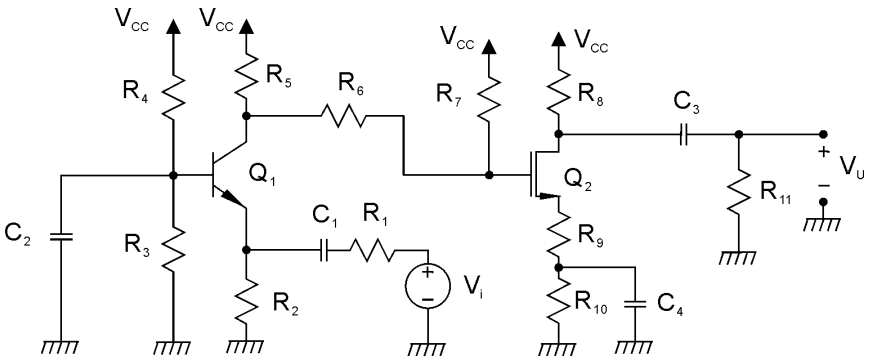
ELETTRONICA DIGITALE

Corso di Laurea in Ingegneria Informatica

Prova scritta del 18 febbraio 2019

Esercizio A

R_1 = 300 Ω	R_8 = 12 kΩ
R_2 = 2100 Ω	R_9 = 200 Ω
R_3 = 245 kΩ	R_{10} = 15.8 kΩ
R_5 = 5500 Ω	R_{11} = 12 kΩ
R_6 = 2 kΩ	V_{CC} = 18 V
R_7 = 20 kΩ	



Q_1 è un transistore BJT BC109B resistivo con $h_{re} = h_{oe} = 0$; Q_2 è un transistore MOS a canale n resistivo con $V_T = 1$ V e la corrente di drain in saturazione 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 verificare la saturazione di Q_2. (R: R_4 = 487051 Ω)
2) Determinare l'espressione e il valore di V_U/Vi alle frequenze per le quali C_1, C_2, C_3 e C_4 possono essere considerati dei corto circuiti. (R: V_U/Vi = -62.64)

Esercizio B

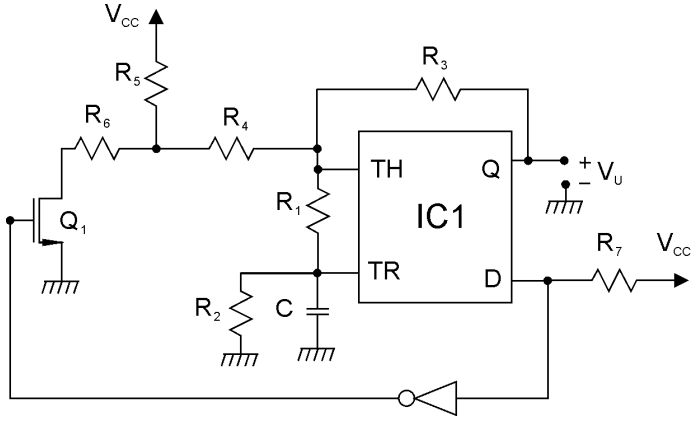
Progettare una porta logica in tecnologia CMOS, utilizzando la tecnica della pull-up network e della pull-down network, che implementi la funzione logica:

$$Y = \left(\overline{AE} + \bar{C}\,D\right)\left(\bar{B}\,D + E\right) + \bar{C}\,\bar{D}\,E + \bar{B}\left(AC + D\right)$$

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 di tutti i transistori. (R: N = 22)

