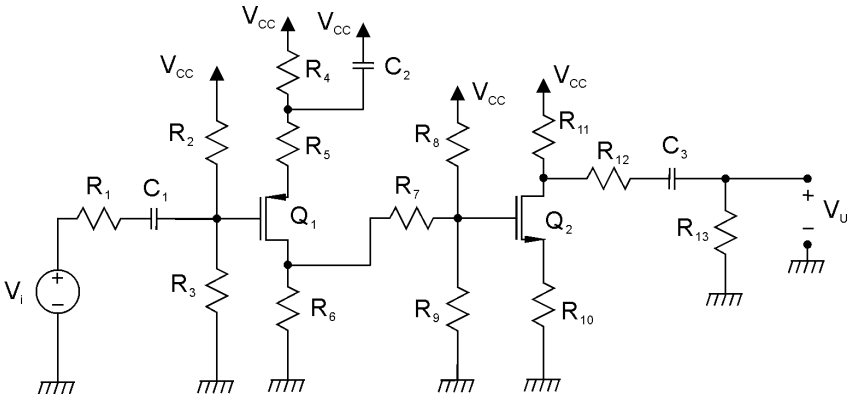
ELETTRONICA DIGITALE

Corso di Laurea in Ingegneria Informatica

Prova scritta del 01 febbraio 2017

Esercizio A

R_1 = 100 Ω	R_{10} = 2 kΩ
R_2 = 30 kΩ	R_{11} = 3 kΩ
R_3 = 30 kΩ	R_{12} = 1 kΩ
R_5 = 400 Ω	R_{13} = 25 kΩ
R_6 = 5 kΩ	C_1 = 1 nF
R_7 = 1 kΩ	C_2 = 220 nF
R_8 = 22 kΩ	C_3= 470 nF
R_9 = 7 kΩ	V_{CC} = 18 V



Q_1 è un transistore MOS a canale p resistivo con V_{T1} = -1 V; Q_2 è un transistore MOS a canale n resistivo con V_{T2} = 1 V; per entrambi la corrente di drain in saturazione è data da $I_D=k(V_{GS}-V_T)^2$ con k = 0.5 mA/V^2.
Con riferimento al circuito in figura:

1) Calcolare il valore della resistenza R_4 in modo che, in condizioni di riposo, la tensione sul drain di Q_2 sia 12 V. Determinare, inoltre, il punto di riposo dei due transistori e verificarne la saturazione. (R: R_4 = 2600 Ω)
2) Determinare l'espressione e il valore di V_U/Vi alle frequenze per le quali C_1, C_2, e C_3 possono essere considerati dei corto circuiti. (R: V_U/Vi = 2.68)
3) (**Solo per 12 CFU**) Determinare la funzione di trasferimento V_U/V_i e tracciarne il diagramma di Bode quotato asintotico del modulo. (R: f_{z1}=0 Hz; f_{p1}=10540 Hz; f_{z2}=278 Hz; f_{p2}=1082 Hz; f_{z3}=0 Hz; f_{p3}=11.7 Hz;)

Esercizio B

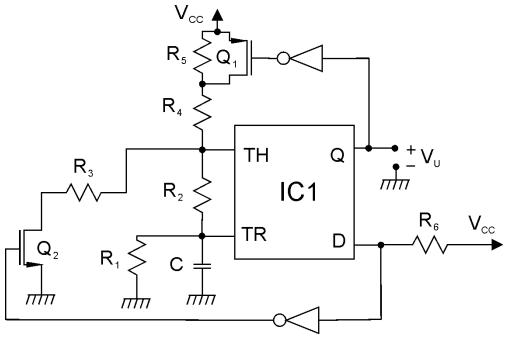
Progettare una porta logica in tecnologia CMOS, utilizzando la tecnica della pull-up network e della pull-down network, che implementi la funzione logica:

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

Determinare il numero dei transistori necessari e disegnarne lo schema completo. Dimensionare inoltre il rapporto (W/L) di tutti i transistori, assumendo, per l'inverter di base, W/L pari a 2 per il MOS a canale *n* e pari a 5 per quello a canale *p*. Si specifichino i dettagli della procedura di dimensionamento dei transistori.

