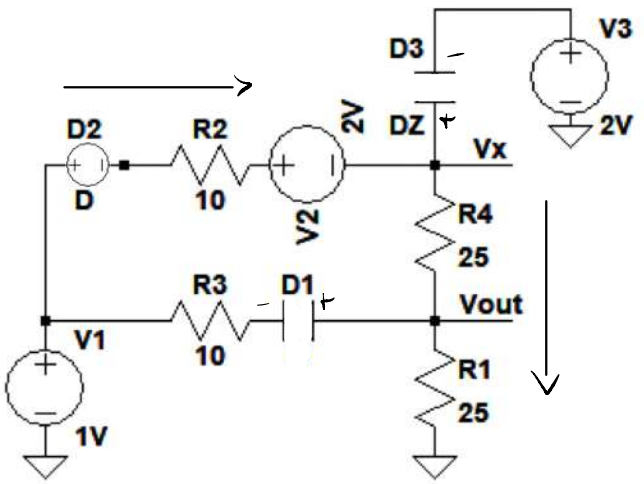
D_2: $I_D = -\frac{V_{OUT}}{R_1} > 0 \longrightarrow \frac{5}{7} V_1 + \frac{5}{14} > 0 \longrightarrow V_1 < -0.5$

D_2: $V_1 - V_{OUT} - 2 < 0.5 \longrightarrow V_1 \frac{2}{7} < \frac{20}{7} \longrightarrow V_1 < 10$

D_3: $\begin{cases} V_{OUT} - 2 < 1 \longrightarrow V_{OUT} < 3 \longrightarrow V_1 < 3.7 \\ -7 < V_{OUT} - 2 \longrightarrow V_{OUT} > -5 \longrightarrow V_1 > -7.5 \end{cases}$

3) PER $-7.5 < V_I < -0.5$

4) D_1 OFF, D_2 ON, D_3 OFF



NOTO CHE LA CORRENTE È LA STESSA PER TUTTO IL CIRCUITO

$$V_1 - V_\gamma - R_2 I - 2 - I(R_4 + R_3) = 0$$

$$I = \frac{V_1 - V_\gamma - 2}{R_1 + R_2 + R_4} = \frac{1}{60} V_1 - \frac{1}{24}$$

$$V_{OUT} = I R_1 = \frac{25}{60} V_1 - \frac{25}{24}$$

$$V_X = V_{OUT} + I R_4 = \frac{5}{6} V_1 - \frac{25}{12}$$

D_1: $V_{OUT} - V_1 < 0.5 \longrightarrow V_1 > -2.64$ V

D_2: $I > 0 \longrightarrow \frac{V_1 - V_\gamma - 2}{R_1 + R_2 + R_4} > 0 \longrightarrow V_1 > 2.5$ V

D_3: $\begin{cases} V_X - 2 < 1 \longrightarrow V_1 < 6.1 \\ V_X - 2 > -7 \longrightarrow V_1 > -3.5 \end{cases}$

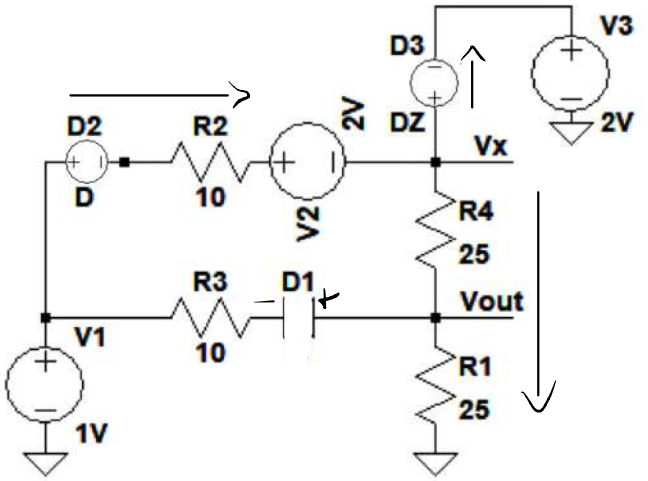
4) PER $2.5 < V_I < 6.1$

5) D_1 OFF, D_2 ON, D_3 ON

$$V_X = 2 + 1 = 3 \text{ V}$$

$$I_4 = I_1 = \frac{V_X}{R_1 + R_4} = 60 \text{ mA}$$

$$V_{OUT} = R_1 I_1 = 1.5 \text{ V}$$



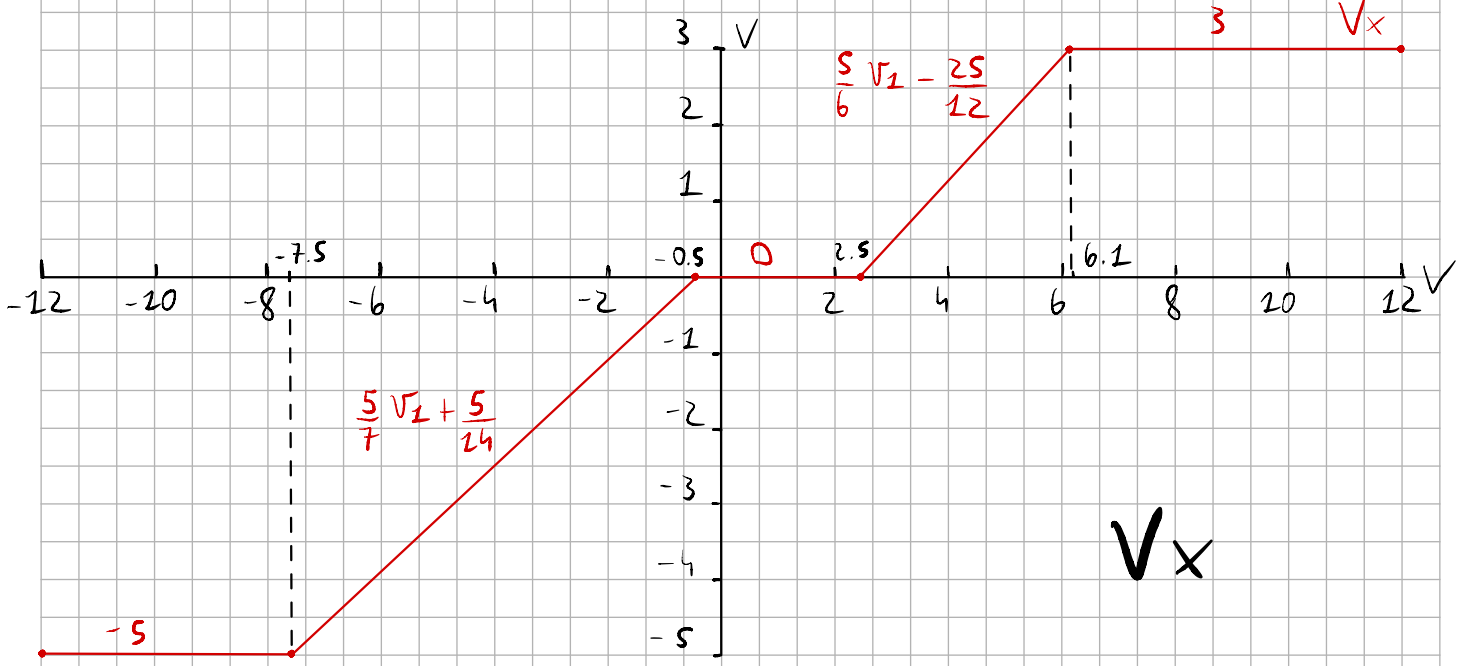
D_1: $V_{OUT} - V_1 < 0.5 \longrightarrow V_1 > 1$

