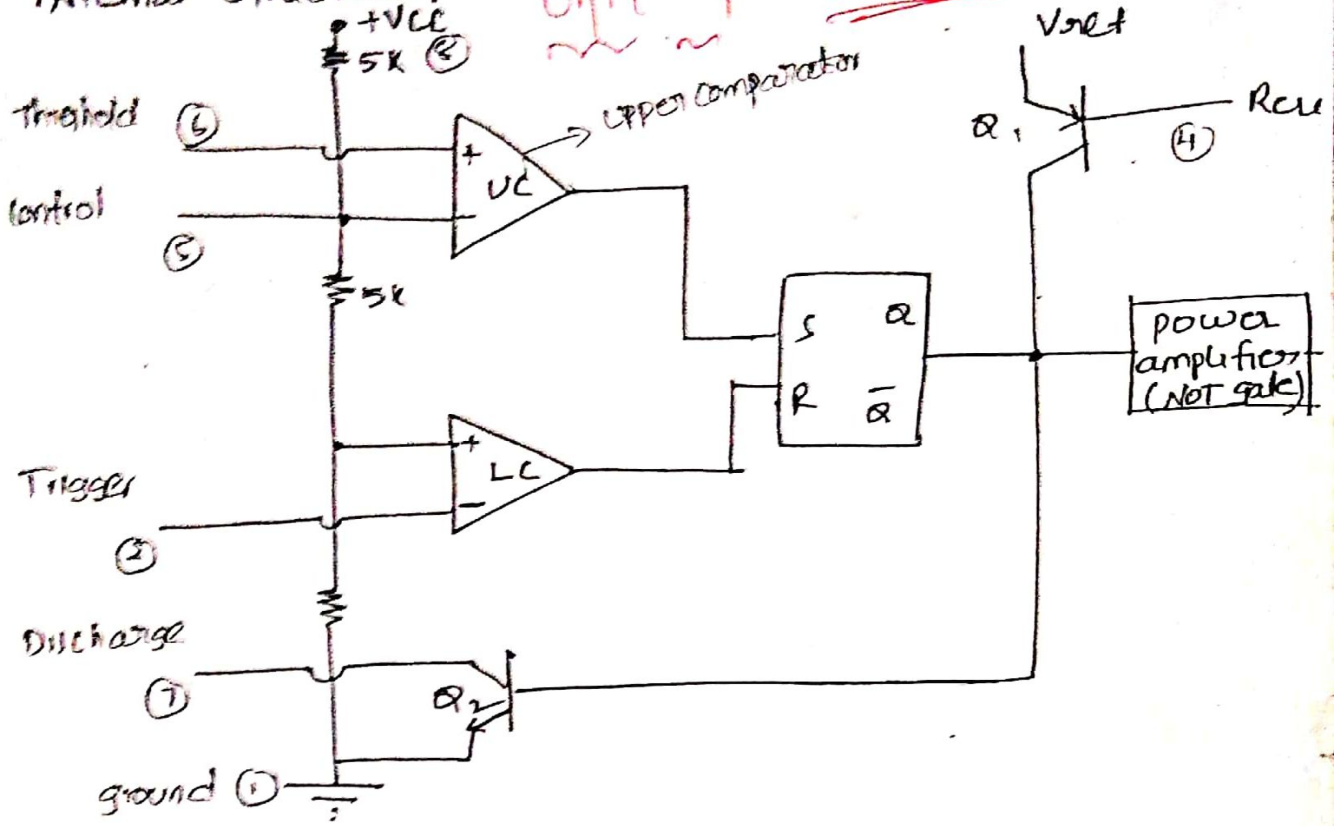
Unit - 4

Waveform Generators

Introduction to

IC - 555 timer

Internal structure: unit - 4 IC 555



→ The 3 5K resistors form voltage divider network.

→ IC has two internal comparator circuits known as upper comparator and lower comparator.

→ If non inverting voltage is greater than inverting volta... comparator generates logic '1' output otherwise its output is z...

