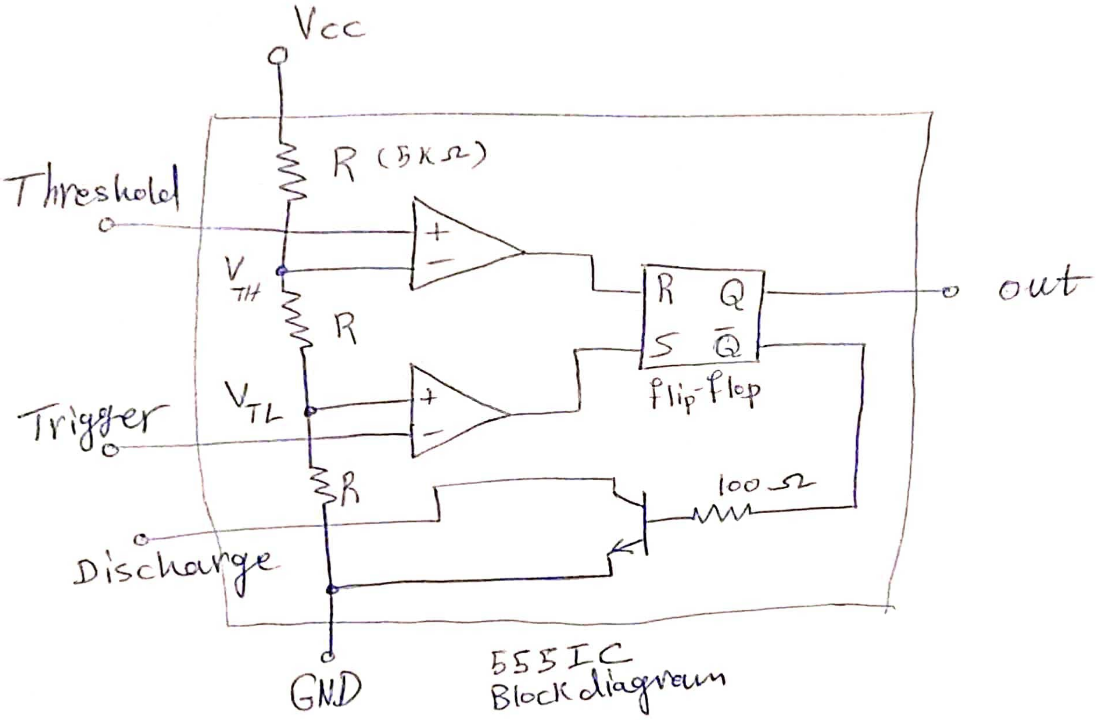
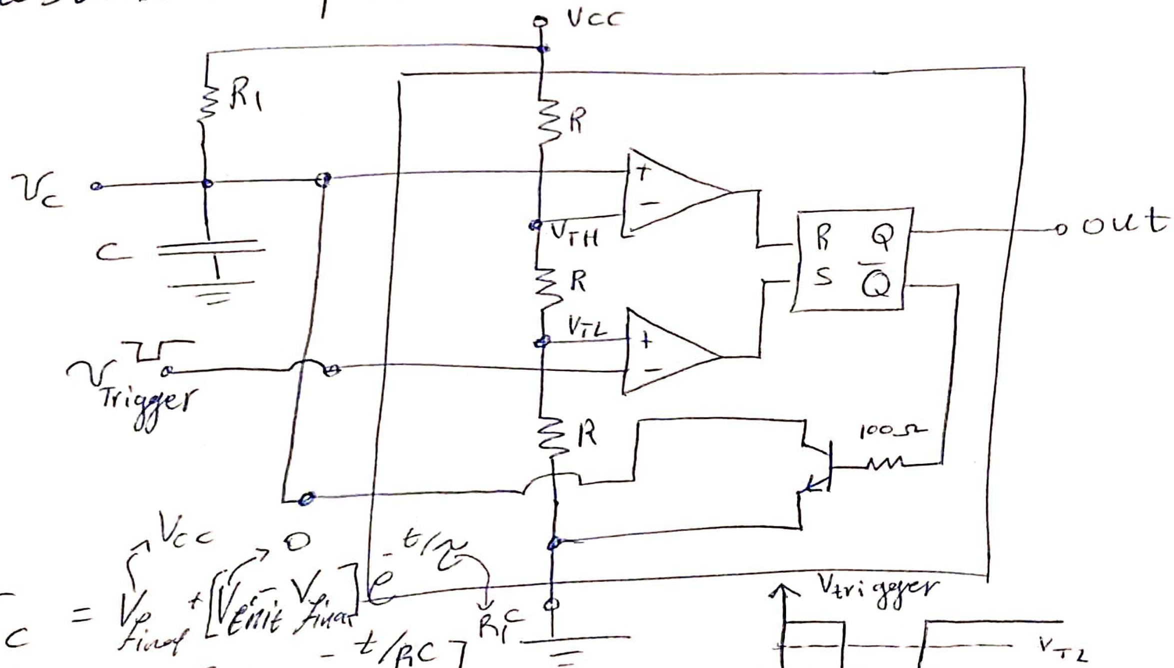
555 Timer :