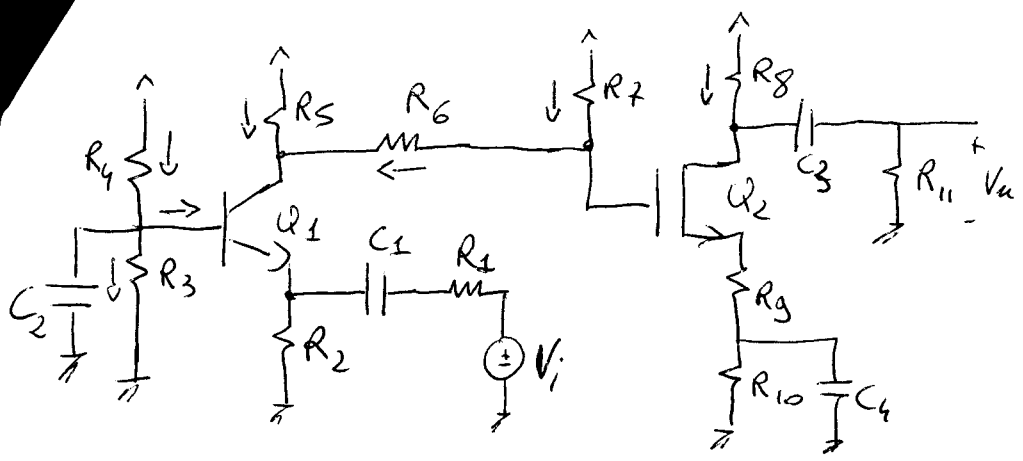
Esercizio C

R_1 = 80 Ω	R_6 = 800 Ω
R_2 = 2 kΩ	R_7 = 1 kΩ
R_3 = 400 Ω	C = 60 nF
R_4 = 400 Ω	V_{CC} = 6 V
R_5 = 1200 Ω	



Il circuito IC_1 è un NE555 alimentato a V_{CC} = 6 V; Q_1 ha una R_{on} = 0 e V_T = 1V; l'inverter è ideale. Determinare la frequenza del segnale di uscita del multivibratore in figura. (R: f = 36645.6 Hz)

APPELLO 18/02/2019



$R_1 = 300\,\Omega$
$R_2 = 2100\,\Omega$
$R_3 = 245\,K\Omega$
$R_5 = 5500\,\Omega$
$R_6 = 2\,K\Omega$
$R_7 = 20K\Omega$
$R_8 = 12K\Omega$
$R_9 = 200\,\Omega$
$R_{10} = 15.8K\Omega$
$R_{11} = 12K\Omega$
$V_{CC} = 18V$

Det R_4 per $V_D = 12V$

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

$I_G = \phi \Rightarrow I_D = I_S$

$V_S = I_D (R_9 + R_{10}) = 8V$

hp: Q_2 SATURO $\Rightarrow I_D = K(V_{GS} - V_T)^2$

$\Rightarrow V_{GS} = V_T \overset{(+)}{\underset{\uparrow}{}} \sqrt{\frac{I_D}{K}} = 2V$

NMOS

$V_{DS} = V_D - V_S = 12 - 8 = 4V > V_{GS} - V_T = 1V \Rightarrow$ hp OK

$g_m = 2K(V_{GS} - V_T) = 1 \times 10^{-3}\,A/V$

$V_G = V_{GS} + V_S = 2 + 8 = 10V$

$I_7 = \frac{V_{CC} - V_G}{R_7} = 0.4\,mA = I_6$

$V_C = V_G - R_6 I_6 = 9.2V$

$I_5 = \frac{V_{CC} - V_C}{R_5} = 1.6\,mA$

$I_C = I_5 + I_6 = 2\,mA$

hp: $I_B << I_C \Rightarrow I_C \simeq I_E$

$V_E = I_E R_2 = 4.2V$

$V_{CE} = V_C - V_E = 9.2 - 4.2 = 5V$

$\Rightarrow h_{FE} = 290$; $h_{ie} = 4800\,\Omega$; $h_{fe} = 300$; $I_B = \frac{I_C}{h_{FE}} = 6.896\,\mu A$

$\Rightarrow$ hp OK

Q_2:
- $I_D = 0.5\,mA$
- $V_{DS} = 4V$
- $V_{GS} = 2V$
- $g_m = 1 \times 10^{-3}\,A/V$

