COMPITI D'ESAME SVOLTI DI

ELETTRONICA DIGITALE

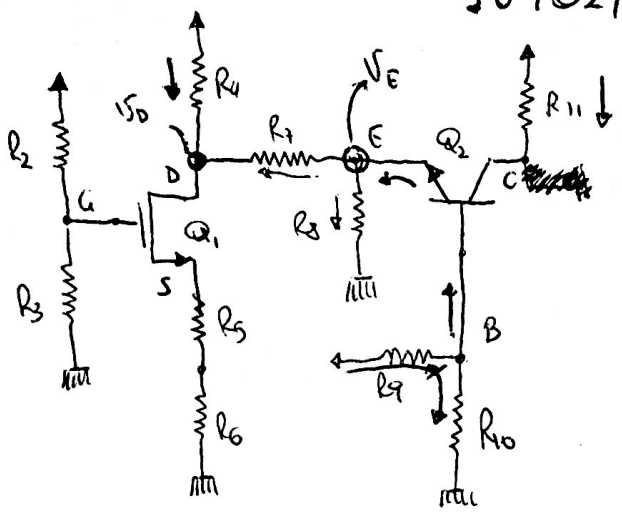
DAL 2014 AL 2016

SIPAN AHMED

Spero vi facciano comodo!

1)

16/02/2016



- $I_4 = \frac{V_{CC} - V_D}{R_4} = 2 \cdot 10^{-4}$ A
- $I_8 = \frac{V_E}{R_8} = 2 \cdot 10^{-4}$ A
- $I_7 = \frac{V_E - V_D}{R_7} = 1.8$ mA
- $I_E = I_8 + I_7 = 2$ mA
- $V_B = V_{CC} \cdot \frac{R_{10}}{R_9 + R_{10}} =$

Si suppone che sia in ZONA ATTIVA DIRETTA : $I_C \gg I_B$

$I_C = I_E$

- $V_C = V_{CC} - R_{11} I_C = 13$ V

DIMOSTRO CHE $V_{CE} > V_{CE,SAT} \Rightarrow 5\text{ V} > 0.2\text{ V}$ → OK

Quindi $h_{FE} = 290$ $h_{fe} = 300$ $h_{ie} = 4.8$ kΩ

- $I_B = \frac{I_C}{h_{FE}} = 6,8965$ μA
- $V_{BE} = V_B - V_E \Rightarrow V_B = V_E + V_{BE} = 8.7$ V
- $I_9 = \frac{V_{CC} - V_B}{R_9} = 5 \cdot 10^{-5}$ A = 50 μA
- $I_{10} = I_9 - I_B = 43.1035$ μA → $R_{10} = \frac{V_B}{I_{10}} = 201\,839.7518$ Ω

- $I_D = I_4 + I_7 = 2\,mA$
- $I_D = I_S$
- $V_S = (R_5 + R_6)\, I_S = 3\,V$
- ~~$V_a = \frac{V_{cc} \cdot R_3}{R_2 + R_3}$~~ =
- $V_{GS} = V_T + \sqrt{\frac{I_D}{k}} = 3\,V$

VERIFICO LA SATURAZIONE

$\rightarrow V_{DS} > V_{GS} - V_T \rightarrow 4.1 > 2$ ok

- $V_{GS} = V_G - V_S \Rightarrow V_G = V_{GS} + V_S = 6\,V$
- $I_3 = \frac{V_G}{R_3} = 60\,\mu A$ $\qquad I_3 = I_2$
- $R_2 = \frac{V_{CC} - V_G}{I_3} = 200\,000\,\Omega$

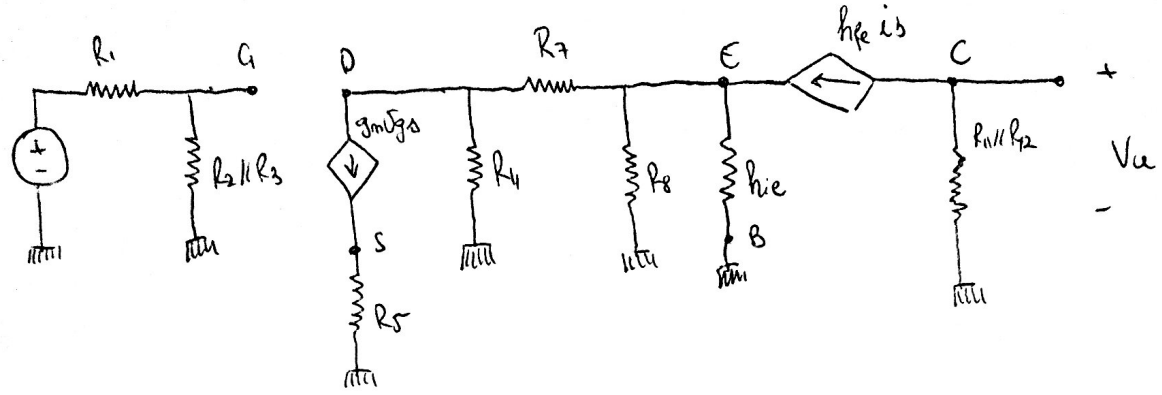
PUNTI DI RIPOSO

- Q_2

$h_{fe} = 300$ $\quad h_{FE} = 290$ $\quad h_{ie} = 4.8\,k\Omega$ $\quad I_C = 2\,mA$ $\quad V_{CE} = 5\,V$

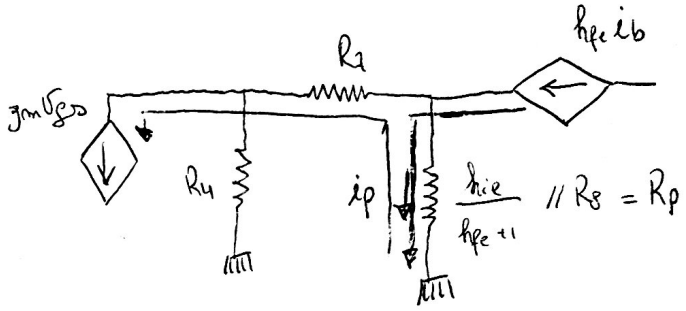
- Q_1

$I_D = 2\,mA$ $\quad V_{DS} = 4.1\,V$ $\quad g_m = 2k\,|(V_{GS} - V_T)| = 2 \cdot 10^{-3}\,\frac{A}{V}$



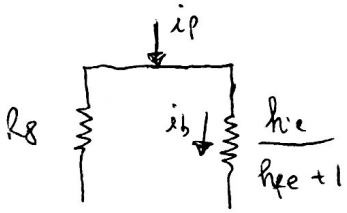
- $V_u = -h_{fe}\, i_b\, (R_{11} \parallel R_{12})$

- $i_p = \dfrac{h_{fe}\, i_b\, (R_4 + R_7)}{R_4 + R_7 + R_p} - \dfrac{g_m V_{gs}\, R_4}{R_4 + R_7 + R_p}$



- $i_p = h_{fe}\, i_b\, R_{eq1} - g_m V_{gs}\, R_{eq2}$

- $i_b = i_p \cdot \dfrac{R_8}{R_8 + \frac{h_{ie}}{h_{fe}+1}} = i_p \cdot R_{eq3}$



- $\dfrac{i_b}{R_{eq3}} = h_{fe}\, R_{eq1}\, i_b - g_m V_{gs}\, R_{eq2}$

- $i_b \left(\dfrac{1}{R_{eq3}} - h_{fe} R_{eq1} \right) = -g_m V_{gs}\, R_{eq2}$

- $i_b = \dfrac{-g_m R_{eq2}}{\frac{1}{R_{eq3}} - h_{fe} R_{eq1}} \cdot V_{gs}$

- $R_p = 15.9404\ \Omega$
- $R_{eq1} = 0.9997\ \Omega$
- $R_{eq2} = 0.99062\ \Omega$
- $R_{eq3} = 0.9996\ \Omega$
- $R_{11} \parallel R_{12} = 2222.2222\ \Omega$
- $R_2 \parallel R_3 = 66666.6667\ \Omega$

- $V_{gs} = V_g - V_s = V_g - g_m V_{gs} R_5 \Rightarrow V_{gs} = \dfrac{V_g}{1 + g_m R_5}$

- $V_g = V_i \cdot \dfrac{R_2 \parallel R_3}{R_1 + R_2 \parallel R_3}$

- $\dfrac{V_u}{V_i} = h_{fe}\, (R_{11} \parallel R_{13}) \cdot \underbrace{\dfrac{g_m R_{eq2}}{\frac{1}{R_{eq3}} - h_{fe} R_{eq1}}}_{\text{negativo}} \cdot \dfrac{1}{1 + g_m R_5} \cdot \dfrac{R_2 \parallel R_3}{R_1 + R_2 \parallel R_3}$

16/02/16

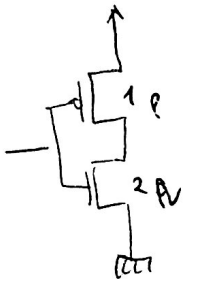
$$Y = (\overline{A+B})(\bar{C}+\bar{D}\bar{E}) + \bar{A}\cdot\bar{B}(\bar{C}+\bar{E}) + \bar{D}(AB+E)$$

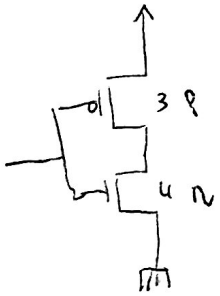
$$Y = (\bar{A}\cdot B)(\bar{C}+\bar{D}+\bar{E}) + \bar{A}\bar{B}\bar{C} + \bar{A}\bar{B}\bar{E} + \bar{D}AB + \bar{D}E$$

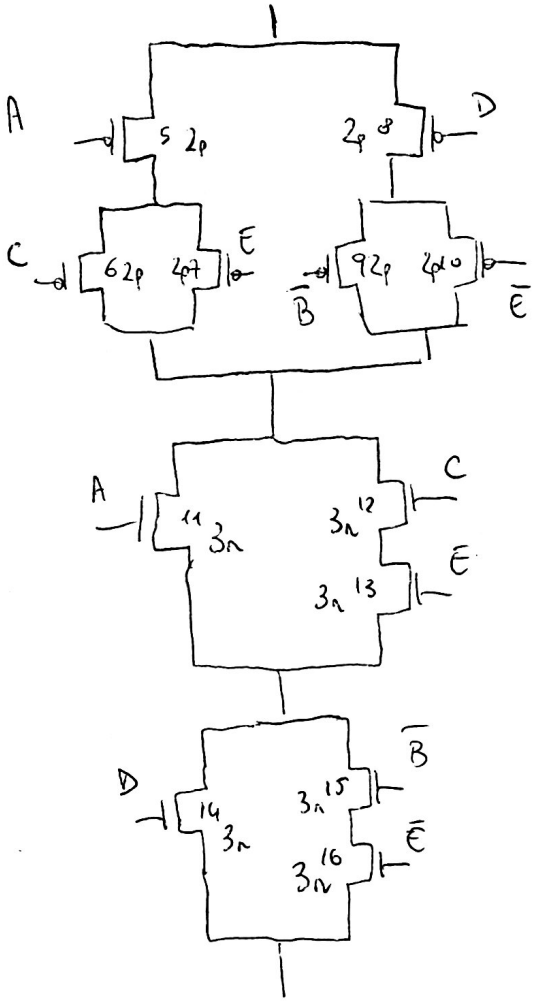
$$Y = \cancel{\bar{A}B\bar{C}} + \cancel{\bar{A}B\bar{D}} + \bar{A}B\bar{E} + \cancel{\bar{A}\bar{B}\bar{C}} + \bar{A}\bar{B}\bar{E} + \cancel{AB\bar{D}} + \bar{D}E$$

$$Y = \bar{A}\bar{C} + B\bar{D} + \bar{A}\bar{E} + \bar{D}\bar{E}$$

$$Y = \bar{A}(\bar{C}+\bar{E}) + \bar{D}(B+E)$$







- INVERTER DI BASE

$$\left(\frac{W}{L}\right)_1 = \left(\frac{W}{L}\right)_3 = p = 5$$

$$\left(\frac{W}{L}\right)_2 = \left(\frac{W}{L}\right)_4 = n = 2$$

- PUN

- WORST CASE: Q_5, Q_6 o Q_5, Q_7 o Q_8, Q_9 o Q_8, Q_{10}

$$\left(\frac{W}{L}\right)_5 = \left(\frac{W}{L}\right)_6 = x$$

$$\frac{1}{x} + \frac{1}{x} = \frac{1}{p} \Rightarrow \frac{2}{x} = \frac{1}{p} \Rightarrow x = 2p$$

- PDN

- WORST CASE : $Q_{12}, Q_{13}, Q_{15}, Q_{16}$ → NON È POSSIBILE PERCHÈ presenti $\bar{E}$ ed E.

- WORST CASE : Q_{11}, Q_{15}, Q_{16} o Q_{12}, Q_{13}, Q_{14}

$$\left(\frac{W}{L}\right)_{11} = \left(\frac{W}{L}\right)_{15} = \left(\frac{W}{L}\right)_{16} = X$$

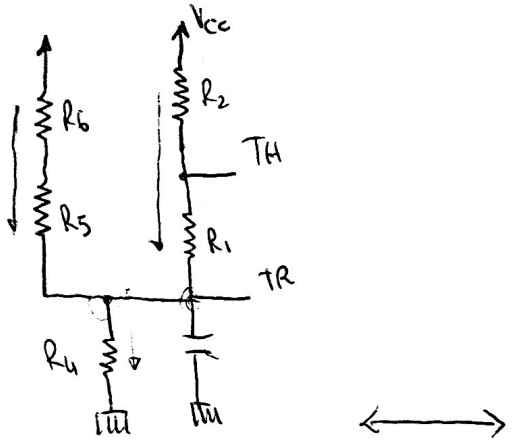
$$\frac{1}{X} + \frac{1}{X} + \frac{1}{X} = \frac{1}{n} \qquad \frac{3}{X} = \frac{1}{n} \Rightarrow X = 3n$$

16/02/2016

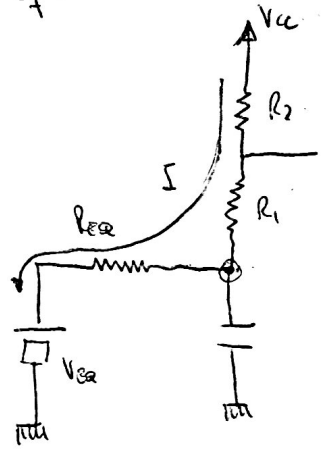
ESERCIZIO c)

$Q=1 \rightarrow D='Hz'$

$Q_1 \rightarrow$ OFF



$\longleftrightarrow$



- $V_i = \frac{1}{3} V_{cc} = 2\,V$
- $V_f =$

$$V_{eq} = V_{cc} \cdot \frac{R_4}{R_4+R_5+R_6} = \frac{90}{17}\,V$$

$$R_{eq} = R_4 \,//\, (R_5+R_6) = \frac{9000}{17}\,\Omega$$

$$I = \frac{V_{cc}-V_{eq}}{R_1+R_2+R_{eq}} = \frac{1}{5000}\,A \rightarrow V_f = V_{cc} - (R_1+R_2)\,I = 5.4\,V$$

- V_{comm} se $V_{TH} = \frac{2}{3} V_{cc} = 4\,V$

$$I_2 = \frac{V_{cc}-V_{TH}}{R_2} = \frac{1}{1000}\,A$$

$$V_{comm} = V_{TH} - R_1 I_2 = 3\,V$$

VERIFICO: $V_i < V_{comm} < V_f \rightarrow$ OK

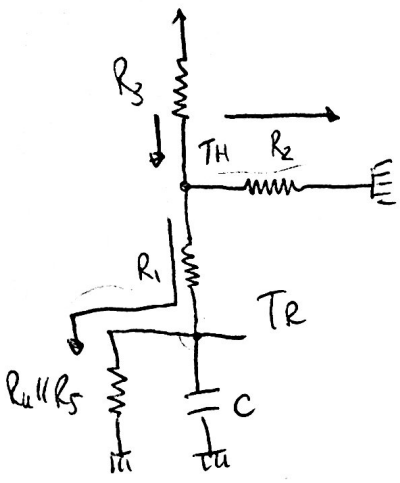
$$T_1 = T_2 \ln\left(\frac{V_i - V_f}{V_{comm} - V_f}\right) = 3.46823 \cdot 10^{-6}$$

$$T_1 = R_{V_1} C = \left[R_1 + R_2 \,//\, (R_4 \,//\, (R_5+R_6))\right] \cdot C$$

$$= \frac{60000}{17} \cdot C = 7.1667 \cdot 10^{-5}\,s$$

$$= 9,9 \cdot 10^{-6}\,s$$

$Q = 0 \rightarrow D = 0 \rightarrow Q_1 = ON$



$V_{comm} = 2\ V$

$V_i = 3\ V$

$V_f =$

Per la V_f:

$$\begin{cases} I_3 = \dfrac{V_{cc}}{R_3} - \dfrac{V_{TH}}{R_3} \\ I_2 = \dfrac{V_{TH}}{R_2} \\ I_1 = -I_2 + I_3 = \dfrac{V_{TH}}{R_1 + R_u \| R_5} \end{cases} *$$

$$* \; -\frac{V_{TH}}{R_2} + \frac{V_{cc}}{R_3} - \frac{V_{TH}}{R_3} = \frac{V_{TH}}{R_1 + R_u \| R_5} \rightarrow V_{TH} = \left(\frac{\frac{V_{cc}}{R_3}}{\frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_1 + R_u \| R_5}} \right) = \frac{201}{446}\ V$$

Quindi: $I_1 =$ sostituendo V_{TH}: $I_1 = \dfrac{147}{446000}$

$$V_f = V_{TH} - R_1 I_1 = \frac{27}{223} = 0{,}121\ V$$

Verifica che: $V_i > V_{comm} > V_f$

$$T_2 = \tau_2 \ln\left(\frac{V_i - V_f}{V_{comm} - V_f}\right) = 3.0309\ 10^{-6}\ s$$

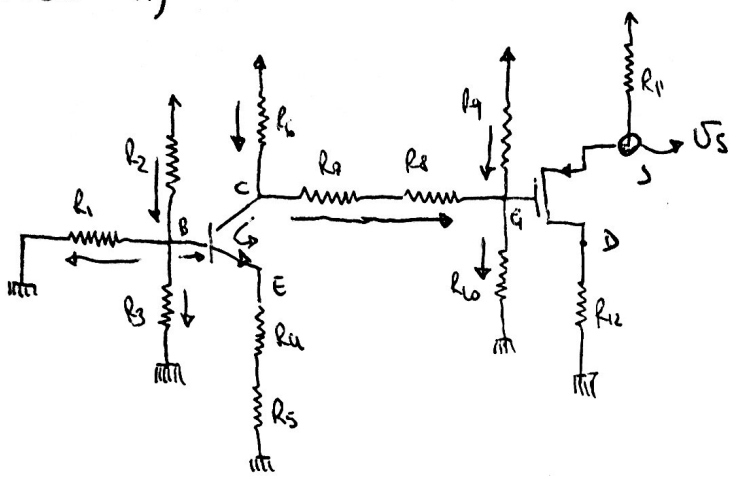
$$\tau_2 = R_{u_2} C = \left[\left[R_1 + R_2 \| R_3\right] \| \left[R_u \| R_5\right]\right] \cdot C \qquad \left(\frac{8000}{3} \quad \frac{15000}{49}\right)$$

$$= 322.8699 \cdot C = 7{,}10314\ 10^{-6}\ s$$

$$T_2 = T_1 + T_2 = 6.67913 \cdot 10^{-6}$$

$$f = \frac{1}{T} = 156341.7\ Hz$$

ESERCIZIO A)



- $I_S = \frac{V_{cc} - V_S}{R_1} = 2\,mA$
- $I_G = 0 \rightarrow I_S = I_D = 2\,mA$
- $V_D = R_{12} \cdot I_D = 7\,V$

IPOTIZZO ZONA SATURAZIONE $\rightarrow V_{GS} = V_T - \sqrt{\frac{I_D}{K}} = -3\,V$

- $V_{GS} = V_G - V_S \rightarrow V_G = V_{GS} + V_S = 8\,V$

VERIFICO ZONA SATURAZIONE $\rightarrow V_{DS} < V_{GS} - V_T \rightarrow -4\,V < -2\,V \rightarrow OK$

- $I_9 = \frac{V_{cc} - V_G}{R_9} = 0{,}5\,mA$
- $I_{10} = \frac{V_G}{R_{10}} = 1\,mA$
- $I_8 + I_9 = I_{10} \rightarrow I_8 = I_{10} - I_9 = 0{,}5\,mA$
- $V_C - V_G = (R_7 + R_8) I_8 \rightarrow V_C = V_G + (R_7 + R_8) I_8 = 12\,V$
- $I_6 = \frac{V_{cc} - V_C}{R_6} = 2.5\,mA$
- $I_C = I_6 - I_8 = 2\,mA$

IPOTIZZO ZAD $\rightarrow I_C \gg I_B \Rightarrow I_C \approx I_E = 2\,mA$

- $V_E = (R_4 + R_5) I_E = 7\,V$

VERIFICO Z.A.D: $V_{CE} > V_{CESAT} \rightarrow 5V > 0.2\,V$

- $I_B = \frac{I_C}{h_{FE}} =$
- $V_{BE} = V_B - V_E \rightarrow V_{BB} = V_{BE} + V_E = 7.7\,V$

- $I_2 = \frac{V_{cc} - V_B}{R_2} = 1{,}03$ mA

- $I_1 = \frac{V_B}{R_1} = 0{,}5$ mA

- $I_2 = I_1 + I_3 + I_B \rightarrow I_3 = I_2 - I_1 - I_B = 0{,}5231$ mA

- $R_2 = \frac{V_B}{I_2} = 14719{,}84\ \Omega$

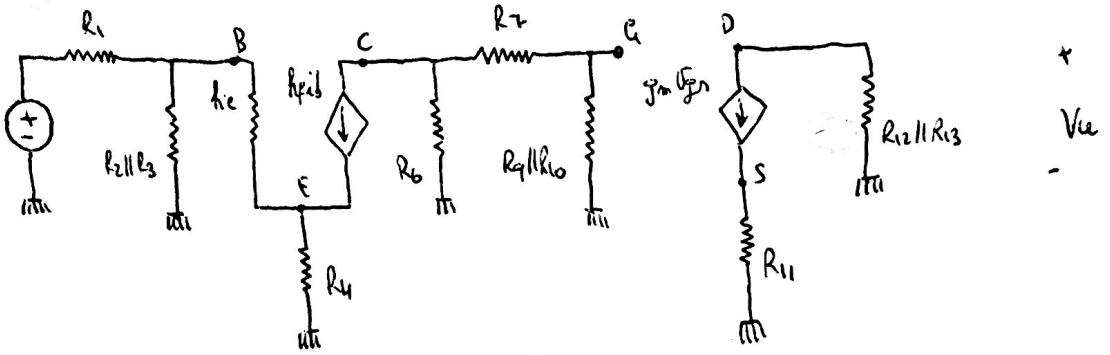
PUNTI DI RIPOSO

Q_1:

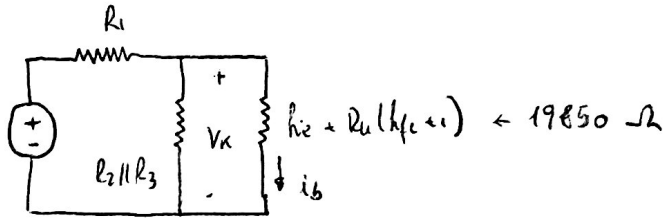
$h_{fe} = 300$ $\quad h_{FE} = 290$ $\quad h_{ie} = 4.8$ KΩ $\quad I_C = 2$mA $\quad V_{CE} = 5$ V

Q_2:

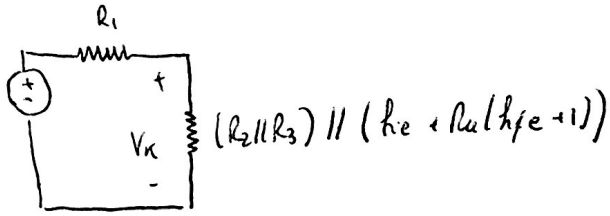
$I_D = 2$mA $\quad V_{DS} = -4$V $\quad g_m = 2k|V_{GS} - V_T| = 2\frac{mA}{V}$



- $V_u = -g_m V_{gs} (R_{12} \| R_{13})$
- $V_{gs} = V_g - U_s = V_g - g_m V_{gs} R_{11} \rightarrow V_{gs} = \frac{V_g}{1 + g_m R_{11}}$
- $V_g = -h_{fe} i_b \cdot \frac{R_6 \cdot R_8 \| R_{10}}{R_6 + R_7 + R_8 \| R_{10}}$
- $i_b = \frac{V_K}{h_{ie} + (h_{fe}+1) R_4}$



- $V_K = V_i \cdot \frac{(R_2 \| R_3) \| (h_{ie} + R_4 (h_{fe}+1))}{R_1 + (R_2 \| R_3) \| (h_{ie} + R_4 (h_{fe}+1))}$



- $\frac{V_u}{V_i} = \underbrace{\frac{g_m (R_{12} \| R_{13})}{1 + g_m R_{11}}}_{\frac{35}{54}} \cdot \underbrace{\frac{h_{fe} \cdot R_6 \cdot R_8 \| R_{10}}{R_6 + R_7 + R_8 \| R_{10}}}_{C} \cdot \underbrace{\frac{1}{h_{ie} + (h_{fe}+1) R_4}}_{\frac{1}{19850}} \cdot \underbrace{\frac{(R_2 \| R_3) \| (h_{ie} + R_4 (h_{fe}+1))}{R_1 + (R_2 \| R_3) \| (h_{ie} + R_4 (h_{fe}+1))}}_{D}$ $= 3,1704$

ESERCIZIO B)

$$Y = \overline{A\bar{E}}\,(\bar{B}C + \bar{D}) + A\bar{B}C + \bar{D}\,\bar{C}$$

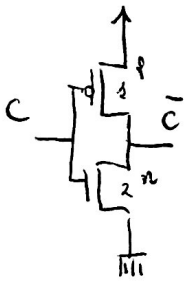
$$Y = (\bar{A} + \bar{E})(\bar{B}C + \bar{D}) + A\bar{B}C + \bar{D}\bar{C}$$

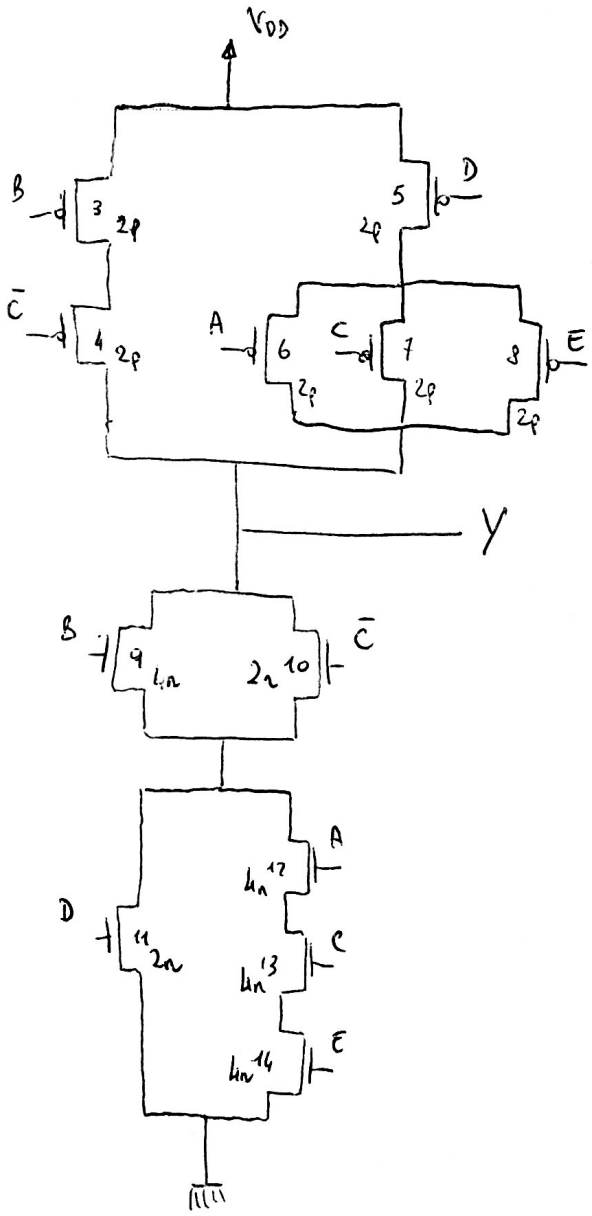
$$Y = \bar{A}\bar{B}C + \bar{A}\bar{D} + \bar{B}C\bar{E} + \bar{D}\bar{E} + A\bar{B}C + \bar{D}\bar{C}$$

$$Y = \bar{B}C + \bar{A}\bar{D} + \bar{B}C\bar{E} + \bar{D}\bar{E} + \bar{D}\bar{C}$$

$$Y = \bar{B}C + \bar{D}(\bar{A} + \bar{C} + \bar{E})$$

16 mosfet





- INVERTER DI BASE

$$\left(\frac{W}{L}\right)_1 = p = 5$$

$$\left(\frac{W}{L}\right)_2 = n = 2$$

• PUN

- WORST CASE : Q_3, Q_4 o Q_5, Q_6, o Q_5, Q_7 o Q_5, Q_8

$$\left(\frac{W}{L}\right)_{3,4,5,6,7,8} = X$$

$$\frac{1}{X} + \frac{1}{X} = \frac{1}{P} \rightarrow \frac{2}{X} = \frac{1}{P} \rightarrow X = 2P = 10$$