555 IC
Block diagram

* Monostable operation :



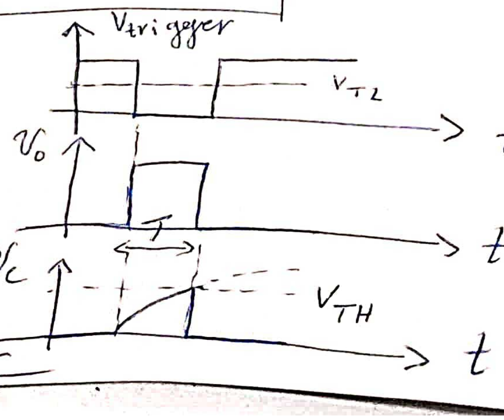
$$v_c = \overset{V_{cc}}{V_{final}} + [\overset{0}{V_{init}} - V_{final}]\, e^{-t/\overset{}{\underset{R_1C}{\tau}}}$$

$$v_c = V_{cc}\left[1 - e^{-t/R_1C}\right]$$

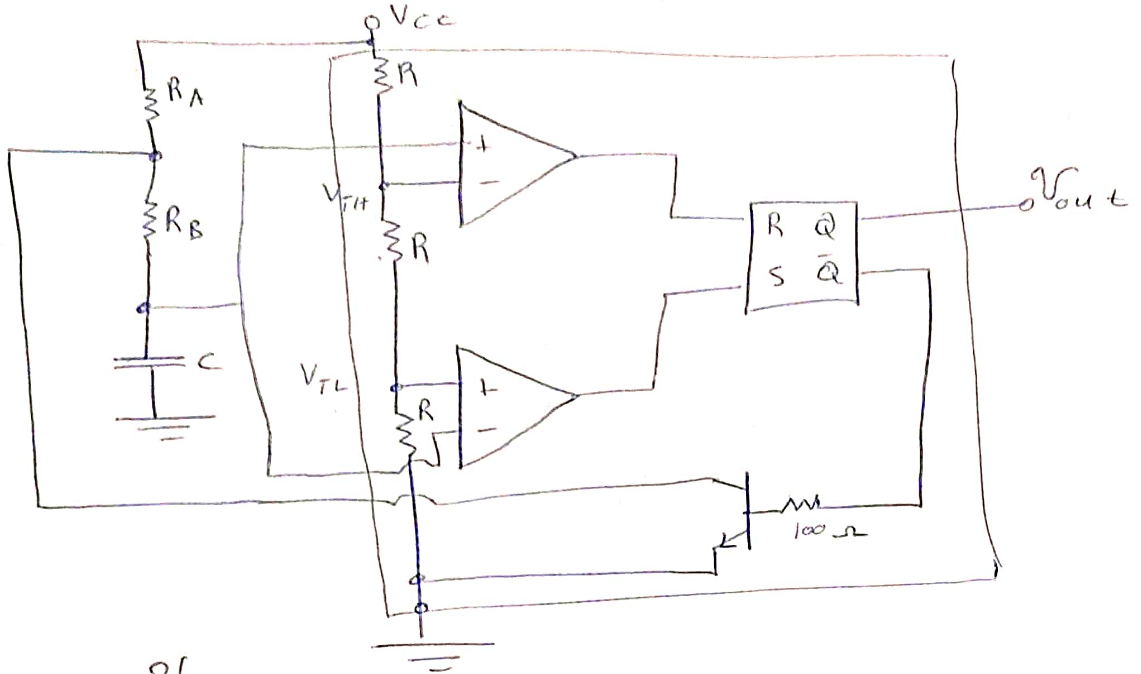
at $t = T \Rightarrow v_c = \frac{2}{3} V_{cc} = V_{TH}$

