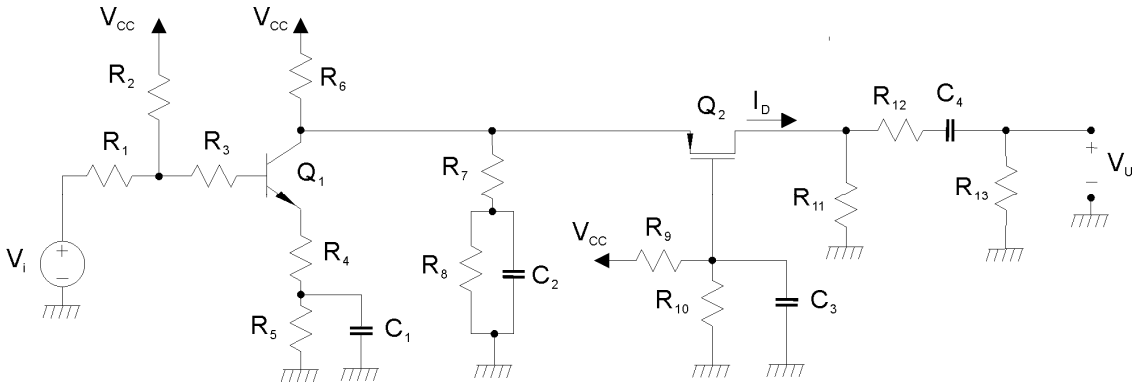
ELETTRONICA DIGITALE

Corso di Laurea in Ingegneria Informatica

Prova scritta del 19 luglio 2013

Esercizio A



R_1 = 10 k Ω	R_2 = 20.4 k Ω	R_4 = 100 Ω	R_5 = 2.4 k Ω	R_6 = 1250 Ω	R_7 = 1 k Ω	R_8 = 24 k Ω	R_9 = 26 k Ω	R_{10} = 10 k Ω
R_{11} = 1 k Ω	R_{12} = 1 k Ω	R_{13} = 20 k Ω	C_1= 1 μF	C_2= 250 nF	C_3= 1 μF	C_4= 700 pF	V_{CC} = 18 V	

Q_1 è un transistore BJT BC109B resistivo con $h_{re} = h_{oe}= 0$. Q_2 è un transistore MOS a canale p resistivo, con la corrente di drain in saturazione data da $I_D = k\,(V_{GS} - V_T)^2$ con k = 0.25 mA/V^2 e V_T = -1 V.
Con riferimento al circuito in figura:

1) Calcolare il valore della resistenza R_3 in modo che, in condizioni di riposo, la tensione di drain di Q_2 sia 4 V. Determinare, inoltre, il punto di riposo dei due transistori e verificare la saturazione di Q_2. (R: R_3 = 25342.1 Ω)
2) Determinare 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 = - 1.44)
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} = 66.31 Hz; f_{p1} = 7781.83 Hz; f_{z2} = 663.14 Hz; f_{p2} = 495.61 Hz; f_{z4} = 0 Hz; f_{p4} = 10334.74 Hz)

Esercizio B

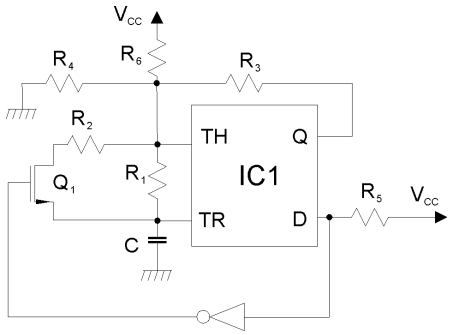
Progettare una porta logica in tecnologia CMOS, utilizzando la tecnica della pull-up network e della pull-down network, che implementi la funzione logica:

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

Determinare il numero di 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.