• PDN

- WORST CASE $\begin{cases} Q_9, Q_{12}, Q_{13}, Q_{14} \\ Q_{10}, Q_{12}, Q_{13}, Q_{14} \rightarrow \text{NON POSSIBILE PERCHÈ } \bar{C} \text{ e } C \text{ sono presenti} \end{cases}$

$$\left(\frac{W}{L}\right)_{9,12,13,14} = X$$

$$\frac{1}{X} + \frac{1}{X} + \frac{1}{X} + \frac{1}{X} = \frac{1}{n} \rightarrow \frac{4}{X} = \frac{1}{n} \rightarrow X = 4n = 8$$

- WORST CASE ②:

2 CASI POSSIBILI $\begin{cases} 1)\ Q_{10}, Q_{11} \\ 2)\ Q_9, Q_{11} \text{ e poi } Q_{10}, Q_{11} \end{cases}$

1) Q_{10}, Q_{11}

$$\left(\frac{W}{L}\right)_{10,11} = Y$$

$$\frac{1}{Y} + \frac{1}{Y} = \frac{1}{n} \rightarrow \frac{2}{Y} = \frac{1}{n} \rightarrow Y = 2n = 4$$

2) Q_9, Q_{11}

$$\left(\frac{W}{L}\right)_{11} = Z$$

$$\frac{1}{Z} + \frac{1}{4n} = \frac{1}{n} \rightarrow \frac{1}{Z} = \frac{3}{4n} \rightarrow 3Z = 4n \Rightarrow Z = \frac{4n}{3}$$

Q_{10}, Q_{11}

$$\left(\frac{W}{L}\right)_{10} = K$$

$$\frac{1}{K} + \frac{1}{Z} = \frac{1}{n} \rightarrow \frac{1}{K} = \frac{3}{4n} = \frac{1}{n} \rightarrow \frac{1}{K} = \frac{4-3}{4n} \rightarrow \frac{1}{K} = \frac{1}{4n} \rightarrow K = 4n = 8$$

AREE :

1) • $2n * 2n = 4 * 4 = 8$ ⟶ SCELGO QUESTA CONFIGURAZIONE

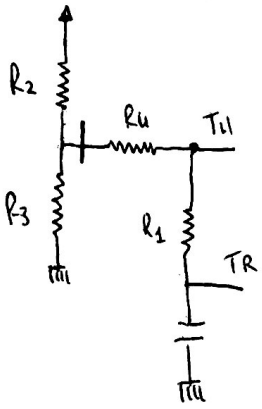
2) $\frac{4}{3}n * 4n = \frac{8}{3} * 8 = \frac{32}{3}$ $(\approx 10{,}67)$

28/01/2016

ESERCIZIO c)

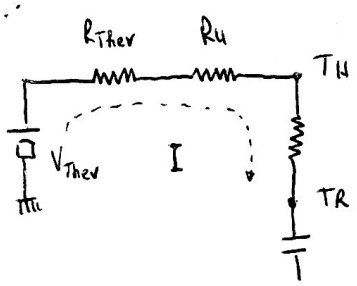
$Q=1 \rightarrow D='1'$

$V_{en_1} = V_{cc} \quad V_{S_1} = V_{cc} \rightarrow V_{GS_1} = 0V > V_{T_1} = -1V \Rightarrow Q_1 = OFF$



- $V_i = \frac{1}{3} V_{cc} = 2V$
- $V_f = V_{cc} \cdot \frac{R_3}{R_2 + R_3} = \frac{24}{5} V \quad (= 4.8V)$
- V_{comp} se $V_{TH} = \frac{2}{3} V_{cc} = 4V$

Applico THEVENIN



$V_{THev} = V_{cc} \cdot \frac{R_3}{R_2 + R_3} = 4.8V \qquad R_{TR} = R_2 \| R_3$

$I = \frac{V_{THev} - V_{TH}}{R_{THev} + R_4} = 8 \cdot 10^{-4} A$

$V_{comp} = V_{TH} - R_1 I = 3.04 V$

VERIFICO CHE $V_i < V_{comp} < V_f \rightarrow OK$

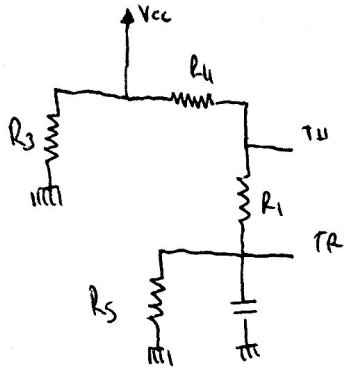
$T_1 = T_1 \ln\left(\frac{V_i - V_f}{V_{comp} - V_f}\right)$

$T_1 = R_{V_1} \cdot C = \left[R_1 + R_4 + R_2 \| R_3\right] \cdot C = 2200 \cdot C = 1.034 \cdot 10^{-4} s$

$T_1 = 4.801 \cdot 10^{-5} s$

$Q=0 \rightarrow D=0$

$V_{GS1}=0 \quad V_{S1}=V_{CC} \quad V_{GS1}=-V_{CC}=-5V < V_{T1}=-1V \qquad Q_1 = ON$



- $V_i = 3.04\ V$
- $V_{com} = 2\ V$
- $V_f = V_{CC} \cdot \frac{R_5}{R_4 \| R_H + R_5} = 0{,}75\ V$

VERIFICO CHE $V_i > V_{com} > V_f \rightarrow OK$

$$T_1 = T_1 \cdot \ln\left(\frac{V_i - V_f}{V_{com} - V_f}\right)$$

$$T_1 = R_{V1} \cdot C = \left[R_5 \| (R_4 + R_H)\right] \cdot C = 175 \cdot C = 8.225 \cdot 10^{-6}\ s$$

$$T_1 = 4.97968299 \cdot 10^{-6}\ s$$

- - - - -

$$T = T_1 + T_2 = 5.298868287 \cdot 10^{-5}\ s$$

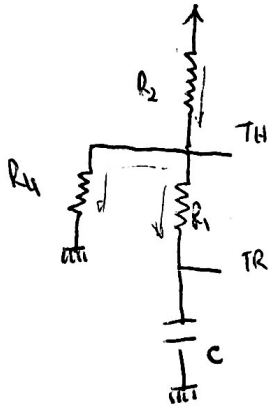
$$\boxed{f = \frac{1}{T} = 18871{,}95\ Hz}$$

ESERCIZIO c)

$Q = 1 \rightarrow D = \text{'H2}$

$V_{G_1} = 0V \quad V_{S_1} = 0V \quad V_{GS_1} = 0V < V_{T_1} = 1V \quad Q_1$ OFF

$V_{G_2} = 0V \quad V_{S_2} = V_{CC} \quad V_{GS_2} = -6V < V_{T_2} = -1V \quad Q_2$ ON



- $V_i = \frac{1}{3} V_{CC} = 2V$
- $V_f = V_{CC} \cdot \frac{R_L}{R_2 + R_L} = 5V$
- $V_{comm} = \approx V_{TH} = \frac{2}{3} V_{CC} = 4V$

$I_2 = \frac{V_{CC} - V_{TH}}{R_2} = 2\,mA \qquad I_L = \frac{V_{TH}}{R_L} = \frac{1}{1250}\,A$

$I_1 = I_2 - I_L = 1{,}2\,mA$

- $V_{comm} = V_{TH} - R_1 I_1 = 3{,}4V$

VERIFICO CHE $V_i < V_{comm} < V_f \rightarrow$ OK

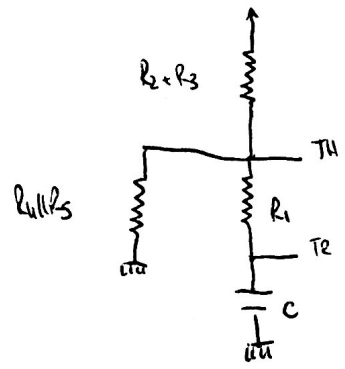
$$T_1 = \tau_1 \ln\left(\frac{V_i - V_f}{V_{comm} - V_f}\right)$$

$$\tau_1 = R_{V_2} \cdot C = \left[R_1 + R_2 // R_L\right] \cdot C = \frac{1000}{3} \cdot C = \frac{17}{187500}\ s$$

$T_1 = 5{,}699385179 \cdot 10^{-5}\ s$

$Q = 0 \rightarrow D = 0$

- $V_{cs_1} = V_{cc}$ $V_{S_1} = 0V$ $V_{es_1} = 6V > V_{T_1} = 1\ V$ Q_1 ON
- $V_{cs_2} = V_{cc}$ $V_{S_2} = V_{cc}$ $V_{es_2} = 0V > V_{T_2} = -1V$ Q_2 OFF



- $V_i = 3{,}4\ V$
- $V_{com} = 2\ V$
- $V_f = V_{cc} \cdot \frac{R_4 \| R_5}{R_2 + R_3 + R_4 \| R_5} = \frac{30}{47}\ V$

$$T_2 = T_2 \ln\left(\frac{V_i - V_f}{V_{com} - V_f}\right)$$

$$T_2 = R_{V_2} \cdot C = \left[R_1 + R_4 \| R_5 \| (R_2 + R_3)\right] \cdot C = \frac{33500}{47} \cdot C = 4.846808511 \cdot 10^{-5}\ s$$

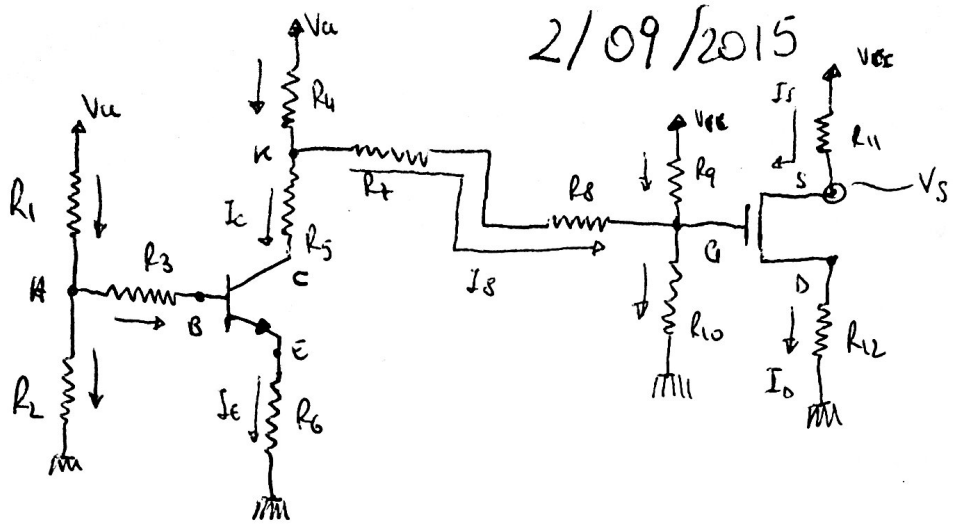
$$T_2 = 3{,}627235107 \cdot 10^{-5}\ s$$

- - -

$$T = T_1 + T_2 = 9{,}126620286 \cdot 10^{-5}\ s$$

$$\boxed{f = \frac{1}{T} = 10956.95853\ Hz}$$

1) 2/09/2015



- $I_S = \frac{V_{cc} - V_S}{R_{11}} = 2.25\ mA$
- $I_G = 0 \Rightarrow I_S = I_D = 2.25\ mA$
- $V_D = R_{12} I_D = 6.75\ V$
- $V_{GS} = V_T \pm \sqrt{\frac{I_D}{K}}$ ma poiche' deve valere $V_{GS} < V_T < 0 \Rightarrow V_{GS} = V_T - \sqrt{\frac{I_D}{K}} = -4V$
- $V_{GS} = V_G - V_S \Rightarrow V_G = V_S + V_{GS} = 8.6\ V$

VERIFICO LA SATURAZIONE $[V_{DS} < V_{GS} - V_T \Rightarrow -5.85 < -3]$ OK

- $I_9 = \frac{V_{cc} - V_G}{R_9} = 0.5\ mA$
- $I_{10} = \frac{V_G}{R_{10}} = 1\ mA$
- $I_B = I_{10} - I_9 = 0.5\ mA$
- $V_K - V_G = (R_4 + R_8) I_B \Rightarrow V_K = 10\ V$
- $I_4 = \frac{V_{cc} - V_K}{R_4} = 2.5\ mA$
- $I_5 = I_4 - I_B = 2\ mA$
- $I_C = I_5 = 2\ mA$

IPOTIZZIAMO 2.A.D $\Rightarrow I_B \ll I_C \Rightarrow I_E \approx I_C = 2\ mA$

- $V_E = R_6 I_E = 3V$

- $V_K - V_C = R_5 I_C \Rightarrow V_C = V_K - R_5 I_C = 8\ V$

VERIFICO LA Z.A.D $[\ V_{CE} > V_{CE\,SAT} \rightarrow 5 > 0.2\ V\ ]$

- $V_{BE} = V_B - V_C \Rightarrow V_B = 3.7\ V$

- $I_B = \frac{I_C}{h_{FE}} = 6.8965\ \mu A$

- $V_H - V_B = R_3 I_B \Rightarrow V_H = 3.7275\ V$

- $I_1 = \frac{V_{CC} - V_H}{R_1} = 0.7136\ mA$

- $I_2 = I_1 - I_B = 0.7067\ mA$

- $\boxed{R_2 = \frac{V_H}{I_2} = 5274.51\ \Omega}$

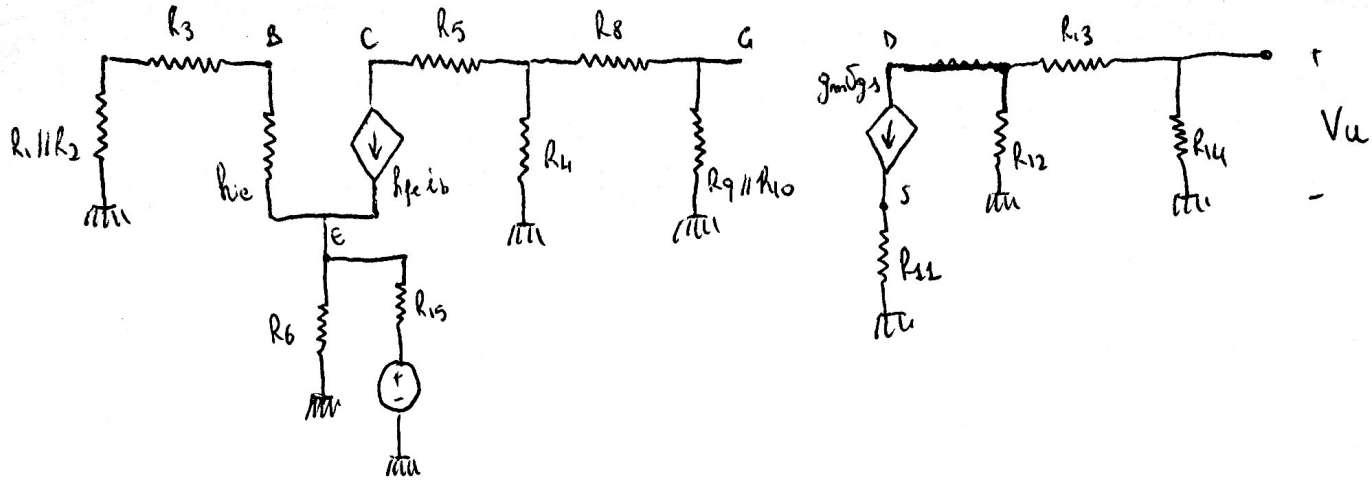
Q_1

$h_{FE} = 290 \quad h_{fe} = 300 \quad h_{ie} = 4.8\ k\Omega \quad I_C = 2mA \quad V_{CE} = 5\ V$

Q_2

$g_m = |2k(V_{GS} - V_T)| = 1.5\ \frac{mA}{V} \quad I_D = 2.25\ mA \quad V_{DS} = 5.85\ V$

21/09/2015



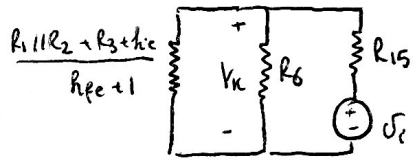
- $V_u = -g_m V_{gs} \dfrac{R_{12}}{R_{12}+R_{13}+R_{14}} \cdot R_{14}$

- $V_{gs} = V_g - V_s = V_g - g_m V_{gs} R_{11} \Rightarrow V_{gs} = \dfrac{V_g}{1+g_m R_{11}}$

- $V_g = -h_{fe} i_b \dfrac{R_4}{R_4 + R_8 + R_9 // R_{10}} \cdot R_9 // R_{10}$

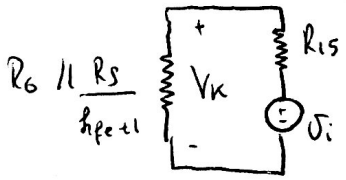
- $(h_{fe}+1)\, i_b = -\dfrac{V_K}{\dfrac{R_S}{(h_{fe}+1)}}$ ⟶

$(h_{fe}+1)\, i_b$



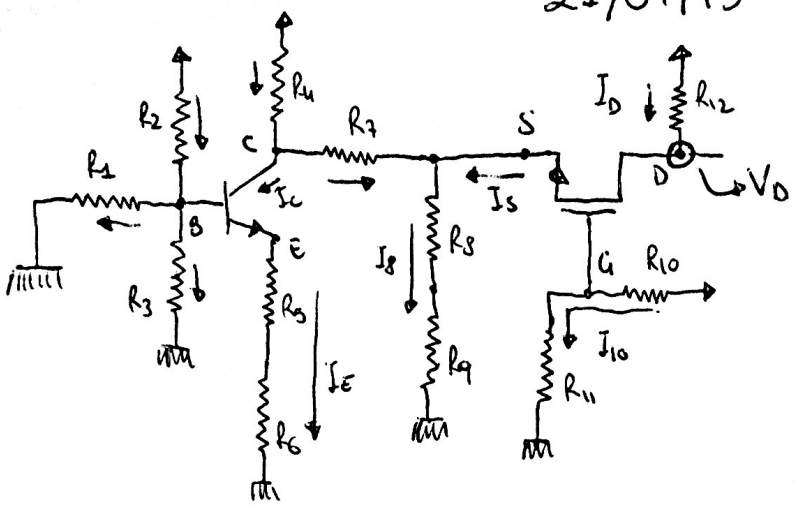
Sia:
$R_1 // R_2 + R_3 + h_{ie} = R_S$

- $V_K = V_i \dfrac{R_6 // \dfrac{R_S}{h_{fe}+1}}{R_{15} + R_6 // \dfrac{R_S}{h_{fe}+1}}$ ⟶



- $\dfrac{V_u}{V_i} = -g_m \dfrac{R_{12} \cdot R_{14}}{R_{12}+R_{13}+R_{14}} \cdot \dfrac{1}{1+g_m R_{11}} \cdot h_{fe} \dfrac{R_4 \cdot R_9 // R_{10}}{R_4 + R_8 + R_9 // R_{10}} \cdot \dfrac{1}{R_S} \cdot \dfrac{R_6 // \dfrac{R_S}{h_{fe}+1}}{R_{15} + R_6 // \dfrac{R_S}{h_{fe}+1}} = \boxed{-16{,}9}$

1)



- $I_D = \frac{V_{cc} - V_D}{R_{12}} = 2mA$ poiché $I_G = 0 \Rightarrow I_S = 2mA = I_D$
- $V_{GS} = V_T \pm \sqrt{\frac{I_D}{K}} = V_T + \sqrt{\frac{I_D}{K}}$ (perché deve valere $V_{GS} > V_T > 0$) $\Rightarrow V_{GS} = 3V$
- $I_{10} = \frac{V_{cc}}{R_{10} + R_{11}} = 60\,\mu A$
- $V_G = I_{10} \cdot R_{11} = 12\ V$
- $V_{GS} = V_G - V_S \Rightarrow V_S = V_G - V_{GS} = 9\ V$ ✓

VERIFICHIAMO LA SATURAZIONE [$V_{DS} > V_{GS} - V_T$ ovvero $12,5 - 9 > 3 - 1 \rightarrow 3,5 > 2$]

- $I_8 = \frac{V_S}{R_8 + R_9} = 1\ mA$
- $I_S + I_7 = I_8 \Rightarrow I_7 = I_8 - I_S = -1\ mA$ (la corrente è negativa perché abbiamo sbagliato verso. Ma non è un problema)
- $V_C - V_S = R_7 \cdot I_7 \Rightarrow V_C = R_7 I_7 + V_S = 8V$
- $I_4 = \frac{V_{cc} - V_C}{R_4} = 1\ mA$
- $I_C = I_4 - I_7 = 2\ mA$

SUPPONIAMO Z.A.D $\Rightarrow I_B \ll I_C \Rightarrow I_E \approx I_C = 2mA$

- $V_E = (R_5 + R_6)\, I_E = 3\ V$
- $V_{BE} = V_B - V_E \Rightarrow V_B = 3.7\ V$
- $V_{CE} = V_C - V_E = 5\ V$

Con $I_C = 2mA$ e $V_{CE} = 5V$ abbiamo : $h_{FE} = 290$ $h_{fe} = 300$ $h_{ie} = 4.8\ K\Omega$ (2)

VERIFICHIAMO Z.A.D [$V_{CE} > V_{CE\,SAT}$ ovvero $5 > 0.2\ V$] ✓

$I_B = \frac{I_C}{h_{FE}} = 6.8965\ \mu A$

- $I_3 = \frac{V_B}{R_3} = 40\ \mu A$
- $I_1 = \frac{V_B}{R_1} = 3.7\ mA$
- $I_2 = I_B + I_1 + I_3 = 3.74689\ mA$

- $R_2 = \frac{V_{cc} - V_B}{I_2} = 3816,69\ \Omega$

PUNTI DI RIPOSO

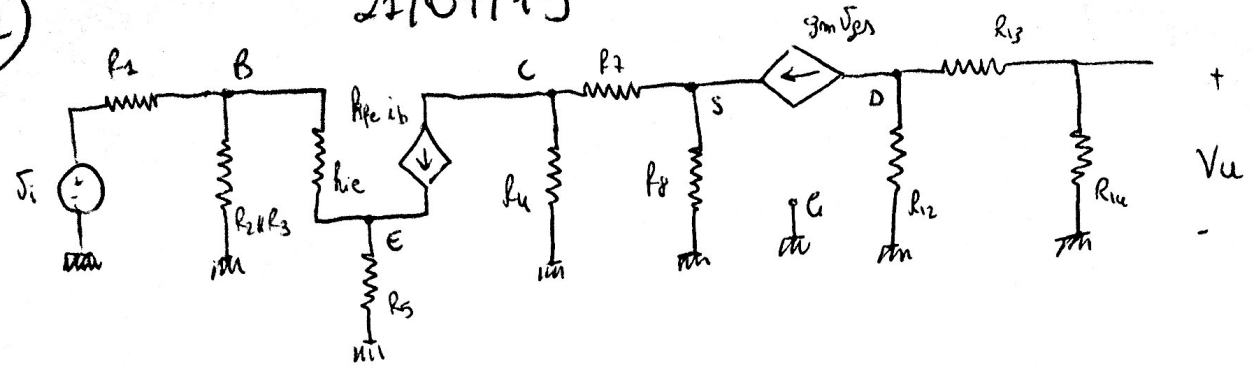
Q_1:

- $I_C = 2mA$ $V_{CE} = 5\ V$ $h_{FE} = 290$ $h_{fe} = 300$ $h_{ie} = 4.8\ K\Omega$

Q_2:

$I_D = 2\ mA$ $V_{DS} = 3.5\ V$ $g_m = |2k(V_{GS} - V_T)| = \frac{2mA}{V}$

2) 21/07/15

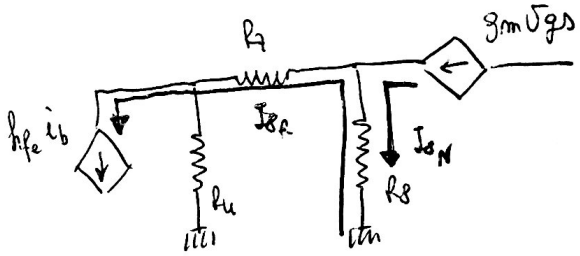


- $V_u = -g_m V_{gs} \dfrac{R_{12}}{R_{13} + R_{12} + R_{14}} \cdot R_{14}$

- $V_{gs} = V_g - V_s = -V_s$

- $V_s = R_8 I_8$

PRINCIPIO DI SOVRAPPOSIZIONE



$$I_{8ROSSO} = -\frac{h_{fe}\, i_b \cdot R_4}{R_4 + R_7 + R_8}$$

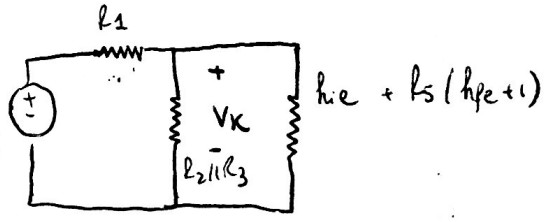
$$I_{8NERO} = \frac{g_m V_{gs} \cdot (R_4 + R_7)}{R_4 + R_7 + R_8}$$

$$I_8 = -\frac{g_m V_s (R_4 + R_7)}{R_4 + R_7 + R_8} - \frac{h_{fe}\, i_b\, R_4}{R_4 + R_7 + R_8}$$

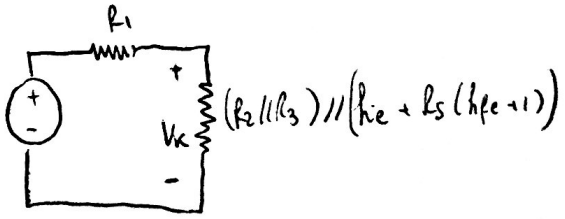
- $V_s = R_8 \left(-\dfrac{g_m V_s (R_4 + R_7)}{R_4 + R_7 + R_8} - \dfrac{h_{fe}\, i_b\, R_4}{R_4 + R_7 + R_8} \right) \Rightarrow V_s \left(1 + \dfrac{g_m (R_4 + R_7) R_8}{R_4 + R_7 + R_8} \right) = -\dfrac{h_{fe}\, i_b\, R_4 R_8}{R_4 + R_7 + R_8}$

$$V_s = -\frac{h_{fe}\, R_4\, R_8}{R_4 + R_7 + R_8 + (R_4 + R_7) R_8 g_m} \cdot i_b$$

- $i_b = \dfrac{V_K}{h_{ie} + R_5 (h_{fe} + 1)}$



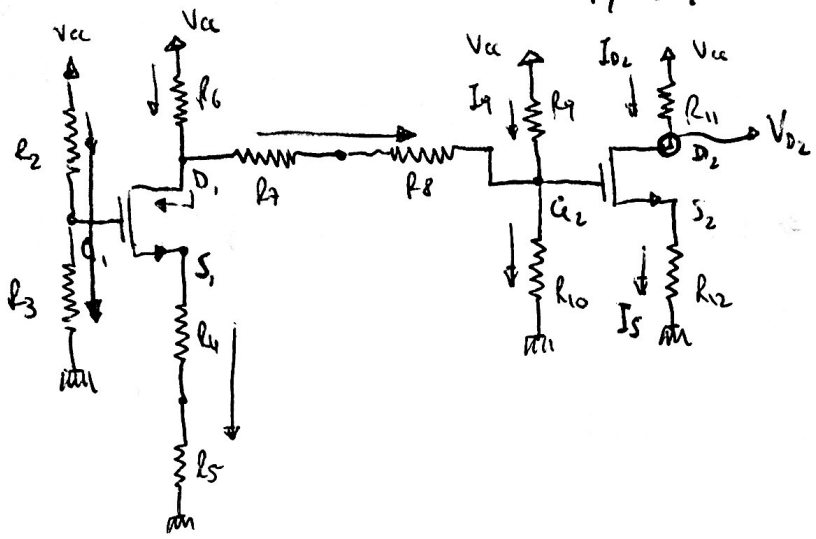
- $V_K = V_i \dfrac{(R_2 // R_3) // (h_{ie} + R_5 (h_{fe}+1))}{R_1 + [(R_2 // R_3) // (h_{ie} + R_5 (h_{fe}+1))]}$



- $\dfrac{V_u}{V_i} = -g_m \dfrac{R_{12} R_{14}}{R_{12} + R_{13} + R_{14}} \cdot \dfrac{h_{fe}\, R_4 R_8}{R_4 + R_7 + R_8 + (R_4 + R_7) R_8 g_m} \cdot \dfrac{1}{h_{ie} + R_5 (h_{fe}+1)} \cdot \dfrac{(R_2 // R_3) // (h_{ie} + R_5 (h_{fe}+1))}{R_1 + [(R_2 // R_3) // (h_{ie} + R_5 (h_{fe}+1))]} = \boxed{-6.47}$

9/6/15

1)



- $I_{D_2} = \frac{V_{cc} - V_{D_2}}{R_{11}} = 2mA$ poiché $I_{G_2} = 0 \Rightarrow I_{S_2} = 2mA = I_{D_2}$
- $V_{S_2} = R_{12} I_{S_2} = 5V$
- $V_{GS_2} = V_T \pm \sqrt{\frac{I_{D_2}}{K}} = V_T + \sqrt{\frac{I_{D_2}}{K}}$ perché deve valere $V_{GS_2} > V_T > 0 \Rightarrow V_{GS_2} = 3V$
- $V_{GS_2} = V_{G_2} - V_{S_2} \Rightarrow V_{G_2} = 8V$

VERIFICO LA SATURAZIONE [$V_{DS_2} > V_{GS_2} - V_T$ ovvero $10 - 5 > 3 - 1 \rightarrow 5 > 2$ ✓]

- $I_9 = \frac{V_{cc} - V_{G_2}}{R_9} = 0.5\ mA$
- $I_{10} = \frac{V_{G_2}}{R_{10}} = 1\ mA$
- $I_8 = I_{10} - I_9 = 0.5\ mA$

L'incognita non la posso trovare momentaneamente. Continuo il circuito per poi tornare indietro.