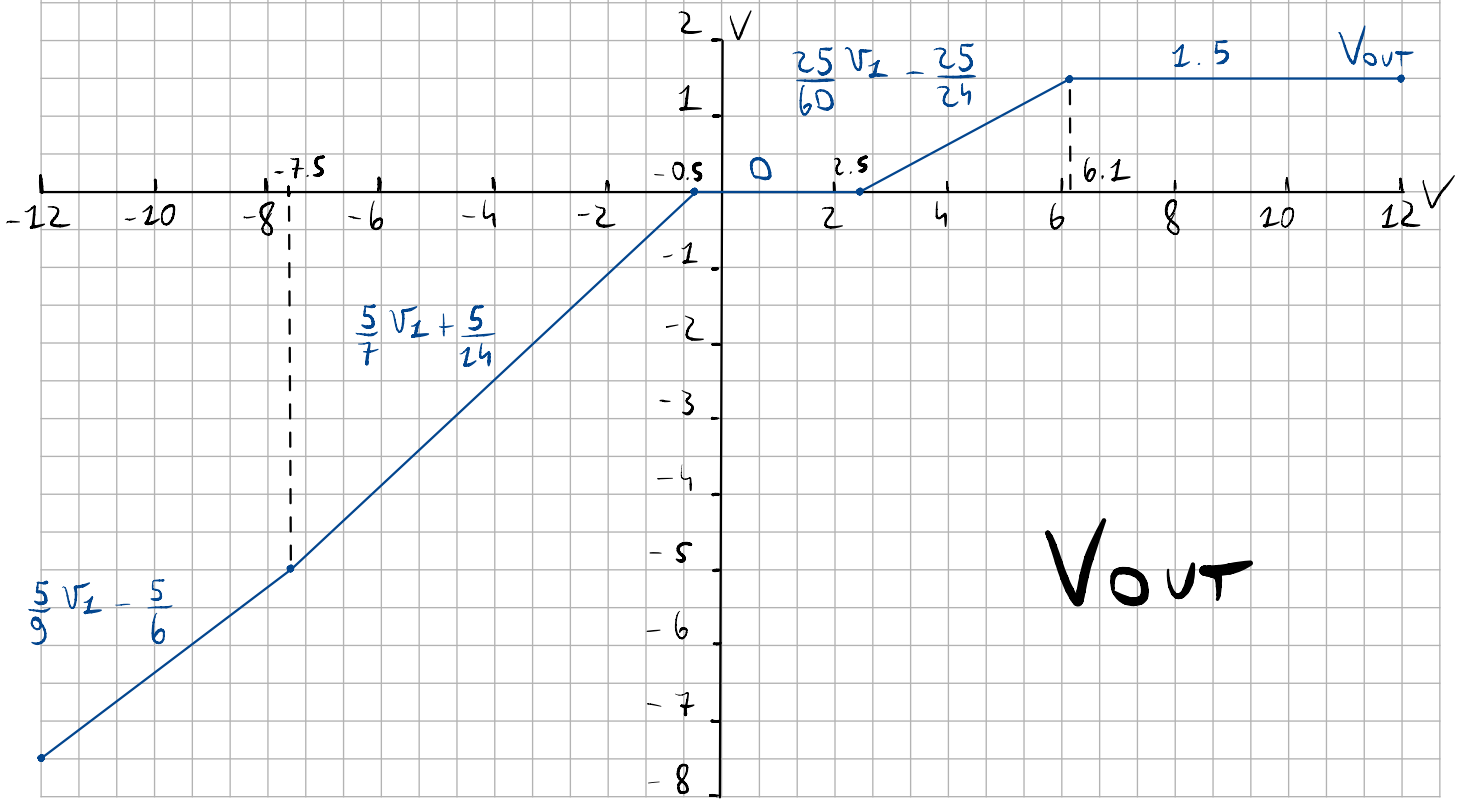
D_2: $I_2 > 0 \longrightarrow \frac{V_1 - V_\gamma - V_X - V_2}{R_2} > 0 \longrightarrow V_1 > 5.5\,V$

D_3: $I_D = I_2 - I_4 > 0 \longrightarrow \frac{V_1 - 5.5}{R_2} - \frac{V_X}{R_1 + R_4} > 0 \longrightarrow V_1 > 6.1$