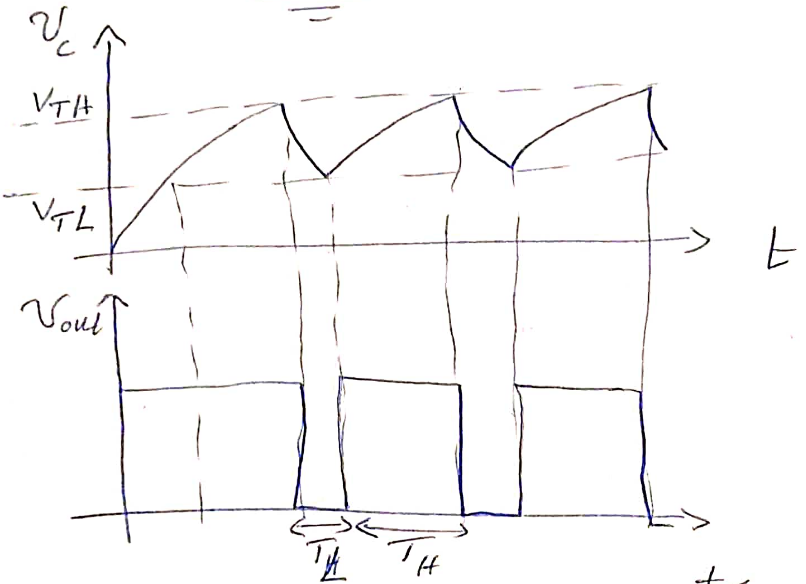
$$\Rightarrow \frac{2}{3} \cancel{V_{cc}} = \cancel{V_{cc}}\left[1 - e^{-T/R_1C}\right]$$

$$\Rightarrow T = R_1 C \ln(3) = 1.1\, R_1 C$$



* Astable operation:





\#

$\because \; v_c = V_f + (V_{init} - V_f)\, e^{-t/\tau}$

* at charging:

$(v_{out} = V_{cc})$

$v_c = V_{cc} + (V_{TL} - V_{cc})\, e^{-t/\tau}$, $\tau = (R_A + R_B)C$

$\Rightarrow v_c = V_{TH}$ at $t = T_H$

$V_{TH} = 2/3 \, V_{cc}$, $V_{TL} = 1/3 \, V_{cc}$

$\Rightarrow \frac{2}{3} \cancel{V_{cc}} = \cancel{V_{cc}} + \left(\frac{1}{3} \cancel{V_{cc}} - \cancel{V_{cc}}\right) e^{-\frac{T_H}{(R_A+R_B)C}}$

$\Rightarrow \cancel{-}\frac{1}{3} = \cancel{-}\frac{2}{3} e^{-\frac{T_H}{\tau}}$

$\Rightarrow T_H = (R_A + R_B)C(\ln(2)) = 0.69(R_A+R_B)C$

* at discharging ($V_{out} = 0$):

$$V_c = \underset{V_f}{0} + (\underset{V_{init}}{V_{TH}} - 0) e^{-t/\tau} \quad , \tau = R_B C$$

$$V_c = V_{TH} e^{-t/\tau} = \frac{2}{3} V_{cc} e^{-\frac{t}{R_B C}}$$

at $V_c = \frac{1}{3} V_{cc}$, $\Rightarrow$ $t = T_L$

$$\frac{1}{3} \cancel{V_{cc}} = \frac{2}{3} \cancel{V_{cc}} e^{-\frac{T_L}{R_B C}}$$

$$\Rightarrow T_L = \ln(2) R_B C = 0.69 R_B C$$

$\Rightarrow$ Duty cycle $= \dfrac{T_H}{T_H + T_L} = \dfrac{R_A + R_B}{R_A + 2R_B}$

period. $\Rightarrow T = T_H + T_L \Rightarrow f = \frac{1}{T}$

EX 1 : using 10 nF capacitor, find the value of R_1 that yields an o/p pulse of 100 μs in monostable ct.