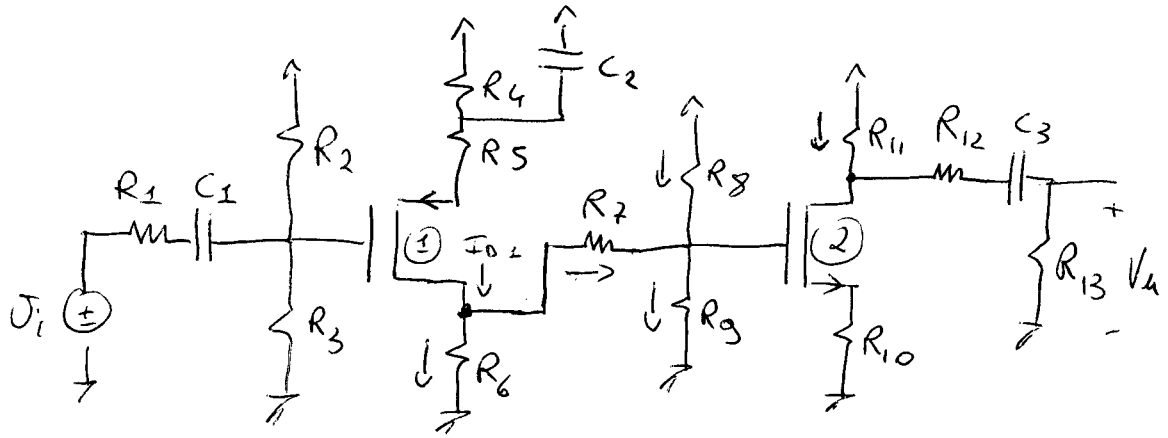
Esercizio C

R_1 =2 kΩ	R_5 = 2 kΩ
R_2 = 150 Ω	R_6 = 3 kΩ
R_3 = 200 Ω	C = 330 nF
R_4 = 250 Ω	V_{CC} = 6 V



Il circuito IC_1 è un NE555 alimentato a V_{CC} = 6 V; Q_1 ha una R_{on} = 0 e V_T = -1V; Q_2 ha una R_{on} = 0 e V_T = 1V; gli inverter sono ideali. Determinare la frequenza del segnale di uscita del multivibratore in figura. (R: f = 13741 Hz)

APPELLO 01/02/2017



$R_1 = 100\,\Omega$
$R_2 = 30\,k\Omega$
$R_3 = 30\,k\Omega$
$R_5 = 400\,\Omega$
$R_6 = 5\,k\Omega$
$R_7 = 1\,k\Omega$
$R_8 = 22\,k\Omega$
$R_9 = 7\,k\Omega$
$R_{10} = 2\,k\Omega$
$R_{11} = 3\,k\Omega$
$R_{12} = 1\,k\Omega$
$R_{13} = 25\,k\Omega$
$C_1 = 1\,nF$
$C_2 = 220\,nF$
$C_3 = 420\,nF$
$V_{CC} = 18\,V$
$K = 0.5\ \frac{mA}{V^2}$

1) Det. R_4 per $V_{D2} = 12\,V$

$$I_{11} = \frac{V_{CC} - V_{D2}}{R_{11}} = 2\,mA$$

$$I_{11} = I_{D2} = I_{S2} = I_{10}$$

$$V_{S2} = R_{10}\, I_{11} = 4\,V$$

$$V_{DS2} = V_{D2} - V_{S2} = 12 - 4 = 8\,V$$

$$(V_{GS2} - V_{T2}) = + \sqrt{\frac{I_D}{K}} = 2\,V$$

$$V_{GS2} = 2 + V_{T2} = 3\,V$$

$V_{DS2} > V_{GS2} - V_{T2} \Rightarrow$ hp. sat. OK

$$g_{m2} = 2K(V_{GS2} - V_{T2}) = 2\times10^{-3}\ \frac{A}{V}$$

$$V_{G2} = V_{GS2} + V_{S2} = 3 + 4 = 7\,V$$

$$I_8 = \frac{V_{CC} - V_{G2}}{R_8} = 0.5\,mA$$

$$I_9 = \frac{V_{G2}}{R_9} = 1\,mA$$

$$I_7 = I_9 - I_8 = 0.5\,mA$$

$$V_{D1} = V_{G2} + R_7 I_7 = 7.5\,V$$

$$I_6 = \frac{V_{D1}}{R_6} = 1.5\,mA$$

$$I_{D1} = I_6 + I_7 = 2\,mA$$

Q_2:
- $I_{D2} = 2\,mA$
- $V_{DS2} = 8\,V$
- $V_{GS2} = 3\,V$
- $g_{m2} = 2\times10^{-3}\ \frac{A}{V}$