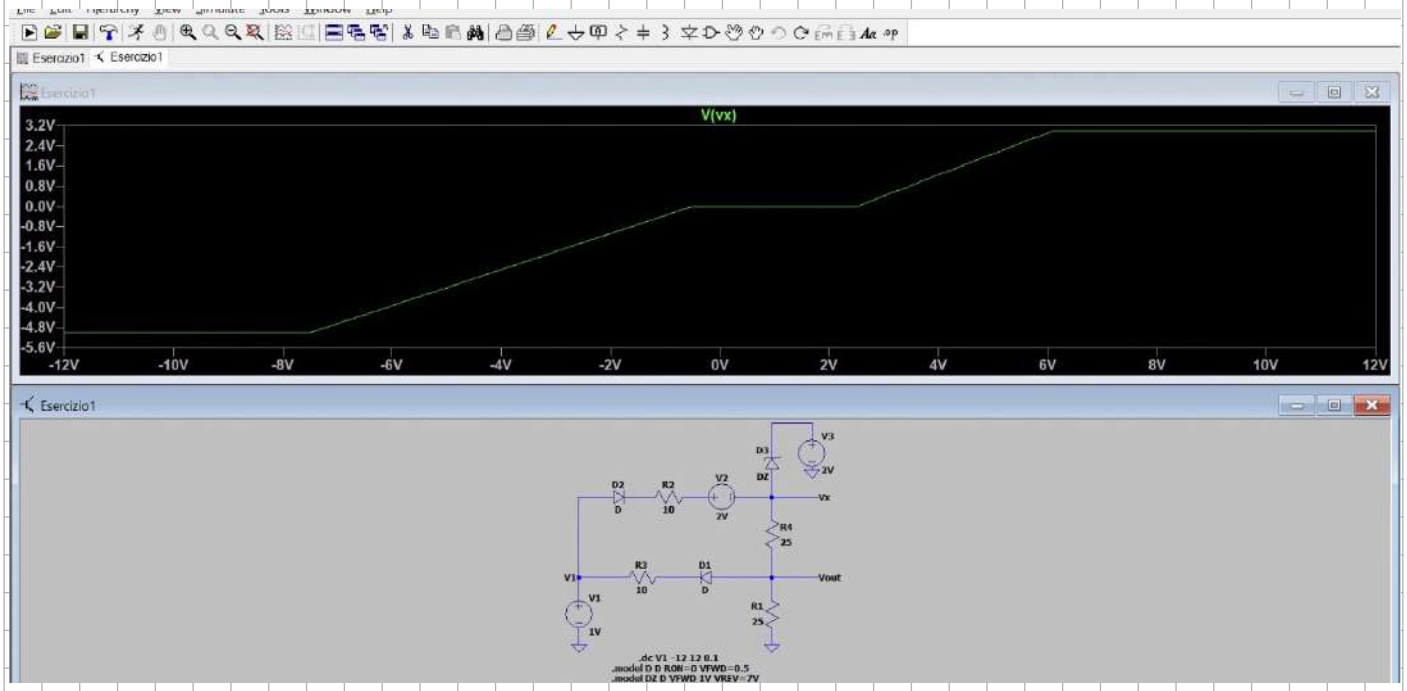
5) PER $6.1 < V_1 < 12$

GRAFICI CON I RISULTATI OTTENUTI

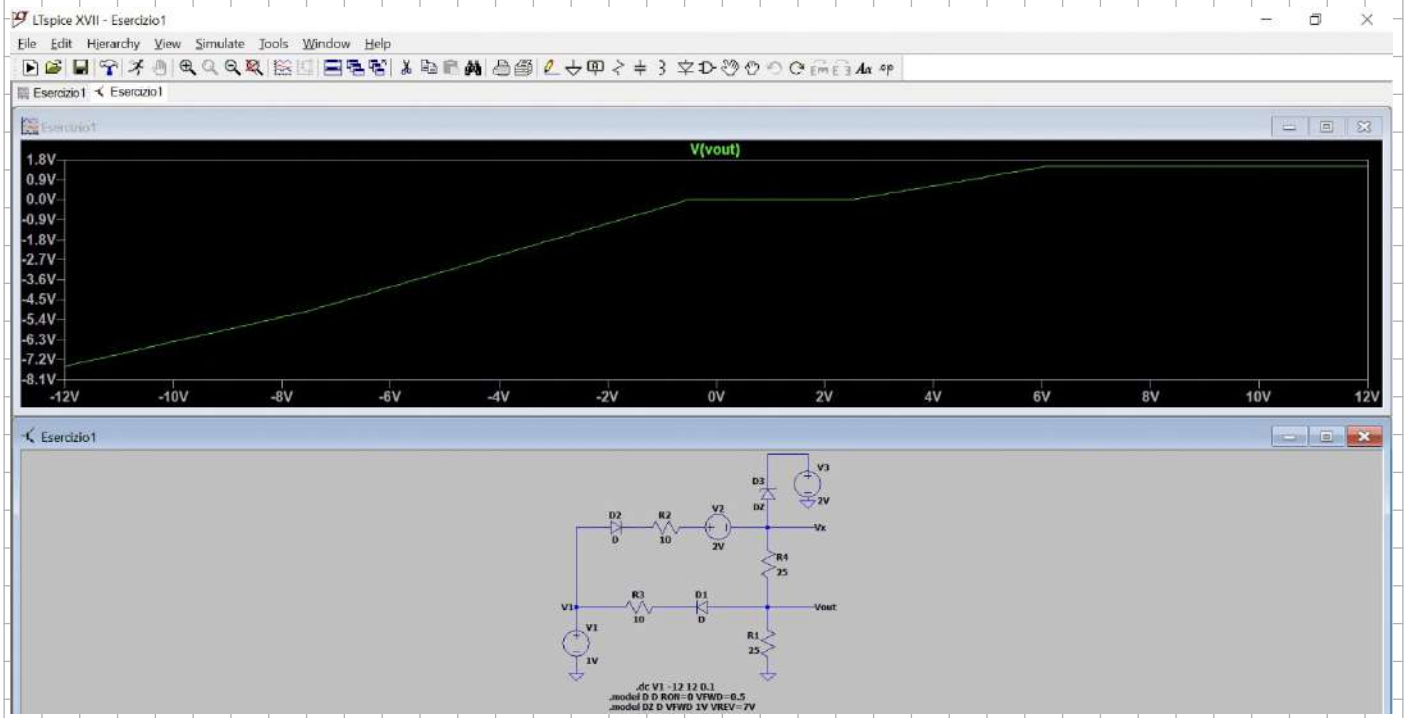




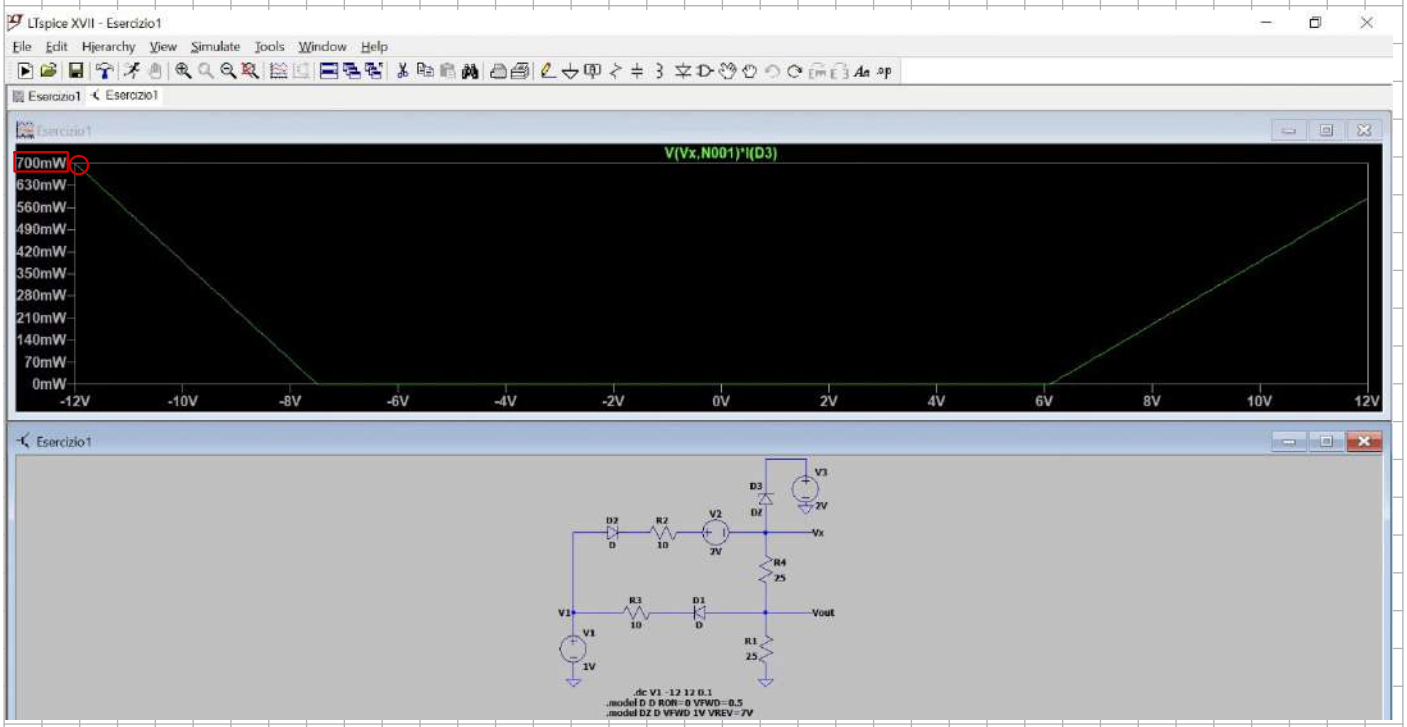
B.



COME SI PUÓ NOTARE I GRAFICI SONO UGUALI A QUELLI TROVATI ANALITICAMENTE



C.



COME SI PUÒ NOTARE DAL GRAFICO LA MASSIMA POTENZA DISSIPATA DAL DIODO ZENER SI HA QUANDO QUESTO È IN BRK

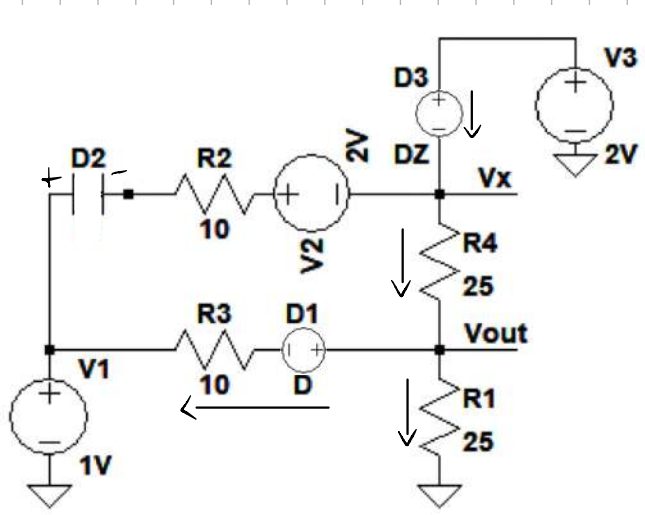
$$V_X = 2 - 7 = -5\,V$$

$$V_{OUT} = \frac{5}{9} V_I - \frac{5}{6}$$

$$I_4 = I_{D3} = \frac{V_X - V_{OUT}}{R_4} =$$

$$= -\frac{5}{9}\frac{V_I}{R_4} - \frac{25}{6}\frac{1}{R_4} =$$

$$= -\frac{V_I}{45} - \frac{1}{6}$$



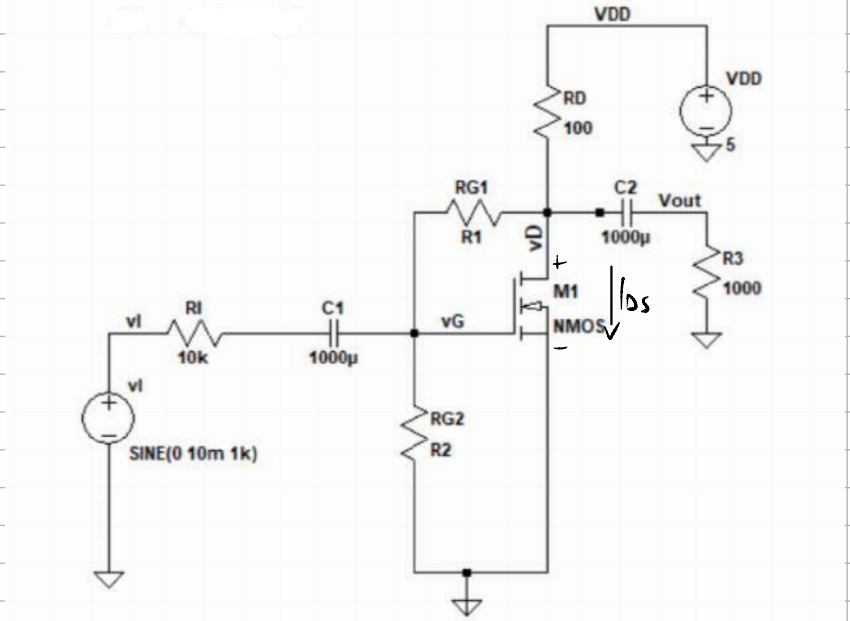
$$P_{D3} = (V_+ - V_-) \cdot I_{D3} = \left(2 - (-5)\right) \cdot \left(-\frac{V_I}{45} - \frac{1}{26}\right)$$

PIÙ BASSA È V_I, MAGGIORE SARÀ LA POTENZA IN QUESTO CASO. PRENDIAMO $V_I = -12\,V$

$$P_{D3} = 700\,mW$$

ESERCIZIO 2

1 NUMERO DI MATRICOLA: 1188356



1.1

$RG1 = 1188356\ \Omega$ $\qquad$ $RG2 = \infty$

APRO TUTTI CONDENSATORI E DATO CHE $RG2 = \infty$, LA CONSIDERO COME CIRCUITO APERTO

NOTO ALLORA CHE SU RG1 NON PUÒ SCORRERE CORRENTE, QUINDI $V_G = V_D$

$V_D = V_G \longrightarrow V_{DS} = V_{GS} \longrightarrow$ TRANSISTOR IN SATURAZIONE

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

$V_{DD} = R_D k_n (V_{GS} - V_{TN})^2 + V_{DS}$ $\qquad$ $k_n = \frac{W}{L} k_n'$

$20 V_{GS}^2 - 39 V_{GS} + 15 = 0$

$V_{GS} < \begin{cases} 0.53 \longrightarrow \text{NON ACCETTABILE POICHÈ} \\ 1.42 \quad \text{OK} \end{cases}$