- $I_6 = \frac{V_{cc} - V_{D_1}}{R_6}$
- $V_{D_1} - V_{G_2} = (R_7 + R_8) I_8 \Rightarrow V_{D_1} = V_{G_2} + (R_7 + R_8) I_8$
- $I_{D_1} = I_6 - I_8$
- $V_{S_1} = (R_4 + R_5) I_{D_1}$
- $V_{G_1} = R_3 I_3 = 6V$
- $I_3 = I_2 = \frac{V_{cc}}{R_2 + R_3} = 60\ \mu A$ (perché $I_{G_1} = 0$)

• $V_{GS_1} = V_{e_1} - V_{S_1} = 6 - (R_4 + R_5) I_{D_1}$

Supponiamo che $I_{D_1} = K (V_{GS_1} - V_T)^2 = K (6 - (R_4 + R_5) I_D - 1)^2 = K (5 - (R_4 + R_5) I_D)^2$

$I_{D_1} = K ((R_4 + R_5)^2 I_D^2 - 10 (R_4 + R_5) I_D + 25)$ $\quad K (R_4 + R_5)^2 I_{D_1}^2 - (1 + 10 (R_4 + R_5) K) I_{D_1} + 25 K = 0$

$1125\, I_{D_1}^2 + 8.5\, I_D + \frac{1}{80} = 0$ $\quad \rightarrow I_{D_1}' = 2\,mA$ $\quad \rightarrow I_{D_1}'' = 5.56\,mA$

Dobbiamo scegliere fra le due:

Avremo:

$V_{S_1}' = 3\,V$ $\quad I_6' = 2.5\,mA$ $\quad V_{D_1}' = 9\,V$ $\quad \leftarrow$ si sceglie $I_{D_1} = I_{D_1}'$

$V_{S_1}'' = 8.25$ $\quad I_6'' = 6.05\,mA$ $\quad V_{D_1}'' = -3.78\,V$

Quindi:

$V_{D_1} - V_{e_2} = R_7 I_8 + R_8 I_8 \Rightarrow R_8 = \dfrac{V_{D_1} - V_{e_2} - R_7 I_8}{I_8} \Rightarrow \boxed{R_8 = 1900\,\Omega}$

Verifichiamo la saturazione $[V_{DS_1} > V_{GS_1} - V_T$ ovvero $6 > 2$ ✓ $]$

PUNTI DI RIPOSO

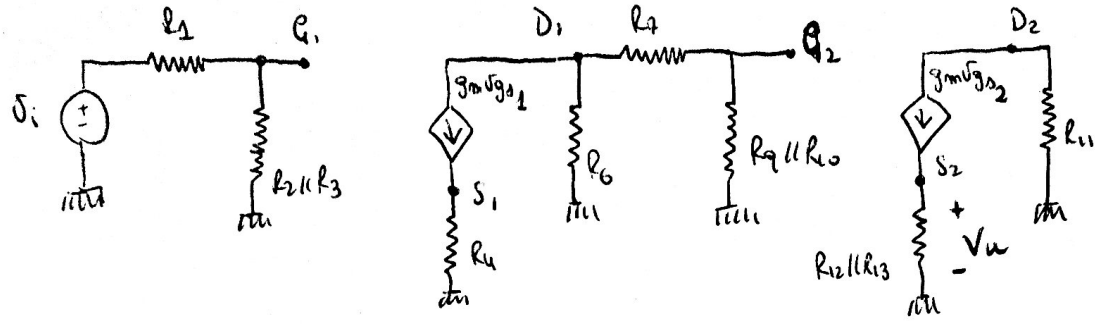
Q_1:

$I_D = 2\,mA$ $\quad V_{DS} = 6\,V$ $\quad g_m = |2K (V_{GS} - V_T)| = 2 \cdot 10^{-3}\,\frac{A}{V}$

Q_2:

$I_D = 2\,mA$ $\quad V_{DS} = 6\,V$ $\quad g_m = |2K (V_{GS} - V_T)| = 2 \cdot 10^{-3}\,\frac{A}{V}$

9/06/15



- $V_u = g_m V_{gs_2} (R_{12} // R_{13})$

- $V_{gs_2} = V_{g_2} - V_{s_2} = V_{g_2} - g_m V_{gs_2} (R_{12} // R_{13}) \Rightarrow V_{gs_2} = \dfrac{V_{g_2}}{1 + g_m (R_{12} // R_{13})}$

- $V_{g_2} = - g_m V_{gs_1} \cdot \dfrac{R_6}{R_6 + R_7 + R_9 // R_{10}} \cdot R_9 // R_{10}$

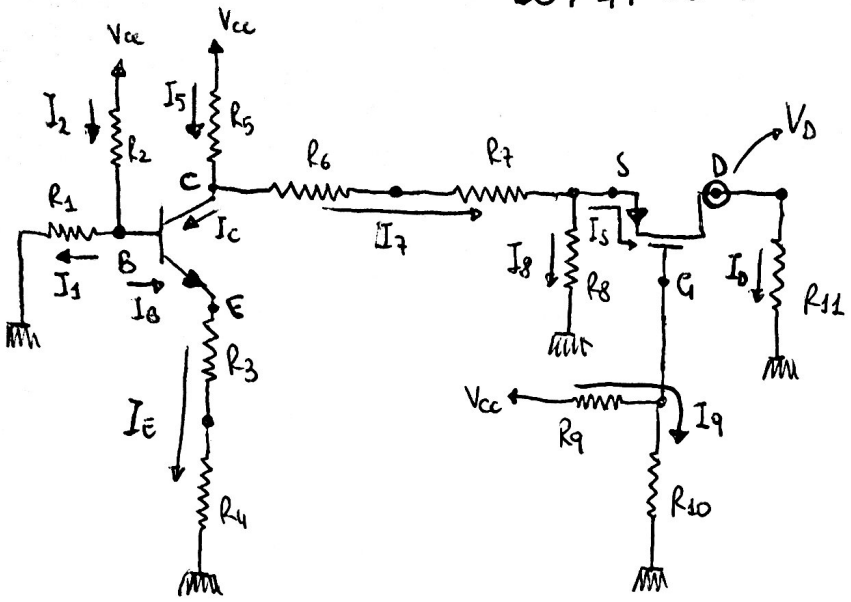
- $V_{gs_1} = V_{g_1} - V_{s_1} = V_{g_1} - g_m V_{gs_1} \cdot R_4 \Rightarrow V_{gs_1} = \dfrac{V_{g_1}}{1 + g_m R_4}$

- $V_{g_1} = V_i \cdot \dfrac{R_2 // R_3}{R_1 + R_2 // R_3}$

- $\dfrac{V_u}{V_i} = \dfrac{g_m^2 (R_{12} // R_{13})}{1 + g_m (R_{12} // R_{13})} \cdot \dfrac{R_6 \cdot (R_9 // R_{10})}{R_6 + R_7 + (R_9 // R_{10})} \cdot \dfrac{1}{1 + g_m R_4} \cdot \dfrac{R_2 // R_3}{R_1 + R_2 // R_3} = \boxed{-2.91}$

16/4/2015

1)



- $I_{11} = \frac{V_D}{R_{11}} = 2mA = I_D$
- Poiché $I_G = 0 \Rightarrow I_S = I_D = 2mA$
- $V_{GS} = V_T - \sqrt{\frac{I_D}{K}} = -3V$ (il segno - perché deve valere $V_{GS} < V_T < 0$)
- $I_9 = \frac{V_{cc}}{R_9 + R_{10}} = 0.9\ mA$
- $V_G = R_{10} I_9 = 9V$
- $V_{GS} = V_G - V_S \Rightarrow V_S = V_G - V_{GS} = 12\ V$

VERIFICO LA SATURAZIONE [$V_{DS} < V_{GS} - V_T \Rightarrow 8 - 12 < -3 + 1 \Rightarrow -4 < -2$ OK]

- $I_8 = \frac{V_S}{R_8} = 0.5\ mA$
- $I_7 = I_8 + I_S = 2.5\ mA$
- $V_C - V_S = (R_6 + R_7) I_7 \Rightarrow V_C = V_S + (R_6 + R_7) I_7 = 13.5\ V$
- $I_5 = \frac{V_{cc} - V_C}{R_5} = 4.5\ mA$
- $I_C = I_5 - I_7 = 2mA$

IPOTIZZO ZONA ATTIVA DIRETTA $\Rightarrow I_B \ll I_C \Rightarrow I_E \approx I_C$

- $V_E = (R_3 + R_4) I_E = 8.5\ V$
- $V_{CE} = V_C - V_E = 5\ V$

VERIFICO Z.A.D $\Rightarrow$ $V_{CE} > V_{CE\,SAT}$ $\Rightarrow$ $5 > 0.2\ V$ OK

Se $I_C = 2mA$ e $V_{CE} = 5\ V$, dalla id $h_{FE} = 290$ $h_{fe} = 300$ $h_{ie} = 4.8\ k\Omega$

- $V_{BE} = V_B - V_E \Rightarrow V_B = 9.2\ V$
- $I_B = \frac{I_C}{h_{FE}} = 6,8965\ \mu A$
- $I_2 = \frac{V_{CC} - V_B}{R_2} = 50\ \mu A$
- $I_1 = I_2 - I_B = 43,1035\ \mu A$

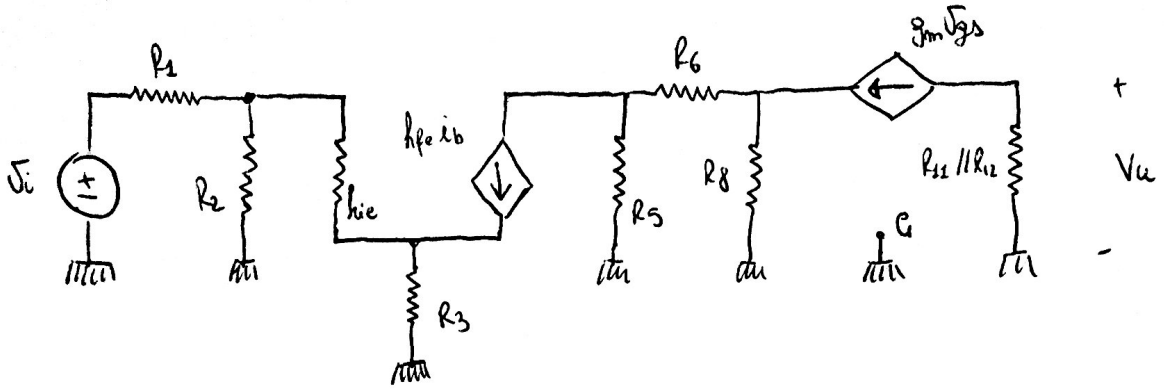
- $R_1 = \frac{V_B}{I_1} = 213439,74\ \Omega$

Q_1: $h_{FE} = 290$ $h_{fe} = 300$ $h_{ie} = 4.8\ k\Omega$ $V_{CE} = 5V$ $I_C = 2mA$

Q_2: $g_m = |2K(V_{GS} - V_T)| = 2\ \frac{mA}{V}$

$I_D = 2mA$

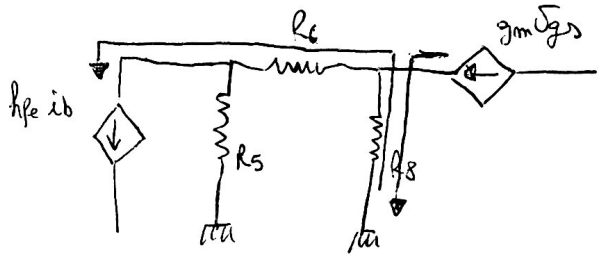
$V_{DS} = -4$



- $V_u = - g_m V_{gs} \cdot R_1 // R_2$
- $V_{gs} = V_g - V_s = - V_s$
- $V_s = R_8 I_8$

Principio di sovrapposizione

$$I_{8_{Rosso}} = - \frac{h_{fe}\, i_b\, R_5}{R_5 + R_6 + R_8}$$



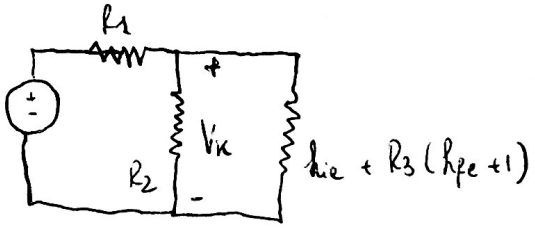
$$I_{8_{NERO}} = \frac{g_m V_{gs} (R_5 + R_6)}{R_5 + R_6 + R_8}$$

$$I_8 = \frac{g_m V_{gs} (R_5 + R_6)}{R_5 + R_6 + R_8} - \frac{h_{fe} R_5\, i_b}{R_5 + R_6 + R_8}$$

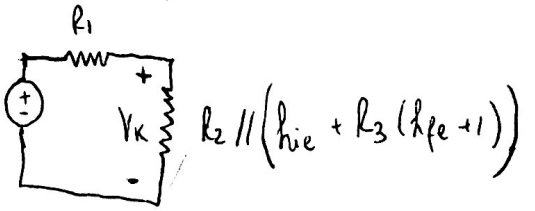
- $V_S = R_8 \left(- \frac{g_m V_s (R_5 + R_6)}{R_5 + R_6 + R_8} - \frac{h_{fe} R_5\, i_b}{R_5 + R_6 + R_8} \right) \Rightarrow V_S \left(1 + \frac{R_8 (R_5 + R_6) g_m}{R_5 + R_6 + R_8} \right) = - \frac{h_{fe} R_5\, i_b R_8}{R_5 + R_6 + R_8}$

$$V_S = - \frac{h_{fe} R_5 R_8\, i_b}{R_5 + R_6 + R_8 + (R_5 + R_6) R_8 g_m}$$

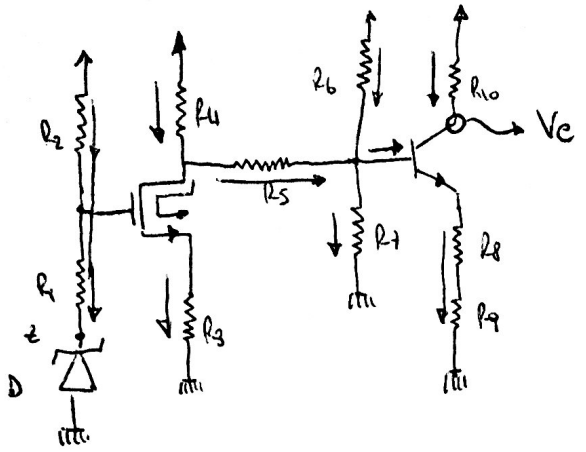
- $i_b = \frac{V_K}{h_{ie} + R_3 (h_{fe} + 1)}$ →



- $V_K = V_i \cdot \frac{R_2 // (h_{ie} + R_3 (h_{fe} + 1))}{R_1 + R_2 // (h_{ie} + R_3 (h_{fe} + 1))}$ →



$$\frac{V_u}{V_i} = - g_m R_{11} // R_{12} \cdot \frac{h_{fe} R_5 R_8}{R_5 + R_6 + R_8 + (R_5 + R_6) R_8 g_m} \cdot \frac{1}{h_{ie} + R_3 (h_{fe} + 1)} \cdot \frac{R_2 // (h_{ie} + R_3 (h_{fe} + 1))}{R_1 + R_2 // (h_{ie} + R_3 (h_{fe} + 1))} = -1{,}73$$



- $I_C = \frac{V_{cc} - V_C}{R_{10}} = 2\,mA$

IPOTIZZO ZAD $\quad I_C >> I_B \rightarrow I \approx I_C = 2\,mA$

- $V_E = (R_8 + R_9) I_E = 5\,V$

VERIFICO ZAD $\Rightarrow \quad V_{CE} > V_{CESAT} \rightarrow 5V > 0.2V \rightarrow$ OK

- $I_B = \frac{I_C}{h_{FE}} = 6.8965\,\mu A$

- $V_{BE} = V_B - V_E \rightarrow V_B = V_E + V_{BE} = 5.7\,V$

- $I_6 = \frac{V_{cc} - V_B}{R_6} = 20\,\mu A$

- $I_7 = \frac{V_B}{R_7} = 0.19\,mA$

- $I_5 + I_6 = I_7 + I_B \rightarrow I_5 = I_7 + I_B - I_6 = 1.768965 \cdot 10^{-4}\,A$

- $V_D = R_5 I_5 + V_B = \frac{8151}{1160} = 7.026724\,V$

- $I_4 = \frac{V_{cc} - V_D}{R_4} = 3.376392573\,mA$

- $I_D = I_4 - I_5 = 3.199696021\,mA$

- $I_G = 0 \rightarrow I_S = I_D$

IPOTIZZIAMO SATURAZIONE: $V_{GS} = V_T + \sqrt{\frac{I_D}{K}} = 3.529622905\,V$

IPOTIZZO ZENER IN BREAKDOWN $\Rightarrow V_Z = 3.6\,V$

$I_Z = \frac{V_{cc} - V_Z}{R_2 + R_1} = 2\,mA \Rightarrow$ VERIFICATA IPOTESI DI DIODO IN BREAKDOWN, poiché $I_Z > 0$ da ANODO A CATODO

- $V_G = V_{cc} - R_2 I_2 = 6\ V$
- $V_{GS} = V_G - V_S \rightarrow V_S = V_G - V_{GS} = 2.470377095\ V$

VERIFICO SATURAZIONE : $V_{DS} > V_{GS} - V_T \rightarrow 9,497101233\ V > 2,529622905\ V$

- $R_3 = \frac{V_S}{I_D} = 772,114\ \Omega$

PUNTI DI RIPOSO

Q_1:

$I_D = 3.199496021\ mA \quad V_{DS} = 9,497101233\ V \quad g_m = 2k\,|V_{GS} - V_T| = 2.529622905\ \frac{mA}{V}$ (M)

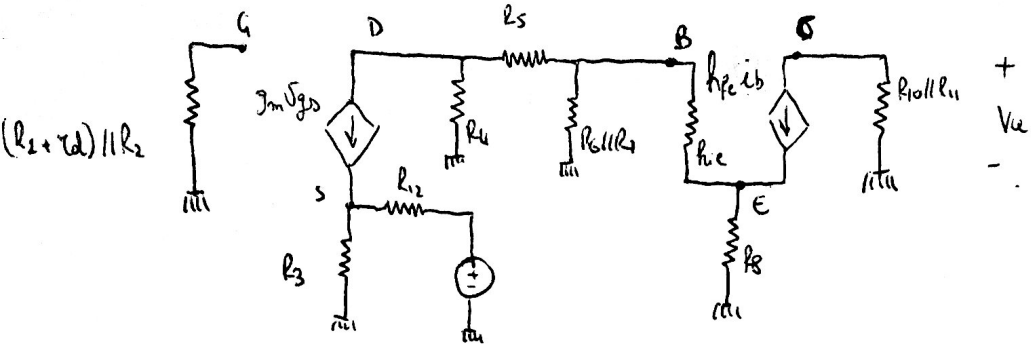
Q_2:

$I_C = 2mA \quad V_{CE} = 5V \quad h_{fe} = 300 \quad h_{FE} = 290 \quad h_{ie} = 4.8\ k\Omega$

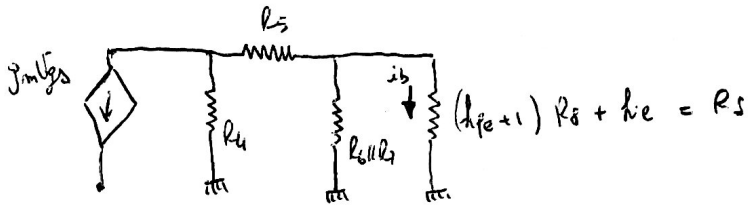
D:

$V_Z = 3.6\ V \quad I_Z = 2mA \quad r_d = \frac{V_T}{I_Z} = 13\ \Omega$

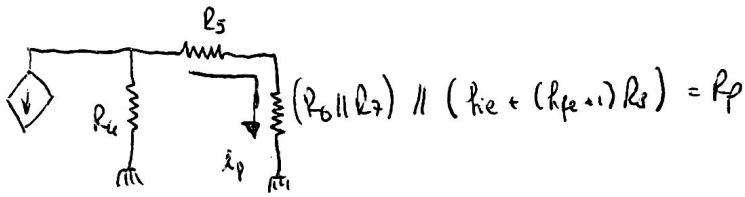
16/02/2015



- $V_u = -h_{fe} i_b \; (R_{10} \| R_{11})$

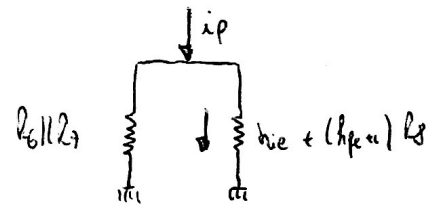


- $i_p = -g_m V_{gs} \dfrac{R_4}{R_4 + R_S + R_P}$



- $i_b = i_p \cdot \dfrac{R_6 \| R_7}{R_6 \| R_7 + R_S}$

- $V_{gs} = V_g - V_S = -V_S$



$$\begin{cases} V_S = R_3 I_3 \\ V_S - V_i = R_{12} I_{12} \\ g_m V_{gs} = I_3 + I_{12} \rightarrow -g_m V_S = I_3 + I_{12} \end{cases}$$

$$-g_m V_S = \frac{V_S}{R_3} + \frac{V_S}{R_{12}} - \frac{V_i}{R_{12}} \rightarrow V_S \left(g_m + \frac{1}{R_3} + \frac{1}{R_{12}} \right) \rightarrow V_S = \frac{V_i}{R_{12}} \left(g_m + \frac{1}{R_3} + \frac{1}{R_{12}} \right)^{-1}$$

$$\frac{V_u}{V_i} = - \underbrace{h_{fe} \overbrace{(R_{10} \| R_{11})}^{A}}_{960000} \cdot \overbrace{g_m}^{M} \underbrace{\frac{R_4}{R_4 + R_S + \underbrace{[(R_6 \| R_7) \| (h_{ie} + R_8 (h_{fe}+1))]}_{D}}}_{3{,}10586793 \cdot 10^{-4}} \cdot \underbrace{\frac{R_6 \| R_7}{R_6 \| R_7 + h_{ie} + R_8 (h_{fe}+1)}}_{0{,}6506339567} \cdot \underbrace{\frac{1}{R_{12}} \left(g_m + \frac{1}{R_3} + \frac{1}{R_{12}} \right)^{-1}}_{0{,}8396218682} = \boxed{-112{,}74}$$

D: C, E

E

F

X

ESERCIZIO B)

$$Y = (\overline{AC} + \bar{B})(\bar{B}D + \bar{D}) + \bar{E}(\bar{B} + D)$$

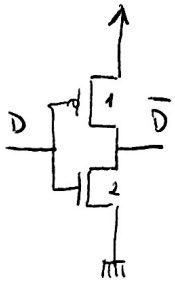
$$Y = (\bar{A} + \bar{C} + \bar{B})(\bar{B}D + \bar{D}) + \bar{E}\bar{B} + D\bar{E}$$

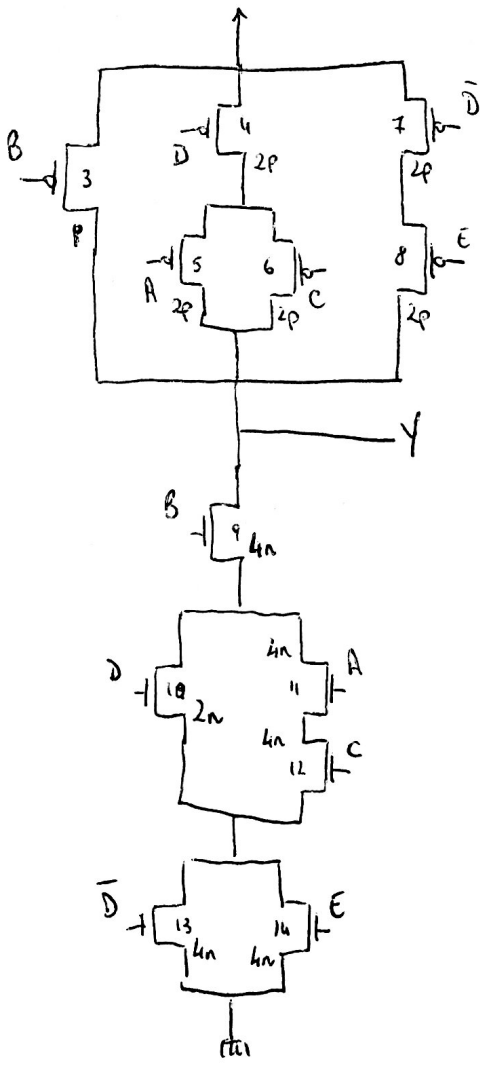
$$Y = \bar{A}\bar{B}D + \bar{A}\bar{D} + \bar{B}\bar{C}D + \bar{C}\bar{D} + \bar{B}D + \bar{B}\bar{D} + \bar{B}\bar{E} + D\bar{E}$$

$$Y = \bar{A}\bar{B}D + \bar{A}\bar{D} + \bar{B}\bar{C}D + \bar{C}\bar{D} + \bar{B} + \bar{B}\bar{E} + D\bar{E}$$

$$Y = \bar{B}(\bar{A}D + \bar{C}D + 1 + \bar{E}) + \bar{A}\bar{D} + \bar{C}\bar{D} + D\bar{E}$$

$$Y = \bar{B} + \bar{D}(\bar{A} + \bar{C}) + D\bar{E}$$ ___ 14 mosfet





- INVERTER DI BASE

$$\left(\frac{W}{L}\right)_1 = p = 5$$

$$\left(\frac{W}{L}\right)_2 = n = 2$$

- PUN

WORST CASE : Q_4, Q_5 o Q_4, Q_6 o Q_7, Q_8

$$\left(\frac{W}{L}\right)_{4,5,6,7,8} = X$$

$$\frac{1}{X} + \frac{1}{X} = \frac{1}{P} \rightarrow \frac{2}{X} = \frac{1}{P} \rightarrow X = 2P = 10$$

WORST CASE (2) Q_3:

$$\left(\frac{W}{L}\right)_3 = Y$$

$$\frac{1}{Y} = \frac{1}{P} \rightarrow Y = P = 5$$

- PDN :

WORST CASE : $Q_9, Q_{11}, Q_{12}, Q_{13}$ o $Q_9, Q_{11}, Q_{12}, Q_{14}$

$$\left(\frac{W}{L}\right)_{9,11,12,13,14} = X$$

$$\frac{1}{X} + \frac{1}{X} + \frac{1}{X} + \frac{1}{X} = \frac{1}{n} \rightarrow \frac{4}{X} = \frac{1}{n} \rightarrow X = 4n = 8$$

WORST - CASE (2) : Q_9, Q_{10}, Q_{13} → NON POSSIBILE PERCHÉ PRESENTI D e $\bar{D}$

Q_9, Q_{10}, Q_{14}

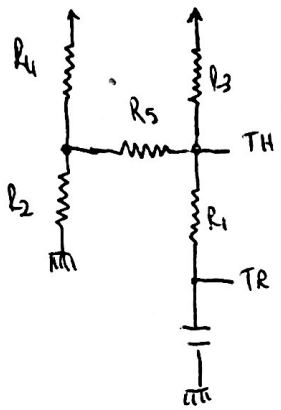
$$\left(\frac{W}{L}\right)_{10} = Y$$

$$\frac{1}{Y} + \frac{1}{4n} + \frac{1}{4n} = \frac{1}{n} \rightarrow \frac{1}{Y} = \frac{4-2}{4n} \rightarrow \frac{1}{Y} = \frac{1}{2n} \rightarrow Y = 2n = 4$$

ESERCIZIO c)

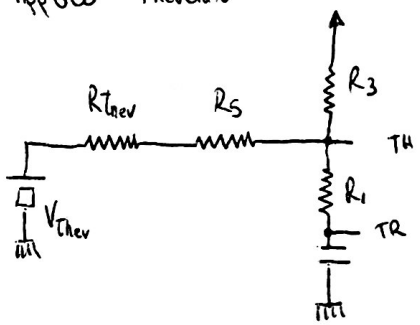
$Q=1 \rightarrow D='1'$

- $V_{e_2}=V_{cc}$ $V_{S_2}=0V$ $V_{cs_2}=V_{cc}=6V > V_{T_2}=1V$ $Q_2=ON$
- $V_{e_1}=0V$ $V_{S_1}=0V$ $V_{cs_1}=0V < V_T=1V$ $Q_1=OFF$



$\bullet V_i = \frac{1}{3}V_{cc} = 2V$

Applico Thevenin



$V_{Thev} = V_{cc}\cdot\frac{R_2}{R_2+R_4} = 3V$ $R_{Thev} = R_2 \| R_4 = 1000\ \Omega$

- $V_f \rightarrow$ se non scorre corrente sul condensatore

$I = \frac{V_{cc}-V_{Thev}}{R_3+R_5+R_{Thev}} = 1,5\ mA \rightarrow \boxed{V_f = V_{cc}-R_3 I = 4,95\ V}$

