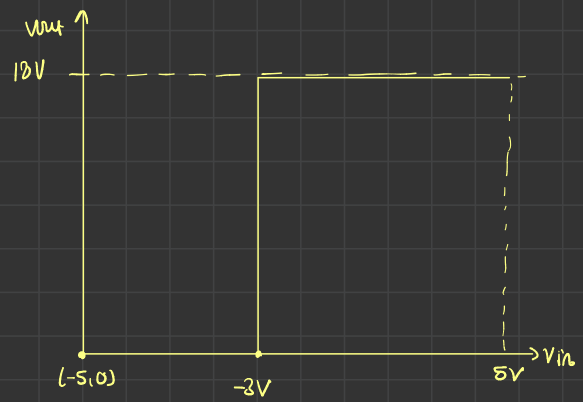
Q1 $V_{out} = (v^+ - v^-)A$

$= (v_{in} - v_{ref}) \times 10^6$

$V_{out} = (v_{in} - v_{ref}) \times 10^6$ $\quad -5V \le V_{in} \le +5V$

(a)

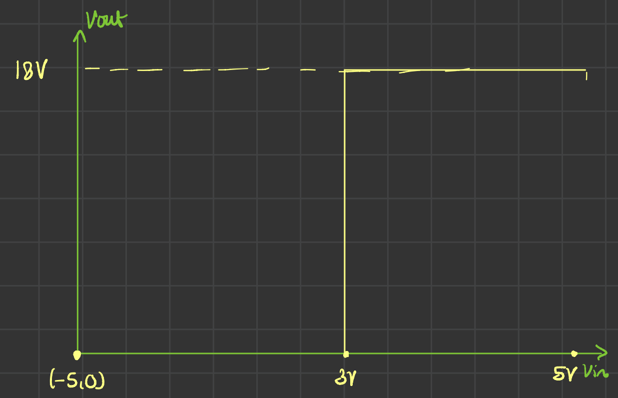


$V_{ref} = -3$

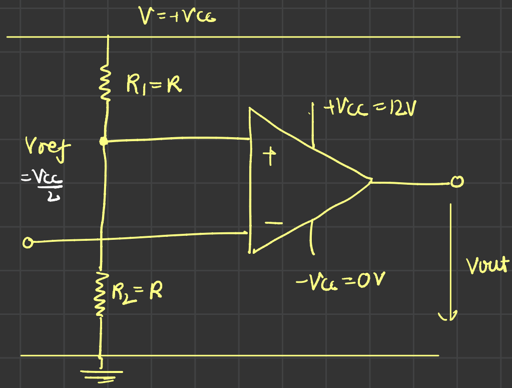
$V_{out} = (V_{in} + 3) \times 10^6$

(b) $V_{out} = (V_{in} - 3) \times 10^6$

$-5V \le V_{in} \le +5V$



Q2



$$v_{out} = (v^+ - v^-) \times A_v$$

$$v_{out} = (v_{ref} - v_{in}) \times 10^6$$

$$v_{out} = (6 - v_{in}) \times 10^6$$

Q3

$T_{ON} = 0.693(R_A+R_B) * C_{ext}$