Q_1:
- $I_{D1} = 2\,mA$
- $V_{DS1} = -4.5\,V$
- $V_{GS1} = -3\,V$
- $g_{m1} = 2\times10^{-3}\ \frac{A}{V}$

$(V_{GS1} - V_{T1}) = -\sqrt{\frac{I_{D1}}{K}} = -2V$

$V_{GS1} = -2 + V_{T1} = -3V$

$V_{G1} = V_{CC} \frac{R_3}{R_2 + R_3} = 9V$

$V_{S1} = V_{G1} - V_{GS1} = 9 - (-3) = 12V$

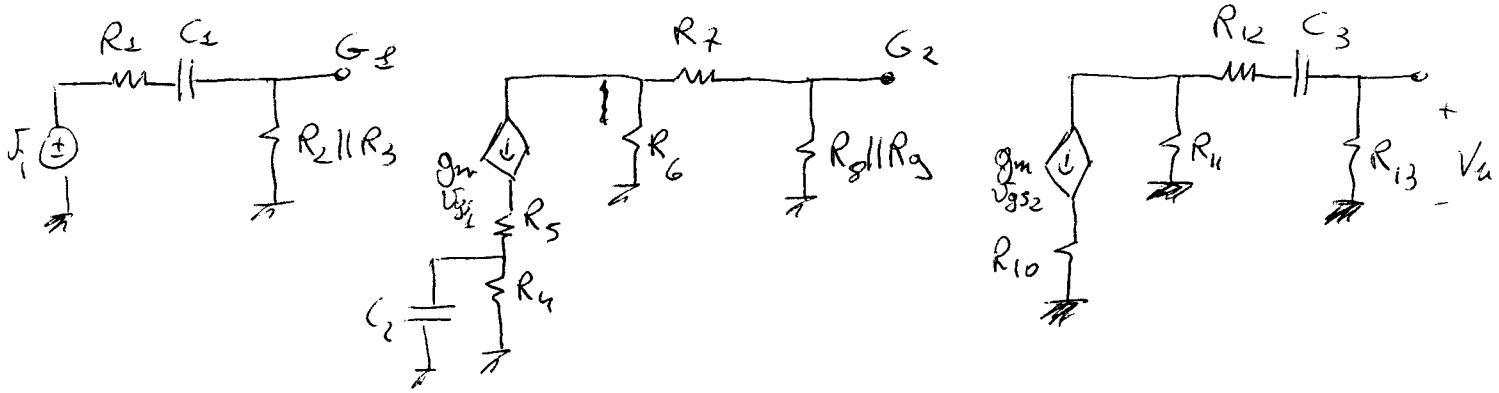
$V_{DS1} = V_{D1} - V_{S1} = 7.5 - 12 = -4.5V$

$V_{DS1} < (V_{GS1} - V_{T1})$ ok hp di saturazione
$-4.5 < -2$

$g_{m1} = 2K|(V_{GS1} - V_{T1})| = 2 \times 10^{-3} \frac{A}{V}$

$V_{R4} = V_{S1} + R_5 I_{D1} = 12 + 0.8 = 12.8V$

$R_4 = \frac{V_{CC} - V_{R4}}{I_{D1}} = \frac{18 - 12.8}{2 \times 10^{-3}} = 2600\ \Omega$



) A_{CB}

$V_u = (-g_m V_{gs2}) \frac{R_{11}}{R_{11} + R_{12} + R_{13}} \cdot R_{13}$

$V_{s2} = (g_m V_{gs2}) R_{10}$

$V_{gs2} = V_{g2} - g_m V_{gs2} R_{10} = \frac{V_{g2}}{1 + g_m R_{10}}$

$$v_2 = (-g_m v_{gs1}) \frac{R_6}{R_6 + R_7 + R_8 \| R_9} \cdot (R_8 \| R_9)$$

$$v_{s1} = (g_m v_{gs1}) R_5$$

$$v_{gs1} = v_{g1} - g_m v_{gs1} R_5 = \frac{v_{g1}}{1 + g_m R_5}$$

$$v_{g1} = v_i \frac{R_2 \| R_3}{R_1 + (R_2 \| R_3)}$$

$$A_{CB} = \frac{V_u}{V_i} = (-g_m) \frac{R_{11} \cdot R_{13}}{R_{11} + R_{12} + R_{13}} \frac{1}{1 + g_m R_{10}} (-g_m) \frac{R_6}{R_6 + R_7 + R_8 \| R_9} (R_8 \| R_9) \frac{1}{1 + g_m R_5}$$