$V_{OV} = V_{GS} - V_{TN} = -0.47 < 0$

IL TRANSISTOR SAREBBE SPENTO

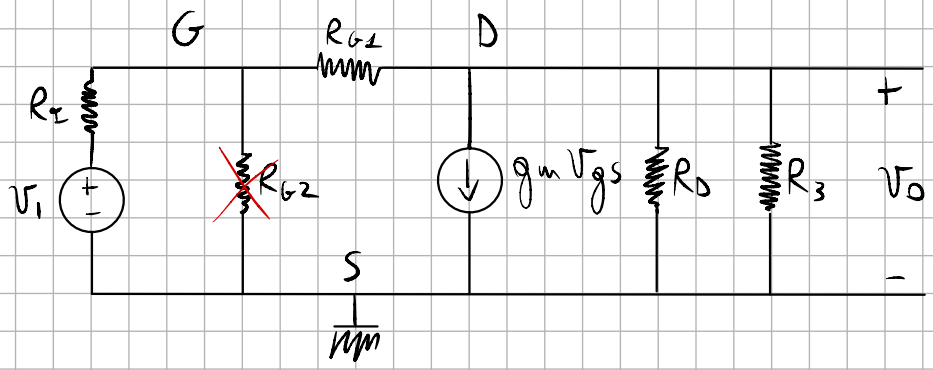
$V_{OV} = V_{GS} - V_{TN} = 0.42\ V$

$V_{GS} = V_{DS} = 1.42\ V$

$$I_{DS} = \frac{k_n}{2}(V_{GS} - V_{TN})^2 = 35.76\ mA$$

1.2 $$g_m = \frac{2 I_{DS}}{V_{OV}} = 0.1691 \qquad r_o = \infty$$

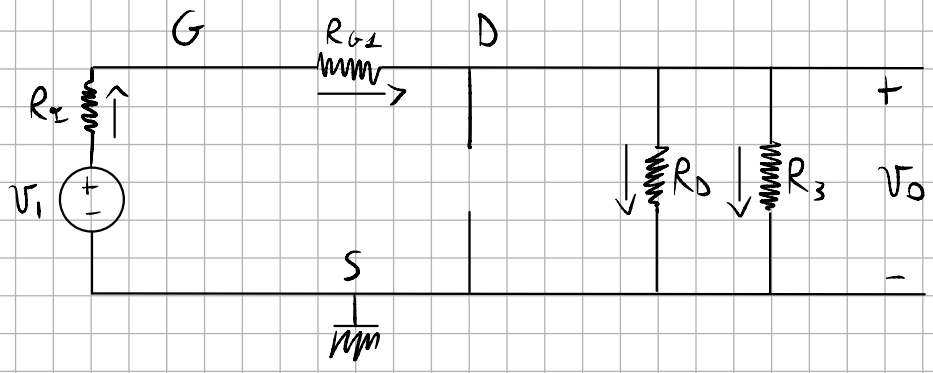
1.3 RG2 LA CONSIDERO COME CIRCUITO APERTO



QUESTA RAPPRESENTAZIONE È A SOURCE COMUNE

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

SPENGO $g_m V_{gs}$

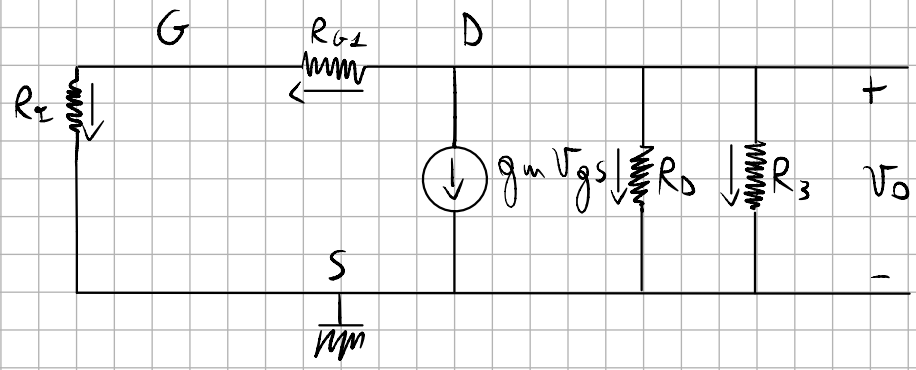


$$R_D // R_3 = 90.90\ \Omega$$

$$V_{gs1} = \frac{V_I}{R_I + R_{G1} + R_D // R_3} \cdot (R_{G1} + R_D // R_3) = 0.99\ V_I$$

$$V_{O1} = \frac{V_I}{R_I + R_{G1} + R_D // R_3} \cdot R_D // R_3 = 7.58 \cdot 10^{-5}\ V_I$$

SPENGO V_I



$$V_{gs2} = R_I I_I = -0.13\ V_{gs}$$

$$I_I = \frac{V_{DS}}{R_{G1}+R_I} = -1.28 \cdot 10^{-5} V_{gs}$$

$$V_{DS} = -g_m V_{gs} \cdot \left[(R_{G1}+R_I) \,||\, R_3 \,||\, R_D\right] = -15.37\ V_{gs}$$

$$V_{O2} = V_{DS} = -15.37\ V_{gs}$$

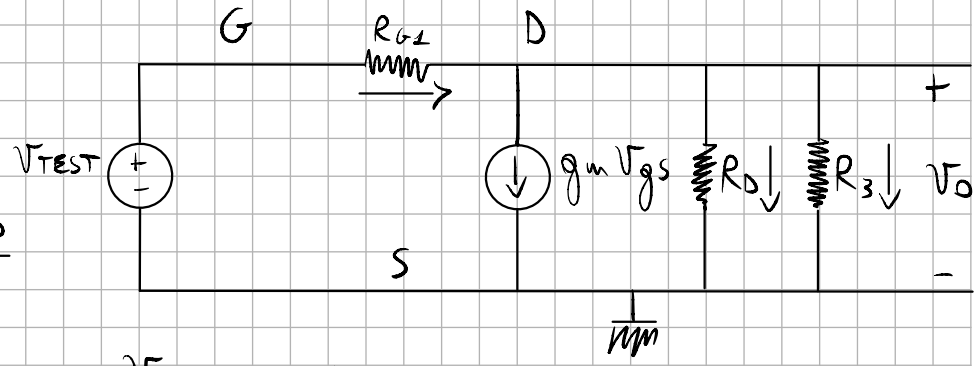
UNISCO LE DUE PARTI

$$V_{gs} = V_{gs1} + V_{gs2} = 0.99\ V_I - 0.13\ V_{gs} = 0.88\ V_I$$

$$V_O = V_{O2} + V_{O2} = 7.58 \cdot 10^{-5} V_I - 15.37 \cdot (0.88\ V_I) =$$
$$= -13.51\ V_I$$

$$A_V = \frac{V_O}{V_I} = -13.51$$

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



$$I_{TEST} = \frac{V_{TEST} - V_O}{R_{G1}}$$

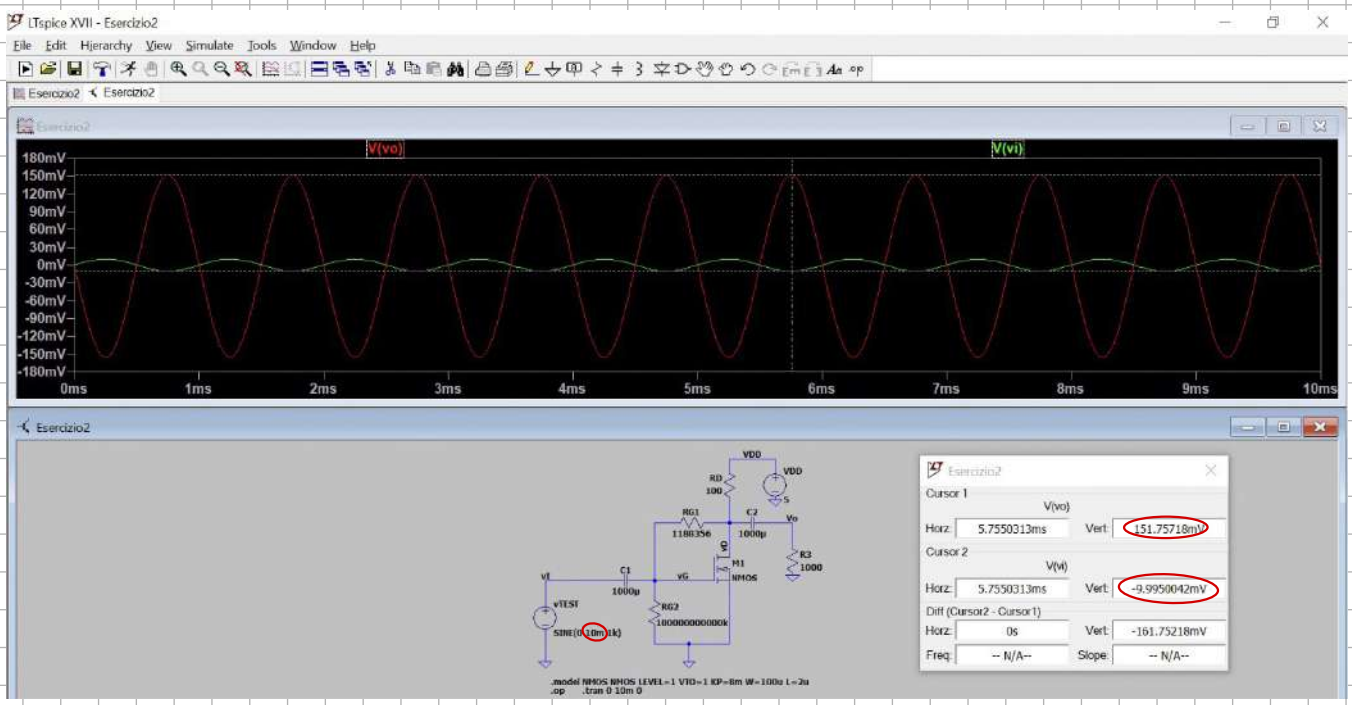
$$V_O = \frac{V_{TEST}}{R_{G1}+R_D \,||\, R_3} - g_m V_{gs}\ R_{G1} \,||\, R_D \,||\, R_3$$

$V_{GS} = V_{TEST}$ $\qquad R_{G1} // R_D // R_3 = 90.90\ \Omega$

$V_O = -15.18\ V_{TEST}$

$$I_{TEST} = \frac{V_{TEST} - (-15.18\ V_{TEST})}{R_{G1}} = 1.36 \cdot 10^{-5}\ V_{TEST}$$

$$R_{IN} = \frac{V_{TEST}}{I_{TEST}} = \frac{1}{1.36 \cdot 10^{-5}} = 73529\ \Omega$$