$T_{ON} = 0.693(2.2+4.7)\times10^3 \times 0.022\times10^{-6}$

$= 1.052\times10^{-4}s$

$T_{OFF} = 0.693 R_B \times C_{ext}$

$= 0.693\times4.7\times10^3\times 0.022\times10^{-6}$

$T_{OFF} = 7.165\times10^{-5}s$

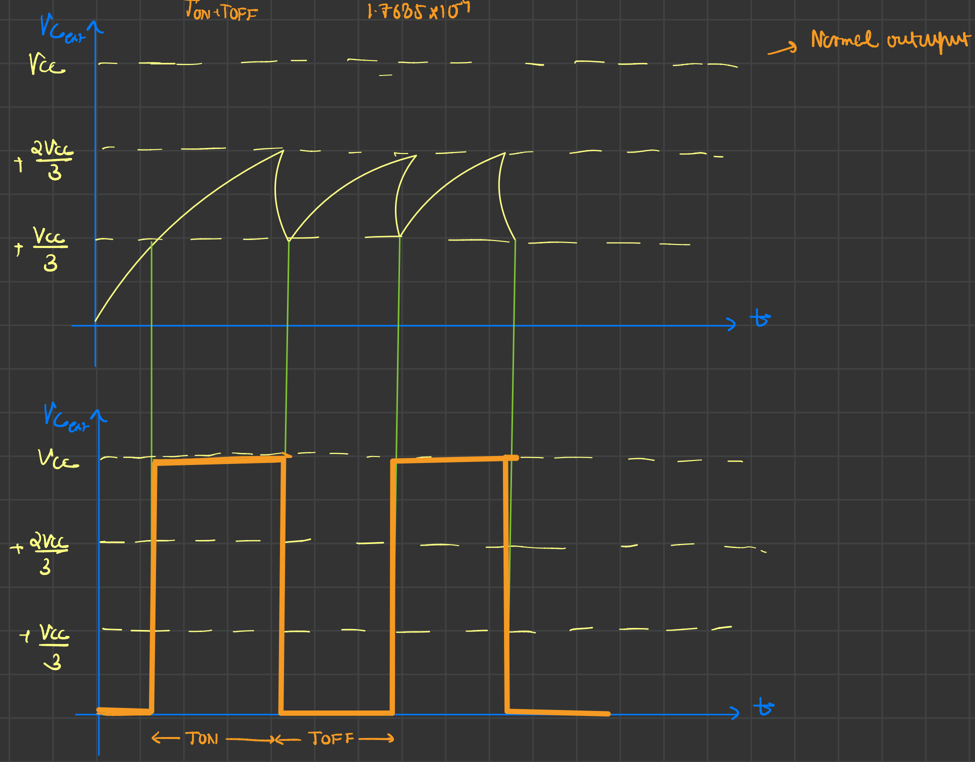
$T = T_{ON}+T_{OFF} = 1.052\times10^{-7} + 7.165\times10^{-5}$

$= 1.7685\times10^{-4}s$

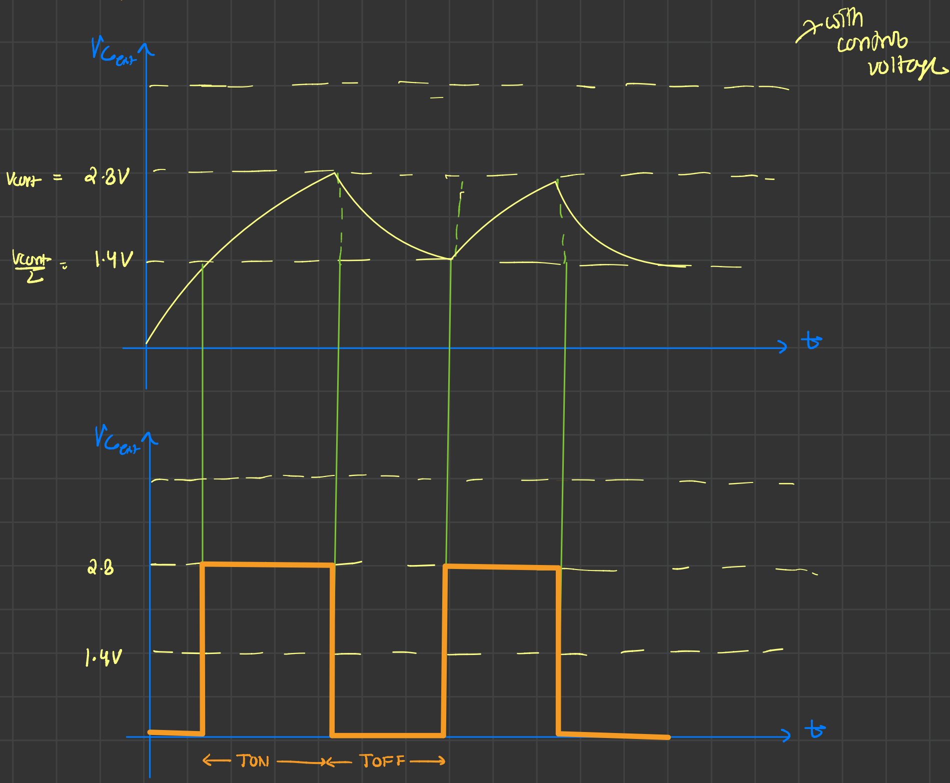
$f = \frac{1}{T} = 5654.311Hz$

$= 5.6kHz$

Duty cycle $= \frac{T_{ON}}{T_{ON}+T_{OFF}} \times100 = \frac{1.052\times10^{-4}}{1.7685\times10^{-7}}\times100 = 59.48\%$