- V_{comm} se $V_{TH}=\frac{2}{3}V_{cc}=4V$

$I_3 = \frac{V_{cc}-V_{TH}}{R_3} = \frac{1}{350}\ A$ $I_{Thev} = \frac{V_{TH}-V_{Thev}}{R_5+R_{Thev}} = \frac{1}{1300}\ A$ $I_1 = I_3 - I_{Thev} = \frac{19}{9100}\ A$

- $V_{comm} = V_{TH} - R_1\cdot I_1 = \frac{269}{91}\ V$

VERIFICO CHE $V_i < V_{comm} < V_f \rightarrow$ ok

$T_1 = \tau_1 \ln\left(\frac{V_i - V_f}{V_{comm}-V_f}\right)$

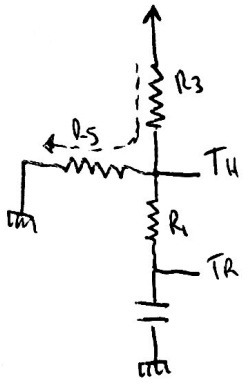
$T_1 = R_{V_1}\cdot C = \left[R_1 + R_3 \| (R_5 + R_{Thev})\right]\cdot C = 955\cdot C = 6,496\cdot 10^{-5}\ s$

$T_1 = 2,543599424\cdot 10^{-5}\ s$

$Q = 0 \rightarrow D = 0$

$V_{G_2} = 0V \quad V_{S_2} = 0V \quad V_{GS_2} = 0V < V_T = 1V$ $\quad Q_2$ OFF

$V_{G_1} = V_{CC} \quad V_{S_1} = 0V \quad V_{GS_1} = V_{CC} = 6V > V_T = 1V$ $\quad Q_1 = ON$



- $V_i = \frac{269}{91} V$
- $V_{comm} = 2V$
- $V_f = V_{CC} \cdot \frac{R_5}{R_3 + R_5} = \frac{9}{5} V = 1,8 V$

VERIFICO CHE $V_i > V_{comm} > V_f \rightarrow$ OK

$$T_2 = T_2 \ln\left(\frac{V_i - V_f}{V_{comm} - V_f}\right)$$

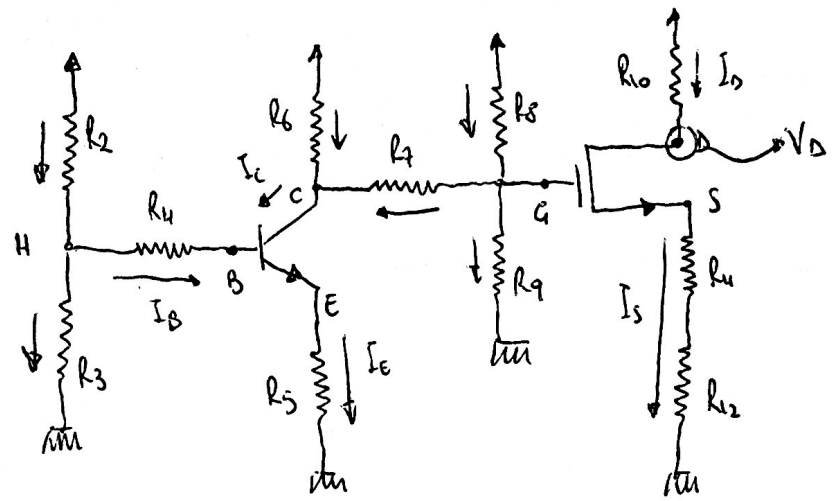
$$T_2 = R_{V_2} \cdot C = \left[R_1 + R_3 \| R_5\right] \cdot C = 710 \cdot C = 4,828 \cdot 10^{-5} \, s$$

$$T_2 = 8,470644558 \cdot 10^{-5} \, s$$

$$T = T_1 + T_2 = 1,101406398 \cdot 10^{-4} \, s$$

$$\boxed{f = \frac{1}{T} = 9079,31 \ Hz}$$

1) 27/01/2015



$V_D = 12\ V$

$R_3 = ?$

- $I_D = I_{10} = \frac{V_{cc} - V_D}{R_{10}} = 8\ mA$
- $I_G = 0 \Rightarrow I_S = I_D$
- $V_S = (R_{11} + R_{12})\, I_S = 5V$
- $V_{GS} = V_T \pm \sqrt{\frac{I_D}{K}}$ → scelgo $V_{GS} = V_T + \sqrt{\frac{I_D}{K}}$ perché deve valere $V_{GS} > V_T > 0$
- $V_{GS} = 5\ V$
- $V_{GS} = V_G - V_S \Rightarrow V_G = V_{GS} + V_S = 10\ V$

VERIFICO LA SATURAZIONE $[V_{DS} > V_{GS} - V_T$ ovvero $7 > 4]$ ✓

- $I_8 = \frac{V_{cc} - V_a}{R_8} = 1\ mA$
- $I_9 = \frac{V_a}{R_9} = 0.5\ mA$
- $I_7 = I_8 - I_9 = 0.5\ mA$
- $V_a - V_c = R_7 I_7 \Rightarrow V_c = V_a - R_7 I_7 = 9\ V$
- $I_6 = \frac{V_{cc} - V_c}{R_6} = 1.5\ mA$
- $I_c = I_7 + I_6 = 2\ mA$

IPOTIZZO Z.A.D $\Rightarrow I_B \ll I_C \Rightarrow I_E \approx I_C$

- $V_E = R_5 \cdot I_E = 4.V$

VERIFICO Z.A.D [$V_{CE} > V_{CE\,SAT}$ ovvero $5 > 0.2\ V$]

Quindi so che: $h_{fe} = 300$ $h_{FE} = 290$ $h_{ie} = 4.8\ K\Omega$

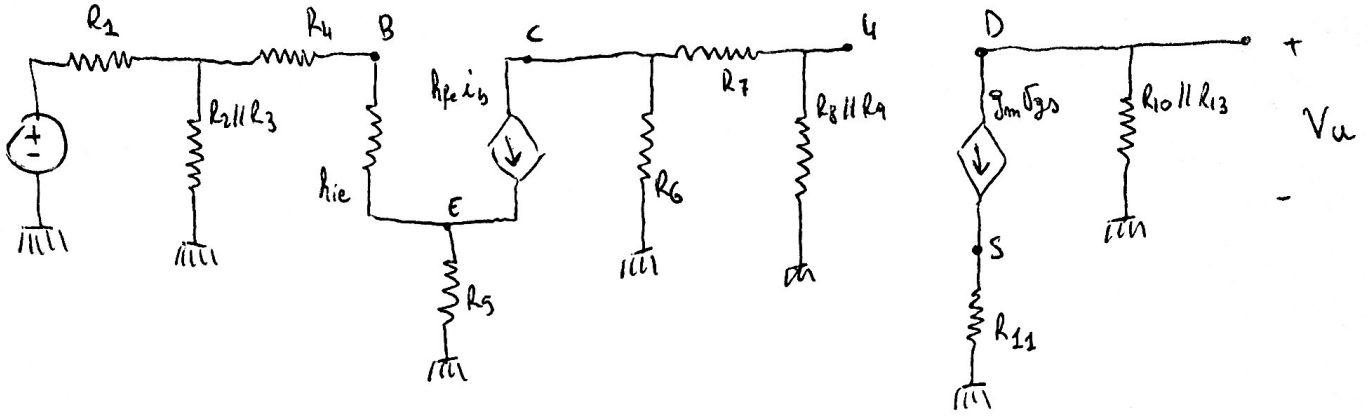
- $I_B = \frac{I_C}{h_{FE}} = 6.8965\ \mu A$
- $V = V_{BE} + V_E = 4.7\ V$
- $V_{H.} = V_B + R_4 I_B = 4.768965\ V$
- $I_2 = \frac{V_{CC} - V_H}{R_2} = 22.051725\ \mu A$
- $I_3 = I_2 - I_B = 15.155225\ \mu A$
- $R_3 = \frac{V_H}{I_3} = 314674,64$

Q_1

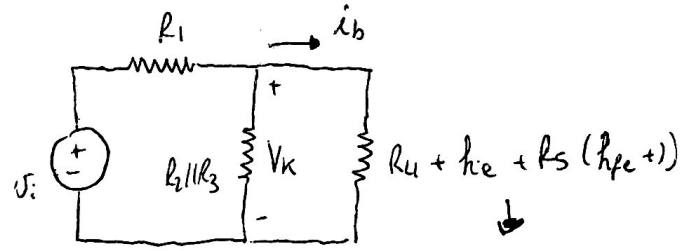
$h_{FE} = 290$ $h_{ie} = 6.8\ k\Omega$ $h_{fe} = 300$ $I_C = 2mA$ $V_{CE} = 5V$

Q_2

$I_D = 8mA$ $V_{DS} = 7\ V$ $g_m = |2k(V_{GS} - V_T)| = 4\ m\frac{A}{V}$

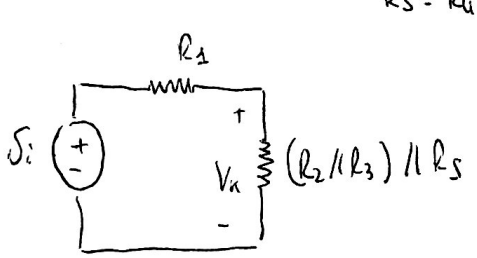


- $V_u = -g_m V_{gs} \cdot R_{10} // R_{13}$
- $V_{gs} = V_g - V_s = V_g - g_m V_{gs} R_{11} \Rightarrow V_{gs} = \dfrac{V_g}{1 + g_m \cdot R_{11}}$
- $V_g = -h_{fe} i_b \dfrac{R_6}{R_6 + R_7 + R_8 // R_9} \cdot R_8 // R_9$
- $i_b = \dfrac{V_K}{R_S}$ ⟶



$R_S = R_4 + h_{ie} + R_5 (h_{fe}+1)$

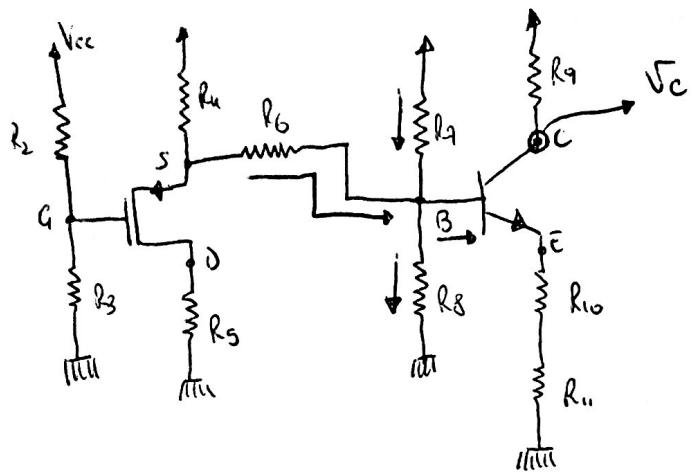
- $V_K = V_i \cdot \dfrac{(R_2 // R_3) // R_S}{1 + (R_2 // R_3) // R_S}$ ⟶



- $\dfrac{V_u}{V_i} = g_m R_{10} // R_{13} \cdot \dfrac{1}{1 + g_m R_{11}} \cdot \dfrac{h_{fe} R_6 \; R_8 // R_9}{R_6 + R_7 + R_8 // R_9} \cdot \dfrac{1}{R_S} \cdot \dfrac{(R_2 // R_3) // R_S}{1 + (R_2 // R_3) // R_S} = \boxed{3.08}$

9/01/ 2015

ESERCIZIO A)



- $I_9 = \frac{V_{cc} - V_C}{R_9} = 2\ mA = I_C$

SUPPONIAMO Z.A.D $\Rightarrow I_C >> I_B \Rightarrow I_C = I_E = 2mA$

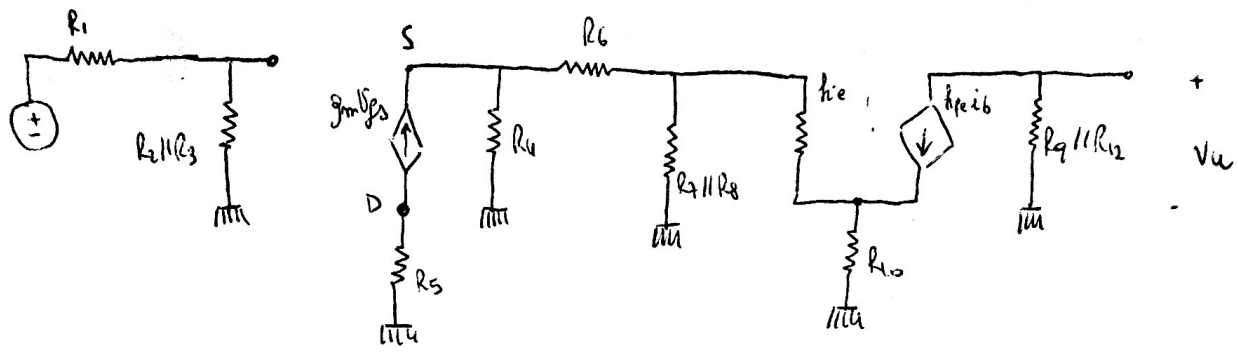
- $V_E = (R_{10} + R_{11})\, I_E = 8.\ V$
- $V_{BE} = V_B - V_E \Rightarrow V_B = V_{BE} + V_E = 8.7\ V$
- VERIFICO ZAD $\rightarrow V_{CE} > V_{CESAT} \rightarrow 5 > 0.2$ OK
- $I_B = \frac{I_C}{h_{FE}} = 6,8965\ \mu A$
- $I_7 = \frac{V_{cc} - V_B}{R_7} = 20\ \mu A$
- $I_8 = \frac{V_B}{R_8} = 0.435\ mA = 435\ \mu A$
- $I_7 + I_6 = I_8 + I_B \Rightarrow I_6 = I_8 + I_B - I_7 = 421,8965\ \mu A$
- $V_S - V_B = R_6 I_6 \rightarrow V_S = V_B + R_6 I_6 = 12,918965 V$
- $I_4 = \frac{V_{cc} - V_S}{R_4} = 5.0811\ mA$
- $I_S = I_4 - I_6 = 4.6592\ mA$
- $I_G = 0 \Rightarrow I_D = I_S = 4.6592\ mA$
- $V_D = R_S\, I_D = 4,6592\ V$
- $V_{GS} = V_T - \sqrt{\frac{I_D}{K}} = -3,1585\ V$

VERIFICO SATURAZIONE : $V_{DS} < V_{GS} - V_T \rightarrow -8,259 < -2,1585$ OK (2)

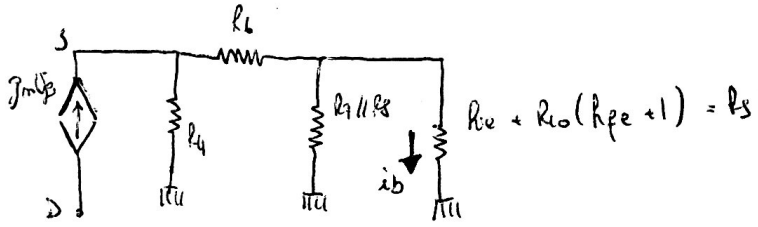
- $V_{GS} = V_G - V_S \Rightarrow V_G = V_{GS} + V_S = 9760665$ V

- $I_2 = \frac{V_{CC} - V_G}{R_2} = 0,82395$ mA

- $R_3 = \frac{V_G}{I_2} = 11845,94\ \Omega$

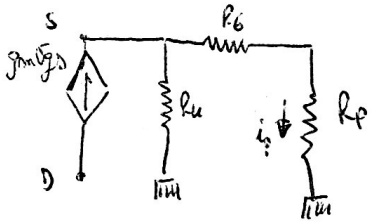


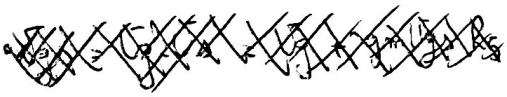
- $V_u = - h_{fe}\, i_b \cdot (R_q \,//\, R_{12})$

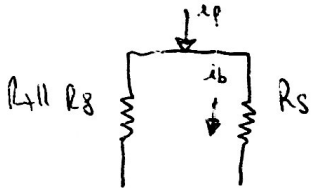


- $i_p = g_m V_{gs} \cdot \dfrac{R_L}{R_6 + R_p + R_L}$

- $i_b = i_p \cdot \dfrac{R_7 \,//\, R_8}{R_5 + R_7 \,//\, R_8}$







- $V_{gs} = V_g - V_s$

- $I_L = g_m V_{gs} \cdot \dfrac{R_6 + R_p}{R_L + R_6 + R_p}$

- $V_s = R_L \cdot I_L = R_L \cdot g_m V_{gs} \cdot \dfrac{R_6 + R_p}{R_L + R_6 + R_p}$

- $V_{gs} = V_g - R_L g_m V_{gs} \dfrac{R_6 + R_p}{R_L + R_6 + R_p} = V_g - g_m R_L \cdot R_{eq_1} \cdot V_{gs} \Rightarrow V_{gs} = \dfrac{V_g}{1 + g_m R_{eq_1} R_L}$

- $V_g = V_i \cdot \dfrac{R_2 \,//\, R_3}{R_1 + R_2 \,//\, R_3}$

- $\dfrac{V_u}{V_i} = - h_{fe} (R_q \,//\, R_{12}) \cdot \dfrac{R_7 \,//\, R_8}{R_5 + R_7 \,//\, R_8} \cdot g_m \dfrac{R_L}{R_6 + R_L + R_p} \cdot \dfrac{1}{1 + g_m R_{eq_1} R_L} \cdot \dfrac{R_2 \,//\, R_3}{R_1 + R_2 \,//\, R_3}$

9/01/2015

$$Y = (\overline{\bar{A} + C})(\bar{C}D + \bar{D}E) + (\overline{D + \bar{E}})(A + B\bar{C}) + B\bar{C} + \bar{D}E$$

$$Y = (A \cdot \bar{C})(\bar{C}D + \bar{D}\bar{E}) + (\bar{D} \cdot E)(A + B\bar{C}) + B\bar{C} + \bar{D}E$$

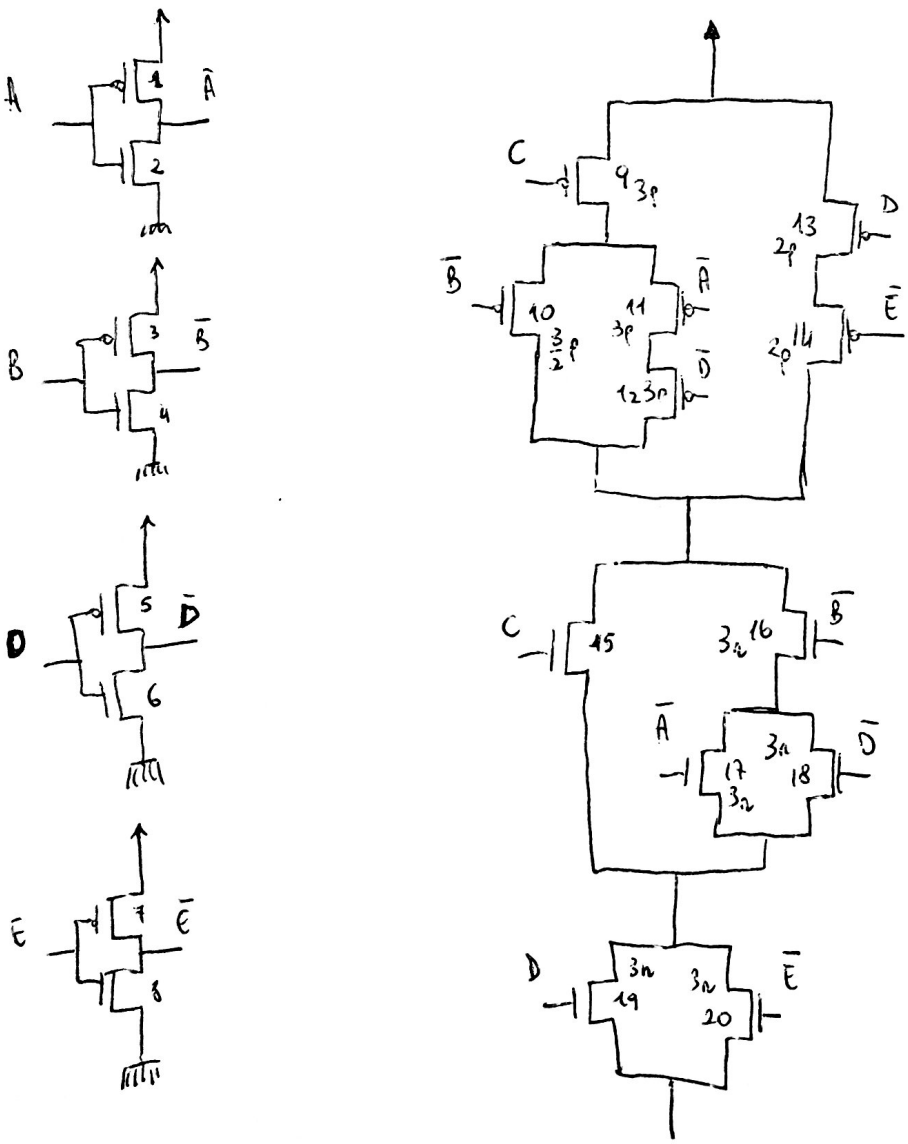
$$Y = A\bar{C}D + A\bar{C}\bar{D}E + A\bar{D}E + B\bar{C}\bar{D}E + B\bar{C} + \bar{D}E$$

$$Y = A\bar{D}E + A\bar{C}D + B\bar{C}\bar{D}E + B\bar{C} + \bar{D}E$$

$$Y = A\bar{C}D + A\bar{D}E + B\bar{C}(1 + \bar{D}E) + \bar{D}E \quad \circ \quad Y = A\bar{D}E + A\bar{C}D + B\bar{C} + \bar{D}E(1 + B\bar{C})$$

$$Y = A\bar{C}D + \bar{D}E(1 + A) + B\bar{C}$$

$$Y = B\bar{C} + \bar{D}E + A\bar{C}D = \bar{C}(B + AD) + \bar{D}E$$



- INVERTER

$\left(\frac{W}{L}\right)_1 = \left(\frac{W}{L}\right)_3 = \left(\frac{W}{L}\right)_5 = \left(\frac{W}{L}\right)_7 = p = 5$

$\left(\frac{W}{L}\right)_2 = \left(\frac{W}{L}\right)_4 = \left(\frac{W}{L}\right)_6 = \left(\frac{W}{L}\right)_8 = n = 2$

PUN

- WORST CASE Q_9, Q_{10}, Q_{11}

$\left(\frac{W}{L}\right)_9 = \left(\frac{W}{L}\right)_{11} = \left(\frac{W}{L}\right)_{12} = x$

$\frac{1}{x} + \frac{1}{x} + \frac{1}{x} = \frac{1}{p} \Rightarrow \frac{3}{x} = \frac{1}{p} \Rightarrow x = 3p$

- WORST CASE 2 : Q_{13}, Q_{14} o $Q_9 - Q_{10}$

$\left(\frac{W}{L}\right)_{13} = \left(\frac{W}{L}\right)_{14} = y$

$\frac{1}{y} + \frac{1}{y} = \frac{1}{p} \Rightarrow \frac{2}{y} = \frac{1}{p} \rightarrow y = 2p$

$\left(\frac{W}{L}\right)_9 = 3p \quad \left(\frac{W}{L}\right)_{10} = z$

$\frac{1}{z} + \frac{1}{3p} = \frac{1}{p} \rightarrow \frac{1}{z} = \frac{2}{3p} \Rightarrow z = \frac{3}{2}p$

- PDN

- WORST CASE : Q_{16}, Q_{17}, Q_{19} o Q_{16}, Q_{17}, Q_{20} o Q_{16}, Q_{18}, Q_{20}

Q_{16}, Q_{18}, Q_{19} non si può perché sono presenti D e $\bar{D}$

$\left(\frac{W}{L}\right)_{16} = \left(\frac{W}{L}\right)_{17} = \left(\frac{W}{L}\right)_{19} = x$

$\frac{1}{x} + \frac{1}{x} + \frac{1}{x} = \frac{1}{n} \rightarrow x = 3n$

$\left(\frac{W}{L}\right)_{16} = \left(\frac{W}{L}\right)_{17} = 3n \quad \left(\frac{W}{L}\right)_{20} = y$

$\frac{1}{y} + \frac{1}{3n} + \frac{1}{3n} = \frac{1}{n} \rightarrow \frac{1}{y} = \frac{1}{n} - \frac{2}{3n} \rightarrow \frac{1}{y} = \frac{1}{3n} \rightarrow y = 3n$

- WORST CASE 2 : Q_{15}, Q_{19} o Q_{15}, Q_{20}

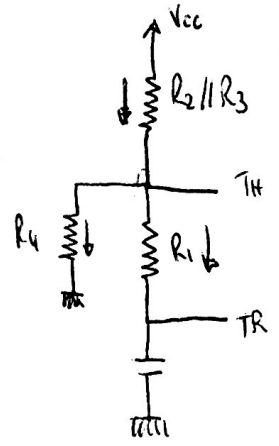
$\left(\frac{W}{L}\right)_{15} = z \quad \left(\frac{W}{L}\right)_{19} = 3n$

$\frac{1}{z} + \frac{1}{3n} = \frac{1}{n} \rightarrow z = \frac{3}{2}n$

9/01/2015

ESERCIZIO c)

$Q = 1 \rightarrow D = 117 \rightarrow Q_1 = ON$



- $V_i = \frac{1}{3} V_{cc} = 2\,V$
- $V_f = V_{cc} \frac{R_4}{R_4 + R_2 // R_3} = 5{,}4782\,V = \frac{126}{23}\,V$

V_{comm} si calcola con $V_{TH} = \frac{2}{3} V_{cc} = 4\,V$

$$I_{2/3} = \frac{V_{cc} - V_{TH}}{R_2 // R_3} = \frac{21}{1000}\,A$$

$$I_4 = \frac{V_{TH}}{R_4} = \frac{4}{1000}\,A \rightarrow I_1 = I_{2/3} - I_4 = \frac{17}{1000}\,A$$

- $V_{comm} = V_{TH} - R_1 I_1 = \frac{63}{20}\,V = 3{,}15$

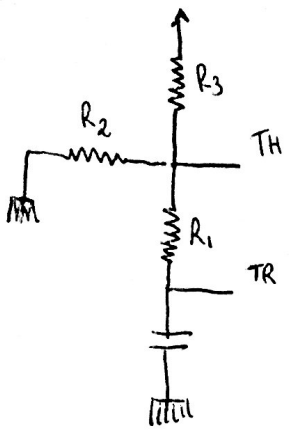
VERIFICO CHE: $V_i < V_{comm} < V_f \rightarrow OK$

$$T_1 = \tau_1 \ln\left(\frac{V_i - V_{f\infty}}{V_{comm} - V_f}\right) =$$

$$\tau_1 = R_{eq} \cdot C = \left[R_1 + R_2 // R_3 // R_4\right] \cdot C = \frac{3150}{23} \cdot C = \frac{63}{460000}\,s \approx 1{,}36956 \cdot 10^{-4}\,s$$

$$T_1 = 5.4975832 \cdot 10^{-5}\,s$$

$Q = 0 \rightarrow D = 0 \rightarrow Q_1 = OFF$



- $V_i = 3.15\ V$
- $V_{comm} = 2\ V$
- $V_f = V_{cc} \cdot \frac{R_2}{R_2 + R_3} = \frac{2}{7}\ V$

VERIFICO CHE $V_i > V_{comm} > V_f \rightarrow$ OK

$$T_2 = \tau_2 \ln\left(\frac{V_i - V_f}{V_{comm} - V_f}\right)$$

$$T_2 = R_{V_2} \cdot C = \left[R_1 + R_2 // R_3\right] \cdot C = \frac{3050}{21} \cdot C = \frac{61}{420000}\ s \approx 1.4523809 \cdot 10^{-4}\ s$$

$T_2 \approx$ ~~$2.5571809 \cdot 10^{-5}\ s$~~
$7.455398272 \cdot 10^{-5}\ s$

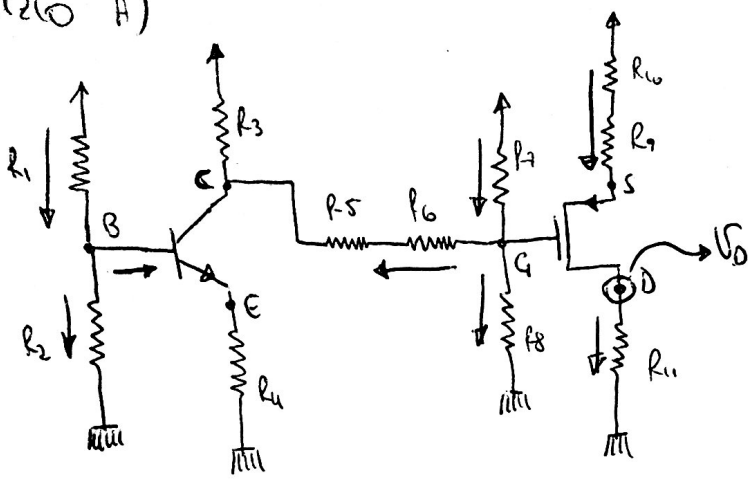
- - -

$T = T_1 + T_2 =$ ~~$5.755335009 \cdot 10^{-5}\ s$~~ $1.295298147 \cdot 10^{-4}\ s$

$$f = \frac{1}{T} = 7720\ Hz$$

15/09/2014

(ESERCIZIO A)