(2×10^{-3}, 2586.2, 0.2, 2×10^{-3}, 0.442, 5310.364, 0.5, 0.9934)

$$\frac{R_2 \| R_3}{R_1 + R_2 \| R_3} = +2.68 \qquad A_{CB} = 8.56 \text{ dB}$$

) POLI E ZERI

C_1: $f_{z1} = \phi$ Hz

$$f_{p1} = \frac{1}{2\pi C_1 R_{v1}} = 10540.06 \text{ Hz}$$

$R_{v1} = R_1 + R_2 \| R_3 = 15100\ \Omega$

C_2: $f_{z2} = \frac{1}{2\pi C_2 R_4} = 278.24$ Hz

$$f_{p2} = \frac{1}{2\pi C_2 R_{v2}} = 1082.05 \text{ Hz}$$

$$R_{v2} = R_4 \| \left(R_5 + \frac{1}{g_m}\right) = 668.57\ \Omega$$

C_3: $f_{z3} = \phi$ Hz

$$f_{p3} = \frac{1}{2\pi C_3 R_{v3}} = 11.672 \text{ Hz}$$

$R_{v3} = R_{11} + R_{12} + R_{13} = 29\ k\Omega$

ESERCIZIO B

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

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

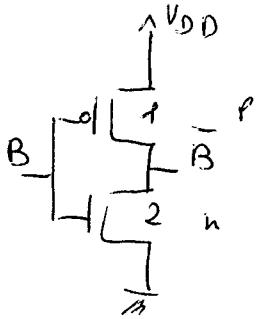
$$= \bar{A}BC + B\bar{D} + \bar{A}C\bar{E} + \bar{D}\bar{E} + \bar{A}CE + \bar{A}\bar{B} + \bar{D}\bar{C} =$$

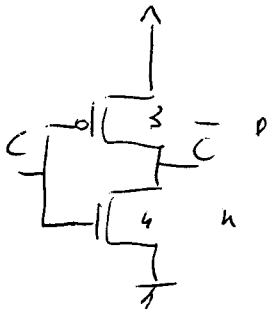
$$= \bar{A}BC + B\bar{D} + \bar{A}C + \bar{D}\bar{E} + \bar{A}\bar{B} + \bar{D}\bar{C} =$$

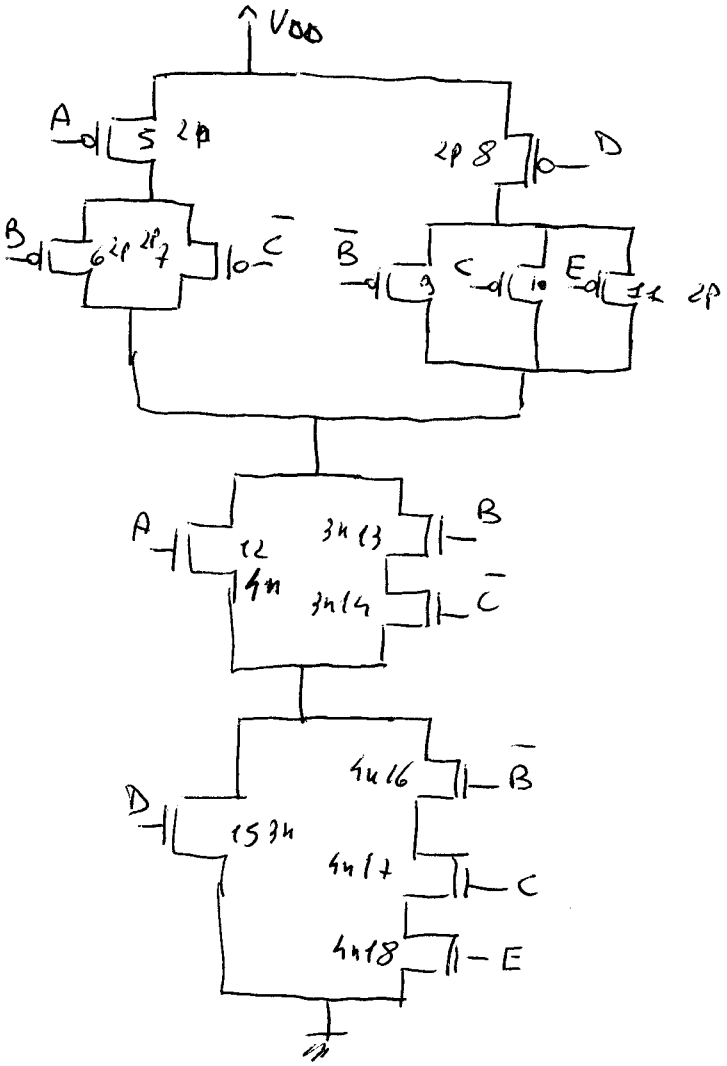
$$= \bar{A}C + B\bar{D} + \bar{D}\bar{E} + \bar{A}\bar{B} + \bar{D}\bar{C} =$$