With control pin at 2.8V

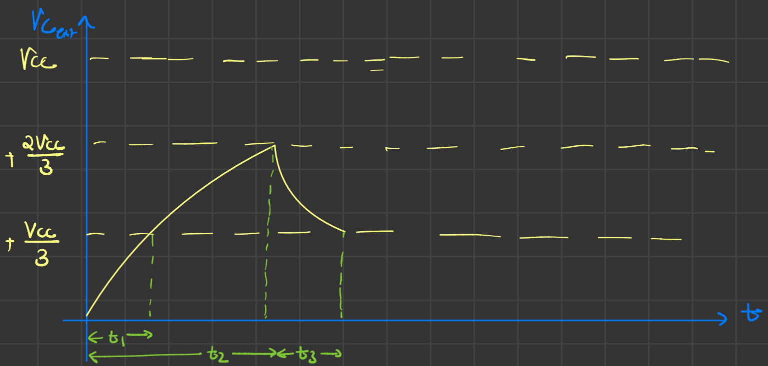


Charging of a capacitor

max voltage

Charging = $V_C(t) = V_{CC}\left[1 - \exp(-t/\tau_2)\right]$ — charging

$V_d(t) = V_{max}\exp(-t/\tau_d)$ — discharging



$\tau_c = (R_A + R_B)C$

$\tau_d = R_B C$

Charging

For t_1

$$\frac{V_{CC}}{3} = V_{CC}\left[1 - \exp\left(\frac{t_1}{\tau_c}\right)\right]$$

For t_2

$$\frac{2V_{CC}}{3} = V_{CC}\left[1 - \exp\left(-\frac{t_2}{\tau_c}\right)\right]$$