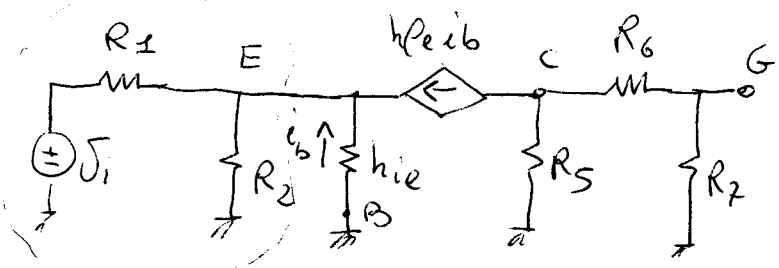
Q_1:
- $I_C = 2mA$
- $V_{CE} = 5V$
- $I_B = 6.896\,\mu A$
- $h_{FE} = 290$
- $h_{fe} = 300$
- $h_{ie} = 4800\,\Omega$

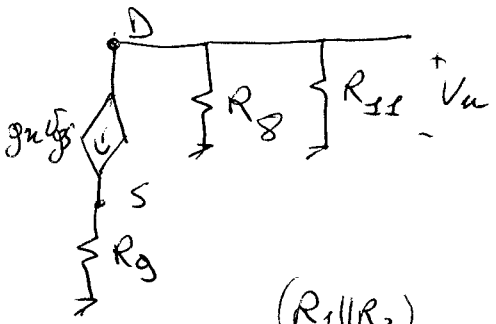
$V_B = V_E + V_\gamma = 4.2 + 0.7 = 4.9\,V$

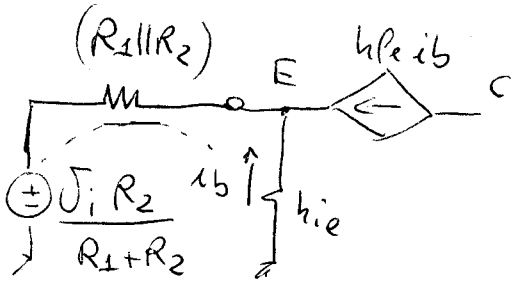
$I_3 = \frac{V_B}{R_3} = 20\,\mu A$

$I_4 = I_3 + I_B = 26.8965\,\mu A$

$R_4 = \frac{V_{cc} - V_B}{I_4} = \frac{13.1}{26.8965 \times 10^{-6}} = 487051.28\,\Omega$







$V_u = (-g_m V_{gs})(R_8 \| R_{11})$

$V_s = (g_m V_{gs}) R_g$

$V_{gs} = V_g - g_m V_{gs} R_g \Rightarrow V_{gs} = \frac{V_g}{1 + g_m R_g}$

$V_g = (-h_{fe} i_b) \frac{R_5}{R_5 + R_6 + R_7} . R_7$

$\frac{V_i R_2}{R_1 + R_2} = -(R_1 \| R_2)(h_{fe}+1) i_b - h_{ie} i_b = -[h_{ie} + (R_1 \| R_2)(h_{fe}+1)] i_b$

$\Rightarrow i_b = V_i \frac{R_2}{R_1 + R_2} \frac{(-1)}{h_{ie} + (R_1 \| R_2)(h_{fe}+1)}$

$\frac{V_u}{V_i} = (-g_m)(R_8 \| R_{11}) \frac{1}{1 + g_m R_g} (-h_{fe}) \frac{R_5 R_7}{R_5 + R_6 + R_7} (-1) \frac{R_2}{R_1 + R_2} \frac{1}{h_{ie} + (R_1 \| R_2)(h_{fe}+1)}$

$(10^{-3})\ (6 \times 10^3)\quad 0.83\quad 300\quad 4 \times 10^3\quad 0.875\quad 1/858 \pm 2.5 = 1.193 \times 10^{-3}$