→ Trigger voltage is compared with $\frac{VCC}{3}$ in lower compar... and threshold voltage is compared with $\frac{2VCC}{3}$ in upper comp...

→ comparator o/p's control the operation of SR flip-flop.

→ Complimented output of the flip-flop is connected to a po... amplifier which also acts as not gate.

→ IC 555 is able to provide higher AC output power be... of power amplifier block.

→ PNP Transistor Q_1 is used to reset the output V_o.

→ If reset pin is grounded Q_1 turns on, the internally c... voltage Vref appears as logic '1' ~~output~~ input to the ... and thus ...

→ NPN transistor Q_2 is used to discharge a capacitor conn in the external circuit.

if $\bar{Q} = 1$ ⟹ Q_2 = ON

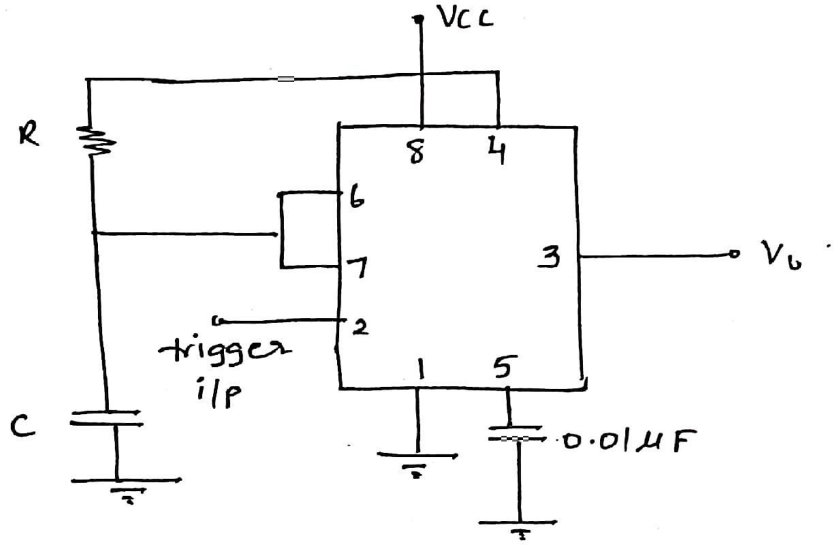
If $\bar{Q} = 0$ ⟹ Q_2 = OFF.

→ Control PIN is used to change the voltage appearing a inverting node of upper comparator.

→ If not used, control pin is grounded through a capacitor

APPLICATIONS OF IC 555:

1) MONOSTABLE MULTIVIBRATOR:



This circuit generates a pulse output if trigger input is applied.

Operation:

