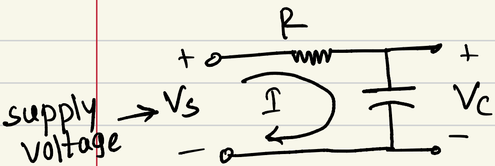
Signal Generator:

→ Basic R-C ckt:



$\begin{cases} \text{if } V_s > V_c \to \text{capa store charge} \\ \text{if } V_s < V_c \to \text{capa discharge} \end{cases}$

Suppose at initial time t_1 the capacitor has a voltage of $V_c(t_1) = V_{initial}$

For capacitor → $\boxed{Q = CV}$

↳ current, $I = \frac{dQ}{dt} = \frac{d(CV)}{dt} = C\frac{dV_c}{dt}$ — (i)

From ckt → $I = \frac{V_s - V_c}{R}$ — (ii)

equating (i) & (ii)

$$C\frac{dV_c}{dt} = \frac{V_s - V_c}{R} \quad \text{— (iii)}$$

We can determine the voltage across capacitor, $V_c(t)$ for the time $t_1 < t < \infty$, by solving the Differential eqn (iii) –

$$C\frac{dV_c}{dt} = \frac{V_s - V_c}{R}$$

$$\Rightarrow \int_{V_c(t_1)}^{V_c(t)} \frac{dV_c}{V_s - V_c} = \int \frac{dt}{RC} \Rightarrow V_c(t) = V_s + (V_c(t_1) - V_s)\exp\left(-\frac{t-t_1}{RC}\right)$$

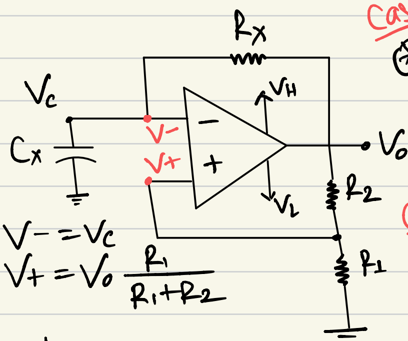
at $t \to \infty$ $V_c(\infty) = V_s \to V_{Final}$

$\boxed{\text{Time constant, } \tau = RC}$

$$\boxed{V_c(t) = V_{Final} + (V_{initial} - V_{final})\exp\left(-\frac{t-t_1}{\tau}\right)}$$

Schmitt Oscillator / Astable Multivibrator:

↳ Square Wave generator.



$$\begin{cases} V_- = V_c \\ V_+ = V_0 \dfrac{R_1}{R_1+R_2} \end{cases}$$

Case-1

⊛ initially → $V_- = 0$, $V_+ = V_{OOT}$ (V_{OOT} → O/P offset voltage)

$\therefore V_+ > V_-$

↳ $\boxed{V_0 = V_H}$

↳ capacitor starts charging

Case-2

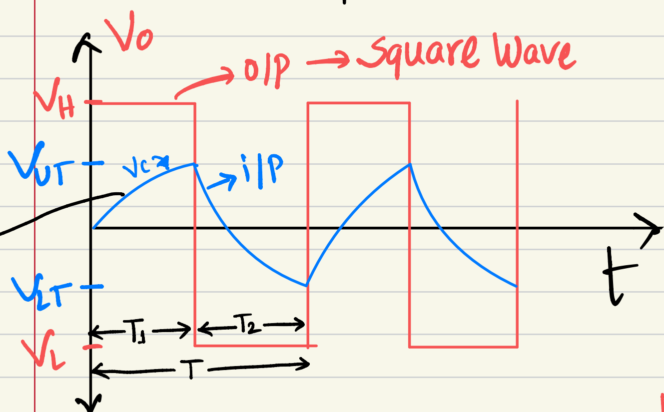
⊛ After some time -

$V_- = V_c$. and $V_- > V_+$

↳ $\boxed{V_0 = V_L}$

↳ capacitor starts Discharging

this two cases repeat & we will get consecutive high & low value in the o/p. (square wave)



$$\boxed{\begin{aligned} V_{UT} &= \frac{R_1}{R_1+R_2} V_H \\ V_{LT} &= \frac{R_1}{R_1+R_2} V_L \end{aligned}}$$

period, $\boxed{T = T_1 + T_2}$, → Duty cycle, $\boxed{D = \frac{T_1}{T_1+T_2} \times 100\%}$