- $I_D = \frac{V_D}{R_{11}} = 4.5$ mA
- $I_G = 0 \Rightarrow I_S = I_D = 4.5$ mA
- $V_S = V_{CC} - (R_9 + R_{10}) I_S = 13.5$ V
- $V_{GS} = -V_T - \sqrt{\frac{I_D}{K}} = -1 - \sqrt{\quad} = -4$
- VERIFICO LA SATURAZIONE $V_{DS} < V_{GS} - V_T \rightarrow -6,3 < -3$ OK
- $V_{GS} = V_G - V_S \rightarrow V_G = V_{GS} + V_S = 9.5$ V
- $I_7 = \frac{V_{CC} - V_G}{R_7} = 2$ mA
- $I_8 = \frac{V_G}{R_8} = 0.5$ mA
- $I_5 = I_7 - I_8 = 1,5$ mA
- $V_C = V_G - (R_5 + R_6) I_5 = 8$ V
- $I_3 = \frac{V_{CC} - V_C}{R_3} = 0,5$ mA
- $I_C = I_3 + I_5 = 2$ mA

SUPPONIAMO Z.A.D : $I_C \gg I_B \Rightarrow I_E \approx I_C = 2$ mA

- $V_E = R_4 \cdot I_E = 3$ V

VERIFICHIAMO Z.A.D $V_{CE} > V_{CE\,SAT} \rightarrow 5V > 0.2$ V OK

- $I_B = \frac{I_C}{h_{FE}} = 6,8965$ μA

- $V_{BE} = V_B - V_E \Rightarrow V_B = V_E + V_{BE} = 3.7\ V$
- $I_1 = \frac{V_{CC} - V_B}{R_1} = 20\ \mu A$
- $I_2 = I_1 - I_B = 13,1035\ \mu A$
- $R_2 = \frac{V_B}{I_2} = 282361,3064\ \Omega$

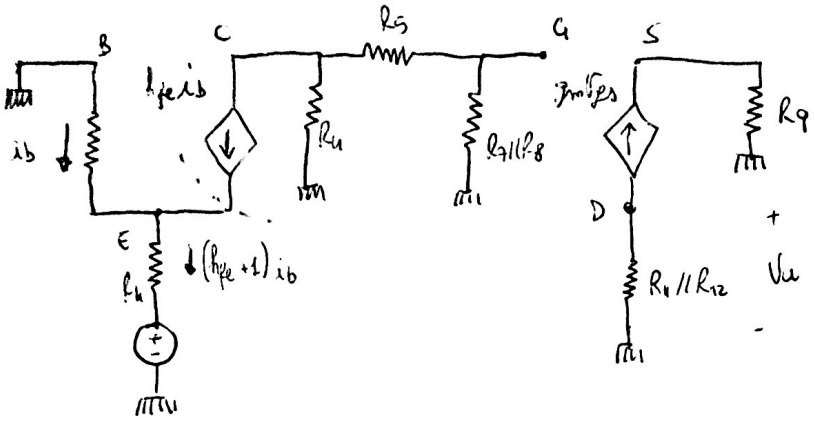
PUNTI DI RIPOSO

Q_1:

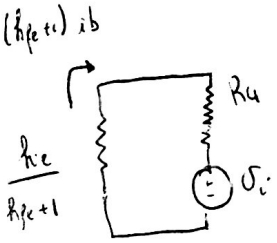
$h_{fe} = 300 \quad h_{FE} = 290 \quad h_{ie} = 6.8\ K\Omega \quad I_C = 2\ mA \quad V_{CE} = 5\ V$

Q_2:

$I_D = 6.5\ mA \quad V_{DS} = -6,3\ V \quad g_m = 2K\,|V_{GS} - V_T| = 3\ \frac{mA}{V}$



- $V_u = -g_m V_{gs} \; (R_{11} // R_{12})$
- $V_{gs} = V_g - V_s = V_g - g_m V_{gs} R_g \rightarrow V_{gs} = \dfrac{V_g}{1 + g_m R_g}$
- $V_g = -h_{fe}\, i_b \cdot \dfrac{R_3}{R_3 + R_5 + R_7 // R_8} \cdot R_7 // R_8$



- $(h_{fe}+1)\, i_b = -\dfrac{V_i}{R_4 + \dfrac{h_{ie}}{h_{fe}+1}}$
- $(h_{fe}+1)\, i_b = -\dfrac{V_i}{\dfrac{(h_{fe}+1)R_4 + h_{ie}}{h_{fe}+1}} \rightarrow i_b = -\dfrac{V_i}{h_{ie} + R_4 (h_{fe}+1)}$

- $\dfrac{V_u}{V_i} = -g_m (R_{11} // R_{12}) \cdot \dfrac{1}{1 + g_m R_g} \cdot h_{fe} \dfrac{R_3 \cdot (R_7 // R_8)}{R_3 + R_5 + R_7 // R_8} \dfrac{1}{h_{ie} + R_4 (h_{fe}+1)} = \boxed{-6,1665}$

ESERCIZIO B)

15/09/2014

$$Y = \overline{BC}\,(\bar{A} + D + \bar{E}) + \bar{B}(\bar{D} + AC) + CD$$

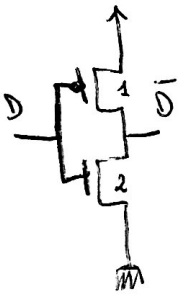
$$Y = (\bar{B} + \bar{C})(\bar{A} + D + \bar{E}) + \bar{B}\bar{D} + A\bar{B}C + CD$$

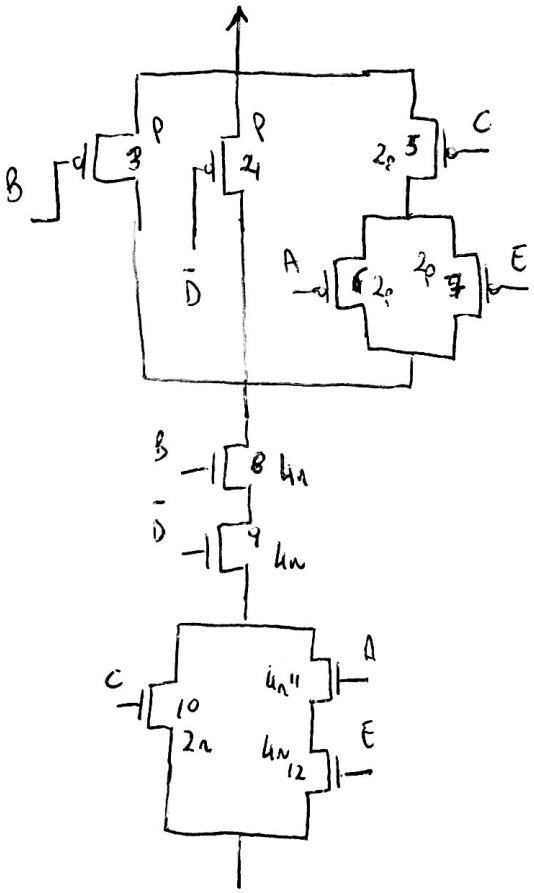
$$Y = \bar{A}\bar{B} + \bar{B}D + \bar{B}\bar{E} + \bar{A}\bar{C} + \bar{C}D + \bar{C}\bar{E} + \bar{B}\bar{D} + \bar{A}\bar{B}C + CD$$

$$Y = \bar{B} + D + \bar{A}\bar{B} + \bar{B}\bar{E} + \bar{A}\bar{C} + \bar{C}\bar{E} + A\bar{B}C$$

$$Y = \bar{B}(1 + \bar{A} + \bar{E} + AC) + D + \bar{A}\bar{C} + \bar{C}\bar{E}$$

$$Y = \bar{B} + \bar{D} + \bar{C}(\bar{A} + \bar{E})$$





- INVERTER DI BASE

$$\left(\frac{W}{L}\right)_1 : P = 5$$

$$\left(\frac{W}{L}\right)_2 : n = 2$$

- PUN

  - WORST CASE : Q_5, Q_6 e Q_5, Q_7

  $\left(\frac{W}{L}\right)_5 = \left(\frac{W}{L}\right)_6 = x$ onde $\left(\frac{W}{L}\right)_7 = 2p = 10$

  $\frac{1}{x} + \frac{1}{x} = \frac{1}{p} \Rightarrow x = 2p = 10$

  - WORST CASE : Q_3 e Q_4

  $\left(\frac{W}{L}\right)_3 = \left(\frac{W}{L}\right)_4 = y$

  $\frac{1}{y} = \frac{1}{p} \rightarrow y = p = 5$

- PDN

  - WORST CASE : Q_8, Q_9, Q_{11}, Q_{12}

  $\left(\frac{W}{L}\right)_{8,9,11,12} = x$

  $\frac{1}{x} + \frac{1}{x} + \frac{1}{x} + \frac{1}{x} = \frac{1}{n} \rightarrow \frac{4}{x} = \frac{1}{n} \rightarrow x = 4n = 8$

  - WORST CASE : Q_8, Q_9, Q_{10}

  $\left(\frac{W}{L}\right)_{8,9} = 4n \quad \left(\frac{W}{L}\right)_{10} = y$

  $\frac{1}{4n} + \frac{1}{4n} + \frac{1}{y} = \frac{1}{n} \rightarrow \frac{1}{y} = +\frac{1}{n} - \frac{1}{2n} \rightarrow \frac{1}{y} = \frac{1}{2n} \rightarrow y = 2n = 4$

15/09/2014

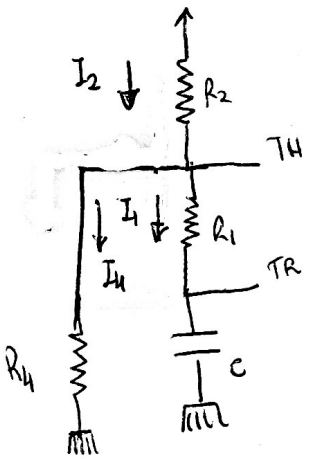
ESERCIZIO c)

Q=1 → D='Hz

~~TH OFF~~ ~~TH ON~~

$V_{g1} = 0 \rightarrow V_{s1} = 0 \Rightarrow V_{gs} = 0\,V < V_{T1} = 1\,V \Rightarrow Q_1 = OFF$

$V_{g2} = 0 \rightarrow V_{s2} = V_{cc} \rightarrow V_{es2} = -V_{cc} < V_{T2} = -1V \Rightarrow Q_2 = ON$



- $V_i = \frac{1}{3} V_{cc} = 2V$
- $V_f = V_{cc} \cdot \frac{R_4}{R_2 + R_4} = 5V$
- V_{comm} con $V_{TH} = \frac{2}{3} V_{cc} = 4V$

$I_2 = \frac{V_{cc} - V_{TH}}{R_2} = 2\,mA \qquad I_4 = \frac{V_{TH}}{R_4} = 8 \cdot 10^{-4}\,A$

$V_{comm} = V_{TH} - R_1 I_1 = V_{TH} - R_1 (I_2 - I_4) = 2.8\,V$

VERIFICO CHE: $V_i < V_{comm} < V_f$ → ok

$$T_1 = T_1 \ln\left(\frac{V_i - V_f}{V_{comm} - V_f}\right)$$

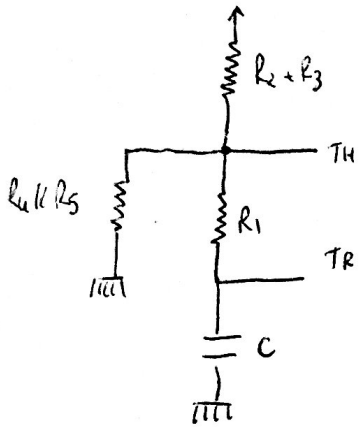
$$T_1 = R_{v_1} \cdot C = \left[R_1 + R_2 // R_4\right] \cdot C = \frac{5500}{8} \cdot C = \frac{11}{60000}\ s$$

$T_1 = 5.68617 \cdot 10^{-5}\ s$

$Q = 0 \rightarrow D = 0$

$V_{g_1} = V_{cc}$ $\quad V_S = 0\,V$ $\quad V_{GS_1} = V_{cc} = 6V > V_{T_1} = 1\,V$ $\quad \Rightarrow Q_1 = ON$

$V_{G_2} = V_{cc}$ $\quad V_{S_2} = V_{cc}$ $\quad V_{GS_2} = 0V > V_{T_2} = -1V$ $\quad \Rightarrow Q_2 = OFF$



- $V_i = 2.8\,V$
- $V_{comando} = 2\,V$
- $V_f = V_{cc} \cdot \dfrac{R_4 // R_5}{R_2 + R_3 + R_4 // R_5} = \dfrac{3}{5} = 0.6\,V$

VERIFICO CHE $V_i > V_{comando} > V_f \rightarrow OK$

$$T_2 = \tau_2 \ln\left(\frac{V_i - V}{V_{comando} - V_f}\right)$$

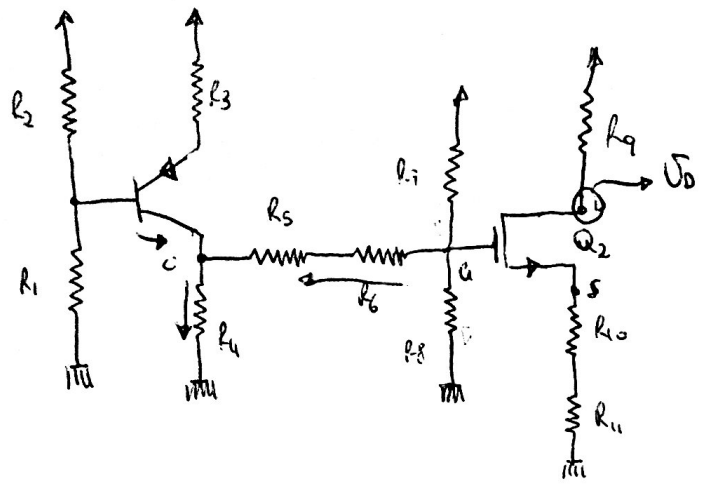
$$T_2 = R_{V_2} \cdot C = \left[R_1 + \underbrace{(R_2+R_3)}_{22500} // \underbrace{(R_4 // R_5)}_{2500}\right] \cdot C = 3250 \cdot C = \frac{13}{60000}\,s$$

$$T_2 = 1.4689516\ 10^{-4}\,s$$

$$T = T_1 + T_2 = 2.037568\ 10^{-4}\,s$$

$$\boxed{f = \frac{1}{T} = 4907.81\,Hz}$$

21/07/2014



- $I_9 = \frac{V_{cc} - V_D}{R_9} = 1\,mA = I_D$
- $I_G = 0 \rightarrow I_S = 4\,mA = I_D$
- $V_S = (R_{10} + R_{11})\, I_S = 4\,V$
- $V_{GS} = V_T + \sqrt{\frac{I_D}{k}} = 5\,V$
- VERIFICO SATURAZIONE: $V_{DS} > V_{GS} - V_T \rightarrow 6 > 4$ OK
- $V_{GS} = V_G - V_S \rightarrow V_G = V_{GS} + V_S = 9V$
- $I_7 = \frac{V_{cc} - V_G}{R_7} = 1\,mA$
- $I_8 = \frac{V_G}{R_8} = 0{,}5\,mA$
- $I_6 = I_7 - I_8 = 0{,}5\,mA$
- $V_G - V_E = (R_5 + R_6)\, I_6 \Rightarrow V_E = V_G - (R_5 + R_6)\, I_6 = 3.7\,V$
- $I_4 = \frac{V_C}{R_4} = 2{,}5\,mA$
- $I_C = I_4 - I_6 = 2mA$ (in realtà è la corrente da E a C, positiva). (La corrente da C ad E è negativa)
- $V_B = V_{cc} \cdot \frac{R_1}{R_1 + R_2} = 8V$

- $V_{BC} = V_B - V_C \Rightarrow V_E = V_B - V_{BE} = 8.7\ V$
- $V_{CE} = V_C - V_E = -5\ V$
- $I_C = I_E$ poiché $I_B = 0$
- $R_3 = \frac{V_{CC} - V_E}{I_E} = 1650\ \Omega$

PUNTI DI RIPOSO

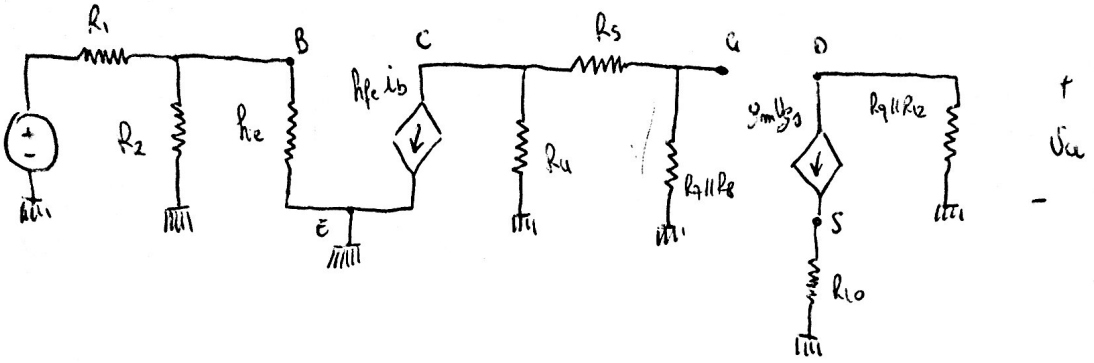
Q_1:

$I_C = -2\ mA$ $V_{CE} = -5\ V$ $h_{fe} = 260$ $h_{ie} = 2.7\ k\Omega$

Q_2:

$I_D = 4.5\ mA$ $V_{DS} = 6\ V$ $g_m = 2k\,|V_{GS} - V_T| = 2\ m\frac{A}{V}$

21/07/2014

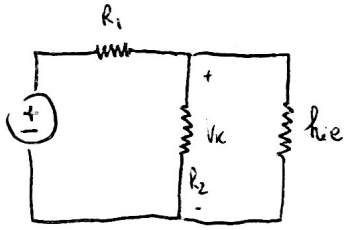


- $\frac{V_u}{V_i} = -g_m V_{gs} \, (R_g \parallel R_{12})$

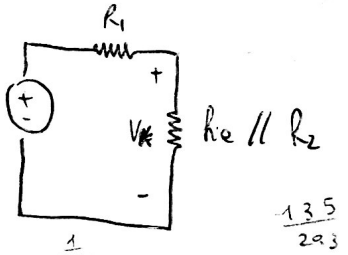
- $V_{gs} = V_g - V_s = V_g - g_m V_{gs} R_{10} \rightarrow V_{gs} = \frac{V_g}{1 + g_m R_{10}}$

- $V_g = -h_{fe} i_b \frac{R_u}{R_u + R_s + R_7 \parallel R_8} \cdot R_7 \parallel R_8$

- $i_b = \frac{V_R}{h_{ie}}$



- $V_R = V_i \cdot \frac{h_{ie} \parallel R_2}{R_1 + h_{ie} \parallel R_2}$



$\frac{4}{41}$ $\frac{5}{6}$ 285762,5763 $\frac{1}{2800}$ $\frac{135}{293}$

- $\frac{V_u}{V_i} = \overbrace{g_m \, (R_g \parallel R_{12})}^{\frac{4}{41}} \cdot \overbrace{\frac{1}{1 + g_m R_{10}}}^{\frac{5}{6}} \cdot \overbrace{h_{fe} \cdot \frac{R_u \cdot R_7 \parallel R_8}{R_u + R_s + R_7 \parallel R_8}}^{285762,5763} \cdot \overbrace{\frac{1}{h_{ie}}}^{\frac{1}{2800}} \cdot \overbrace{\frac{h_{ie} \parallel R_2}{R_1 + h_{ie} \parallel R_2}}^{\frac{135}{293}} = \boxed{3.964}$

ESERCIZIO 3)

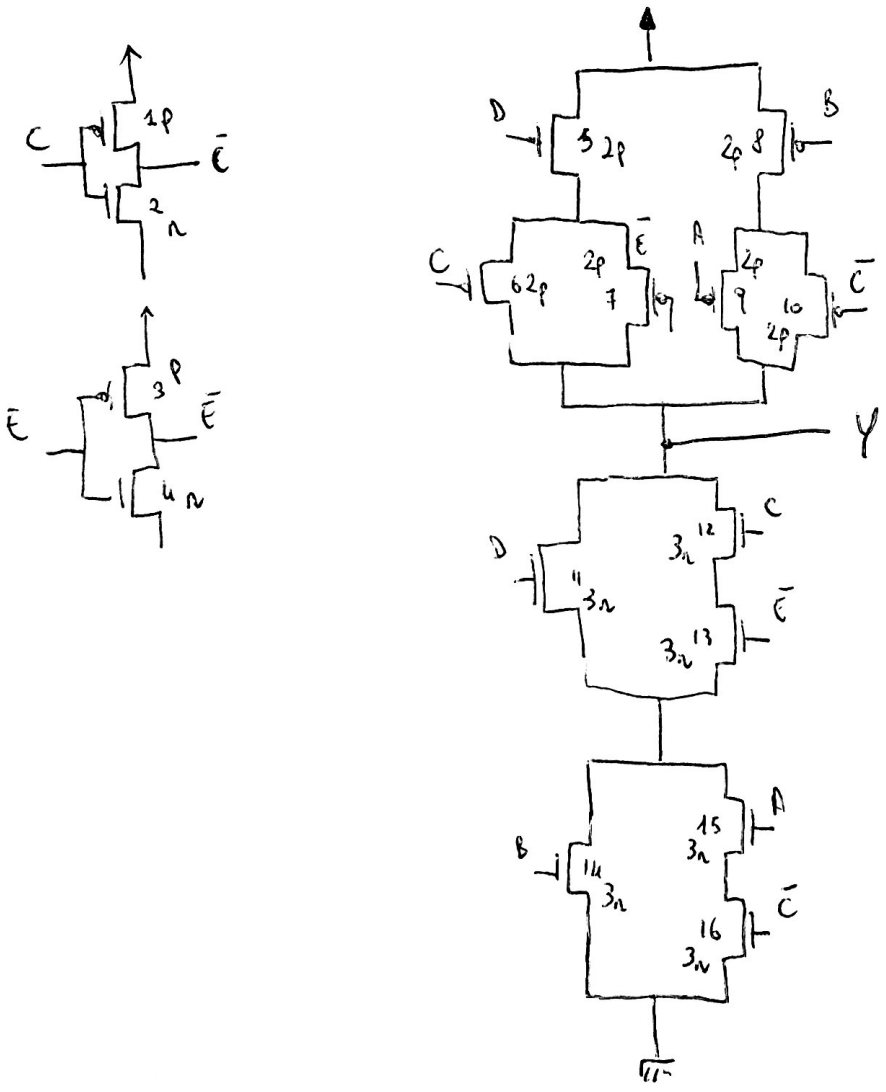
$$Y = \overline{\bar{A}C}\,(\bar{B}C + \bar{C}\bar{D}) + \bar{B}(\bar{A}+C) + \bar{D}E$$

$$Y = (\bar{A}+\bar{C})(\bar{B}C + \bar{C}\bar{D}) + \bar{A}\bar{B} + \bar{B}C + \bar{D}E$$

$$Y = \bar{A}\bar{B}C + \bar{A}\bar{C}\bar{D} + \bar{C}\bar{D} + \bar{A}\bar{B} + \bar{B}C + \bar{D}E$$

$$Y = \bar{C}\bar{D} + \bar{A}\bar{B} + \bar{B}C + \bar{D}E$$

$$Y = \bar{D}(\bar{C}+E) + \bar{B}(\bar{A}+C)$$



- INVERTER DI BASE

$$\left(\frac{W}{L}\right)_1 = \left(\frac{W}{L}\right)_3 = p = 5$$

$$\left(\frac{W}{L}\right)_2 = \left(\frac{W}{L}\right)_4 = n = 2$$

- PUN

- WORST CASE: Q_5, Q_6 o Q_5, Q_7 o Q_8, Q_9 o Q_8, Q_{10}

$\left(\frac{W}{L}\right)_5 = \left(\frac{W}{L}\right)_6 =$ ✗

$\frac{1}{x} + \frac{1}{x} = \frac{1}{p} \rightarrow \frac{2}{x} = \frac{1}{p} \rightarrow x = 2p = 10$

$\left(\frac{W}{L}\right)_{5,6,7,8,9,10} = 2p = 10$

- PDN

- WORST CASE: $Q_{12}, Q_{13}, Q_{15}, Q_{16}$ ma non è possibile perché presenti C e $\bar{C}$.

- WORST CASE 2): Q_{11}, Q_{15}, Q_{16} o Q_{12}, Q_{13}, Q_{14}

$\left(\frac{W}{L}\right)_{12,13,16} = X$

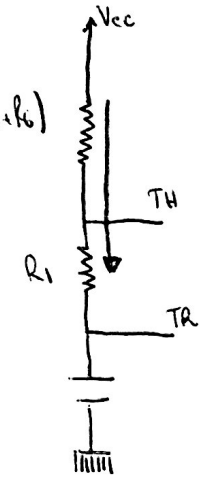
$\frac{1}{x} + \frac{1}{x} + \frac{1}{x} = \frac{1}{n} \rightarrow \frac{3}{x} = \frac{1}{n} \rightarrow x = 3n = 6$

$\left(\frac{W}{L}\right)_{11,12,13,14,15,16} = 3n = 6$

ESERCIZIO C

$Q = 1 \rightarrow D' = HZ$

$V_{G1} = V_{cc} \cdot \frac{R_3}{R_3 + R_4} = 1\,V \qquad V_{S_1} = V_{cc} = 5\,V \qquad V_{GS_1} = -4\,V < V_T = -1\,V \qquad Q_1 = ON$



2250 Ω $R_2 // (R_5 + R_6)$

- $V_i = \frac{1}{3} V_{cc} = \frac{5}{3}\,V$
- $V_f = V_{cc}$
- V_{comm} se $V_{TH} = \frac{2}{3} V_{cc} = \frac{10}{3}\,V$

$$I = \frac{V_{cc} - V_{TH}}{R_2 // (R_5 + R_6)} = \frac{1}{1350}\,A$$

- $V_{comm} = V_{TH} - R_1 I = \frac{70}{27}\,V$

VERIFICO CHE $V_i < V_{comm} < V_f \rightarrow OK$

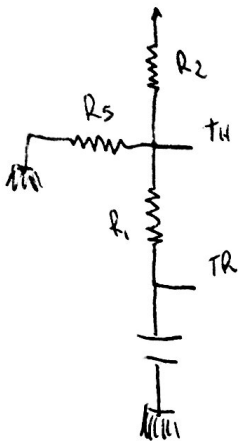
$$T_1 = \tau_1 \ln\left(\frac{V_i - V_f}{V_{comm} - V_f}\right)$$

$$T_1 = R_{eq_1} \cdot C = \left[R_1 + R_2 // (R_5 + R_6)\right] \cdot C = 3250 \cdot C = \frac{429}{400\,000}\,s$$

$$T_1 = 3.490155245 \cdot 10^{-4}\,s$$

$Q = 0 \rightarrow D = 0$

$V_{e1} = 0 \quad V_{S_1} = V_{cc} = 5\,V \quad V_{eS_1} = -V_{cc} = -5 < V_T = -1\,V \quad Q_1 = ON$



- $V_i = \frac{10}{27}\,V$
- $V_{comm} = \frac{5}{3}\,V$
- $V_f = V_{cc} \cdot \frac{R_5}{R_2 + R_5} = \frac{1}{2}\,V$

VERIFICO CHE $V_i > V_{comm} > V_f \rightarrow OK$

$$T_2 = \tau_2 \ln\left(\frac{V_i - V_f}{V_{comm} - V_f}\right)$$

$$\tau_2 = R_{eq} \cdot C = \left[R_1 + R_2 \| R_5\right] \cdot C = 1900 \cdot C = 6.27 \cdot 10^{-4}\,s$$

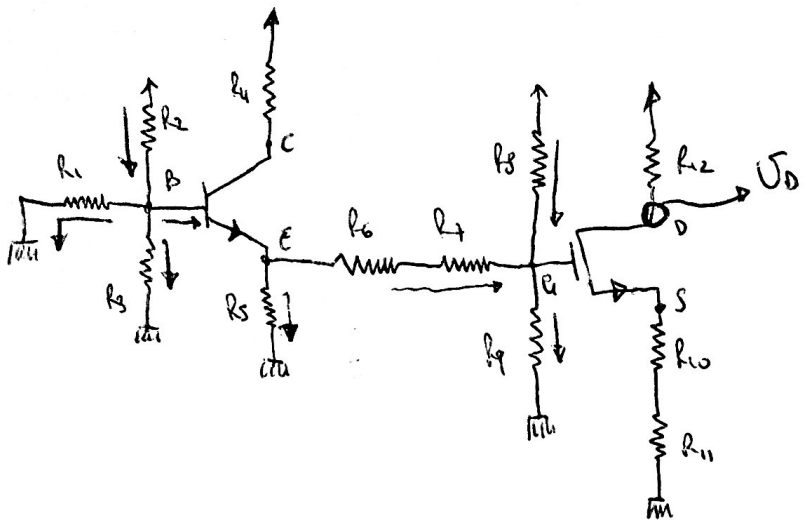
$$T_2 = 3.663266889 \cdot 10^{-4}$$

$$T = T_1 + T_2 = 7.153422134 \cdot 10^{-4}\,s$$

$$\boxed{f = \frac{1}{T} = 1397.93\ Hz}$$

30/06/2014

ESERCIZIO A)



