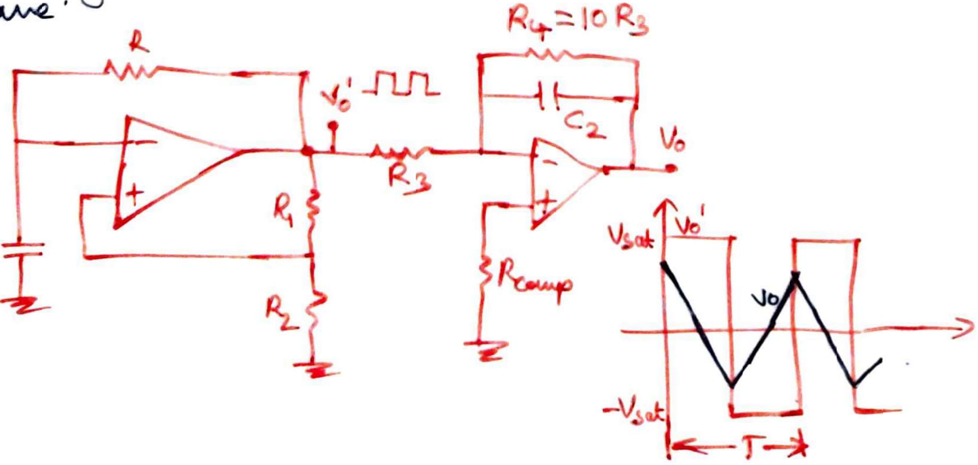
## Triangular Wave Generator

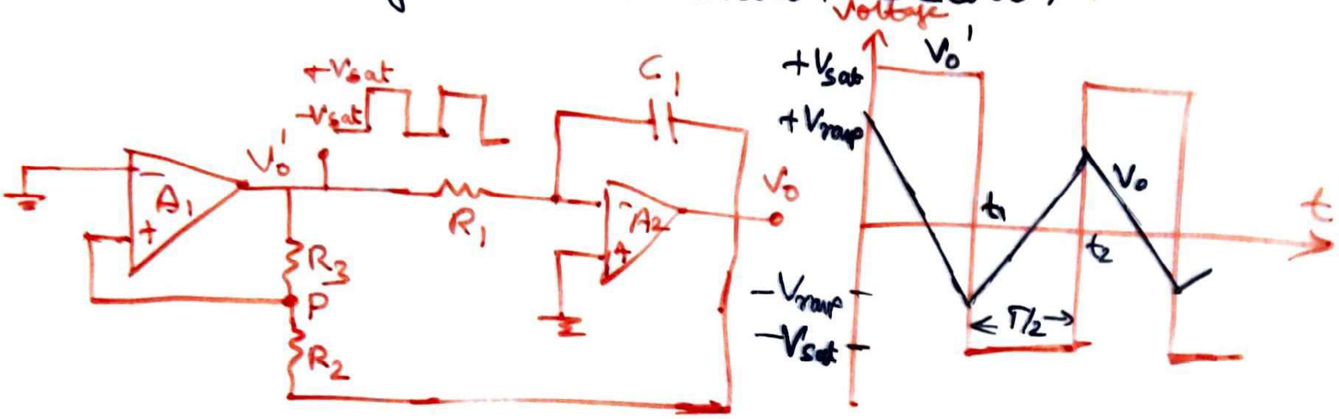
→ A triangular wave can be obtained by integrating a square wave.



→ The amplitude of triangular wave will decrease as freq. increases because reactance of $C_2$ in feedback ckt decreases at high freq.'s.

→ A resistance $R_{f}$ is connected across $C_2$ to avoid the saturation problem at low freq.'s as in case of pratical integrator.

→ Another triangular wave generator using lesser number of components is shown below:




→ It consists of a two level comparator followed by an integrator.

→ Consider that o/p of comparator $A_1$ is at $+V_{sat}$, the o/p of integrator $A_2$ will be a -ve going ramp.

→ At time $t=t_1$, when -ve going ramp attains a value of $-V_{ramp}$, effective voltage at point becomes slightly less than 0V. This switches the o/p of $A_1$ from +ve saturation to -ve saturation level $-V_{sat}$

→ The effective voltage at point P during the time when o/p of $A_1$ is at $+V_{sat}$ level is given by

$$-V_{ramp} + \frac{R_2}{R_2+R_3}\left[+V_{sat} - (-V_{ramp})\right]$$

→ At $t=t_1$ the voltage at point P becomes equal to zero

$$\therefore -V_{ramp} = -\frac{R_2}{R_3}(+V_{sat})$$

→ Similarly at $t=t_2$, when o/p of $A_1$ switches from $-V_{sat}$ to $+V_{sat}$

$$V_{ramp} = \frac{-R_2}{R_3}(-V_{sat}) = \frac{R_2}{R_3}(V_{sat})$$

$\therefore$ peak to peak amplitude of triangular wave is $V_o(pp) = +V_{ramp} - (-V_{ramp}) = 2\frac{R_2}{R_3} V_{sat}$