sol :

$$\because T = R_1 C \ln(3)$$

$$\Rightarrow R_1 = \frac{100 * 10^{-6}}{10 * 10^{-9} \ln(3)} = 9.1 \text{ K}\Omega$$

EX 2: For the 555-Astable multivibrator based ct. with a 1000 pf cap. find the values of R_A & R_B that results in oscillation freq. of 100 KHZ & duty cycle 75%.

Sol:

$f = 100\ KHZ \Rightarrow T = \frac{1}{f} = 10\ \mu sec.$

$\Rightarrow$ duty cycle $= 75\% \Rightarrow T_H = 7.5\ \mu sec$

$\Rightarrow T_L = 2.5\ \mu sec$

$\because$ duty cycle $= \frac{R_A + R_B}{R_A + 2R_B} = 0.75$ (1)

$\because T = \ln(2)\ [R_A + 2R_B]\ C$

$\Rightarrow 10 * 10^{-6} = 0.69\ (1000 * 10^{-12})\ (R_A + 2R_B)$

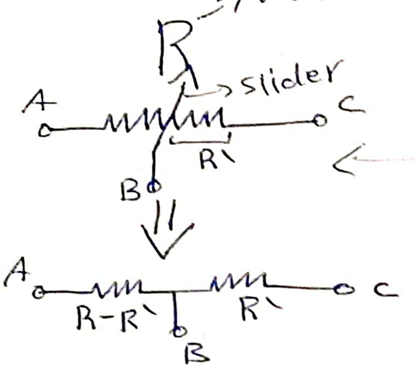
$\Rightarrow \boxed{R_A = 14.5 * 10^{3} - 2R_B}$ sub. in (1)

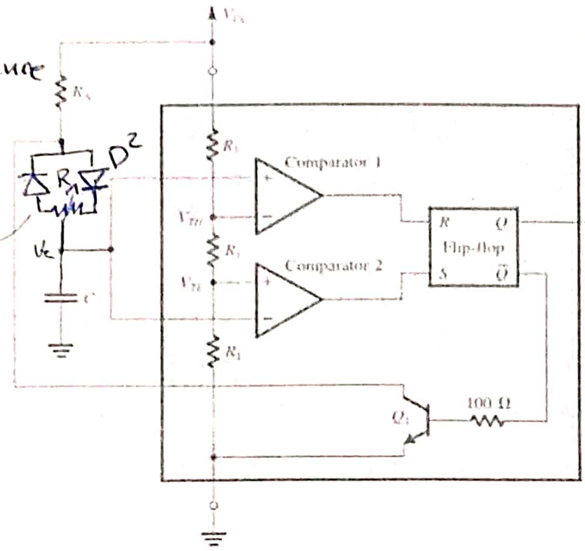
$\Rightarrow 0.75 = \frac{14.5 * 10^{3} - R_B}{14.5 * 10^{3}}$

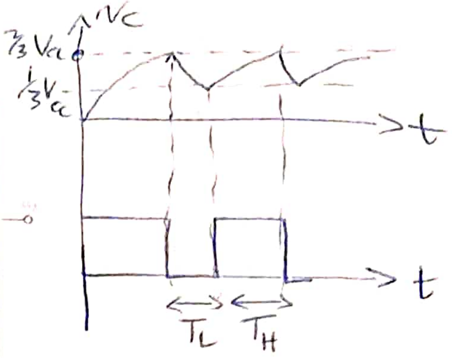
$\Rightarrow R_B = 3.62\ K\Omega$

$\Rightarrow R_A = 7.26\ K\Omega$

Astable ct. for PWM (constant freq.):