- $I_D = \frac{V_{cc} - V_D}{R_{12}} = 2\,mA$
- $I_G = 0 \rightarrow I_S = I_D = 2\,mA$
- $V_S = (R_{10} + R_{11}) \cdot I_S = 6\,V$
- $V_{GS} = V_T + \sqrt{\frac{I_D}{k}} = 3\,V$

VERIFICO SATURAZIONE $V_{DS} > V_{GS} - V_T \rightarrow 4 > 2$ OK

- $V_{GS} = V_G - V_S \Rightarrow V_G = V_{GS} + V_S = 9\,V$
- $I_8 = \frac{V_{cc} - V_G}{R_8} = 0{,}5\,mA$
- $I_9 = \frac{V_G}{R_9} = 1{,}5\,mA$
- $I_7 = I_9 - I_8 = 1\,mA$
- $V_E - V_G = (R_6 + R_7) I_7 \Rightarrow V_E = V_G + (R_6 + R_7) I_7 = 10\,V$
- $I_5 = \frac{V_E}{R_5} = 1\,mA$
- $I_E = 2\,mA$
- SUPPONIAMO ZAD $\Rightarrow I_C \gg I_B \Rightarrow I_C \approx I_E \Rightarrow I_C = 2\,mA$
- $V_{cc} - V_C = R_4 I_C \rightarrow V_C = V_{cc} - R_4 I_C = 15\,V$

VERIFICO ZAD : $V_{CE} > V_{CE_{SAT}} \rightarrow 5\ V > 0.2\ V \rightarrow$ OK

- $I_B = \frac{I_C}{h_{FE}} = 6.8465\ \mu A$
- $V_B = V_{BE} + V_E = 10.7\ V$
- $I_3 = \frac{V_B}{R_3} = 21.4 \cdot \mu A$
- $I_1 = \frac{V_B}{R_1} = 1.07\ mA$
- $I_2 = I_1 + I_3 + I_B = 1.0982965 \cdot 10^{-3}\ mA$

- $R_2 = \frac{V_{cc} - V_B}{I_2} = 6666.65\ \Omega$

PUNTI DI RIPOSO

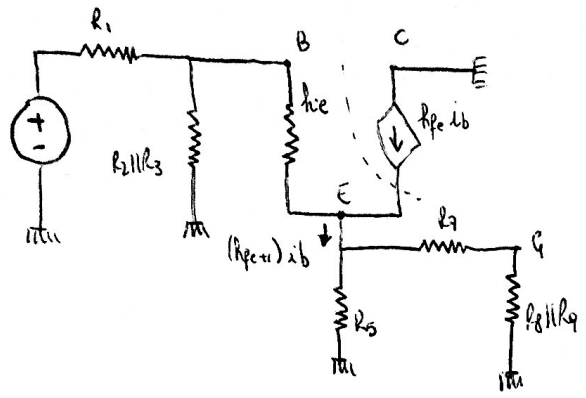
- Q_1 :

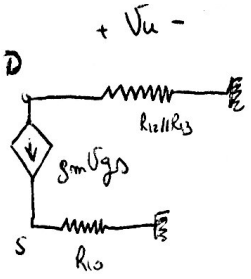
$h_{FE} = 290 \quad h_{fe} = 300 \quad h_{ie} = 6.8\ k\Omega \quad I_C = 2mA \quad V_{CE} = 5\ V$

- Q_2 :

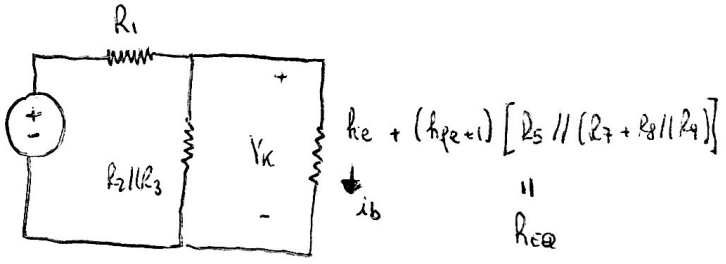
$I_D = 2mA \quad V_{DS} = 4\ V \quad g_m = 2k\,|V_{GS} - V_T| = 2m\frac{A}{V}$

-
-

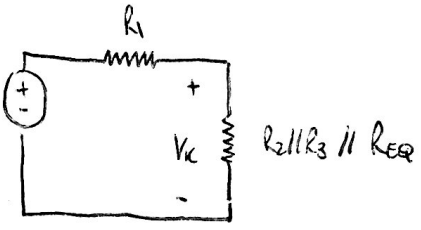




- $V_u = -g_m V_{gs} (R_{12} // R_{13})$
- $V_{gs} = V_g - V_s = V_g - g_m V_{gs} R_{10} \rightarrow V_{gs} = \frac{V_g}{1 + g_m R_{10}}$
- $V_g = (h_{fe}+1)\, i_b \cdot \frac{R_5}{R_5 + R_7 + R_8 // R_9} \cdot R_8 // R_9$
- $i_b = \frac{V_K}{h_{ie} + (h_{fe}+1)\left[R_5 // (R_7 + R_8 // R_9)\right]}$



- $V_K = V_i \; \frac{R_2 // R_3 // \left\{h_{ie} + (h_{fe}+1)\left[R_5 // (R_7 + R_8 // R_9)\right]\right\}}{R_1 + R_2 // R_3 // \left\{h_{ie} + (h_{fe}+1)\left[R_5 // (R_7 + R_8 // R_9)\right]\right\}}$



- $\frac{V_u}{V_i} = -\underbrace{\frac{g_m (R_{12} // R_{13})}{1 + g_m R_{10}}}_{\frac{400}{7}} \cdot \underbrace{\frac{(h_{fe}+1) \cdot R_5 \cdot R_8 // R_9}{R_5 + R_7 \cdot R_8 // R_9}}_{930927\ 8351} \cdot \underbrace{\frac{1}{h_{ie} + (h_{fe}+1)\left[R_5 // (R_7 + R_8 // R_9)\right]}}_{\frac{1}{946071,4776}} \cdot \underbrace{\frac{R_2 // R_3 // \left\{h_{ie} + (h_{fe}+1)\left[R_5 // (R_7 + R_8 // R_9)\right]\right\}}{R_1 + R_2 // R_3 // \left\{h_{ie} + (h_{fe}+1)\left[R_5 // (R_7 + R_8 // R_9)\right]\right\}}}_{0,3944660792}$

$$\boxed{\frac{V_u}{V_i} = -2,01636}$$

30/06/2014

(ESERCIZIO B)

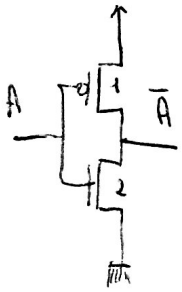
$$Y = (\overline{B+C})(\bar{A}\bar{B} + D + \bar{B}\bar{E}) + \overline{\bar{C}E}(\bar{A} + BD + \bar{E}) + A\bar{B}$$

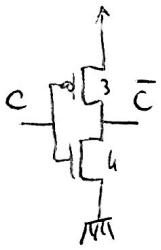
$$Y = (\bar{B}\cdot C)(\bar{A}\bar{B} + D + B\bar{E}) + (C+\bar{E})(\bar{A} + BD + \bar{E}) + A\bar{B}$$

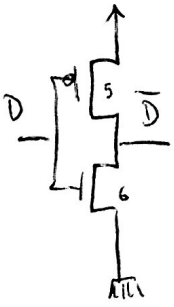
$$Y = A\bar{B}C + \bar{B}CD + \bar{B}C\bar{E} + \bar{A}C + BCD + C\bar{E} + \bar{A}\bar{E} + BD\bar{E} + \bar{E} + A\bar{B}$$

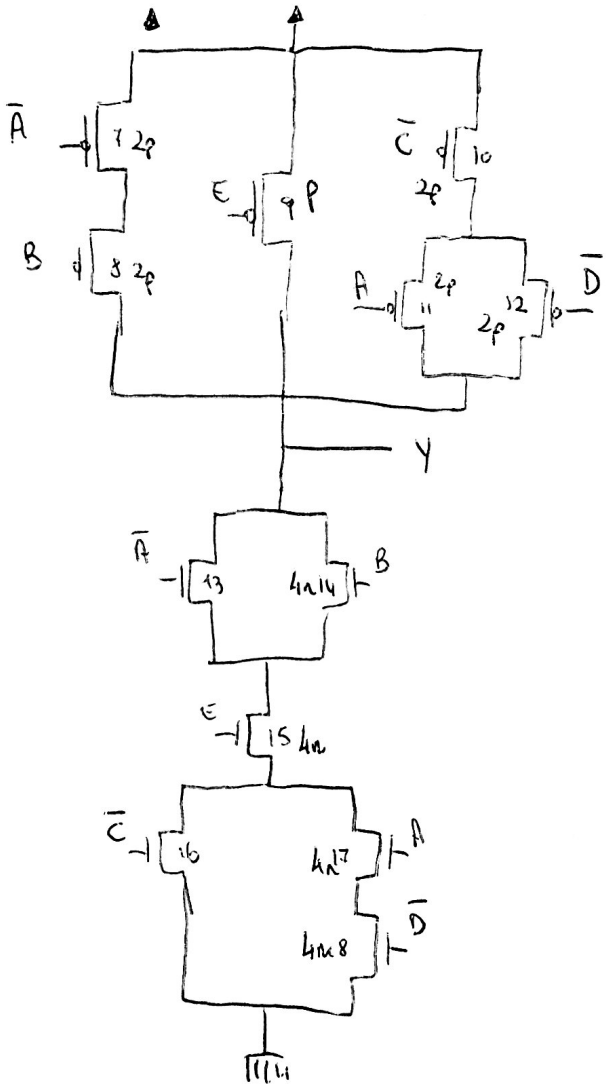
$$Y = A\bar{B} + \bar{E} + CD + \bar{A}C + \bar{B}C\bar{E}$$

$$Y = A\bar{B} + \bar{E} + CD + \bar{A}C = A\bar{B} + \bar{E} + C(\bar{A} + D)$$









- INVERTER DI BASE

$$\left(\frac{W}{L}\right)_1 = \left(\frac{W}{L}\right)_3 = \left(\frac{W}{L}\right)_5 = p = 5$$

$$\left(\frac{W}{L}\right)_2 = \left(\frac{W}{L}\right)_4 = \left(\frac{W}{L}\right)_6 = n = 2$$

- PUN

- WORST CASE : Q_7, Q_8 o Q_{10}, Q_{11} o Q_{10}, Q_{12}

$\left(\frac{W}{L}\right)_{7,8,10,11,12} = x$

$\frac{1}{x} + \frac{1}{x} = \frac{1}{p} \rightarrow \frac{2}{x} = \frac{1}{p} \rightarrow x = 2p = 10$

- WORST CASE : Q_9

$\left(\frac{W}{L}\right)_9 = y$

$\frac{1}{y} = \frac{1}{p} \rightarrow y = p = 5$

- PDN

- WORST CASE : $Q_{13}, Q_{15}, Q_{17}, Q_{18}$ non possibile perché A e $\bar{A}$.

$Q_{14}, Q_{15}, Q_{17}, Q_{18}$

$\left(\frac{W}{L}\right)_{14,15,17,18} = x$

$\frac{1}{x} + \frac{1}{x} + \frac{1}{x} + \frac{1}{x} = \frac{1}{R} \rightarrow x = 4n = 8$

- WORST CASE (2)

Due scelte:

1) Q_{14}, Q_{15}, Q_{16} e calcolo la 16

$\frac{1}{4n} + \frac{1}{4n} + \frac{1}{y} = \frac{1}{n} \rightarrow \frac{1}{y} = \frac{1}{n} - \frac{1}{2n} \rightarrow \frac{1}{y} = \frac{1}{2n} \rightarrow y = 2n$

Poi calcolo

Q_{13}, Q_{15}, Q_{16}

$\left(\frac{W}{L}\right)_{13} = z$

$\frac{1}{z} + \frac{1}{2n} + \frac{1}{4n} = \frac{1}{n} \rightarrow \frac{1}{z} = \frac{-1-2+4}{4n} \rightarrow \frac{1}{z} = \frac{1}{4n} \rightarrow z = 4n$

2) Q_{13}, Q_{15}, Q_{16}

$\left(\frac{W}{L}\right)_{13} = \left(\frac{W}{L}\right)_{16} = k$

$\frac{1}{k} + \frac{1}{k} + \frac{1}{4n} = \frac{1}{n} \Rightarrow \frac{2}{k} = \frac{4-1}{4n} \rightarrow \frac{2}{k} = \frac{3}{4n} \rightarrow 3k = 8n \quad k = \frac{8}{3}n$

SCELGO A SECONDA DELL'AREA

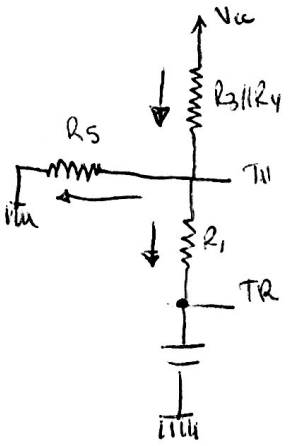
1) $4n + 4n + 4n + 4n + 2n + 4n = 64$

2) $4n + 4n + 4n + 4n + \frac{8}{3}n + \frac{8}{3}n = 62,67$ ⟶ SCELGO QUESTO CASO

ESERCIZIO c)

$Q=1 \rightarrow D='1'$

$V_{C_1}=0\,V \quad V_{S_1}=0\,V \quad V_{CS_1}=0V < V_{i_1}=1\,V \Rightarrow Q_1=OFF$



- $V_i = \frac{1}{3}V_{cc} = \frac{5}{3}\,V$
- $V_f = V_{cc} \cdot \frac{R_5}{R_5 + R_3 \| R_4} = 4\,V$
- V_{comm} se $V_{TH} > \frac{2}{3}V_{cc} = \frac{10}{3}\,V$

$$I_3 = \frac{V_{cc} - V_{TH}}{R_3 \| R_4} = \frac{1}{600}\,A$$

$$I_5 = \frac{V_{TH}}{R_5} = \frac{1}{1200}\,A$$

$$\Rightarrow I_1 = I_3 - I_5 = \frac{1}{1200}\,A$$

- $V_{comm} = V_{TH} - R_1 I_1 = \frac{35}{12}\,V$

VERIFICO CHE $V_i < V_{comm} < V_f \rightarrow OK$

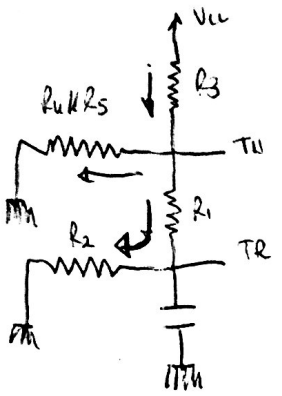
$$T_1 = \tau_1 \ln\left(\frac{V_i - V_f}{V_{comm} - V_f}\right)$$

$$T_1 = R_{u_1} \cdot C = \left[R_1 + R_3 \| R_4 \| R_5\right] \cdot C = 1300 \cdot C = \frac{13}{10000}\,s$$

$$T_1 = 9.974316985 \cdot 10^{-4}\,s$$

$Q = 0 \rightarrow D = 0$

$V_{G1} = V_{CC}$ $V_{S1} = 0$ $V_{GS1} = V_{CC} = 5V > V_T = 1\ V$ $Q_1 = ON$



- $V_i = \frac{35}{12}\ V$
- $V_{comm} = \frac{5}{3}\ V$

$V_f \rightarrow$ calcolo V_{TH} e poi V_{TR}

$$V_{TH} = V_{CC} \cdot \frac{(R_1+R_2)\ //\ (R_u // R_s)}{R_3 + [(R_1+R_2)\ //\ (R_u // R_s)} = \frac{10}{9}\ V$$

- $V_f = V_{TR} = V_{TH} \cdot \frac{R_2}{R_1+R_2} = \frac{5}{9}\ V$

VERIFICO CHE $V_i > V_{comm} > V_f \rightarrow OK$

$$T_2 = \tau_2 \ln\left(\frac{V_i - V_f}{V_{comm} - V_f}\right)$$

$$T_2 = R_{V_2} \cdot C = \left[R_2\ //\ [R_1 + (R_3 // R_u // R_s)]\right] \cdot C = \frac{3250}{9} \cdot C = \frac{13}{36000}\ s$$

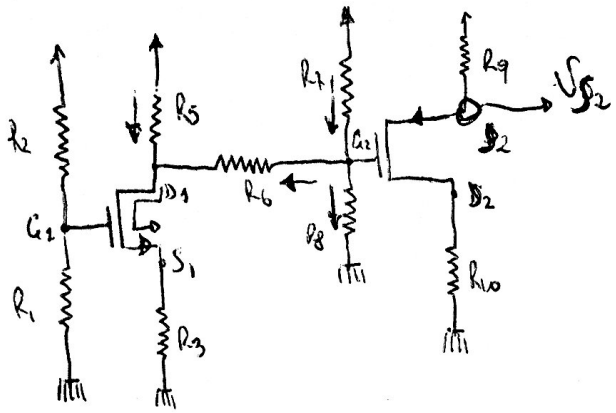
$T_2 = 2.721953731 \cdot 10^{-4}\ s$

- - - -

$T_{tot} = T_1 + T_2 = 1.269627072 \cdot 10^{-3}\ s$

$$\boxed{f = \frac{1}{T} = 787.6328\ Hz}$$

ESERCIZIO A)



- $I_{S_2} = \frac{V_{cc} - V_{S_2}}{R_9} = 2\,mA$
- $I_{G_2} = 0 \rightarrow I_{D_2} = I_{S_2} = 2\,mA$
- $V_{D_2} = R_{10} I_{D_2} = 10\,V$
- $V_{GS_2} = V_T - \sqrt{\frac{I_D}{K}} = -3\,V$

VERIFICO LA SATURAZIONE $\quad V_{DS} < V_{GS} - V_T \rightarrow -5\,V < -2\,V$ ok

$V_{GS} = V_G - V_S \Rightarrow V_G = V_{GS} + V_S = 12\,V$

- $I_8 = \frac{V_{G2}}{R_8} = 0{,}3\,mA$
- $I_7 = \frac{V_{cc} - V_{G2}}{R_7} = 0{,}6\,mA$
- $I_6 = I_7 - I_8 = 0{,}3\,mA$
- $V_{G2} - V_{D_1} = R_6 I_6 \rightarrow V_{D_1} = V_{G2} - R_6 I_6 = 11{,}7\,V$
- $I_5 = \frac{V_{cc} - V_{D_1}}{R_5} = 2.1\,mA$
- $I_{D_1} = I_6 + I_5 = 2.4\,mA$
- $I_{G_1} = 0 \Rightarrow I_{S_1} = I_{D_1} = 2{,}4\,mA$
- $V_G = V_{cc} \cdot \frac{R_1}{R_1 + R_2} = 9\,V$

- $V_{GS} = V_T + \sqrt{\frac{I_D}{k}} = 3{,}19089\ V$

- $V_{GS} = V_G - V_S \Rightarrow V_S = V_G - V_{GS} = 5.80911\ V$

VERIFICO CHE $V_{DS} > V_{GS} - V_T \rightarrow 5.87089\ V > 2{,}19089\ V \rightarrow$ OK

- $R_3 = \frac{V_S}{I_{S_1}} = 2420{,}4625\ \Omega$

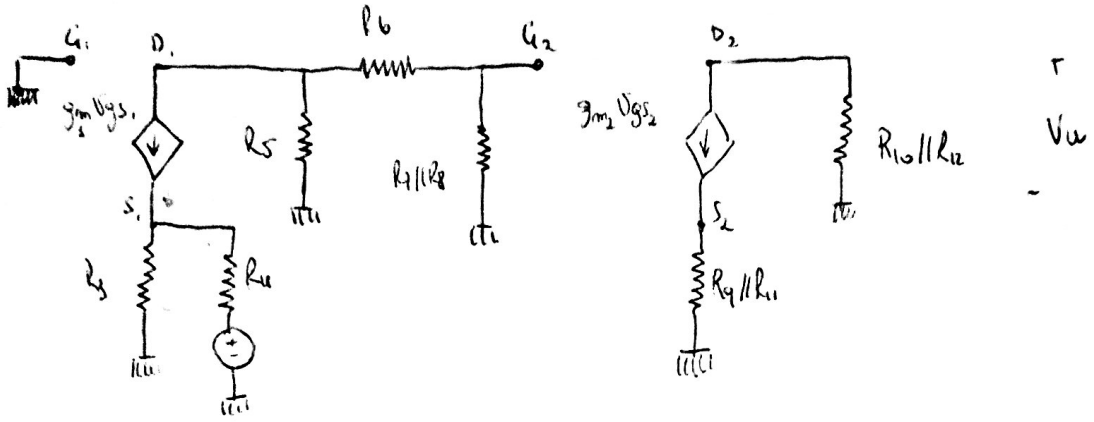
PUNTI DI RIPOSO

Q_1:

$I_{D_1} = 2{,}4\ mA \qquad V_{GS_1} = 5.89089\ V \qquad g_{m_1} = 2k|V_{GS} - V_T| = 2.19089 \cdot m\frac{A}{V}$

Q_2:

$I_{D_2} = 2\ mA \qquad V_{DS_2} = -5\ V \qquad g_{m_2} = 2k|V_{GS} - V_T| = 2\ m\frac{A}{V}$



- $V_u = - g_{m_2} V_{gs_2} \cdot R_{10} // R_{12}$

- $V_{gs_2} = V_{g_2} - V_{s_2} = V_{g_2} - g_{m_2} V_{gs_2} \cdot R_9 // R_{11} \rightarrow V_{gs_2} = \dfrac{V_{g_2}}{1 + g_{m_2}(R_9 // R_{11})}$

- $V_{g_2} = - g_{m_1} V_{gs_1} \cdot \dfrac{R_5}{R_5 + R_6 + R_7 // R_8} \cdot R_7 // R_8$

- $V_{gs_1} = - V_{s_1}$

$$\begin{cases} V_{s_1} = I_3 R_3 \\ V_{s_1} - V_i = R_4 I_4 \\ g_{m_1} V_{gs_1} = I_3 + I_4 \end{cases}$$

$$- g_{m_1} V_{s_1} = \frac{V_{s_1}}{R_3} + I_4 \rightarrow - g_{m_1} V_{s_1} = \frac{V_{s_1}}{R_3} + \frac{V_{s_1}}{R_4} - \frac{V_i}{R_4} \rightarrow V_{s_1}\left(g_{m_1} + \frac{1}{R_3} + \frac{1}{R_4}\right) = \frac{V_i}{R_4}$$

- $V_{s_1} = \dfrac{V_i}{R_4} \cdot \left(g_{m_1} + \dfrac{1}{R_3} + \dfrac{1}{R_4}\right)^{-1}$

- $\dfrac{V_u}{V_i} = - \underbrace{\dfrac{g_{m_2} R_{10} // R_{12}}{1 + g_{m_2}(R_9 // R_{11})}}_{\frac{125}{19}} \cdot \underbrace{\dfrac{g_{m_1} R_5 \cdot R_7 // R_8}{R_5 + R_6 + R_7 // R_8}}_{4,38\ldots} \cdot \underbrace{\dfrac{\left(g_{m_1} + \frac{1}{R_3} + \frac{1}{R_4}\right)^{-1}}{R_4}}_{0,799\ldots} = \boxed{-23,42}$

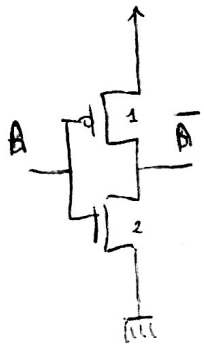
$Y = \overline{\bar{A}B}\,(\bar{C}+\bar{D}) + \overline{DE}\,(B + A\bar{C})$

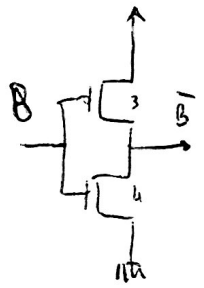
$Y = (A+\bar{B})(\bar{C}+\bar{D}) + (\bar{D}+\bar{E})(B+A\bar{C})$

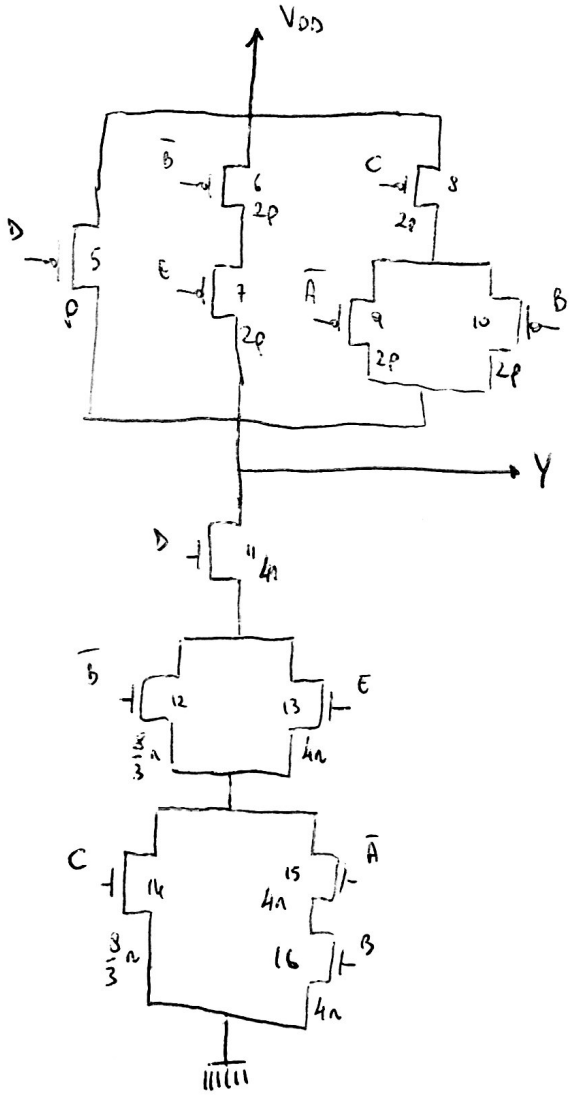
$Y = A\bar{C} + A\bar{D} + \bar{B}\bar{C} + \bar{B}\bar{D} + B\bar{D} + A\bar{C}D + B\bar{E} + A\bar{C}\bar{E}$

$Y = A\bar{C} + \bar{D} + A\bar{D} + \bar{B}\bar{C} + B\bar{E} + A\bar{C}\bar{E}$

$Y = \bar{D} + A\bar{C} + \bar{B}\bar{C} + B\bar{E} = \bar{D} + B\bar{E} + \bar{C}(A+\bar{B})$ 16 mosfet







- INVERTER DI BASE

$\left(\frac{W}{L}\right)_1 = \left(\frac{W}{L}\right)_3 = p = 5$

$\left(\frac{W}{L}\right)_2 = \left(\frac{W}{L}\right)_4 = n = 2$

• PUN

- WORST CASE : Q_6, Q_7 o Q_8, Q_9 o Q_9, Q_{10}

$$\left(\frac{W}{L}\right)_{6,7,8,9,10} = X$$

$$\frac{1}{X} + \frac{1}{X} = \frac{1}{P} \rightarrow \frac{2}{X} = \frac{1}{P} \rightarrow X = 2P = 10$$

- WORST CASE 2 : Q_5

$$\left(\frac{W}{L}\right)_5 = P = 5$$

• PDN

- WORST CASE : $Q_{11}, Q_{12}, Q_{15}, Q_{16}$ → NON POSSIBILE PERCHÉ PRESENTI B e $\overline{B}$

$Q_{11}, Q_{13}, Q_{15}, Q_{16}$ ~~NON VALIDO~~

$$\left(\frac{W}{L}\right)_{11,13,15,16} = Y$$

$$\frac{1}{Y} + \frac{1}{Y} + \frac{1}{Y} + \frac{1}{Y} = \frac{1}{n} \rightarrow \frac{4}{Y} = \frac{1}{n} \rightarrow Y = 4n = 8$$

- WORST CASE 2:

Posso seguire 2 percorsi:

① Q_{11}, Q_{12}, Q_{14}

$$\left(\frac{W}{L}\right)_{12,14} = Y$$

$$\frac{1}{Y} + \frac{1}{Y} + \frac{1}{4n} = \frac{1}{n} \rightarrow \frac{2}{Y} = \frac{3}{4n} \Rightarrow 3Y = 8n \Rightarrow Y = \frac{8}{3}n = \frac{16}{3}$$

② Prima calcolo $\left(\frac{W}{L}\right)_{14}$ e poi $\left(\frac{W}{L}\right)_{12}$

- Q_{11}, Q_{13}, Q_{14}

$$\left(\frac{W}{L}\right)_{14} = Z$$

$$\frac{1}{Z} + \frac{1}{4n} + \frac{1}{4n} = \frac{1}{n} \rightarrow \frac{1}{Z} = \frac{1}{n} - \frac{1}{2n} \rightarrow \frac{1}{Z} = \frac{1}{2n} \rightarrow Z = 2n = 4$$

- Q_{11}, Q_{12}, Q_{14}

$$\left(\frac{W}{L}\right)_{12} = K$$

$$\frac{1}{K} + \frac{1}{2n} + \frac{1}{4n} = \frac{1}{n} \rightarrow \frac{1}{K} = \frac{4-1-2}{4n} \Rightarrow K = 4n = 8$$