→ Time const, $\boxed{\tau = R_x C_x}$

→ $V_c(t) = V_{Final} + (V_{initial} - V_{Final}) \exp\left(-\frac{t-t_1}{\tau}\right)$, $V_{Final} = V_0$

$$\therefore t - t_1 = \tau \ln \left| \frac{V_0 - V_c(t_1)}{V_0 - V_c(t_2)} \right|$$

Case-1 : $\boxed{0 < t < T_1}$

$V_{final} = V_o = V_H$, $V_{initial} = V_{LT}$

$$\boxed{V_c(t) = V_H + (V_{LT} - V_H)\exp\left(-\frac{t-0}{R_x C_x}\right)}$$

at $t = T_1$, $V_c(t) = V_{UT}$

$$\therefore V_c(T_1) = V_{UT} = V_H + (V_{LT} - V_H)\exp\left(-\frac{T_1}{R_x C_x}\right)$$

$$\boxed{\therefore T_1 = R_x C_x \ln\left|\frac{V_H - V_{LT}}{V_H - V_{UT}}\right|}$$

Case-2 : $\boxed{T_1 < t < T}$

$V_{final} = V_o = V_L$, $V_{initial} = V_{UT}$

$$\boxed{\therefore V_c(t) = V_L + (V_{UT} - V_L)\exp\left(-\frac{t-T_1}{R_x C_x}\right)}$$

At $t = T \rightarrow V_c(t) = V_{LT}$

$$\therefore V_c(t) = V_{LT} = V_L + (V_{UT} - V_L)\exp\left(-\frac{T-T_1}{R_x C_x}\right)$$

$$V_{LT} = V_L + (V_{UT} - V_L)\exp\left(-\frac{T_2}{R_x C_x}\right)$$

$$\boxed{\therefore T_2 = R_x C_x \ln\left|\frac{V_L - V_{UT}}{V_L - V_{LT}}\right|}$$

$$T = T_1 + T_2$$

Practice Problem:

For the Schmitt trigger oscillator, the saturation output voltages are +10 V and −5 V. $R_1 = R_2 = 20\,k\Omega$, $R_x = 50\,k\Omega$ and $C_x = 0.01\,\mu F$.
Determine the frequency and duty cycle.

⇒ **Sol^n:**

$$V_H = 10\,V,\ V_L = -5\,V$$

$$V_{UT} = \frac{R_1}{R_1+R_2} V_H = \frac{20}{20+20} \times 10 = 5\,V$$

$$V_{LT} = \frac{R_1}{R_1+R_2} V_L = \frac{20}{20+20}(-5) = -2.5\,V$$

$$\tau = R_x C_x = 50\times10^3 \times 0.01 \times 10^{-6} = 0.5\times10^{-3}\,s$$
$$= 0.5\,ms$$

→ now, $T_1 = \tau \ln\left|\frac{V_H - V_{LT}}{V_H - V_{UT}}\right|$

$$= 0.5 \ln\left|\frac{10-(-2.5)}{10-5}\right| = 0.458\,ms$$

and, $T_2 = \tau \ln\left|\frac{V_L - V_{UT}}{V_L - V_{LT}}\right| = 0.5 \ln\left|\frac{-5-5}{-5+2.5}\right|$

$$= 0.693\,ms$$

∴ Period, $T = T_1 + T_2 = 1.15\,ms$

∴ Frequency, $f = \frac{1}{T} = 0.868\,KHz = \boxed{868\,Hz}$

∴ Duty cycle, $D = \frac{T_1}{T} \times 100\% = \boxed{39.82\%}$

(Ans.)

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