1) No trigger

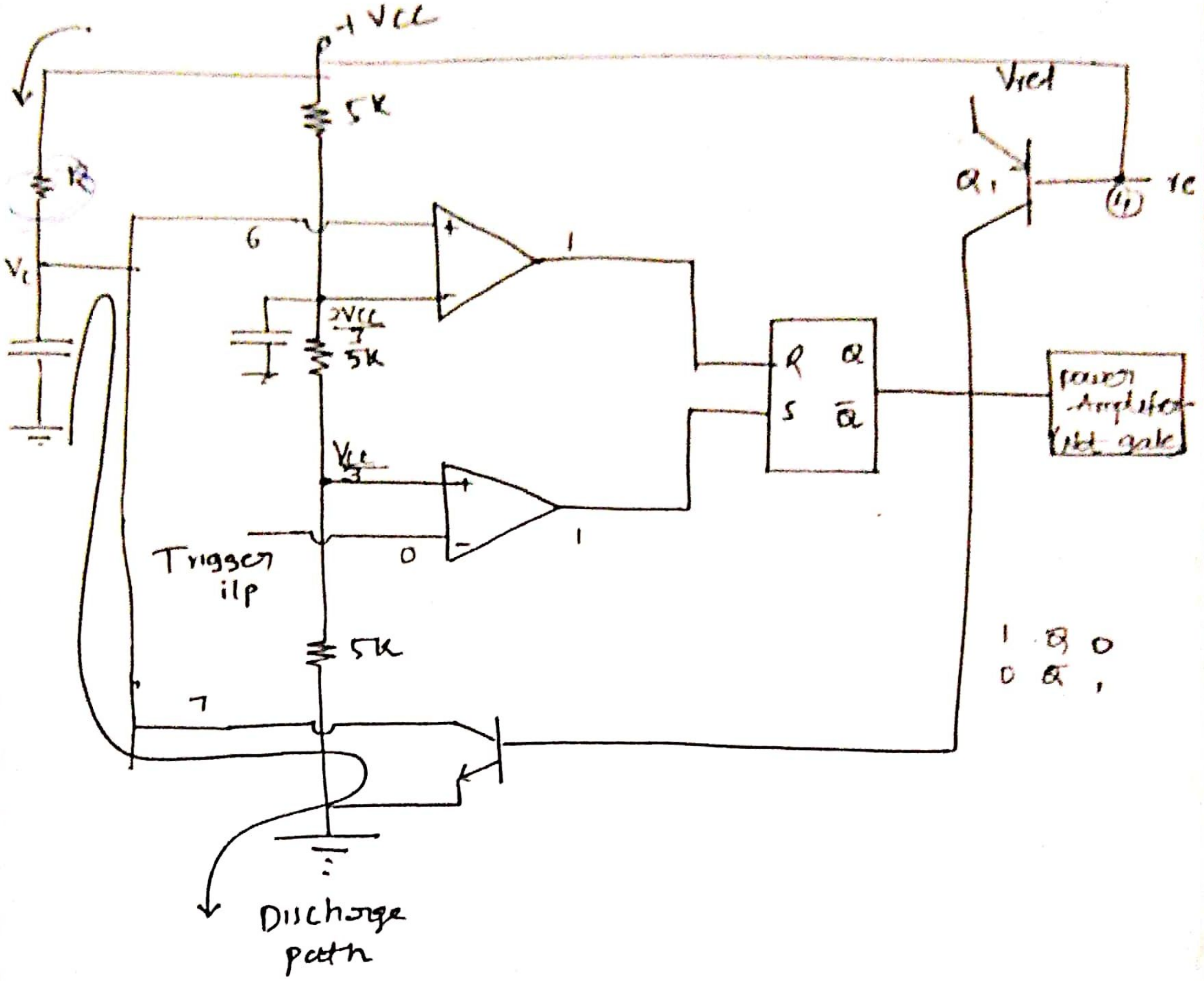
Vo remains in stable state ie, Vo = 0

⟹ $\bar{Q} = 1$ ⟹ Q_2 = ON

Capacitor 'C' full discharges through Q_2 and Vc becom zero.

2) Trigger is applied

Trigger is a negative spike 



→ Due to spike effect voltage at trigger pin becomes ze for a moment.

→ Due to this lower comparator generates logic '1' output which will act as set input to the flip flop.

[if $S=1$; $Q=1$, $\bar{Q}=0$ & $V_o=1$]

→ Thus V_o changes from stable state zero to quasi stables '1'.

→ As $\bar{Q}=0$, Q_1 turns off.

⇒ C cannot discharge

⇒ C starts charging through R.

→ V_c increases upto $\frac{2V_{cc}}{3}$

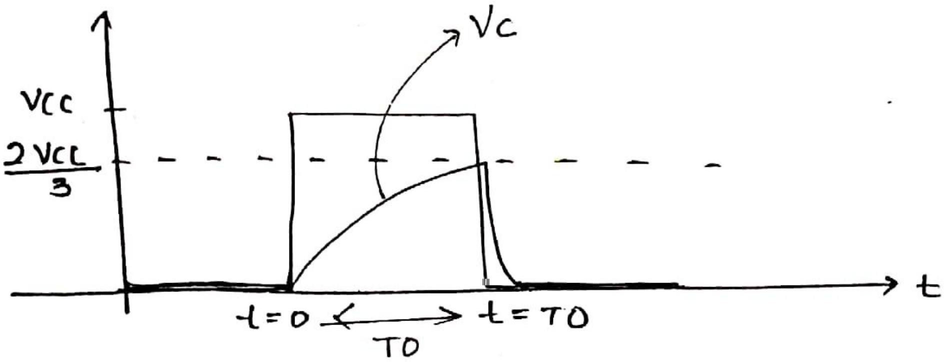
→ If V_c becomes slightly greater than $\frac{2V_{cc}}{3}$. The o/p of up

comparator ...

flip-flop.