$= -62.64$

$|A_V|_{dB} = 35.93\ dB$

EJERCICIO B

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

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

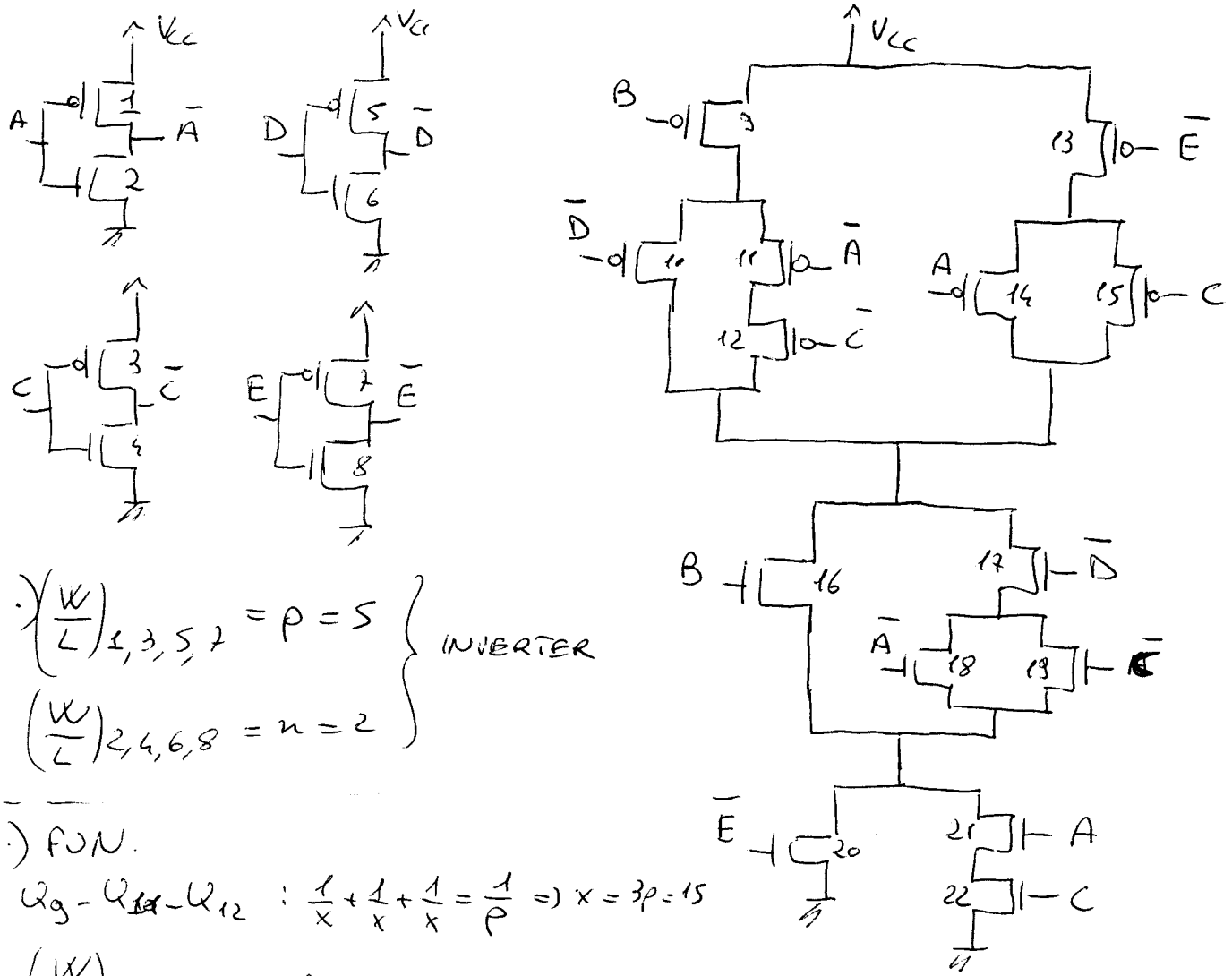
$$= \bar{A}\bar{B}D + \bar{A}E + \bar{B}D\bar{E} + \cancel{E\bar{E}} + \bar{B}\bar{C}D + \bar{C}DE + \bar{C}\bar{D}E + A\bar{B}C + \bar{B}D =$$

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

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

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

MOS = 7x2 + 4x2 = 22 MOS



$\left(\frac{W}{L}\right)_{1,3,5,7} = p = 5$

$\left(\frac{W}{L}\right)_{2,4,6,8} = n = 2$

} INVERTER

) FUN.