→ O/p switches from $-V_{ramp}$ to $+V_{ramp}$ in half the time period $T/2$

$$V_o = -\frac{1}{RC}\int V_i \, dt$$

$$V_o(pp) = -\frac{1}{R_1C_1}\int_0^{T/2}(-V_{sat})\,dt = \frac{V_{sat}}{R_1C_1}\left(\frac{T}{2}\right)$$

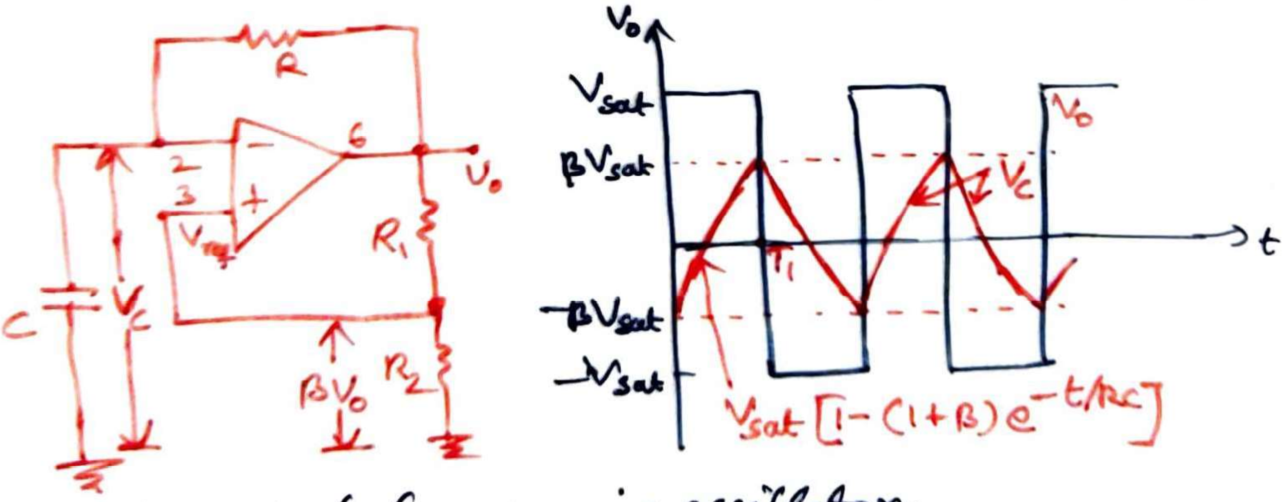
$$\Rightarrow T = 2R_1C_1\frac{V_o(pp)}{V_{sat}}$$

$$\therefore T = 4\frac{R_1C_1R_2}{R_3}$$

→ Hence, freq. of oscillation $f_o$ is

$$f_o = \frac{1}{T} = \frac{R_3}{4R_1C_1R_2}$$

## Square wave Generator (Astable Multivibrator)




→ Also called free running oscillator.

→ Principle of generation of square wave o/p is to force an op-amp to operate in saturation region.

→ In astable multivibrator both states are quasi stable.

→ Consider an instant of time when o/p is at $+V_{sat}$. The capacitor starts charging towards $+V_{sat}$ through resistance.

→ This continues as the charge on C rises, until it has exceeded $+\beta V_{sat}$, reference voltage

→ When the voltage at (−) i/p terminal becomes just greater than ref. voltage, the o/p is driven to $-V_{sat}$

→ At this instant, voltage on capacitor is $+\beta V_{sat}$. It begins to discharge that R toward $-V_{sat}$

→ Freq. is determined by time it takes for capacitor to change from $-\beta V_{sat}$ to $+\beta V_{sat}$ & vice versa

→ Voltage across the capacitor as a function of time is given by $V_c(t) = V_f + (V_i - V_f)e^{-t/RC}$

where final value, $V_f = +V_{sat}$

& initial value, $V_i = -\beta V_{sat}$

$$\therefore V_c(t) = V_{sat} + (-\beta V_{sat} - V_{sat})e^{-t/RC}$$

$$\Rightarrow V_c(t) = V_{sat} - V_{sat}(1+\beta)e^{-t/RC}$$

→ At $t = T_1$, voltage across capacitor reaches $\beta V_{sat}$ & switching takes place

$$\therefore V_c(T_1) = \beta V_{sat} = V_{sat} - V_{sat}(1+\beta)e^{-T_1/RC}$$

$$\Rightarrow T_1 = RC \ln \frac{1+\beta}{1-\beta}$$

→ This gives only half of the period

→ Total time period, $T = 2T_1 = 2RC \ln \frac{1+\beta}{1-\beta}$ & o/p waveform is symmetrical

→ If $R_1 = R_2$, then $\beta = 0.5$ & $T = 2RC \ln 3$

→ For $R_1 = 1.16 R_2$, $T = 2RC \Rightarrow f_0 = \frac{1}{2RC}$

Sawtooth Wave Generator Voltage