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

N MOS = 14 + 4 = 18 MOS







) $\left(\frac{W}{L}\right)_{1,3} = p = 5$

$\left(\frac{W}{L}\right)_{2,4} = n = 2$

) PUN

SERIE DI 2 MOS $\frac{1}{x} + \frac{1}{x} = \frac{1}{p} \Rightarrow x = 2p = 10 = \left(\frac{W}{L}\right)_{5,6,7,8,9,10,11}$

) PDN

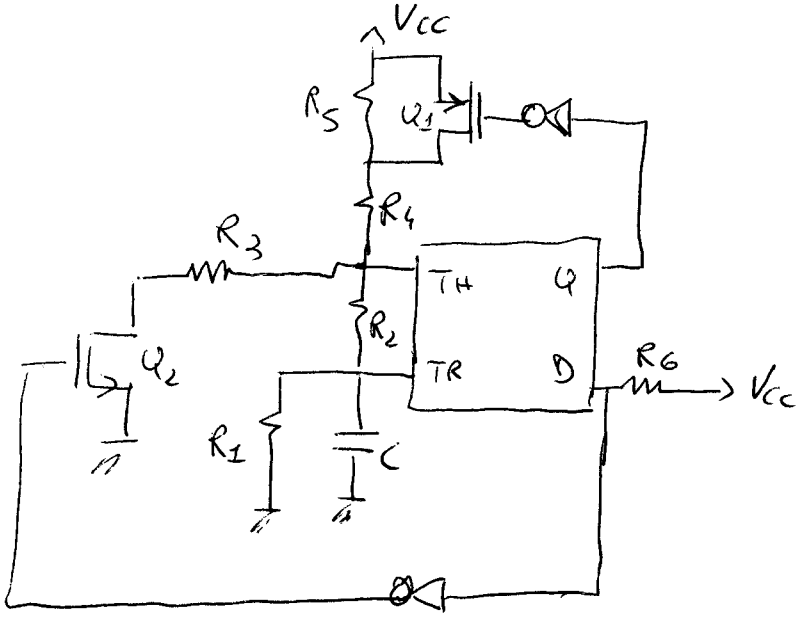
SERIE DI 5 MOS IMPOSSIBILE

SERIE DI 4 MOS $\Rightarrow \left(\frac{W}{L}\right)_{12,16,17,18} = 4n = 8$

SERIE DI 3 MOS

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

ESERCIZIO C



$R_1 = 2K\Omega$

$R_2 = 150\Omega$

$R_3 = 200\Omega$

$R_4 = 250\Omega$

$R_5 = 2K\Omega$

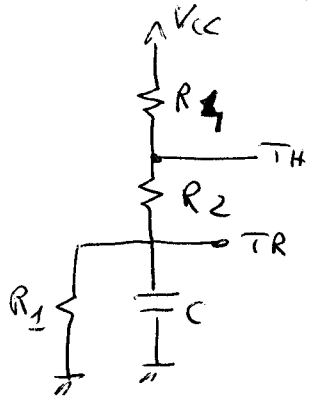
$R_6 = 3K\Omega$

$C = 330\,nF$

$V_{cc} = 6V$

*) $Q=1 \Rightarrow V_{G1} = 0V$; $V_{S1} = V_{cc} = 6V \Rightarrow V_{GS1} = -6V > V_T = -1V \Rightarrow Q_1$ ON