[if $R = 1$: $Q = 0$ $\bar{Q} = 1$ & $V_0 = 0$]

→ Thus V_0 changes from quasistable state '1' to stable state '0' and it continous to remains zero, until next trigger input is applied.



T_0 = pulse duration.

when c is charging $V_C = V_{CC}\left[1 - e^{-t/RC}\right]$

put $t = T_0$ and $V_C = \frac{2V_{CC}}{3}$

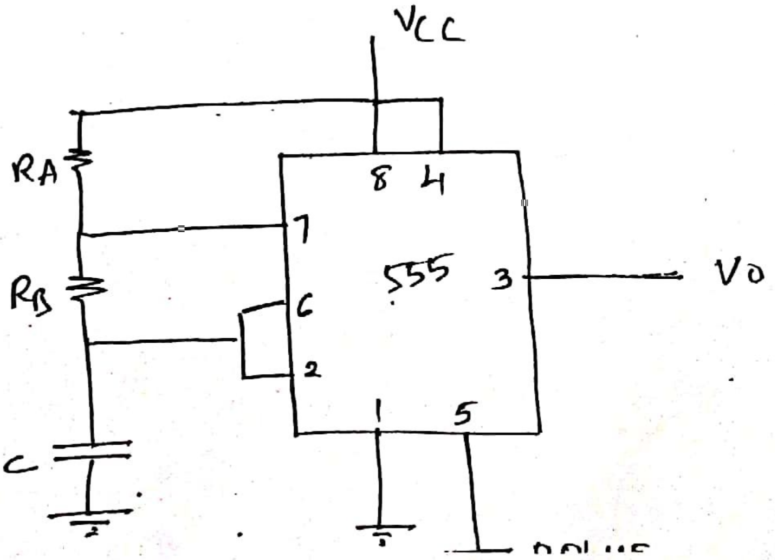
$$\frac{2V_{CC}}{3} = V_{CC}\left(1 - e^{-T_0/RC}\right)$$

$$e^{-T_0/RC} = 1/3 \Rightarrow e^{T_0/RC} = 3$$

Taking ln ⇒ $\boxed{T_0 = RC \ln 3 = 1.1\,RC}$

② ASTABLE MULTI VIBRATOR

→ It is a square wave generator (or) free running oscillator.



If V_c becomes just less than $\frac{V_{cc}}{3}$ the output of lower comparator becomes '1', i.e, S = 1

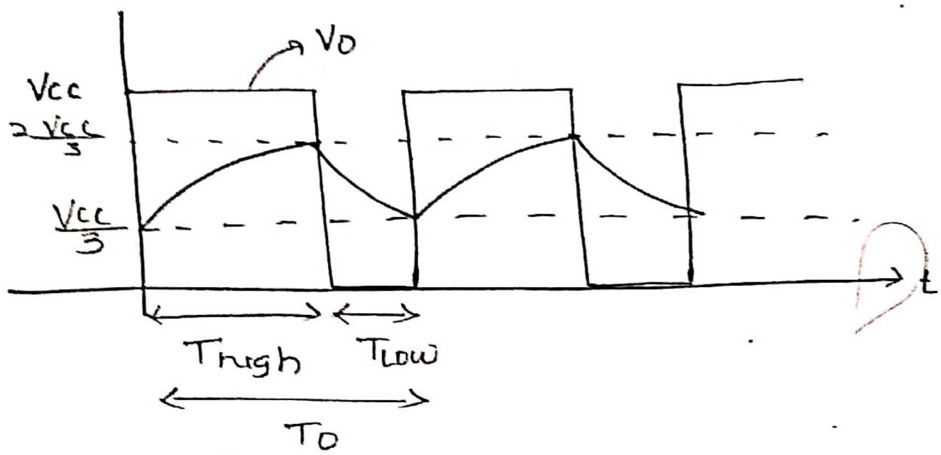
→ Q = 1, $\bar{Q}$ = 0 & V_o = 1 then V_o changes from 0 to 1

