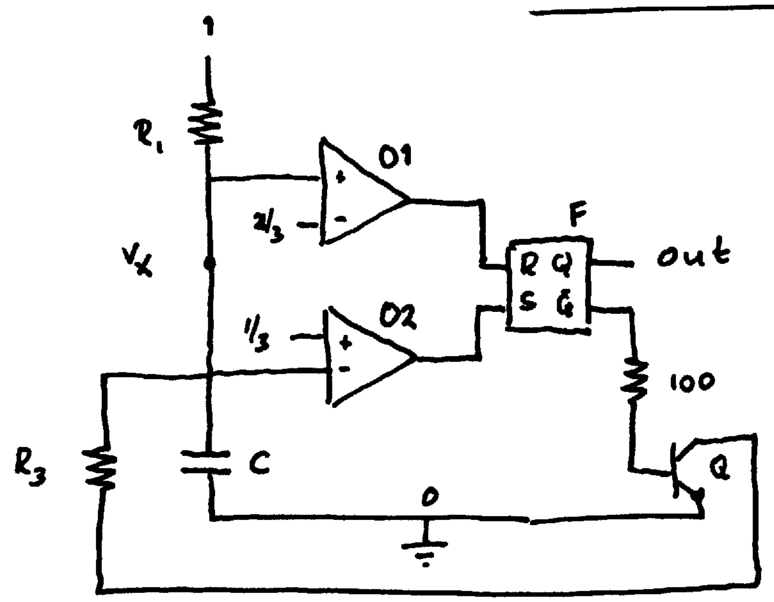
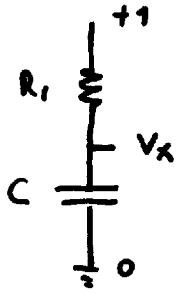
NE555 Solution



$\boxed{R_2 = 0}$

all voltages divided by V_{cc}
($2/3 \Rightarrow 2/3\ V_{cc}$, etc.)

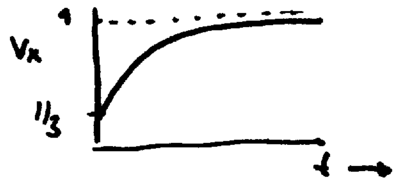
Charging cycle phase:



note: transistor Q is open circuit ($V_B = 0$) and effectively R_3 is disconnected

note: no current enters in the op-amps

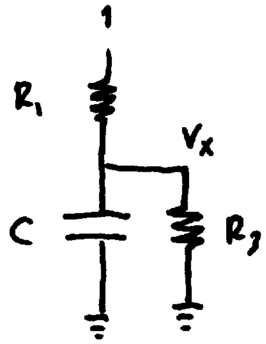
$\tau = R_1 C$, $V_x(\infty)\ (I=0) = 1$, $V_x(0) = 1/3$



note: $1/3$ will be obvious in a moment

when V_x reaches $2/3$ the top op-amp comparator 01 output goes from low to high. or in other words, R input of flipflop F : _⌐. This changes the state of the output Q of the flipflop from high to low and $\bar{Q}$ from low to high. V_B of transistor Q goes from 0 to 1 and the transistor opens. This starts the second half of a cycle

Discharging cycle phase



note : $100\,\Omega$ of transistor is to protect it.

$\tau = (R_1 /\!/ R_3)\, C$

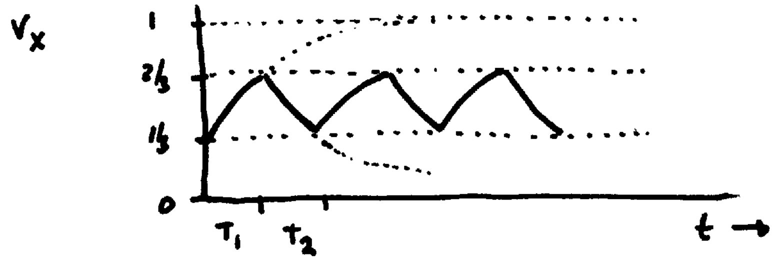
$V_x(0) = 2/3$

$V_x(\infty) = \dfrac{R_3}{R_1 + R_3}$

note $R_3 < R_1/2$!

when V_x drops below $1/3$, the bottom op-amp comparator O2 output goes from low to high. This is the "set" input of flip-flop F. Thus the output of this flip-flop goes from low to high and $\bar{Q}$ from high to low. This closes the transistor Q. And a new charging phase starts.

Note : the flip-flop responds only to changes low to high. (_⌐) and not to high or low inputs itself, nor to changes high to low (‾L_).



T1 : $V_x(t) = 1 - \frac{2}{3}\exp(-t/\tau)$ $\qquad \tau_1 = R_1 C$

$V_x(t) = \frac{2}{3} \Rightarrow t = \tau_1 \ln(2) = T_1$

T2 : $V_x(t) = \alpha + (\frac{2}{3} - \alpha)\exp(-t/\tau_2)$

$$\alpha = \frac{R_3}{R_1+R_3} \qquad (V(\infty))$$

$$\tau_2 = (R_1 /\!/ R_3)\, C$$

$$V_x(t) = \frac{1}{3} \Rightarrow t = \tau_2 \ln\left[\frac{3\alpha-2}{3\alpha-1}\right] = T_2$$

example $(T = T_1 + T_2 = 1\,ms)$

$T_1 = 667\ \mu s$, $T_2 = 333\ \mu s$

$C = 100\ nF \Rightarrow \tau_1 = T_1/\ln(2) = 9.62\ 10^{-4}\ s$

$\tau_1 = R_1 C \Rightarrow R_1 = \tau_1/C = 9.623\ k\Omega$

$$T_2 = \frac{R_1 R_3}{R_1+R_3}\, C\, \ln\left[\frac{R_3 - 2R_1}{2R_3 - R_1}\right] = 333\ \mu s$$

$\Longrightarrow R_3 = 2.948\ k\Omega$

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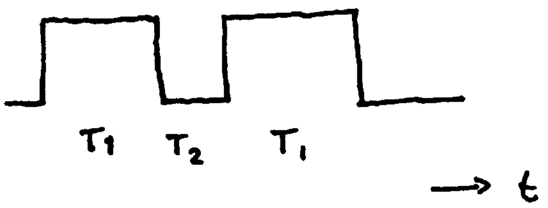
out



duty cycle 67%