$D=H1 \Rightarrow V_{G2} = 0V$; $V_{S2} = 0V \Rightarrow V_{GS2} = 0V < V_T = 1V \Rightarrow Q_2$ OFF



$V_{i1} = \frac{1}{3} V_{cc} = 2V$

$V_{f1} = V_{cc} \frac{R_1}{R_1 + R_2 + R_4} = 5V$

Per $V_{TH} = \frac{2}{3} V_{cc} = 4V$

$I_2 = \frac{V_{cc} - V_{TH}}{R_4} = \frac{2}{250} = 8\,mA \Rightarrow V_{con1} = V_{TH} - R_2 I_2 = 2.8V$

$V_{i1} < V_{con1} < V_{f1} \Rightarrow$ CORRUTA

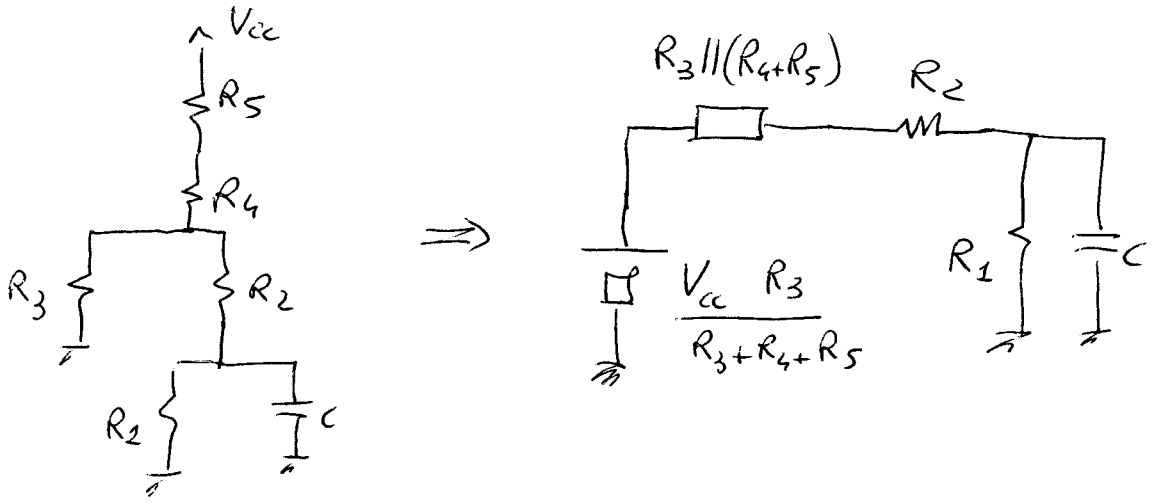
$R_{v1} = R_1 \,||\, (R_2 + R_4) = 333.\overline{3}\,\Omega$

$\tau_1 = R_{v1} C = 110\,\mu s$

$T_1 = \tau_1 \ln\left(\frac{V_{i1} - V_{f1}}{V_{con1} - V_{f1}}\right) = 34.117\,\mu s$

$= \phi \Rightarrow V_{G1} = 6V \quad V_{S1} = 6V \Rightarrow V_{GS1} = \phi V > V_T = -1V \Rightarrow U_1$ OFF (6)

$J = \phi \Rightarrow V_{G2} = 6V \quad V_{S2} = \phi V \Rightarrow V_{GS2} = 6V > V_T = 1V \Rightarrow U_2$ ON



$V_{i2} = V_{con1} = 2.8V$

$V_{con2} = V_{i1} = 2V$

$V_{i2} > V_{con2} > V_{f2} \Rightarrow$ CONMUTA

$$V_{f2} = \frac{V_{cc} \; R_3}{R_3+R_4+R_5} \; \frac{R_1}{[R_3 // (R_4+R_5)] + R_2 + R_1} = 0.41976 \; V$$

$$R_{V2} = R_1 // [R_2 + R_3 // (R_4+R_5)] = 285.96 \; \Omega$$

$$\tau_2 = C R_{V2} = 94.368 \; \mu s$$

$$T_2 = \tau_2 \ln\left(\frac{V_{i2} - V_{f2}}{V_{con2} - V_{f2}}\right) = 38.6555 \; \mu s$$

$$T = T_1 + T_2 = 72.772 \; \mu s$$

$$f = \frac{1}{T} = 13741.44 \; Hz$$