$Q_9 - Q_{11} - Q_{12}$: $\frac{1}{x} + \frac{1}{x} + \frac{1}{x} = \frac{1}{p} \Rightarrow x = 3p = 15$

$\left(\frac{W}{L}\right)_{9,11,12} = 15$

$Q_9 - Q_{10}$: $\frac{1}{9} + \frac{1}{3p} = \frac{1}{p} \Rightarrow 9 = \frac{3}{2}p = 7.5$

$\left(\frac{W}{L}\right)_{10} = 7.5$

$Q_{13} - Q_{14}$
$Q_{13} - Q_{15}$: $\frac{1}{2} + \frac{1}{2} = \frac{1}{\rho} \Rightarrow 2 = 2\rho = 10$

$\left(\frac{W}{L}\right)_{13,14,15} = 10$

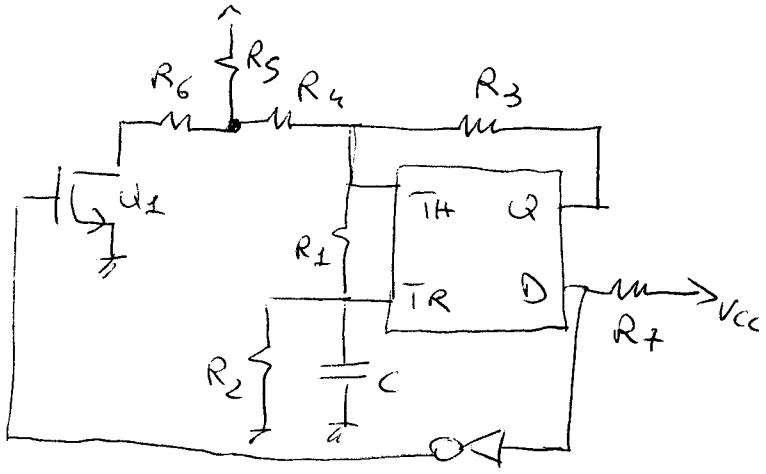
.) PDN

$Q_{17} - Q_{18} - Q_{21} - Q_{22}$ NON È POSSIBILE per A e Ā
$Q_{17} - Q_{19} - Q_{21} - Q_{22}$ " " " " C e C̄

$Q_{17} - Q_{18} - Q_{20}$
$Q_{17} - Q_{19} - Q_{20}$: $\frac{1}{K} + \frac{1}{K} + \frac{1}{K} = \frac{1}{n} \Rightarrow K = 3n = 6$
$Q_{16} - Q_{21} - Q_{22}$

$\left(\frac{W}{L}\right)_{16,17,18,19,20,21,22} = 6$

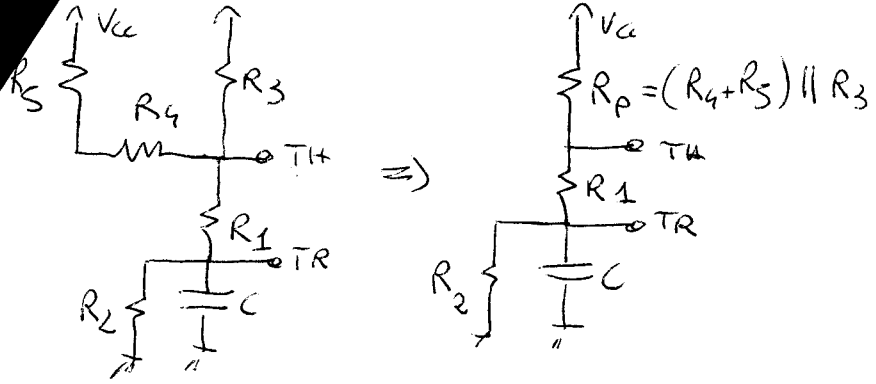
ESERCIZIO C



$R_1 = 80\,\Omega$
$R_2 = 2K\Omega$
$R_3 = 400\,\Omega$
$R_4 = 400\,\Omega$
$R_5 = 1200\,\Omega$
$R_6 = 800\,\Omega$
$R_7 = 1K\Omega$
$C = 60\,nF$
$V_{cc} = 6V$