$$\frac{1}{3} = 1 - \exp(-t_1/\tau_c)$$

$$2/3 = 1 - \exp(-t_2/\tau_c)$$

$$\exp(-t_1/\tau_c) = 2/3$$

$$\exp(-t_2/\tau_c) = 1/3$$

Taking log on both sides

For discharging,

$$\frac{V_{CC}}{3} = \frac{2V_{CC}}{3}\exp(-t_3/\tau_d)$$

$$\frac{1}{\cancel{3}} = \frac{2}{\cancel{3}}\exp(-t_3/\tau_d)$$

$$\frac{1}{2} = \exp(-t_3/\tau_d)$$

$$\cancel{-}\ln 2 = \cancel{-}\frac{t_3}{\tau_d}$$

$$t_3 = \tau_d \ln 2$$

$$\boxed{t_3 = \ln 2\, R_B C}$$

$\tau_d = R_B \times C$

$$-\frac{t_1}{\tau_C} = \ln(2/3)$$

$$-\frac{t_2}{\tau_C} = \ln(1/3)$$

$$t_1 = \tau_C \ln(3/2)$$

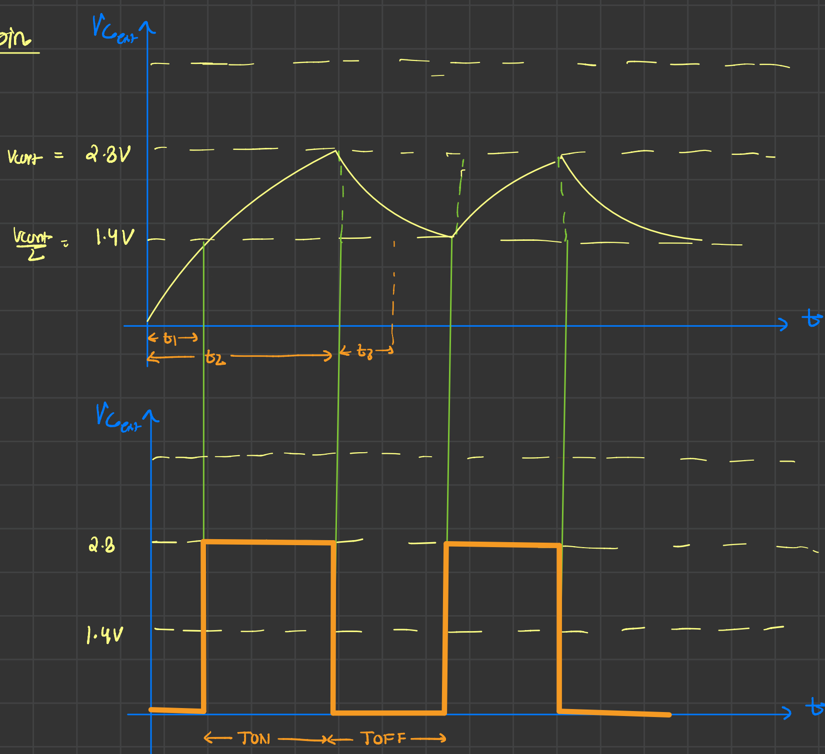
$$t_2 = \tau_C \ln(3)$$

$$T_{ON} = t_2 - t_1 = \tau_C (\ln(3) - \ln(3/2))$$
$$= \tau_C \ln(2)$$
$$=$$

$$T_{ON} = \tau_C \ln(2)$$

$$\boxed{T_{ON} = \ln 2 (R_A + R_B) C} \qquad \tau_C = (R_A + R_B) C$$

For control pin



For charging of capacitor

$t_1 \quad 0 \rightarrow \frac{V_{cont}}{2}$

$$V(t) = V_{cc}\left[1 - \exp\left(\frac{-t_1}{\tau_c}\right)\right]$$

$$\frac{V_{control}}{2} = V_{cc}\left[1 - \exp\left(\frac{-t_1}{\tau_c}\right)\right]$$

$$1.4 = 5.5\left[1 - \exp\left(-\frac{t_1}{\tau_c}\right)\right]$$

$$0.2545 = 1 - \exp(-t_1/\tau_c)$$

$$\exp(-t_1/\tau_c) = 0.7454$$

$$-t_1/\tau_c = \ln(0.7454)$$

$$\cancel{-}\frac{t_1}{\tau_c} = \cancel{-}0.2937$$

$$\boxed{t_1 = 0.2937\,\tau_c}$$

For t_2

$$V(t) = V_{cc}\left[1 - \exp\left(\frac{-t_2}{\tau_c}\right)\right]$$

$$2.8 = 5.5\left(1 - \exp(-t_2/\tau_c)\right)$$

$$0.509 = 1 - \exp(-t_2/\tau_c)$$

$$\exp(-t_2/\tau_c) = 0.491$$

$$\cancel{-}\frac{t_2}{\tau_c} = \cancel{-}0.711$$

$$\boxed{t_2 = 0.711\,\tau_c}$$

$$T_{ON} = t_2 - t_1 = 0.711\,\tau_c - 0.2937\,\tau_c$$

$$= 0.4173\,\tau_c$$

$$\boxed{T_{ON} = 0.4173(R_A + R_B)C}$$

$\tau_c = (R_A + R_B)C$

For discharching,

$$V(t) = V_{max}\left(\exp(-t_3/\tau_d)\right)$$

$$1.4 = 2.8\left(\exp(-t_3/\tau_d)\right)$$

$$\frac{1}{2} = \exp\left(-t_3/\tau_d\right)$$

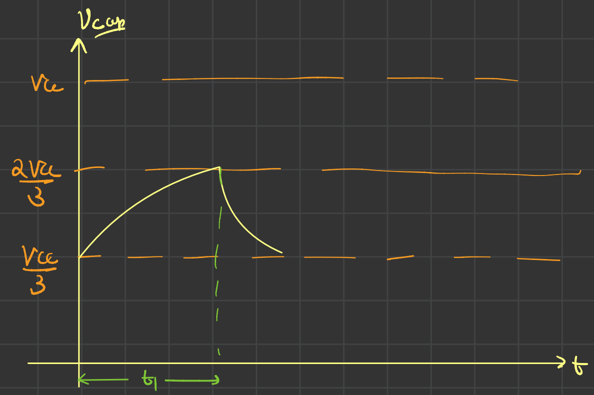
$$\cancel{-}\ln 2 = \cancel{-}t_3/\tau_d$$

new duty cycle $= \frac{T_{ON}}{T}$

$t_3 = \ln 2 \; \tau_d$ $\tau_d = R_B C$

$$\boxed{t_3 = 0.693\, R_B C}$$

For monostable multivibrator



For charging

$$V(t) = V_{cc}\left[1 - \exp\left(\frac{-t_1}{\tau_c}\right)\right]$$

here $\tau_c = RC$

$$\frac{2\cancel{V_{cc}}}{3} = \cancel{V_{cc}}\left(1 - \exp\left(\frac{-t_1}{\tau_c}\right)\right)$$

$$\exp(-t_1/\tau_c) = 1/3$$

Taking log on both side

$$\frac{\cancel{-}t_1}{\tau_c} = \cancel{-}\ln 3$$

$$t_1 = \tau_c \ln 3$$

$$\boxed{T_{ON} = 1.1\, RC}$$

y)

$$T_{ON} = 1.1RC$$
$$= 1.1 \times 10 \times 10^{3} \times 0.1 \times 10^{-6}$$

$$T_{ON} = 1.1 \times 10^{-3} s$$
$$= 1.1 ms$$