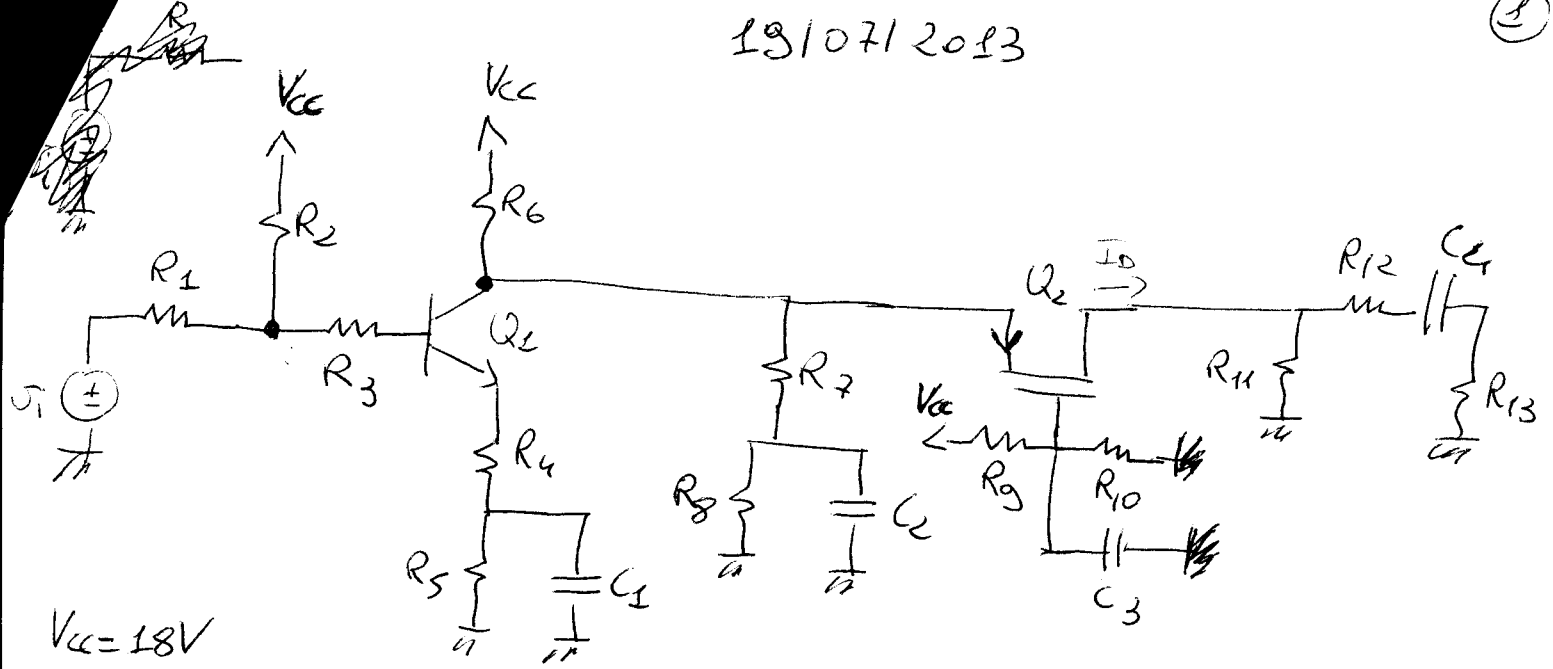
Esercizio C

R_1 =100 Ω
R_2 = 1 k Ω
R_3 = 200 Ω
R_4 = 2 k Ω
R_5 = 1 k Ω
R_6 = 3 k Ω
C = 100 nF
V_{CC} = 5 V



Il circuito IC_1 è un NE555 alimentato a V_{CC} = 5V, Q_1 ha una R_{on} = 0 e V_T = 1 V, l'inverter è ideale. Determinare la frequenza del segnale di uscita del multivibratore in figura. (R: f = 41076.76 Hz)

19/07/2013



$V_{cc} = 18V$

$R_1 = 10K\Omega$ $R_2 = 20.4K$ $R_4 = 100\Omega$ $R_5 = 2400\Omega$

$R_6 = 1250\Omega$ $R_7 = 1K\Omega$ $R_8 = 24K\Omega$ $R_9 = 26K\Omega$

$R_{10} = 10K\Omega$ $R_{11} = 1K\Omega$ $R_{12} = 1K\Omega$ $R_{13} = 20K\Omega$