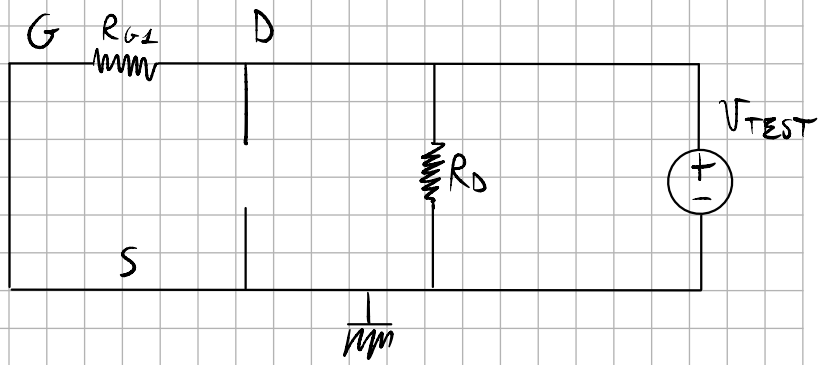


COME SI NOTA IL GUADAGNO SENZA R_I RISULTA:

$$A_V = \frac{151.75\ mV}{-10\ mV} = -15.18$$

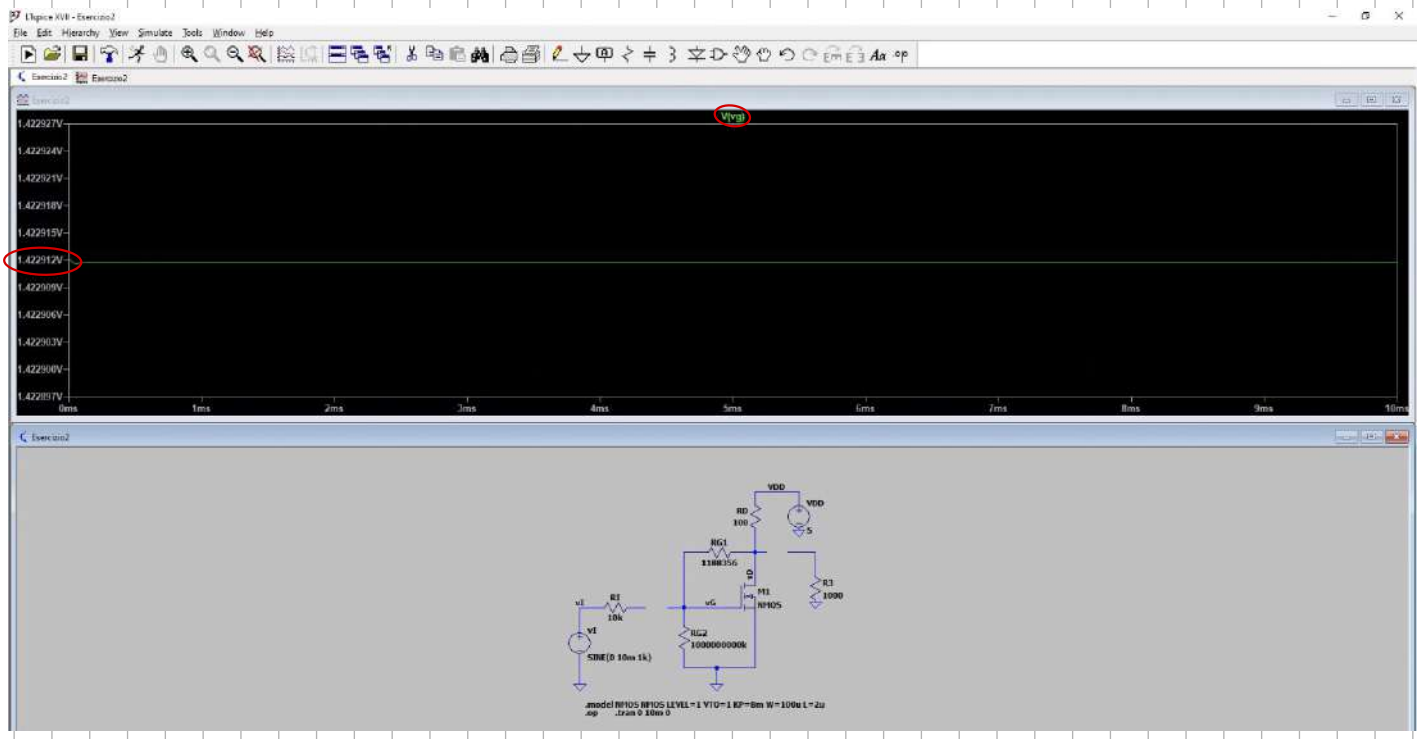
$$R_{OUT} = \frac{V_{TEST}}{I_{TEST}}$$

$$I_{TEST} = \frac{V_{TEST}}{R_{G1} // R_D}$$

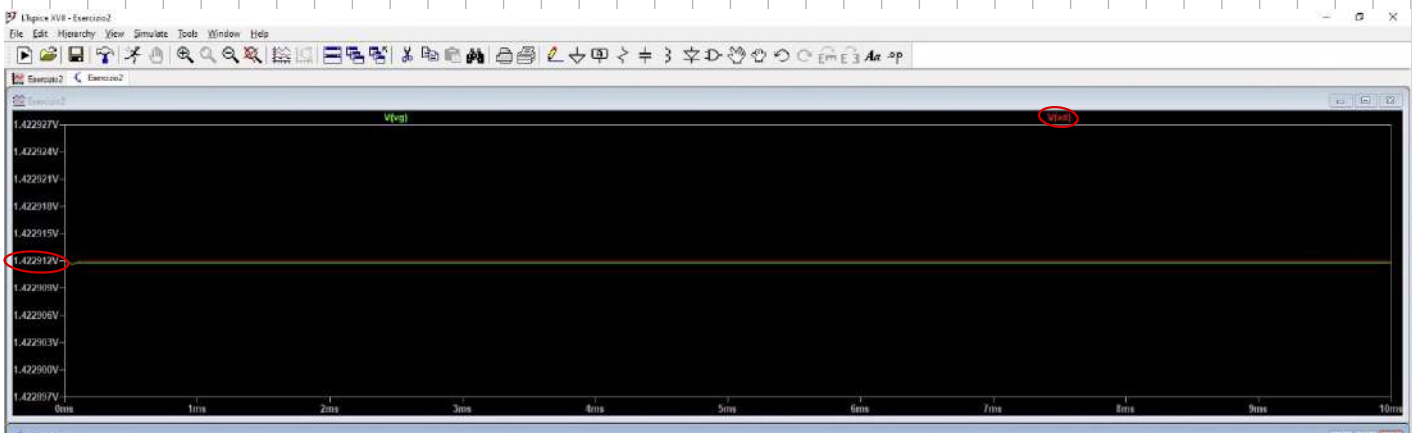


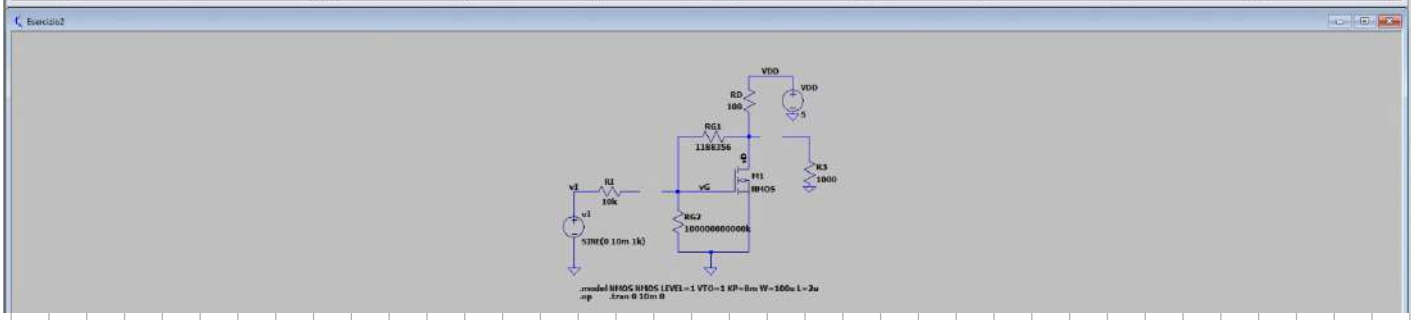
$R_{OUT} = R_{G1} // R_D = 100\ \Omega$