(Assuming Ideal Diodes)

At charging:

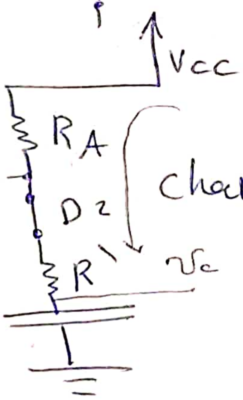
$D_1 \rightarrow$ off

$D_2 \rightarrow$ ON

$$\Rightarrow \tau = (R_A + R`)\,C$$

$$\Rightarrow v_c = (V_F) + (V_{init} - V_F)\,e^{-t/\tau}$$

$V_F \rightarrow V_{cc}$, $V_{init} \rightarrow \frac{1}{3}V_{cc}$



at $t = T_H \rightarrow v_c = \frac{2}{3}V_{cc}$:

$$\frac{2}{3}V_{cc} = V_{cc} + \left(\frac{1}{3}V_{cc} - V_{cc}\right)e^{-T_H/\tau}$$

$$\frac{2}{3}\cancel{V_{cc}}\,e^{-T_H/\tau} = \frac{1}{3}\cancel{V_{cc}}$$

$$\Rightarrow e^{T_H/\tau} = 2$$

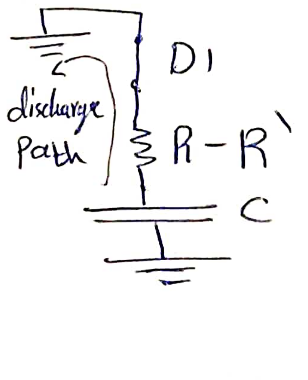
$$T_H = \tau \ln(2) = \ln(2)\,(R` + R_A)\,C$$

A discharging:

$$\Rightarrow \tau = (R - R`)\,C$$

$$\Rightarrow v_c = (V_F) + (V_{init} - V_F)\,e^{-t/\tau}$$

$V_F \rightarrow 0$, $V_{init} \rightarrow \frac{2}{3}V_{cc}$, $V_F \rightarrow 0$



$$\Rightarrow v_{cc} = \frac{2}{3}V_{cc}\,e^{-t/\tau}$$

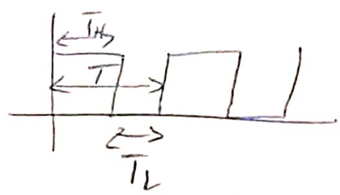
$\Rightarrow$ at $t = T_L \rightarrow v_C = \frac{1}{3} V_{cc}$

$\Rightarrow \frac{1}{\cancel{3}} \cancel{V_{cc}} = \frac{2}{\cancel{3}} \cancel{V_{cc}}\, e^{-T_L/\tau}$

$\Rightarrow e^{T_L/\tau} = 2$

$\Rightarrow T_L = \ln(2)\,\tau$

$\Rightarrow T_L = \ln(2)\,(R - R')\,C$



$\Rightarrow T = T_L + T_H = \ln(2)(R - R')C + \ln(2)(R' + R_A)C$

$= \underline{\ln(2)\,(R + R_A)\,C}$

↳ independent on R'

↳ changing R' (potentiometer slider) only changes the duty cycle, but does not change the frequency

$\Rightarrow$ duty cycle $= \dfrac{T_H}{T_L + T_H}$

$= \dfrac{R' + R_A}{R + R_A}$

$\Rightarrow f = \dfrac{1}{T}$

18.45 Consider the 555 circuit of Fig. 18.29 when the Threshold and the Trigger input terminals are joined together and connected to an input voltage v_I. Verify that the transfer characteristic v_O–v_I is that of an inverting bistable circuit with thresholds $V_{TL} = \frac{1}{3} V_{CC}$ and $V_{TH} = \frac{2}{3} V_{CC}$ and output levels of 0 and V_{CC}.