$I_D = k(V_{GS} - V_T)^2$ $K = 0.25 \times 10^{-3} \frac{A}{V}$

) Det. R_3 tale che $V_D = 4V$

$I_{R11} = I_D = \frac{V_D}{R_{11}} = 4mA$

$(V_{GS} - V_T) = -\sqrt{\frac{I_D}{K}} = -4V$

$V_{GS} = -5V$

$V_G = V_{cc} \frac{R_{10}}{R_9 + R_{10}} = 5V$

$V_S = -V_{GS} + V_G = 10V$

$I_{R7} = \frac{V_S}{R_7 + R_8} = 0.4mA$

$I_{R6} = \frac{V_{cc} - V_S}{R_6} = 6.4mA$

$I_C = I_{R6} - I_{R7} - I_D = 2mA$

$I_C \simeq I_E$

$V_E = I_E (R_4 + R_5) = 5V$

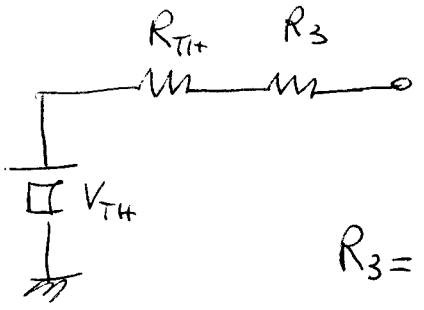
$V_{CE} = V_S - V_E = 5V$

Q_2 { $|I_D| = 4mA$; $V_{DS} = -6V$ > $V_{GS} - V_T = -4V$; $g_m = 2K|V_{GS} - V_T| = 2 \times 10^{-3} \frac{A}{V}$

Q_1 { $I_C = 2mA$ $I_B = 6.8965 \times 10^{-6} A$; $V_{CE} = 5V$; $h_{FE} = 290$; $h_{fe} = 300$; $h_{ie} = 4800\Omega$