1.4

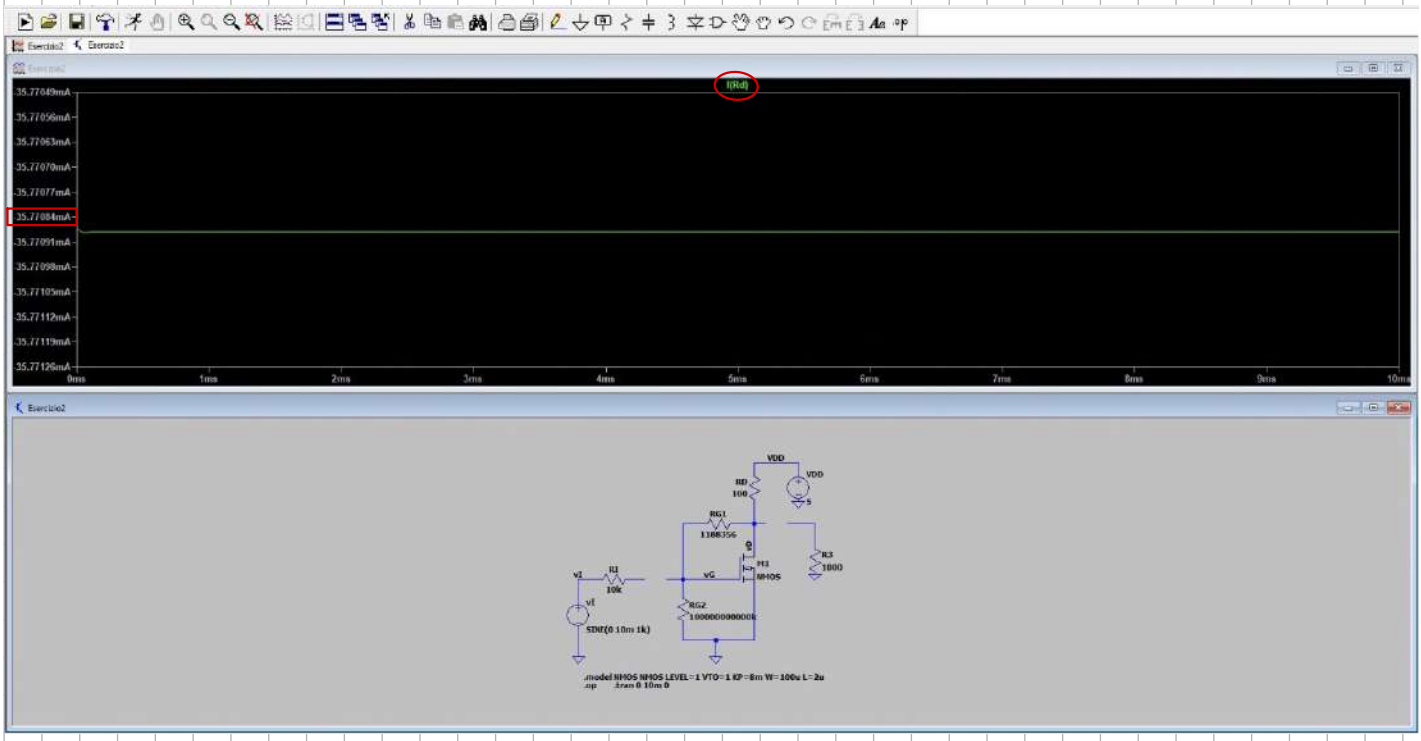


$V_{GS} = 1.42\ V$



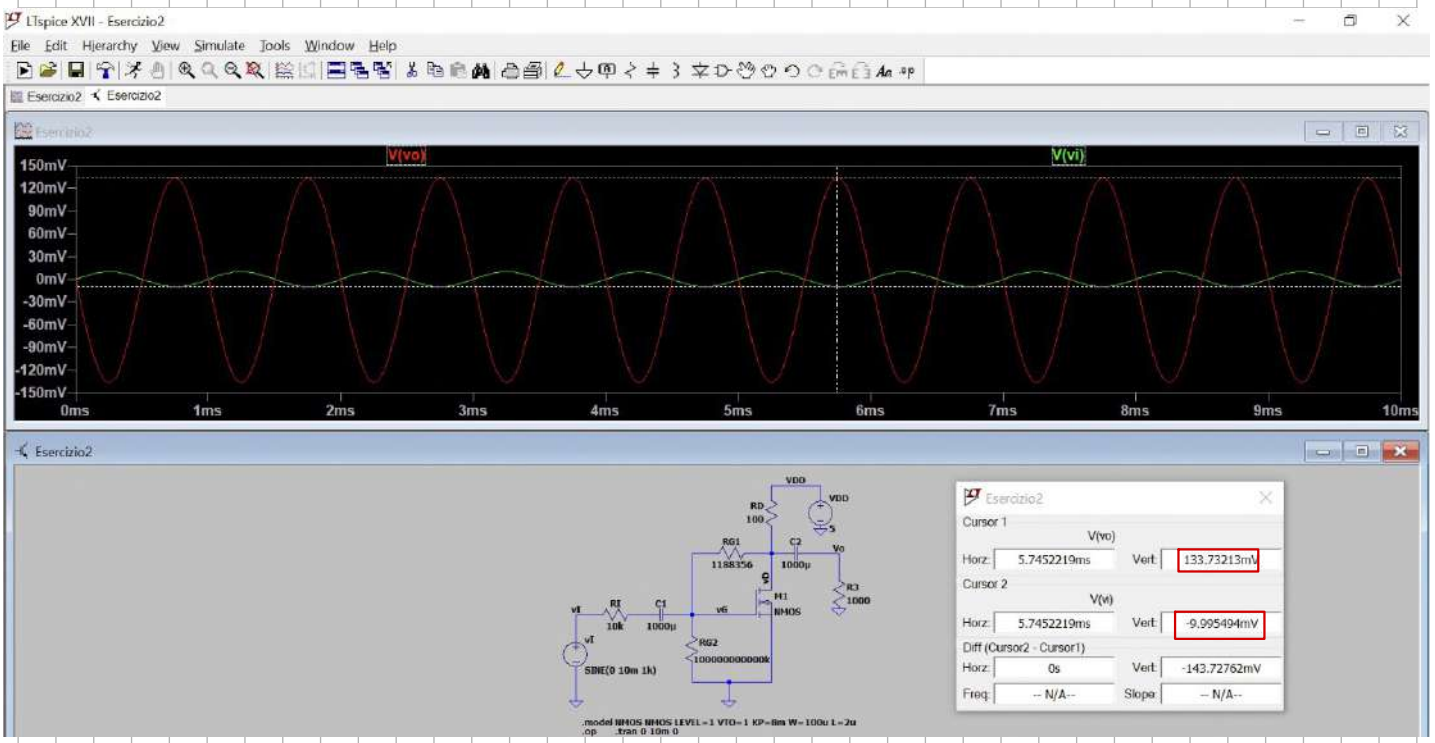


$V_{GS} = V_{DS} = 1.42\ V$

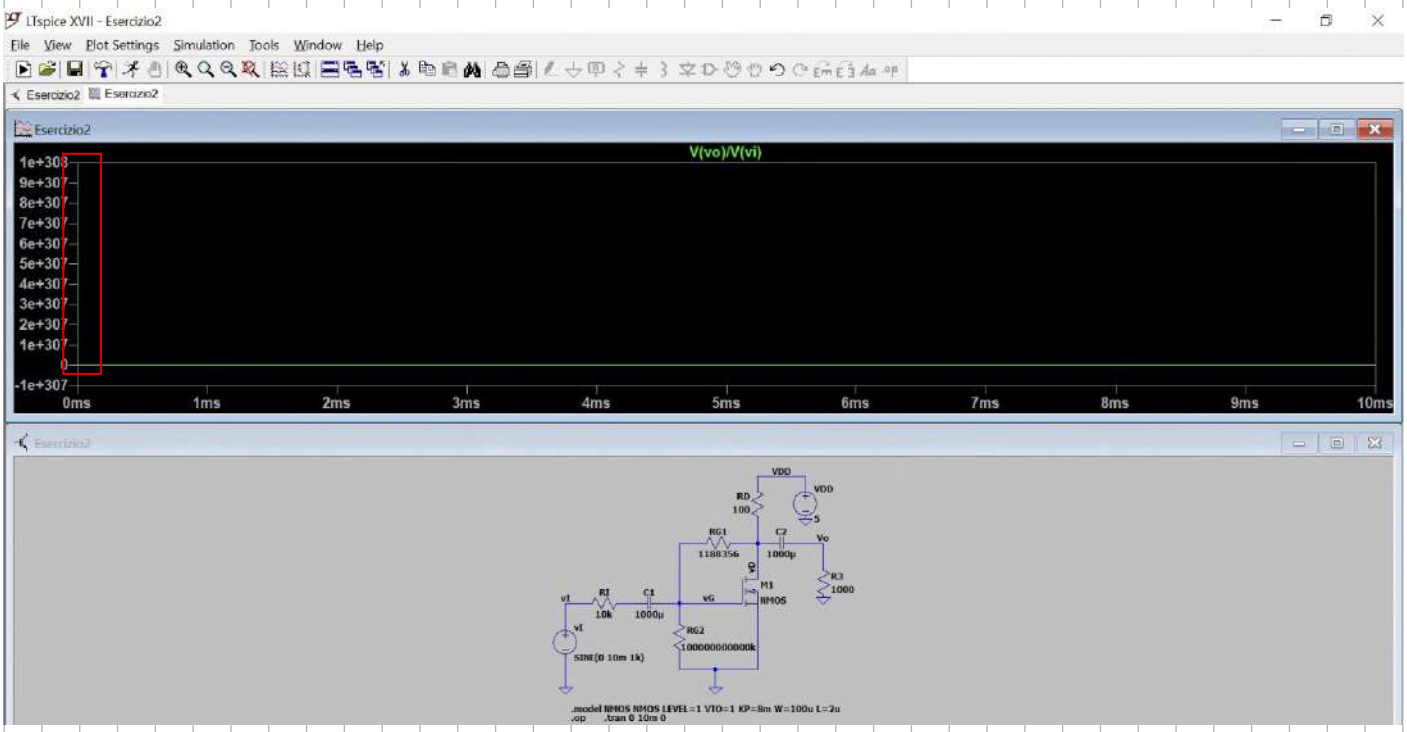


$I_{DS} = 35.76\ mV$

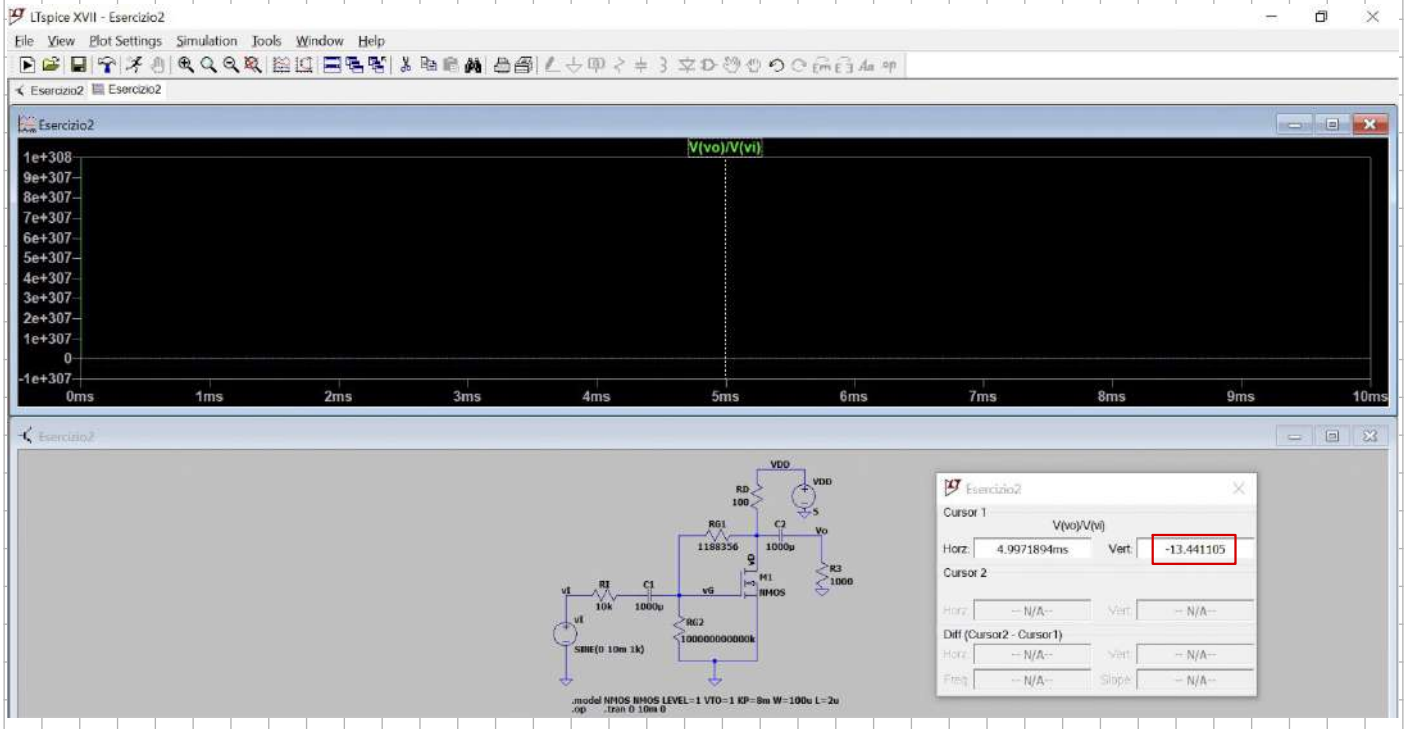
1.5



$$A_V = \frac{V_o}{V_i} = -13.37$$



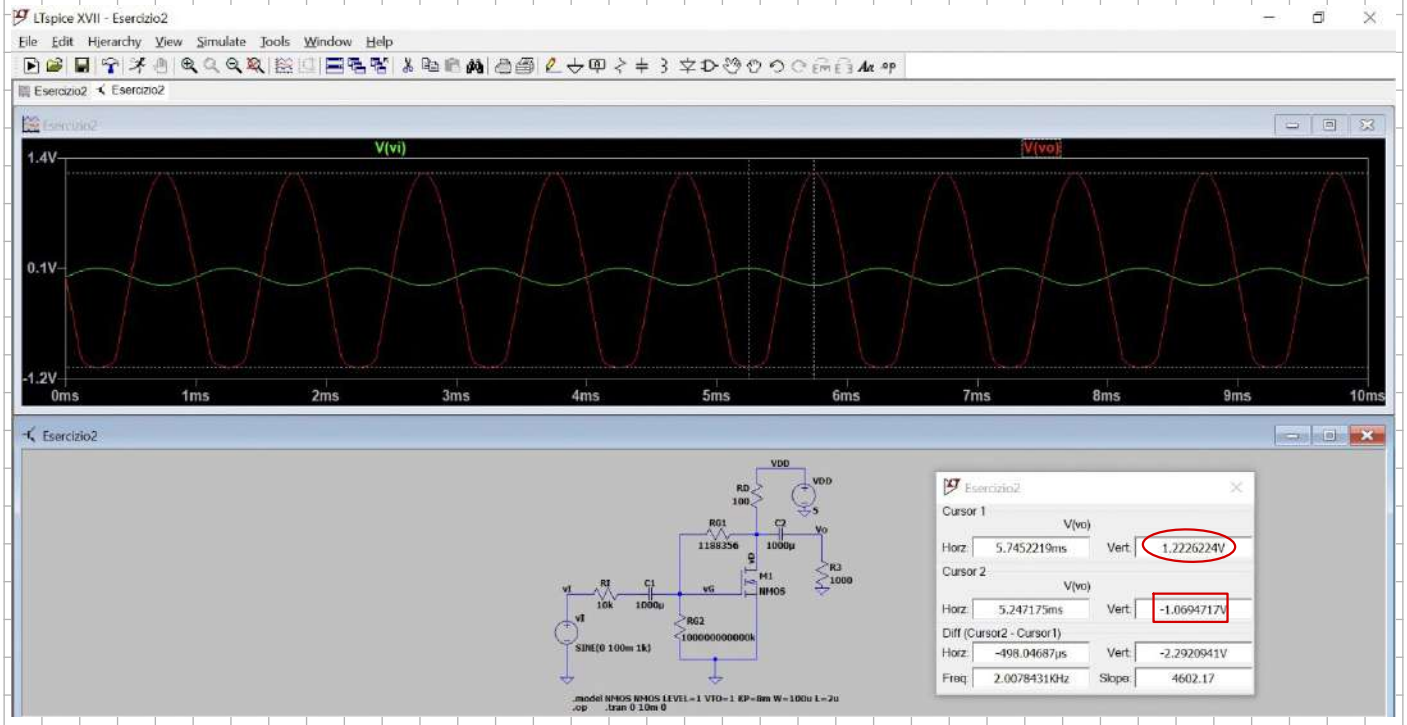
DOPO UN PICCO INIZIALE DOVUTO A $V_I = 0$, IL VALORE DEL GUADAGNO SI STABILIZZA



A_V ANALITICO: -13.51

A_V CON SPICE: -13.44

1.6



QUELLO CHE SUCCEDE È CHE IL TRANSISTOR ENTRA IN SATURAZIONE, INFATTI OLTRE UN CERTO VALORE DI V_I POSITIVO, V_O VIENE CLIPPATO AL VALORE MASSIMO -1 V. NOTIAMO INOLTRE CHE IL VALORE DI V_{OUT} NEGATIVO VIENE CLIPPATO PER V_I PIÙ BASSI RISPETTO AL SUO VALORE POSITIVO