.) $Q = 1$

$D = HI \Rightarrow V_{G1} = \phi V$
$V_S = \phi V \Rightarrow V_{GS} = \phi V < V_T \Rightarrow Q_1$ OFF



$R_p = (R_4+R_5) \parallel R_3 = 320\,\Omega$

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

$V_f = \frac{V_{cc}}{R_p + R_1 + R_2} \cdot R_2 = 5V$

$V_i < V_{COR} < V_f$

$2V < 3.5V < 5V$ OK

$V_{TH+} = 4V$

$I_1 = \frac{V_{cc} - V_{TH}}{R_p} = 6.25\,mA$

$V_{COR} = V_{TH+} - R_1 I_1 = 3.5V$

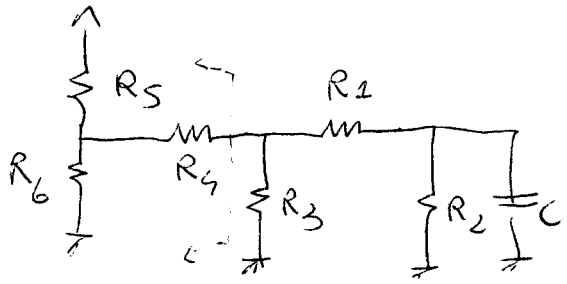
$R_{VC} = R_2 \parallel (R_1 + R_p) = 333.\bar{3}\,\Omega$

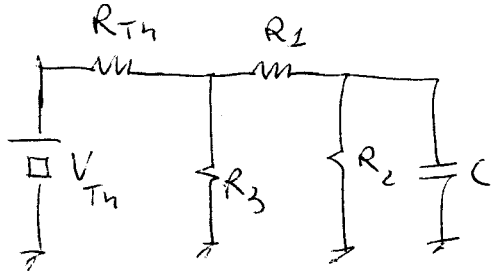
$\tau_1 = C R_{VC} = 20\,\mu s$

$T_1 = \tau_1 \ln\left(\frac{V_{i1} - V_{f1}}{V_{COR1} - V_{f1}}\right) = 13.863\,\mu s$

$Q = 0$ $V_G = 6V$ $V_S = 0V$ $V_{GS} > V_T \Rightarrow Q_1$ ON

$D = 0$





$V_{TH} = V_{cc}\frac{R_6}{R_5 + R_6} = 2.4V$

$R_{TH} = R_4 + (R_5 \parallel R_6) = 880\,\Omega$

$$V_{f2} = V_{Th} \frac{1}{R_{Th} + R_3 \| (R_1 + R_2)} \frac{R_3}{R_3 + R_1 + R_2} R_2 = 0.637\,V$$

$V_{i2} = V_{com1} = 3.5V$

$V_{com2} = V_{i1} = 2V$

$V_{i2} > V_{com2} > V_{f2}$

$3.5V > 2V > 0.637\,V$ OK

$$R_{vc2} = R_2 \| \left[R_1 + (R_3 \| R_{Th}) \right] = 301.486\,\Omega$$

$$\tau_2 = C \cdot R_{vc2} = 18.089\,\mu s$$

$$T_2 = \tau_2 \ln\left(\frac{V_{i2} - V_{f2}}{V_{com2} - V_{f2}} \right) = 13.425\,\mu s$$

$$T = T_1 + T_2 = 27.288\,\mu s$$

$$f = \frac{1}{T} = 36645.6\ Hz$$