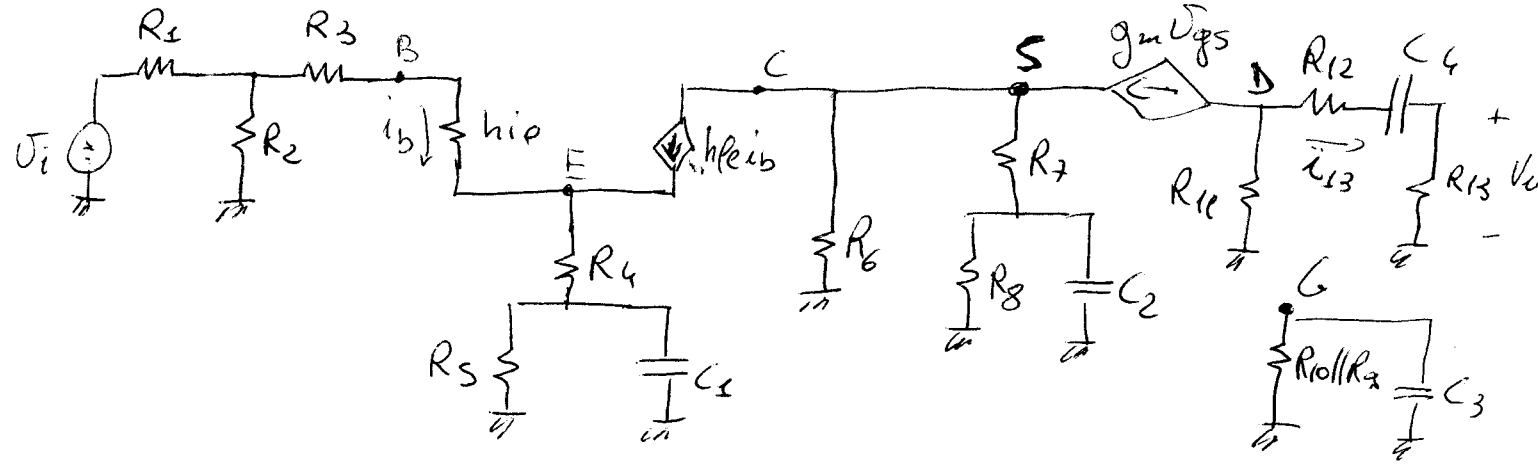
$V_B = V_E + V_\gamma = 5.7\,V$

$R_{TH} = R_1 \| R_2 = 6710.526\ \Omega$



$$V_{TH} = \frac{V_{cc}\, R_1}{R_1 + R_2} = 5.921\ \Omega$$

$$R_3 = \frac{V_{TH} - R_{TH} I_B - V_B}{I_B} = 25342.1\ \Omega$$



A_{CB}

$$v_{ie} = + R_{13}\, i_{13}$$

$$\left.\begin{aligned} i_{13} &= - g_m v_{gs}\, \frac{R_{11}}{R_{11} + R_{12} + R_{13}} \\ v_g &= \phi \end{aligned}\right\} \Rightarrow i_{13} = g_m v_s \frac{R_{11}}{R_{11} + R_{12} + R_{13}}$$

$$v_s = (R_6 \| R_7)\left[g_m v_{gs} - h_{fe}\, i_b \right] = - \frac{(R_6 \| R_7)\, h_{fe}\, i_b}{1 + g_m (R_6 \| R_7)}$$

$$i_b = \frac{v_i}{R_1 + R_2 \| \left[R_3 + h_{ie} + R_4 (h_{fe} + 1) \right]} \cdot \frac{R_2}{R_2 + R_3 + h_{ie} + R_4 (h_{fe} + 1)}$$

$$A_{CB} = \frac{V_o}{V_i} = \left(g_m \frac{R_{13}\, R_{11}}{R_{11} + R_{12} + R_{13}} \left(- \frac{R_6 \| R_7\, h_{fe}}{1 + g_m (R_6 \| R_7)} \right) \cdot \frac{1}{R_1 + R_2 \| \left[R_3 + h_{ie} + R_4 (h_{fe} + 1) \right]} \right) \cdot \frac{R_2}{R_2 + R_3 + h_{ie} + R_4 (h_{fe} + 1)} = -1.43866 \quad \left(|A_{CB}| = 3.159\ dB \right)$$

: $1\mu F$

$f_{z1} = \frac{1}{2\pi C_1 R_S} = 66.314\ Hz$ (R_S: 2400)

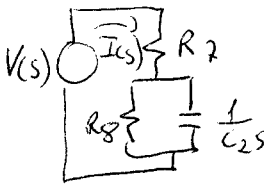
$f_{p1} = \frac{1}{2\pi C_1 \left[R_S \| \left(R_4 + \frac{R_1 \| R_2 + R_3 + h_{ie}}{h_{fe}+1} \right) \right]} = 781.830\ Hz$

222.43

C_2: 250 nF

zero: $Z(s) = R_7 + \left(R_8 \| \frac{1}{C_2 s} \right) = \phi$

* $Y(s) = \frac{1}{Z(s)} \to \infty$



$f_{z2} = \frac{1}{2\pi C_2 \left[R_7 \| R_8 \right]} = 663.14\ Hz$ (960)

polo: $f_{p2} = \frac{1}{2\pi C_2 \left\{ R_8 \| \left[R_7 + \left(R_6 \| \frac{1}{g_m} \right) \right] \right\}} = 495.61\ Hz$

1284.507

C_3: polo e zero concidenti

C_4: $f_{z4} = \phi$ $\quad C_4 = 700pF$

$f_{p4} = \frac{1}{2\pi C_4 \left(R_{11} + R_{12} + R_{13} \right)} = 1034.74\ Hz$ (R_{12}: 22K)