1.7

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

$$V_{DS} - |13.51\,V_I| = V_{GS} - V_{TN} + V_I - R_I I_I$$

$$I_I = \frac{V_I}{1198446} + 1.13 \cdot 10^{-5} V_I = 1.21 \cdot 10^{-5} V_I$$

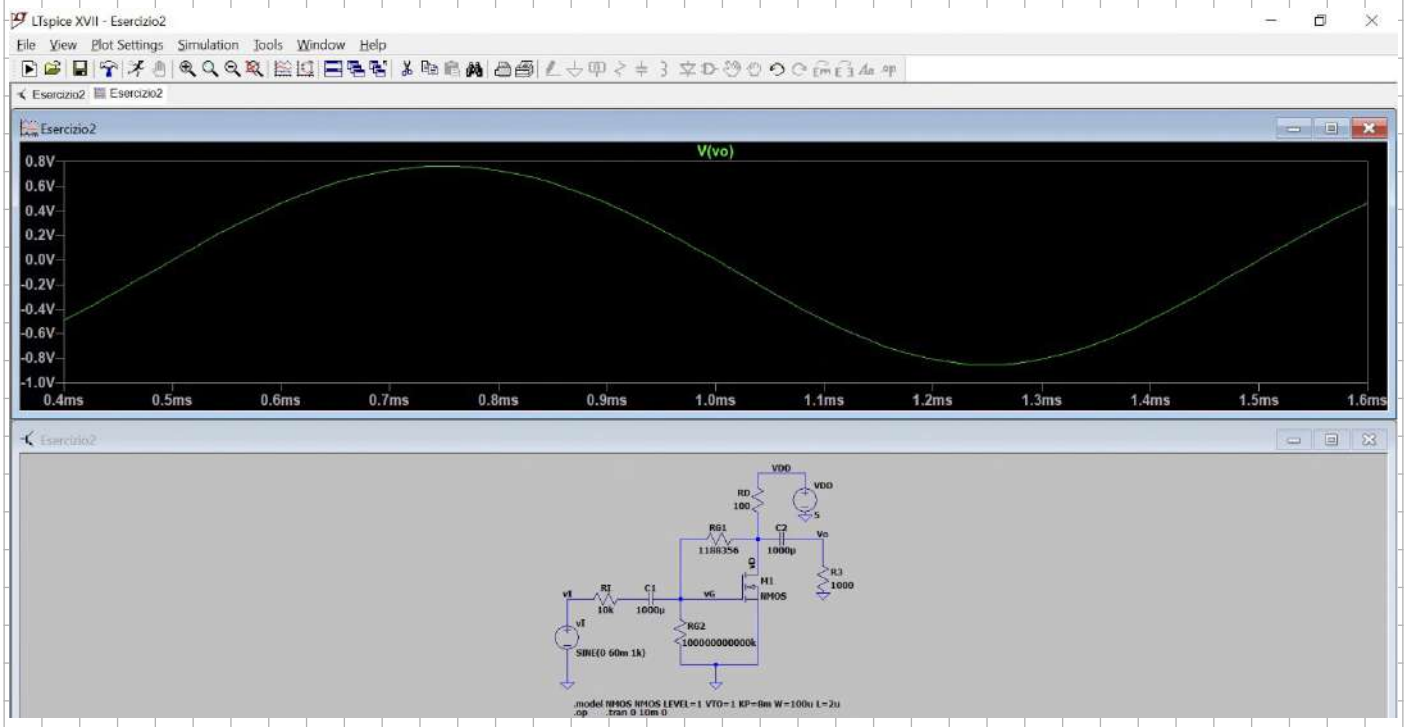
$$V_I > 0 \longrightarrow V_I = 69{,}5\ mV$$

$$V_I < 0 \longrightarrow V_I = -80\ mV$$

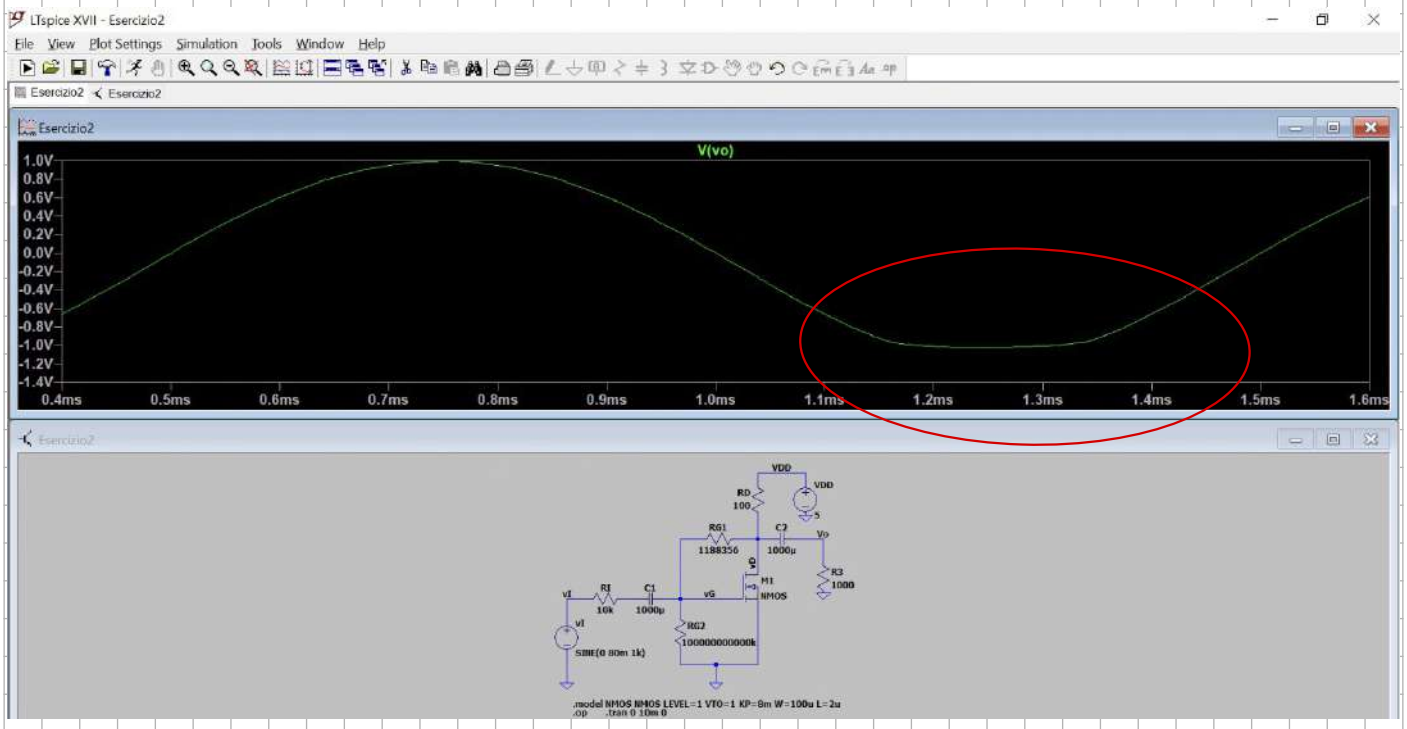
TENGO IL VALORE IN MODULO PIÙ STRINGENTE QUINDI:

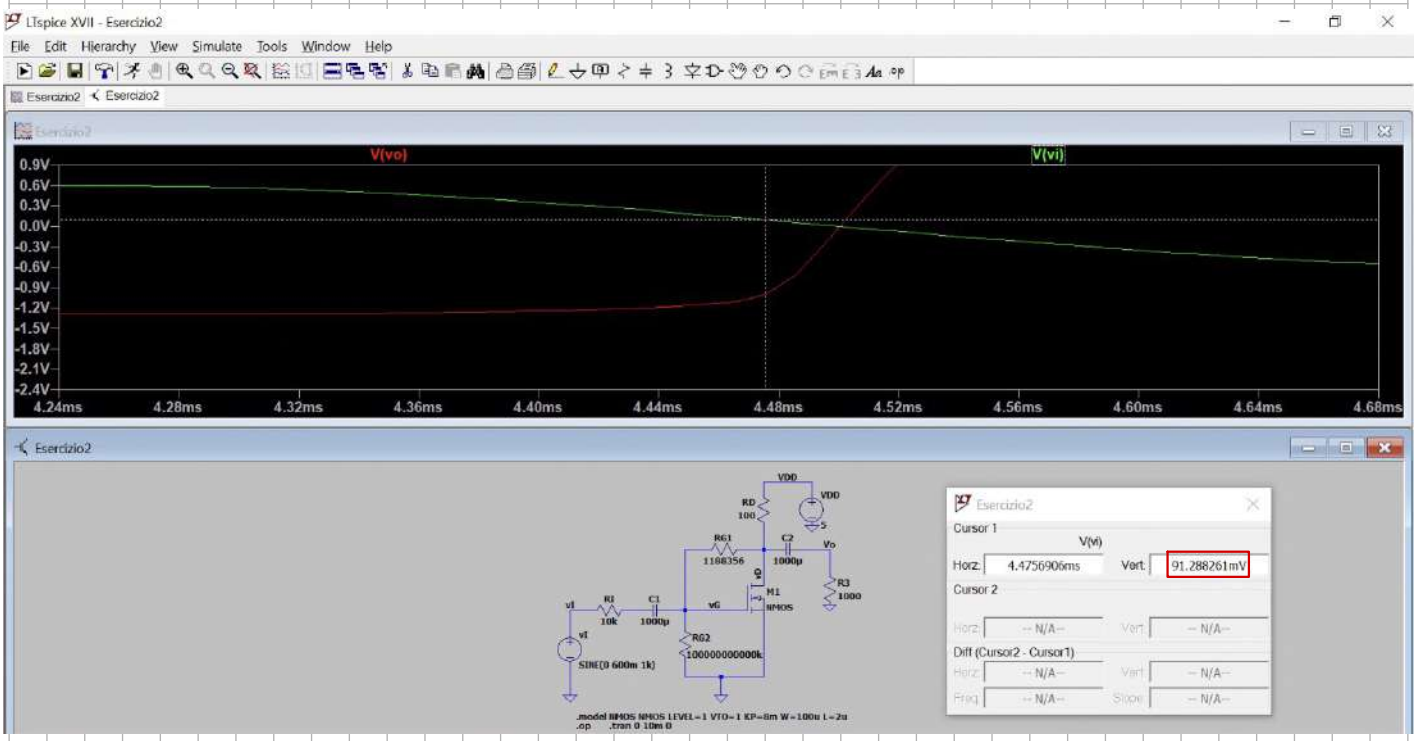
$$V_I = 69{,}5\ mV$$

PROVIAMO PRIMA CON 60 mV IN INGRESSO E NOTIAMO CHE È ANCORA LINEARE



PROVIAMO ORA CON 80 mV E NOTIAMO CHE È IN SATURAZIONE





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