CALCOLO LE AREE

① $\frac{16}{3} + \frac{16}{3} = \frac{32}{3} = 10{,}667$ → SCELGO QUESTA

② $4 + 8 = 12$

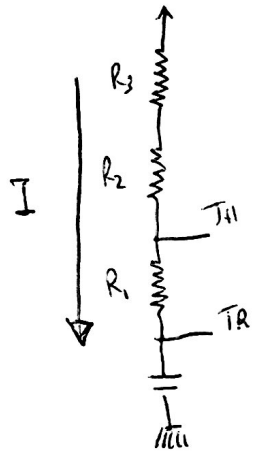
09/06/2016

ESERCIZIO c)

$Q_n = 1 \rightarrow D = \overline{H7}$

$V_{G_1} = 0V \quad V_{S_1} = 0V \quad V_{GS_1} = 0V < V_T = 1V \quad Q_1 = OFF$

$V_{G_2} = V_{CC} \quad V_{S_2} = V_{CC} \quad V_{GS_2} = 5V > V_T = -1V \quad Q_2 = OFF$



- $V_i = \frac{1}{3} V_{cc} = \frac{5}{3} V$
- $V_f = V_{cc}$
- V_{comm}

se $V_{TH} = \frac{2}{3} V_{cc} = \frac{10}{3} V$

$$I = \frac{V_{cc} - V_{TH}}{R_2 + R_3} = \frac{1}{660} A$$

$$V_{comm} = V_{TH} - R_1 I = \frac{85}{33} V$$

VERIFICO CHE $V_i \leq V_{comm} \leq V_f \rightarrow$ OK

$$T_1 = \tilde{T}_1 \ln\left(\frac{V_i - V_f}{V_{comm} - V_f}\right)$$

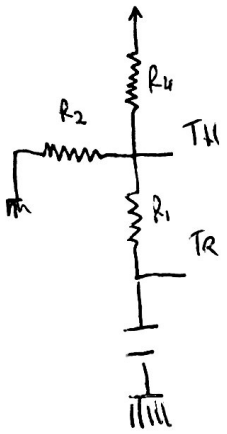
$$T_1 = R_{V_1} \cdot C = \left[R_1 + R_2 + R_3\right] \cdot C = 1600 \cdot C = \frac{1}{6250} s$$

$$\tilde{T}_1 = 5.095259698 \cdot 10^{-5} s$$

$Q_1 = 0 \rightarrow D = 0$

$V_{GS_2} = 0V \quad V_{S_2} = V_{cc} \quad V_{GS_2} = -V_{cc} = -5V < V_{T_2} = -1 \rightarrow Q_2$ ON

$V_{G_1} = V_{cc} \quad V_{S_1} = 0V \quad V_{GS_1} = 5V > V_{T_1} = 1V \rightarrow Q_1$ ON



$\cdot V_i = \frac{85}{33} V$

$\cdot V_{comp} = \frac{5}{3} V$

$\cdot V_f = V_{cc} \cdot \frac{R_2}{R_2 + R_u} = \frac{1}{2} V$

VERIFICO CHE: $V_i > V_{comp} > V_f \rightarrow$ ok

$T_2 = \tau_2 \ln\left(\frac{V_i - V_f}{V_{comp} - V_f}\right)$

$T_2 = R_{V_2} \cdot C = \left[R_1 + R_2 \| R_u\right] \cdot C = 590 \cdot C = \frac{59}{1000000} s$

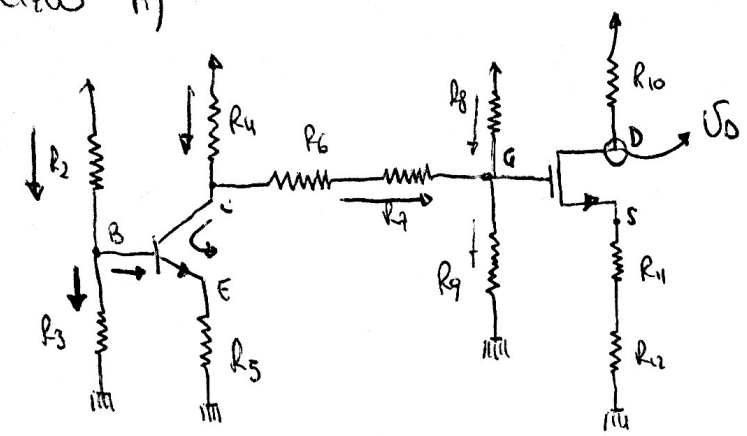
$T_2 = 3.399435473 \cdot 10^{-5} s$

$T = T_1 + T_2 = 8.494695171 \cdot 10^{-5} s$

$f = \frac{1}{T} = 11772.05 \ Hz$

17/02/2014

ESERCIZIO A)



- $I_D = \frac{V_a - V_D}{R_{10}} = 4\ mA$
- $I_G = 0$, $I_S = I_D = 4\ mA$
- $V_S = (R_{11} + R_{12})\, I_S = 4\ V$
- $V_{GS} = V_T + \sqrt{\frac{I_D}{k}} = 2\ V$

VERIFICO LA SATURAZIONE: $V_{DS} > V_{GS} - V_T \rightarrow 4\ V > 1\ V$ ok

- $V_{GS} = V_G - V_S \rightarrow V_G = V_{GS} + V_S = 6\ V$
- $I_8 = \frac{V_{CC} - V_a}{R_8} = 1\ mA$
- $I_9 = \frac{V_a}{R_9} = 3\ mA$
- $I_7 = I_9 - I_8 = 2\ mA$
- $V_{CC} = V_a + (R_6 + R_7)\, I_7 = 7\ V$
- $I_4 = \frac{V_{CC} - V_C}{R_4} = 4\ mA$
- $I_C = I_4 - I_7 = 2\ mA$

IPOTIZZO Z.A.D $I_C \gg I_B \Rightarrow I_E \approx I_C = 2\ mA$

- $V_E = R_5 I_E = 2\ V$
- VERIFICO ZAD $\rightarrow V_{CE} > V_{CE\,SAT} \Rightarrow 5\ V > 0{,}2\ V \rightarrow$ ok
- $I_B = \frac{I_C}{h_{FE}} = 6{,}8965\ \mu A$

- $V_B = 2V_{BE} + V_E = 2.7\ V$
- $I_3 = \frac{V_B}{R_3} = 10\ \mu A$
- $I_2 = I_3 + I_B = 16,8965\ \mu A$
- $R_2 = \frac{V_{cc} - V_B}{I_2} = 727961,41\ \Omega \approx$ **727959,15 Ω**

PUNTI DI RIPOSO

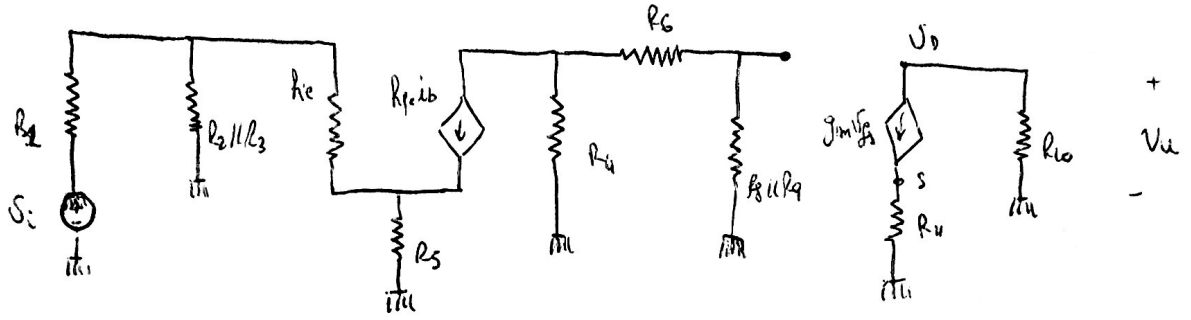
Q_1:

$h_{fe} = 300 \quad h_{FE} = 290 \quad h_{ie} = 4.8\ k\Omega \quad I_C = 2mA \quad V_{CE} = 5V$

Q_2:

$I_D = 4\ mA \quad V_{DS} = 4\ V \quad g_m = 2K|V_{GS} - V_T| = 8\ m\frac{A}{V}$

17/02/2014

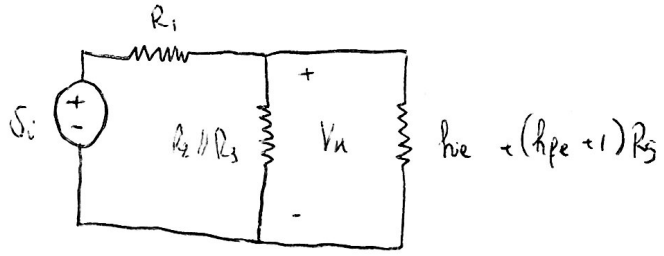


- $V_D = -g_m V_{gs} \cdot R_{10}$

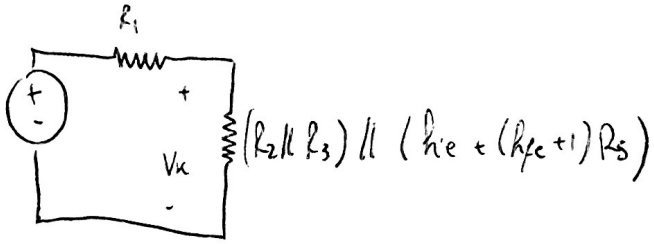
- $V_{gs} = V_g - V_s = V_g - g_m V_g R_{11} \longrightarrow V_{gs} = \dfrac{V_g}{1 + g_m R_{11}}$

- $V_g = -h_{fe}\, i_b \dfrac{R_4}{R_4 + R_6 + R_8 \| R_9} \cdot R_8 \| R_9$

- $i_b = \dfrac{V_K}{h_{ie} + (h_{fe}+1) R_5}$ ⟶



- $V_K = V_{ii} \cdot \dfrac{(R_2 \| R_3) \,//\, (h_{ie} + (h_{fe}+1))}{R_i + \left[(R_2 \| R_3) \,//\, (h_{ie} + (h_{fe}+1) R_5)\right]}$ ⟶



- $\dfrac{V_u}{V_i} = \dfrac{g_m R_{10}}{1 + g_m R_{11}} \cdot \dfrac{h_{fe} \cdot R_4 \cdot R_8 \| R_9}{R_4 + R_6 + R_8 \| R_9} \cdot \dfrac{1}{h_{ie} + (h_{fe}+1) R_5} \cdot \dfrac{(R_2 \| R_3) \,//\, (h_{ie} + (h_{fe}+1) R_5)}{R_i + \left[(R_2 \| R_3) \,//\, (h_{ie} + (h_{fe}+1) R_5)\right]} = \boxed{6.77}$

ESERCIZIO B)

$$Y = (\overline{A+\bar{D}})(\bar{B}D + \bar{C} + \bar{E}) + (\overline{B+\bar{D}})(AD + \bar{C}) + A\bar{C}D + \bar{A}\bar{E}$$

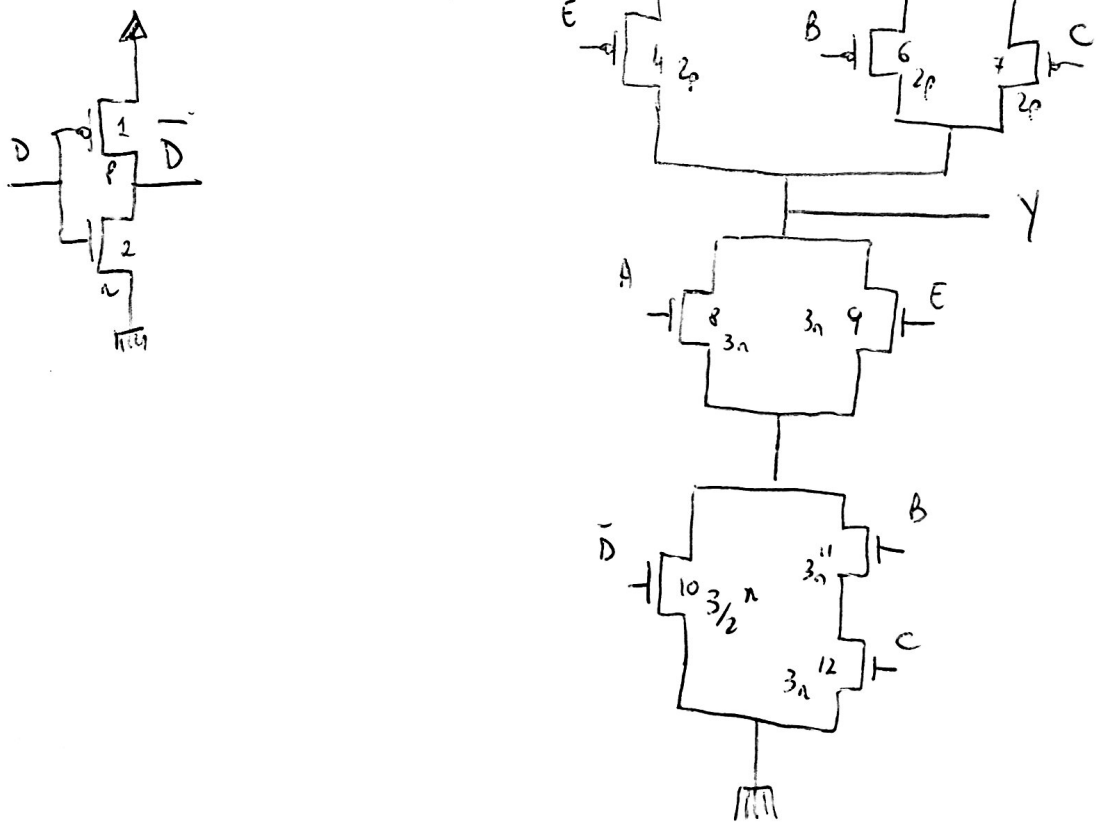
$$Y = (\bar{A}\cdot D)(\bar{B}D + \bar{C} + \bar{E}) + (\bar{B}\cdot D)(AD + \bar{C}) + A\bar{C}D + \bar{A}\bar{E}$$

$$Y = \bar{A}\bar{B}D + \bar{A}\bar{C}D + \bar{A}D\bar{E} + A\bar{B}D + \bar{B}\bar{C}D + A\bar{C}D + \bar{A}\bar{E}$$

$$Y = \bar{B}D + \bar{C}D + \bar{A}\bar{E} + \bar{B}\bar{C}D$$

$$Y = \bar{B}D + \bar{C}D + \bar{A}\bar{E}$$

$$Y = \bar{A}\bar{E} + D(\bar{B}+\bar{C})$$



- INVERTER DI BASE

$$\left(\frac{W}{L}\right)_1 = p = 5$$

$$\left(\frac{W}{L}\right)_2 = n = 2$$

- PUN

- WORST CASE : Q_3, Q_4 o Q_5, Q_6 o Q_5, Q_7

$$\left(\frac{W}{L}\right)_{3,4,5,6,7_a} = X$$

$$\frac{1}{X} + \frac{1}{X} = \frac{1}{P} \rightarrow \frac{2}{X} = \frac{1}{P} \rightarrow X = 2p = 10$$

- PDN

- WORST CASE : Q_8, Q_{11}, Q_{12} o Q_9, Q_{11}, Q_{12}

$$\left(\frac{W}{L}\right)_{8,9,11,12} = X$$

$$\frac{1}{X} + \frac{1}{X} + \frac{1}{X} = \frac{1}{n} \Rightarrow \frac{3}{X} = \frac{1}{n} \rightarrow X = 3n = 6$$

- WORST CASE ②, Q_8, Q_{10} o Q_9, Q_{10}

$$\left(\frac{W}{L}\right)_{10} = Y$$

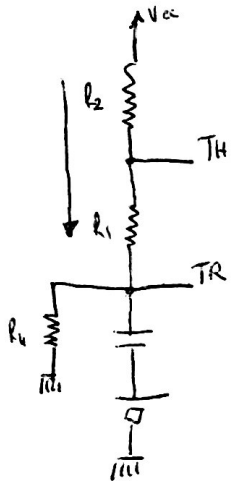
$$\frac{1}{Y} + \frac{1}{3n} = \frac{1}{n} \rightarrow \frac{1}{y} = \frac{3-1}{3n} \rightarrow y = \frac{3}{2}n$$

ESERCIZIO c)

$Q=1 \rightarrow D='H7$

$V_{G_1}=0V \quad V_{S_1}=0V \quad V_{GS_1}=0V < V_{T_1}=1V \quad Q_1=OFF$

$V_{G_2}=0V \quad V_{S_2}=V_{cc}=5V \quad V_{GS_2}=-5V < V_{T_2}=-1V \quad Q_2=ON$



- $V_i = \frac{1}{3}V_{cc} - V_A = \frac{7}{6}\ V$
- $V_f = V_{cc} \cdot \frac{R_L}{R_1+R_2+R_L} - V_A = \frac{39}{22}\ V$
- V_{comm} se $V_{TH} = \frac{2}{3}V_{cc} = \frac{10}{3}\ V$

$I_2 = \frac{V_{cc}-V_{TH}}{R_2} = \frac{1}{4k\Omega}\ A$

$V_{TR} = V_{TH} - R_1 I_2 = \frac{35}{12}\ V$

- $V_{comm} = V_{TR} - V_A = \frac{29}{12}\ V$

VERIFICHIAMO CHE $V_i < V_{comm} < V_f \rightarrow$ Ok

$T_1 = \tau_1 \ln\left(\frac{V_i - V_f}{V_{comm} - V_f}\right)$

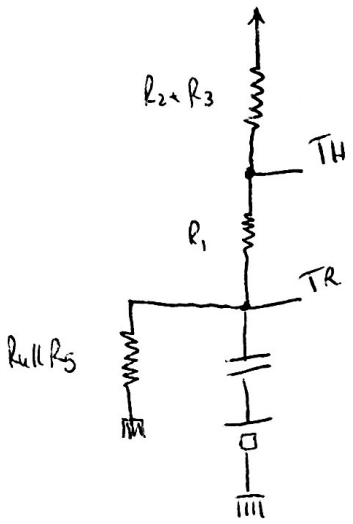
$\tau_1 = R_{V_1} \cdot C = \left[R_L \,//\, (R_1+R_2)\right] \cdot C = \frac{10000}{11} \cdot C = \frac{1}{11000}\ s$

$T_1 = 5,177574769 \cdot 10^{-5}\ s$

$Q = 0 \rightarrow D = 0$

$V_{GS_1} = V_{CC}$ $V_{S_1} = 0V$ $V_{GS_1} = V_{CC} - 5V > V_{T_1} = 1V$ Q_1 ON

$V_{GS_2} = V_{CC}$ $V_{S_2} = V_{CC} = 5V$ $V_{GS_2} = 0V > V_T = -1V$ Q_2 OFF



- $V_i = \frac{29}{12} V$
- $V_{comm} = \frac{7}{6} V$
- $V_f = V_{CC} \cdot \frac{R_4 \| R_5}{R_1 + R_2 + R_3 + R_4 \| R_5} - V_A = -\frac{16}{53} V$

VERIFICO CHE $V_i > V_{comm} > V_f \rightarrow$ OK

$$T_2 = \tau_2 \ln\left(\frac{V_i - V_f}{V_{comm} - V_f}\right)$$

$$\tau_2 = R_{V_2} \cdot C = \left[(R_4 \| R_5) \| (R_1 + R_2 + R_3)\right] C = \frac{5000}{53} C = \frac{1}{106\,000} s$$

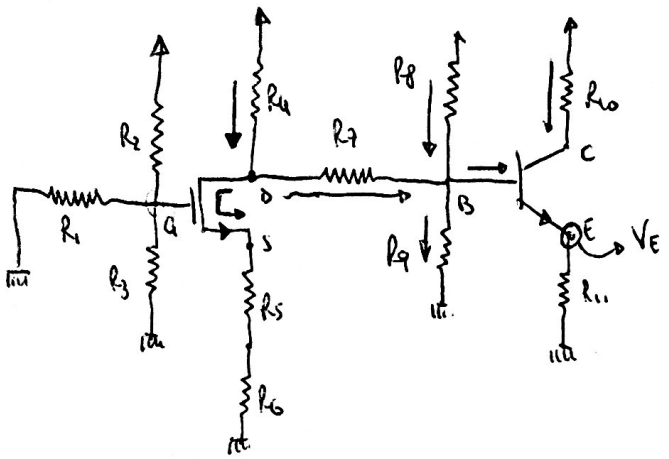
$$T_2 = 5.923356511 \cdot 10^{-6} s$$

- - - -

$$T = T_1 + T_2 = 5.769910\,62 \cdot 10^{-5} s$$

$$\boxed{f = \frac{1}{T} = 17331.2916 \text{ Hz}}$$

28/06/2013



- $I_E = \frac{V_E}{R_{11}} = 2\,mA$
- IPOTIZZO Z.A.D $\rightarrow$ $I_C \gg I_B \Rightarrow I_C \approx I_E = 2mA$
- $V_{cc} - V_C = R_{10} I_C \rightarrow V_C = V_{cc} - R_{10} I_C = 13\,V$

VERIFICO ZAD $\rightarrow$ $V_{CE} > V_{CESA} \rightarrow 5\,V > 0.2\,V$

- $I_B = \frac{I_C}{h_{FE}} = 6,8965\,\mu A$
- $V_{BE} = V_B - V_E \rightarrow V_B = V_{BE} + V_E = 8.7\,V$
- $I_8 = \frac{V_{cc} - V_B}{R_8} = 0,31\,mA$
- $I_9 = 0,87\,mA$
- $I_7 + I_8 = I_9 + I_D \rightarrow I_7 = I_9 + I_D - I_8 = \frac{411}{125000}\,A \approx 0,56689\,mA$
- $V_G = V_{cc} \cdot \frac{R_1 \| R_3}{R_2 + R_1 \| R_3} = 9\,V$

IPOTIZZO SATURAZIONE : $V_{DS} = V_T + \sqrt{\frac{I_D}{K}} =$

- $V_S = (R_5 + R_6) I_D$
- $V_{DS} = 9 - (R_5 + R_6) I_D$

$I_D = K(9 - (R_5 + R_6) I_D - 1)^2 \rightarrow I_D = K(R_5 + R_6) I_D^2 - K\,16 (R_5 + R_6) I_D + 64K$

$K(R_5 + R_6)^2 I_D^2 - (1 + 16K(R_5 + R_6)) I_D + 64K = 0 \rightarrow 250\,I_D^2 - 5\,I_D + 0,016 = 0$

I_D $\leftarrow$ $0,016\,A = 16\,mA$

$\leftarrow 4\,mA$

Adesso devono varie possibili:

$V_{S_1} = 4\,V$ $\quad V_{S_2} = 16\,V$

$V_{GS_1} = 5\,V$ $\quad V_{GS_2} = -7\,V$

Affinché sia in saturazione occorre che $V_{GS} > V_T \Rightarrow$ scelgo $I_D = 4\,mA$

Adesso che ho fissato la $I_D^* = 4\,mA$, ricavo V_D

- $I_4 = I_D + I_7 = 4,566896552 \cdot mA$
- $V_D = V_{CC} - R_4 I_4 = 9,779586207\,V$ → VERIFICO $V_{DS} > V_{GS} - V_T \rightarrow 5,779586\,V > 4\,V$ OK
- $R_7 = \dfrac{V_D - V_B}{I_7} = 1904,3795\,\Omega$

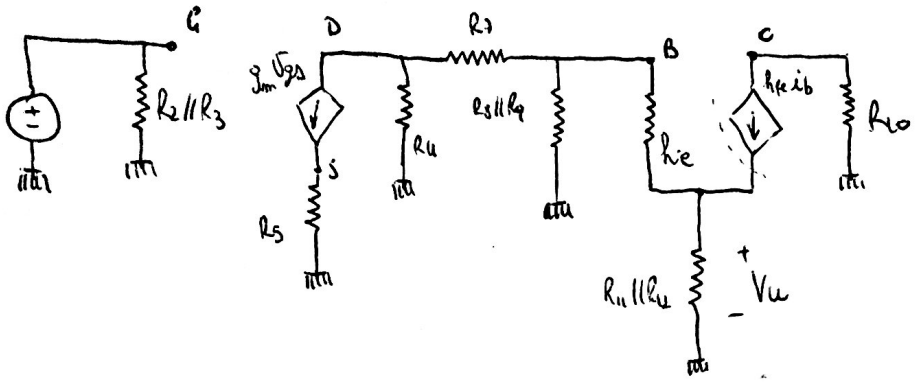
PUNTI DI RIPOSO

Q_1:

$I_D = 4mA$ $\quad V_{DS} = 5,779586207\,V$ $\quad g_m = 2k\,|V_{GS} - V_T| = 2\,m\dfrac{A}{V}$

Q_2:

$h_{ie} = 4.8\,K\Omega$ $\quad h_{fe} = 300$ $\quad h_{FE} = 290$ $\quad I_C = 2mA$ $\quad V_{CE} = 5\,V$



- $V_u = (h_{fe}+1)\, i_b \cdot (R_{L1} // R_{L2})$

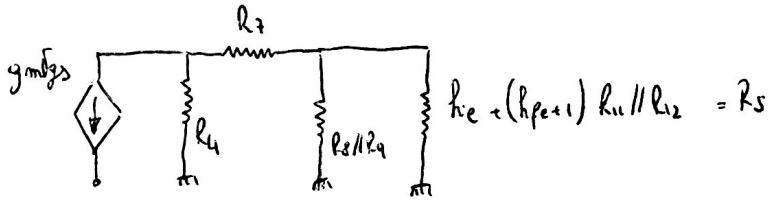
- $i_p = -g_m V_{gs} \cdot \dfrac{R_4}{R_4 + R_7 + R_p}$

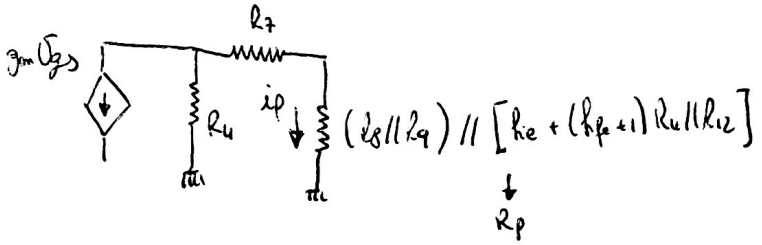
- $i_b = i_p \cdot \dfrac{R_8 // R_9}{R_S + R_8 // R_9}$

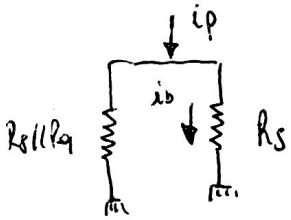
- $V_{gs} = V_g - V_0 = V_g - g_m V_{gs} R_S$

$$V_{gs} = \frac{V_g}{1 + g_m R_S}$$

- $V_g = V_i$







$$\frac{V_u}{V_i} = \overbrace{-(h_{fe}+1)\,(R_{L1} // R_{L2})}^{A} \cdot \underbrace{\frac{R_8 // R_9}{R_8 // R_9 + h_{ie} + (h_{fe}+1)\cdot(R_{L1} // R_{L2})}}_{C} \cdot \underbrace{\frac{g_m R_4}{R_4 + R_7 + \left[(R_8 // R_9) // \left(h_{ie} + (h_{fe}+1)(R_{L1} // R_{L2})\right)\right]}}_{D} \cdot \frac{1}{1 + g_m R_S}$$

$$\boxed{\frac{V_u}{V_i} = -1{,}99308}$$

28/06/13

ESERCIZIO B)

$$Y = (\bar{A} + \overline{CD})(\bar{B}\bar{C} + D) + (\overline{D+E})(\bar{A}\bar{B} + C) + \bar{D}(\bar{E} + \bar{A})$$

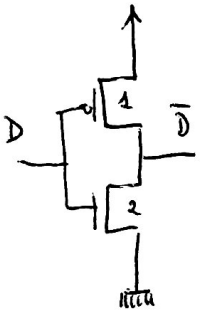
$$Y = (\bar{A} + \bar{C} + \bar{D})(\bar{B}\bar{C} + D) + \bar{D}\bar{E} \cdot (\bar{A}\bar{B} + C) + \bar{D}\bar{E} + \bar{D}\bar{A}$$

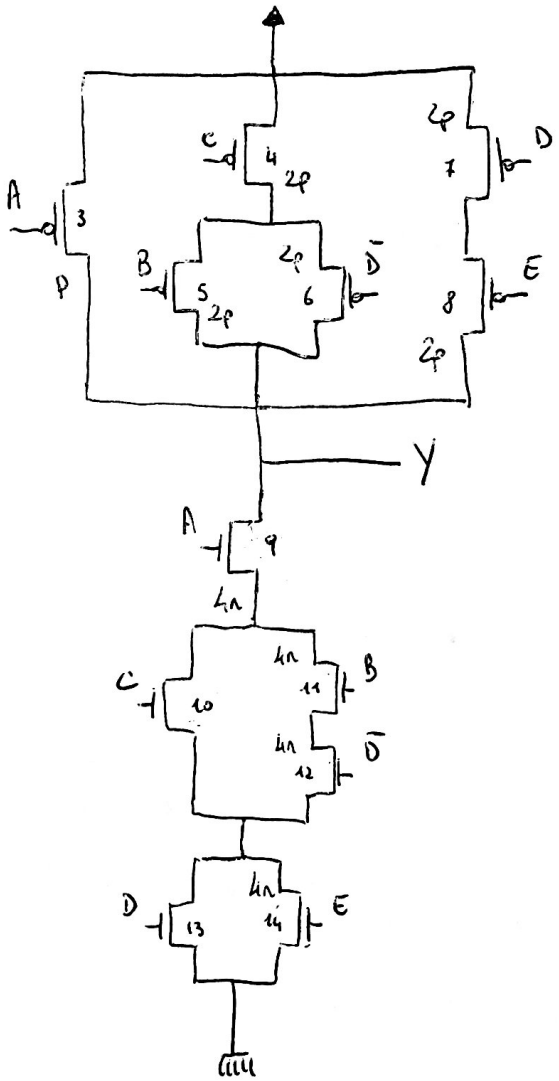
$$Y = \bar{A}\bar{B}\bar{C} + \bar{A}D + \bar{B}\bar{C} + \bar{C}D + \bar{B}\bar{C}\bar{D} + \bar{A}\bar{B}\bar{D}\bar{E} + \bar{C}\bar{D}\bar{E} + \bar{D}\bar{E} + \bar{D}\bar{A}$$

$$Y = \bar{D}\bar{E} + \bar{B}\bar{C} + \bar{A} + \bar{C}D$$

$$Y = \bar{A} + \bar{C}(\bar{B} + D) + \bar{D}\bar{E}$$

14 mosfet





- INVERTER DI BASE
  - $\left(\frac{W}{L}\right)_1 = p = 5$
  - $\left(\frac{W}{L}\right)_2 = n = 2$