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

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

$$= \overline{B}A + \overline{B}\,\overline{D} + \overline{B}\,\overline{C}E + A\overline{C} + \overline{C}\,\overline{D} + \overline{C}E + \overline{B}A + \overline{B}\,\overline{D} + \overline{B}\,\overline{C}E + A\overline{C} +$$

$$+ \overline{C}\,\overline{D} + \overline{C}E =$$

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

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

$$= \underset{O}{\overline{B}A} + \underset{X}{\overline{B}\,\overline{D}} + \underset{X}{\overline{B}\,\overline{C}E} + \underset{O}{A\overline{C}} + \overline{C}\,\overline{D} + \overline{C}E + \underset{O}{AC} + \underset{X}{\overline{B}D} =$$

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

14 MOSFET

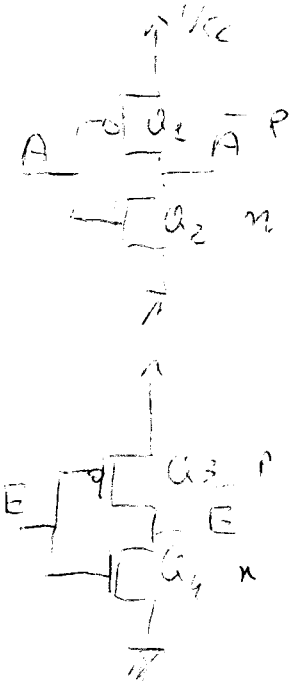
Q_1, Q_3, Q_5, Q_6 : P

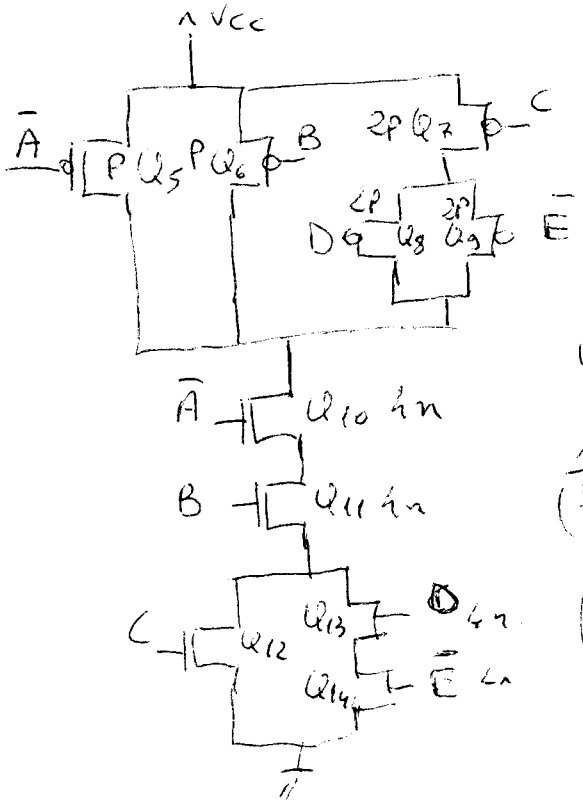
$Q_7, Q_8, Q_9 = 2P$

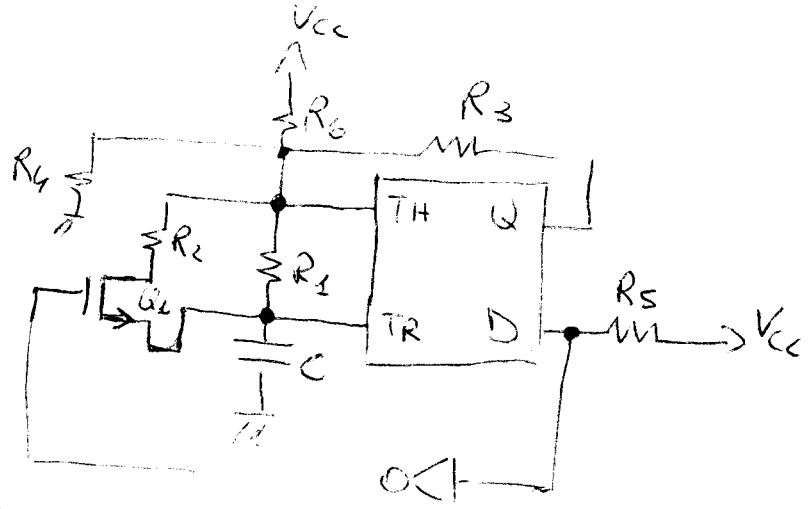
$Q_{10}, Q_{11}, Q_{13}, Q_{14}$: 4n

$$\frac{1}{\left(\frac{W}{L}\right)_{12}} + \frac{1}{4n} + \frac{1}{4n} = \frac{1}{n}$$