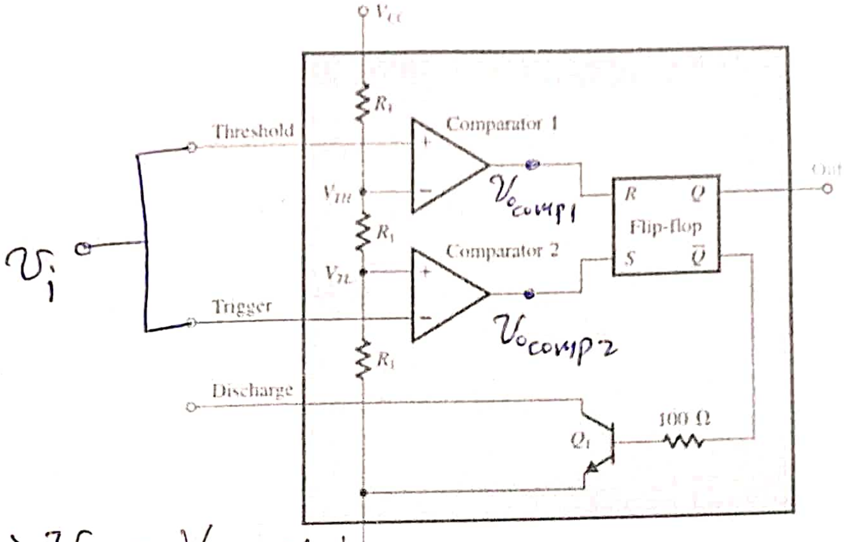


Figure 18.29 A block diagram representation of the internal circuit of the 555 integrated-circuit timer.

Sol:

* at $v_i > \frac{2}{3} V_{cc}$:

$\Rightarrow v_i = V^+_{comp1} > \frac{2}{3} V_{cc}$

$\Rightarrow V^-_{comp1} = \frac{2}{3} V_{cc}$

$\Rightarrow V^+_{comp1} > V^-_{comp1} \Rightarrow V_{o\,comp1} = V_{cc}$ (logic 1)

for comp2:

$v_i = V^-_{comp2} \Rightarrow V^-_{comp2} > V^+_{comp2}$

$\Rightarrow V_{o\,comp2} = 0V$ (logic 0)

$\Rightarrow R \to 1, S \to 0 \Rightarrow V_o = 0$

* at $v_i < \frac{1}{3} V_{cc}$:

for comp1:

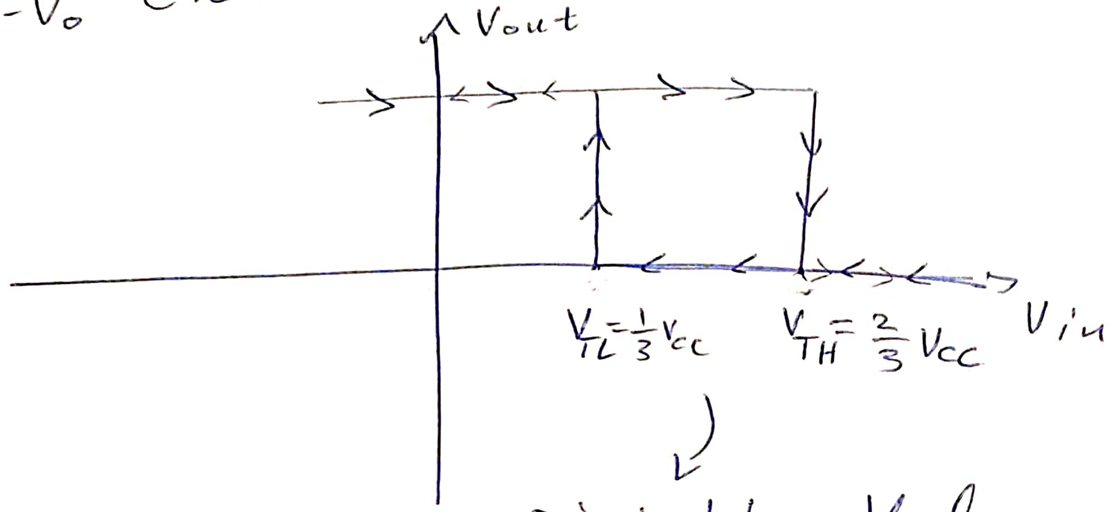
$v_i = V^+_{comp1} < \frac{2}{3} V_{cc} \Rightarrow v_{o\,comp1} = 0$ (logic 0)

for comp2:

$v_i = V^-_{comp2} < \underbrace{\frac{1}{3} V_{cc}}_{V^+_{comp2}} \Rightarrow v_{o\,comp2} = V_{cc}$ (logic(1))

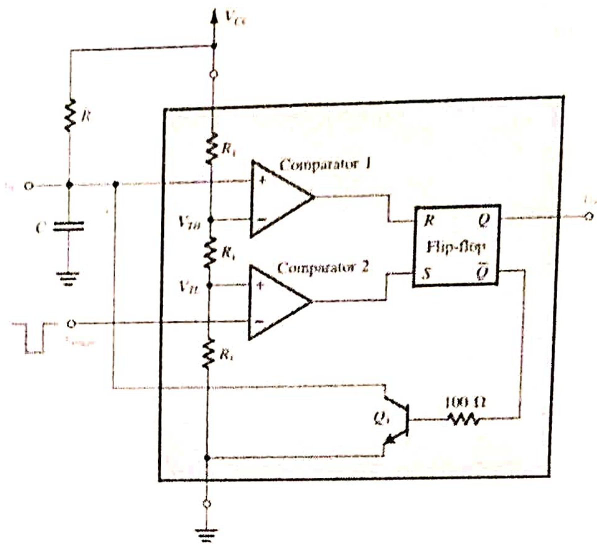
$\Rightarrow R \to 0, S \to 1 \Rightarrow v_o = V_{cc}$

* $V_I - V_o$ characteristic :



Bistable Mode

D 18.46 (a) Using a 0.5-nF capacitor C in the circuit of Fig. 18.30(a), find the value of R that results in an output pulse of 10-μs duration.
(b) If the 555 timer used in (a) is powered with $V_{CC} = 12$ V, and assuming that V_{TH} can be varied externally (i.e., it need not remain equal to $\frac{2}{3}V_{CC}$), find its required value so that the pulse width is increased to 20 μs, with other conditions the same as in (a).



sol:

a) $C = 0.5\ nF$
$T = 10\ \mu s$

∴ for Monostable:

$$T = RC\ln(3)$$

$$\Rightarrow R = \frac{T}{\ln(3)C} = \frac{10 * 10^{-6}}{\ln(3) * 0.5 * 10^{-9}} = 18.2\ K\Omega$$

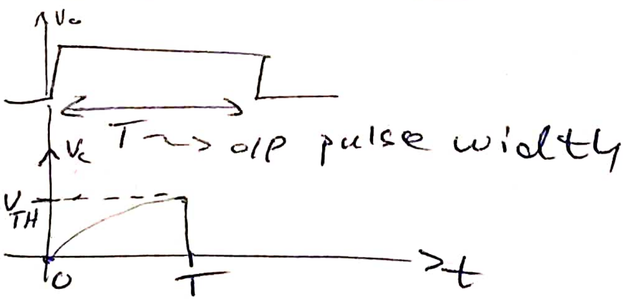
b) adjusting V_{TH} externally so that $T = 20\ \mu s$:
$V_{cc} = 12V$

∴ at charging:

$$v_c = \underbrace{V_{cc}}_{V_F} + (\underbrace{0}_{V_{init}} - V_{cc})e^{-t/\tau}, \quad \tau = RC$$

$$\Rightarrow v_c = V_{cc}\left[1 - e^{-\frac{t}{RC}}\right]$$

at $t = T \rightsquigarrow$
$\Rightarrow v_c = V_{TH}$



$$\Rightarrow V_{TH} = V_{cc}\left[1 - e^{-T/RC}\right]$$

$$\Rightarrow V_{TH} = 12\left[1 - e^{-\frac{20 * 10^{-6}}{18.2 * 10^{3} * 0.5 * 10^{-9}}}\right] = 10.6\ V$$