- PUN

- WORST-CASE Q_4, Q_5 o Q_4, Q_6 o Q_7, Q_8

$$\left(\frac{W}{L}\right)_{4,5,6,7,8} = X$$

$$\frac{1}{X} + \frac{1}{X} = \frac{1}{P} \rightarrow \frac{2}{X} = \frac{1}{P} \rightarrow X = 2P = 10$$

- WORST-CASE 2 Q_3

$$\left(\frac{W}{L}\right)_3 = Y \rightarrow \frac{1}{Y} = \frac{1}{P} \rightarrow Y = P = 5$$

- PDN

WORST-CASE: $Q_9, Q_{11}, Q_{12}, Q_{13}$ → NON POSSIBILE PERCHÈ PRESENTI D e $\bar{D}$

$Q_9, Q_{11}, Q_{12}, Q_{14}$

$$\left(\frac{W}{L}\right)_{9,11,12,14} = X$$

$$\frac{1}{X} + \frac{1}{X} + \frac{1}{X} + \frac{1}{X} = \frac{1}{n} \rightarrow \frac{4}{X} = \frac{1}{n} \rightarrow X = 4n = 8$$

WORST-CASE ②

Ci sono due percorsi:

1) Q_9, Q_{10}, Q_{13}
2) Q_9, Q_{10}, Q_{14} e poi Q_9, Q_{10}, Q_{13}

1) $\left(\frac{W}{L}\right)_{10,13} = Y \rightarrow \frac{1}{Y} + \frac{1}{Y} + \frac{1}{4n} = \frac{1}{n} \rightarrow \frac{2}{Y} = \frac{3}{4n} \rightarrow 8n = 3Y \Rightarrow Y = \frac{8}{3}n = \frac{16}{3}$

2) $\left(\frac{W}{L}\right)_{10} = Z \rightarrow \frac{1}{Z} + \frac{1}{4n} + \frac{1}{4n} = \frac{1}{n} \rightarrow \frac{1}{Z} = \frac{2}{4n} \rightarrow Z = 2n = 4$

$\left(\frac{W}{L}\right)_{13} = K \rightarrow \frac{1}{K} + \frac{1}{2n} + \frac{1}{4n} = \frac{1}{n} \rightarrow \frac{1}{K} = \frac{4-1-2}{4n} \rightarrow K = 4n = 8$

SCELGO IL PERCORSO AD AREA MINIMA

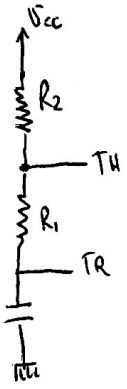
1) $\frac{8}{3}n + \frac{8}{3}n = \frac{16}{8} + \frac{16}{3} = \frac{32}{3} \approx 10,67$ → SCELGO QUESTO

2) $4n + 2n = 6n = 12$

ESERCIZIO c)

$Q = 1 \rightarrow D = 1\,Hz$

- $V_{c_1} = 0 \quad V_{S_1} = 0V \quad V_{GS_1} = 0V < V_T = 1V \quad Q_1 = OFF$
- $V_{c_2} = 0 \quad V_{S_2} = V_{cc} \quad V_{GS_2} = -5V < V_T = -1V \quad Q_2 = ON$



- $V_i = \frac{1}{3} V_{cc} = \frac{5}{3} V$
- $V_f = V_{cc} = 5V$
- $V_{uscita} \Rightarrow V_{TH} = \frac{2}{3} V_{cc}$

$$I = \frac{V_{cc} - V_{TH}}{R_2} = \frac{1}{1200} A$$

- $V_{uscita} = V_{TH} - R_1 I = \frac{5}{2} V = 2{,}5\,V$

- VERIFICO $V_i < V_{uscita} < V_f \rightarrow OK$

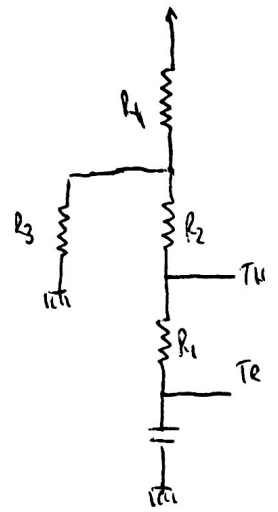
$$T_1 = \tau_1 \ln\left(\frac{V_i - V_f}{V_{uscita} - V_f}\right)$$

$$\tau_1 = [R_1 + R_2] \cdot C = [3000 \cdot C] = 3 \cdot 10^{-4}\,s$$

$$T_1 = 8{,}630462174 \cdot 10^{-5}\,s$$

$Q = 0 \rightarrow D = 0$

- $V_{GS_1} = V_{CC}$ $V_{S_1} = 0V$ $V_{GS_1} = V_{CC} = 5V > V_{T_1} = 1V$ Q_1 ON
- $V_{G_2} = V_{CC}$ $V_{S_2} = V_{CC}$ $V_{GS_2} = 0V > V_{T_2} = -1V$ Q_2 OFF



- $V_i = 2{,}5\ V$
- $V_{comp} = \frac{5}{3}\ V$
- $V_f = V_{CC} \cdot \frac{R_3}{R_3 + R_4} = \frac{1}{2}\ V$

- VERIFICO CHE $V_i > V_{comp} > V_f$ → ok

$$T_2 = \tau_2 \ln\left(\frac{V_i - V_f}{V_{comp} - V_f}\right)$$

$$\tau_2 = R_{V_2} \cdot C = \left[R_1 + R_2 + R_3 \| R_4\right] \cdot C = 3450 \cdot C = 3{,}45 \cdot 10^{-4}\ s$$

$$T_2 = 1{,}859537928 \cdot 10^{-4}$$

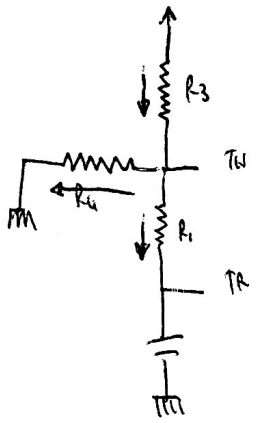
$$T = T_1 + T_2 = 2{,}722584145 \cdot 10^{-4}\ s$$

- $\boxed{f = \frac{1}{T} = 3672{,}98106\ Hz}$

ESERCIZIO c)

$Q=1 \rightarrow D='1'$

$V_{a_1} = V_{cc}$ $\quad V_{S_1} = V_{cc}$ $\quad V_{GS_1} = 0V > V_{T_1} = -1\,V$ $\quad Q_1 = OFF$



- $V_i = \frac{1}{3} V_{cc} = \frac{5}{3}\,V$
- $V_f = V_{cc} \cdot \frac{R_L}{R_3 + R_L} = 4\,V$
- $V_{comm} = V_{TH} = \frac{2}{3} V_{cc} = \frac{10}{3}\,V$

$I_3 = \frac{V_{cc} - V_{TH}}{R_3} = \frac{1}{600}\,A \qquad I_L = \frac{V_{TH}}{R_L} = \frac{1}{1200}\,A$

$I_1 = I_3 - I_L = \frac{1}{1200}\,A$

- $V_{comm} = V_{TH} - R_1 I_1 = \frac{5}{2}\,V$

VERIFICO CHE: $V_i > V_{comm} > V_f \rightarrow OK$

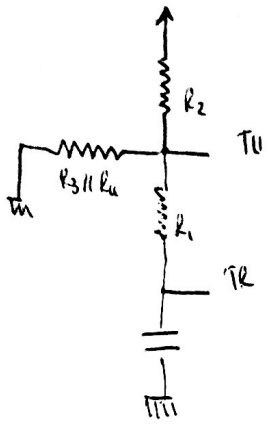
$T_1 = T_1 \ln\left(\frac{V_i - V_f}{V_{comm} - V_f}\right)$

$T_1 = R_{V_1} \cdot C = \left[R_1 + R_3 // R_L\right] \cdot C = 1800 \cdot C = \frac{9}{5000}\,s$

$T_1 = 7{,}952989561 \cdot 10^{-4}\,s$

$Q = 0 \rightarrow D = 0$

$V_{G_1} = 0 \quad V_{S_1} = V_{cc} \quad V_{GS_1} = -V_{cc} = -5\,V < V_{T_1} = -1\,V \rightarrow Q_1 = ON$



$V_i = \frac{5}{2}\,V$

$V_{com} = \frac{5}{3}\,V$

$V_f = V_{cc} \cdot \frac{R_3 // R_4}{R_2 + R_3 // R_4} = \frac{10}{17}\,V$

VERIFICO CHE $V_i > V_{com} > V_f \rightarrow OK$

$$T_2 = \tau_2 \ln\left(\frac{V_i - V_f}{V_{com} - V_f}\right)$$

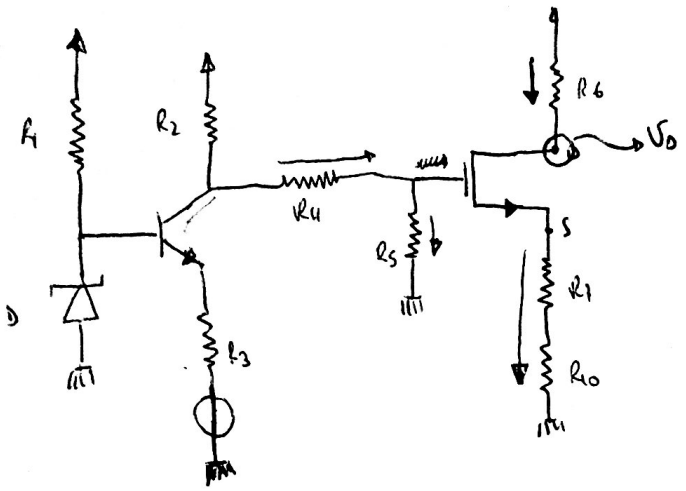
$$T_2 = R_{V_2} \cdot C = \left[R_1 + R_2 // R_3 // R_4\right] \cdot C = \frac{29000}{17} \cdot C = \frac{29}{17000}\,s$$

$$T_2 = 9.766503877 \cdot 10^{-4}\,s$$

$$T = T_1 + T_2 = 1.771949362 \cdot 10^{-3}\,s$$

$$\boxed{f = \frac{1}{T} = 564{,}35\ Hz}$$

ESERCIZIO A)



- $I_D = \frac{V_{cc} - V_D}{R_6} = 2mA$
- $I_G = 0 \rightarrow I_S = I_D = 2mA$
- $V_S = (R_7 + R_8) I_S = 4V$

IPOTIZZO SATURAZIONE $V_{GS} = V_T + \sqrt{\frac{I_D}{K}} = 3V$

- $V_G = V_{GS} + V_S = 7V$
- $I_S = \frac{V_G}{R_5} = 1\ mA$

VERIFICO SATURAZIONE $V_{DS} > V_{GS} - V_T \rightarrow 5V > 2V \rightarrow OK$

- - - -

IPOTIZZO ZENER IN BREAKDOWN $\rightarrow V_B = V_Z$

- $I_1 = \frac{V_{cc} - V_B}{R_1} = 4.\overline{03}\ mA$

IPOTIZZO Q_1 ZAD $\Rightarrow I_C \gg I_B \Rightarrow I_C = I_E$

- $V_{BE} = V_B - V_E \Rightarrow V_E = V_B - V_{BE} = 4V$
- $I_E = \frac{V_E}{R_3} = 2\ mA$

~~$I_B = \frac{I_C}{h_{FE}} = 6.8965\ \mu A$~~

~~$I_E = I_1 - I_2$~~

$V_C = V_G + R_4 I_4 = V_G + R_4 (I_2 - I_C) = V_G + R_4 \frac{V_{cc} - V_C}{R_2} - R_4 I_E = V_G + R_4 \frac{V_{cc}}{R_2} - \frac{R_4}{R_2} V_C - R_4 I_E$

- ~~$\left(1 + \frac{R_1}{R_2}\right) = V_a + \frac{R_1}{R_2} V_{cc} - R_a I_E$~~
- ~~$V_c = \left(V_a + \frac{R_1}{R_2} V_{cc} - R_a I_E\right)\left(1 + \frac{R_1}{R_2}\right)^{-1}$~~

~~$V_c = (R_a + R_5) I_5$~~

~~$V_c = V_{cc} - R_2 I_2$~~

~~$I_2 =$~~

- $I_2 = I_c + I_5 = 3\,mA$
- $V_c = V_{cc} - R_2 I_2 = 9\,V$

VERIFICO Z.A.D → $V_{CE} > V_{CE\,SAT}$ → $5V > 0.2\,V$ → OK

- $I_B = \frac{I_c}{h_{FE}} = 6,8965\,\mu A$
- $I_1 = I_1 - I_B = 4,0236 \cdot$ ~~10~~ mA

VERIFICO IPOTESI SUL ZENER $I_1 > 0$ → OK

→ $\boxed{R_4 = \frac{V_c - V_a}{I_2} = 2000\,\Omega}$

PUNTI DI LAVORO

Q_1:

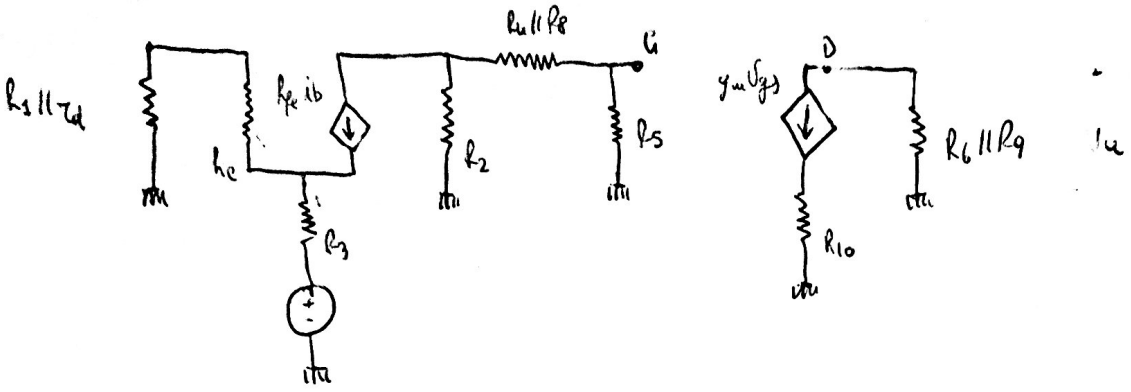
$h_{fe} = 300$ $h_{FE} = 280$ $R_{BE} = 6.8\,k\Omega$ $I_C = 2mA$ $V_{CE} = 5V$

Q_2:

$I_D = 2mA$ $V_{DS} = 5V$ $g_m = 2k|V_{GS} - V_T| = 2m\frac{A}{V}$

D:

$r_d = \frac{V_T}{I_2}$, $6,462185747\,V$

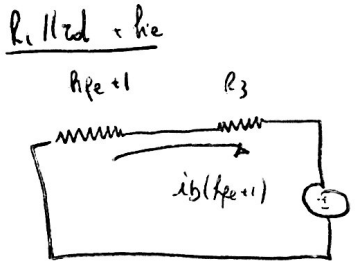


- $V_u = -g_m V_{gs} (R_6 \parallel R_9)$

- $V_{gs} = V_g - V_s = V_g - g_m V_{gs} R_{10} \Rightarrow V_{gs} = \dfrac{V_g}{1 + g_m R_{10}}$

- $V_g = -h_{fe} i_b \cdot \dfrac{R_2 \cdot R_5}{R_2 + R_4 \parallel R_8 + R_5}$

- $i_b (h_{fe}+1) = -\dfrac{V_i}{\dfrac{R_1 \parallel r_d + h_{ie} + (h_{fe}+1) R_3}{(h_{fe}+1)}}$



- $\dfrac{V_u}{V_i} = \underbrace{-\dfrac{g_m (R_6 \parallel R_9)}{1 + g_m R_{10}}}_{\frac{30}{49}} \cdot \underbrace{\dfrac{h_{fe} \cdot R_2 \cdot R_5}{R_2 + R_4 \parallel R_8 + R_5}}_{B} \cdot \dfrac{1}{R_1 \parallel r_d + h_{ie} + (h_{fe}+1) R_3} = \boxed{-6,29649}$

A

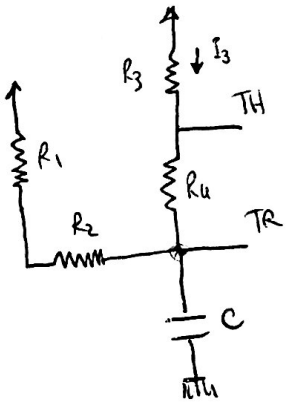
13/02/2012

ESERCIZIO c)

Ipotesi 1:

$Q=1 \rightarrow D = 'H7$

- $V_{G_4} = V_{cc}$ $V_{S_4} = 0$ $V_{GS_4} = V_{cc} = 5V > V_{T_4} = 2V$ Q_4 ON $\rightarrow V_{DS_4} = 0 = V_{D_3}$
- $V_{G_2} = 0V$ $V_{S_2} = V_{cc}$ $V_{GS_2} = -V_{cc} = -5V < V_{T_2} = -2V$ Q_2 ON $\rightarrow V_{D_2} = V_{cc} = V_{G_3}$
- $V_{G_3} = V_{cc}$ $V_{S_3} = V_{cc}$ $V_{GS_3} = 0 <> V_{T_3} = -2V$ Q_3 OFF
- $V_{G_1} = 0$ $V_{S_1} = 0$ $V_{GS_1} = 0 < 2V$ Q_1 OFF



$V_i = \frac{1}{3} V_{cc} = \frac{5}{3} V$

$V_f = V_{cc} = 5V$

$V_{comm.}$ si calcola con $V_{TH} = \frac{2}{3} V_{cc} = \frac{10}{3} V$

$$I_3 = \frac{V_{cc} - V_{TH}}{R_3} = 1,6667 \text{ mA}$$

$$V_{comm} = V_{TH} - R_u I_3 = 1,9666 V$$

Verifica: $V_i < V_{comm} < V_f \rightarrow$ ok

$$T_1 = \tau_1 \cdot \ln\left(\frac{V_i - V_f}{V_{com} - V_f}\right)$$

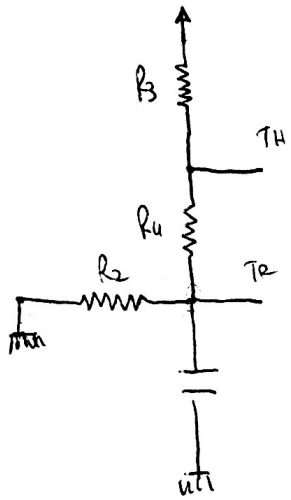
$$\tau_1 = R_{V_1} \cdot C = \left[(R_3 + R_u) \,//\, (R_1 + R_2)\right] \cdot C = 9.2475 \cdot 10^{-6} s$$

$$T_1 = 8.7193 \cdot 10^{-5} s$$

Ipotesi 2)

$Q = 0 \rightarrow D = 0$

- $V_{g_2} = 0$ $V_{s_2} = V_{cc}$ $V_{es_2} = -V_{cc} = -5V < V_{T_2} = -2V$ $Q_2 = ON$ $V_{D_2} = V_{cc} = V_{s_3}$
- $V_{g_3} = 0$ $V_{s_3} = V_{cc}$ $V_{es_3} = -V_{cc} = -5V < V_{T_3} = -2V$ $Q_3 = ON$ $V_{D_3} = V_{cc}$
- $V_{g_4} = 0$ $V_{s_4} = 0$ $V_{es_4} = 0 < V_{T_4} = 2V$ Q_4 OFF
- $V_{g_1} = V_{cc}$ $V_{s_1} = 0$ $V_{es_1} = V_{cc} > V_{T_1} = 2V$ Q_1 ON



$V_i = 1.9666\ V$

$V_{comm} = \frac{5}{3}\ V$

$V_f = V_{cc} \cdot \frac{R_2}{R_2 + R_3 + R_4} = 1.36\ V$

$V_i > V_{comm} > V_f \rightarrow OK$

$T_2 = \tau_2 \cdot \ln\left(\frac{V_i - V_f}{V_{comm} - V_f}\right)$ $\quad \tau_2 = R_{V_2} \cdot C = \left[(R_3 + R_4) \,//\, R_2\right] \cdot C = 0.49504\ ms$

$T_2 = 337.725\ \mu s$

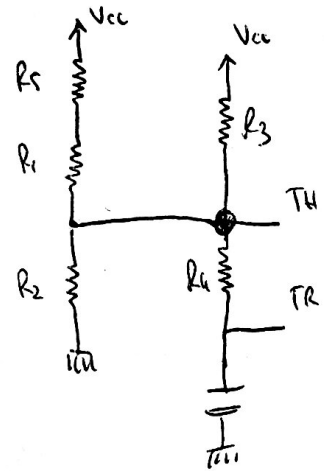
$T = T_1 + T_2 = 424.9396\ \mu s$

$f = \frac{1}{T} = 2353.275\ Hz$

ESERCIZIO c)

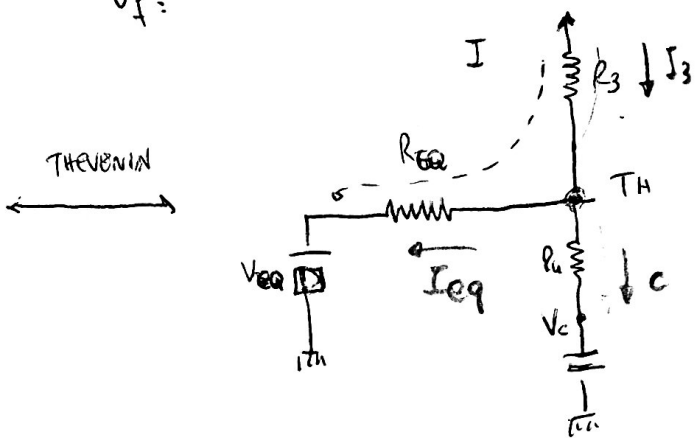
Ipotesi 1:

$Q = 1 \rightarrow D = 1$



$V_i = \frac{1}{3} V_{cc} = \frac{5}{3}$ V

V_f:



V_f

$V_{EQ} = V_{cc} \cdot \frac{R2}{R2+R1+R5} = 3.1161$ V

$R_{EQ} = R4 + R2 \,||\, (R1+R5) = 328.8951\ \Omega$

$I = \frac{V_{cc} - V_{EQ}}{R3 + R_{EQ}} = 2.9303\ 10^{-6}$ A

$V_{Lf} = V_{cc} - R_3 I = 3.359$ V

- V_{comm} con $V_{TH} = \frac{2}{3} V_{cc} = \frac{10}{3}$ V

$I_3 = \frac{V_{cc} - V_{TH}}{R_3}$ $\quad I_{EQ} = \frac{V_{TH} - V_{EQ}}{R_{EQ}}$ $\quad I_C = I_3 - I_{EQ}$

$V_{comm} = V_{TH} - R_4 I_C$

$\begin{cases} I_3 = 2.97619 \cdot 10^{-4}\ A \\ I_{EQ} = 2.620757\ 10^{-4}\ A \\ I_C = 3.55432 \cdot 10^{-5}\ A \end{cases} \rightarrow V_{comm} = 3.134$ V

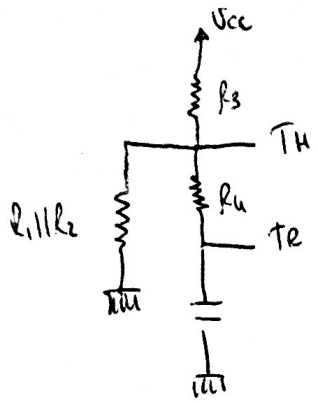
$T_1 = T_i \ln\left(\frac{V_i - V_f}{V_{comm} - V_f}\right)$

$T_i = R_{Vi} C = \left[R_4 + R_3 \,||\, R_2 \,||\, (R_1+R_5)\right] C = 3.54033$ ms

$T_1 = 7.142589$ ms

Fase 2:

$Q = 0 \rightarrow D = 0$



$V_i = 3{,}134\ V$

$V_{comm} = \frac{5}{3}\ V$

$V_f = V_{cc} \cdot \frac{R_1 // R_2}{R_3 + R_1 // R_2} = 0.243722\ V$

$T_2 = \tau_2 \ln\left(\frac{V_i - V_f}{V_{com} - V_f}\right) =$

$\tau_2 = R_{U_2} \cdot C = \left[R_4 + R_3 // (R_1 // R_2)\right] = 3.28886\ ms$

$T_2 = 2.3305\ ms$

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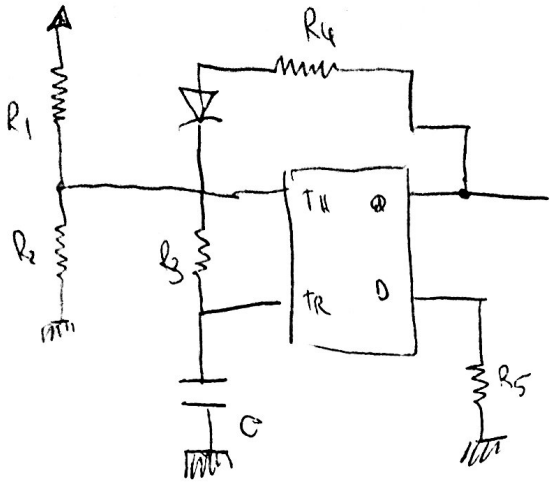
$T = T_1 + T_2 = 9.473124\ ms$

$f = \frac{1}{T} = 105.5618\ Hz$



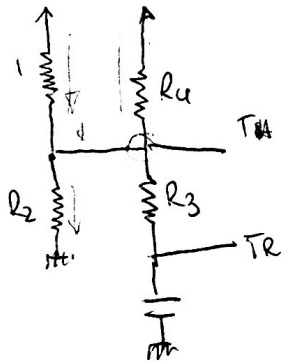
Ipotesi 1:

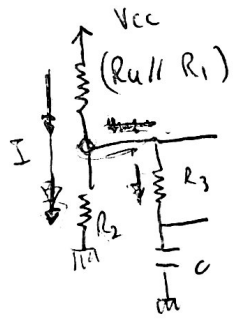
Q=1 → D='H77

→ DIODO ON

$V_i = \frac{V_{cc}}{3} = \frac{5}{3}$ V

$V_f =$





$V_f = V_{cc} \cdot \frac{R_2}{R_2 + R_4 // R_1} = 3.91965$ V

V_{comm} = se $V_{TR} = \frac{2}{3} V_{cc}$

$I_{1/4} = \frac{V_{cc} - V_{TH}}{R_4 // R_1} = 2.7686 \cdot 10^{-3}$ A

$V_{comm} = R V_{TH} - R_3 I_3 = 3.0671$ V

$I_2 = \frac{V_{TH}}{R_2} = 1.5151 \cdot 10^{-3}$ A → $I_3 = I_{1/4} - I_2 = 1.2335 \cdot 10^{-3}$ A

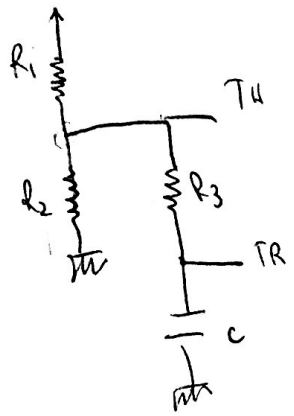
Verifico: $V_i < V_{comm} < V_f$ → ok

$T_1 = R_{v_1} C = \left[R_3 + (R_4 // R_1) // R_2 \right] \cdot C = 695.3517$

$T_1 = T \ln\left(\frac{V_i - V_{comm}}{V_{comm} - V_f} \right) = 376.07022\ \mu s$

Ipotesi 2:

$Q = 0 \rightarrow D : 0 \rightarrow D$ OFF



$V_i = 3.0619\ V$

$V_{comp} = \frac{5}{3}\ V$

$V_{f_2} \; V_{cc} \cdot \frac{R_2}{R_1 + R_2} = 1.6710256\ V$

$T_2 = \tau_2 \ln\left(\frac{V_i - V_f}{V_{comp} - V_f}\right) = 1.877156\ ms$ $\quad \tau_2$ $\quad T_2 = R_{2} \cdot C = \left[R_3 + R_1 // R_2\right] = 1799.48718\ \Omega$

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$T = t_1 + T_2 = 2.253226\ ms$

$f = \frac{1}{T} = 443.808\ Hz$