$$\left(\frac{W}{L}\right)_{12} = 2n$$



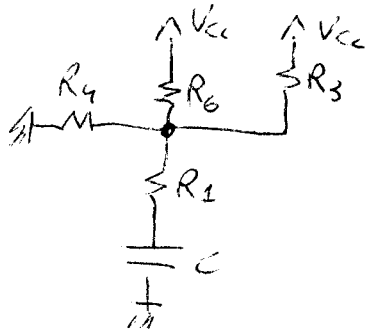




$R_1 = 100\,\Omega$
$R_2 = 1\,K\Omega$
$R_3 = 200\,\Omega$
$R_4 = 2\,K\Omega$
$R_6 = 3\,K\Omega$
$C = 100\,nF$
$R_5 = 1K\Omega$

Q = 1 D: alta impedancia $V_{GS} = \phi V$

$V_S = V_{TR} = \frac{1}{3} V_{cc}$ $\Big\}$ $V_{GS} = -\frac{1}{3} V_{cc} < V_T$ $\Rightarrow$ Q1 OFF



$V_f = \frac{V_{cc}\ R_4}{R_4 + R_3 \| R_6} = 4.5714\ V$

$I_{R1} = \frac{V_{cc} - 2/3 V_{cc}}{R_3 \| R_6} - \frac{2/3 V_{cc}}{R_4} = 7.\bar{2} \times 10^{-3}\ A$

$V_{con} = \frac{2}{3} V_{cc} - R_1 I_{R1} = 2.6\bar{1}\ V$

$V_i < V_{con} < V_f$
$1\ \bar{6}V < 2.6\bar{1}V < 4.5714V$ ok

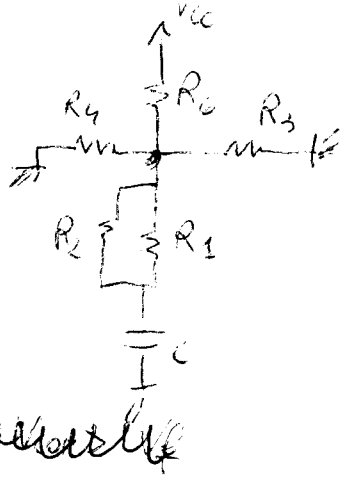
$R_{Vc} = R_1 + R_4 \| R_6 \| R_3 = 271.428\ \Omega$

$\tau_1 = C R_{Vc} = 2.714 \times 10^{-5}\ s$

$T_1 = \tau_1 \ln \frac{V_i - V_f}{V_{con} - V_f} = 1.0674 \times 10^{-5}\ s$

Q = 0 D = 0V $\Rightarrow$ $V_G = 5\,V$

$V_S = V_{con} = 2.6\bar{1}\ V$ $\Big\}$ $\Rightarrow V_{GS} = 2.3\bar{9}\ V > V_T$ ON



$V_i = 2.6\bar{1}\ V$ $\quad V_{con} = \frac{1}{3} V_{cc}$

$V_f = V_{cc} \frac{R_3 \| R_4}{(R_3 \| R_4) + R_6} = 0.2857\ V$

$R_{Vc} = (R_1 \| R_2) + (R_3 \| R_4 \| R_6) = 262,34\ \Omega$

$\tau_2 = 2.623 \times 10^{-5}\ s$

$T_2 = 1.367 \times 10^{-5}\ s$

$V_i > V_{con} > V_f$
$2.6\bar{1} > 1.\bar{6} > 0.2857V$ ok

$T = T_1 + T_2 = 2.4345 \times 10^{-5}\ s$ $\quad f = \frac{1}{T} = 41076.76\ Hz$