$$T_{charge} = (R_A + R_B) C$$

$$T_{discharge} = R_B \cdot C$$

**

→ As charging time is greater than discharging time, remains '1' for a longer duration hence duty cycle of will be greater than 50%.



① $T_{High} = 0.69 (R_A + R_B) C$

② $T_{Low} = 0.69 R_B C$.

③ $T_o = T_{high} + T_{low}$.

$$T_o = 0.69 (R_A + 2R_B) C$$

④ $$f_o = \frac{1}{T_o} = \frac{1.45}{(R_A + 2R_B) C}$$ ***

⑤ Duty cycle of Vo

$$D = \frac{T_{high}}{T_o} \Rightarrow D = \frac{R_A + R_B}{R_A + 2R_B}$$

~~$f_o = \frac{1}{T_o} = \frac{1.45}{R_A + 2}$~~

→ completed for gate

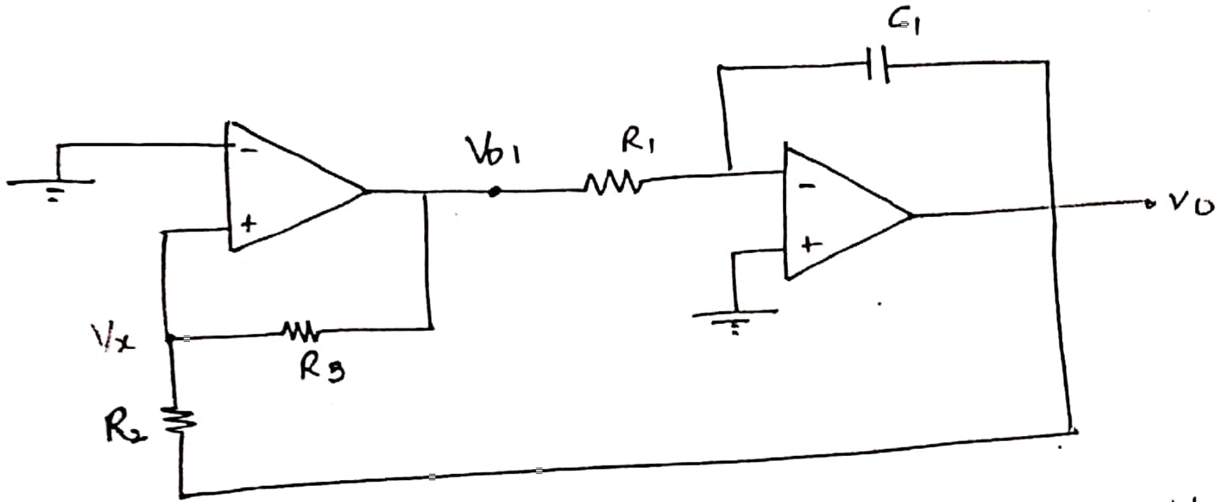
take natural log

$$\frac{T_0}{RC} = \ln \frac{V_\gamma + V_{sat}}{(1-\beta)V_{sat}}$$

$$\Rightarrow \boxed{T_0 = RC \ln \left[\frac{1 + \frac{V_\gamma}{V_{sat}}}{1-\beta}\right]}$$

Practically $V_\gamma << V_{sat}$ $\Rightarrow T_0 \simeq RC \ln \frac{1}{1-\beta}$.

4) Triangular Waveform generator.



→ 1st op-Amp is acting as non inverting type schmitt tri
or regenerative comparator.

→ It compares V_x with zero volt:

If $V_x > 0$: $V_{o1} = +V_{sat}$

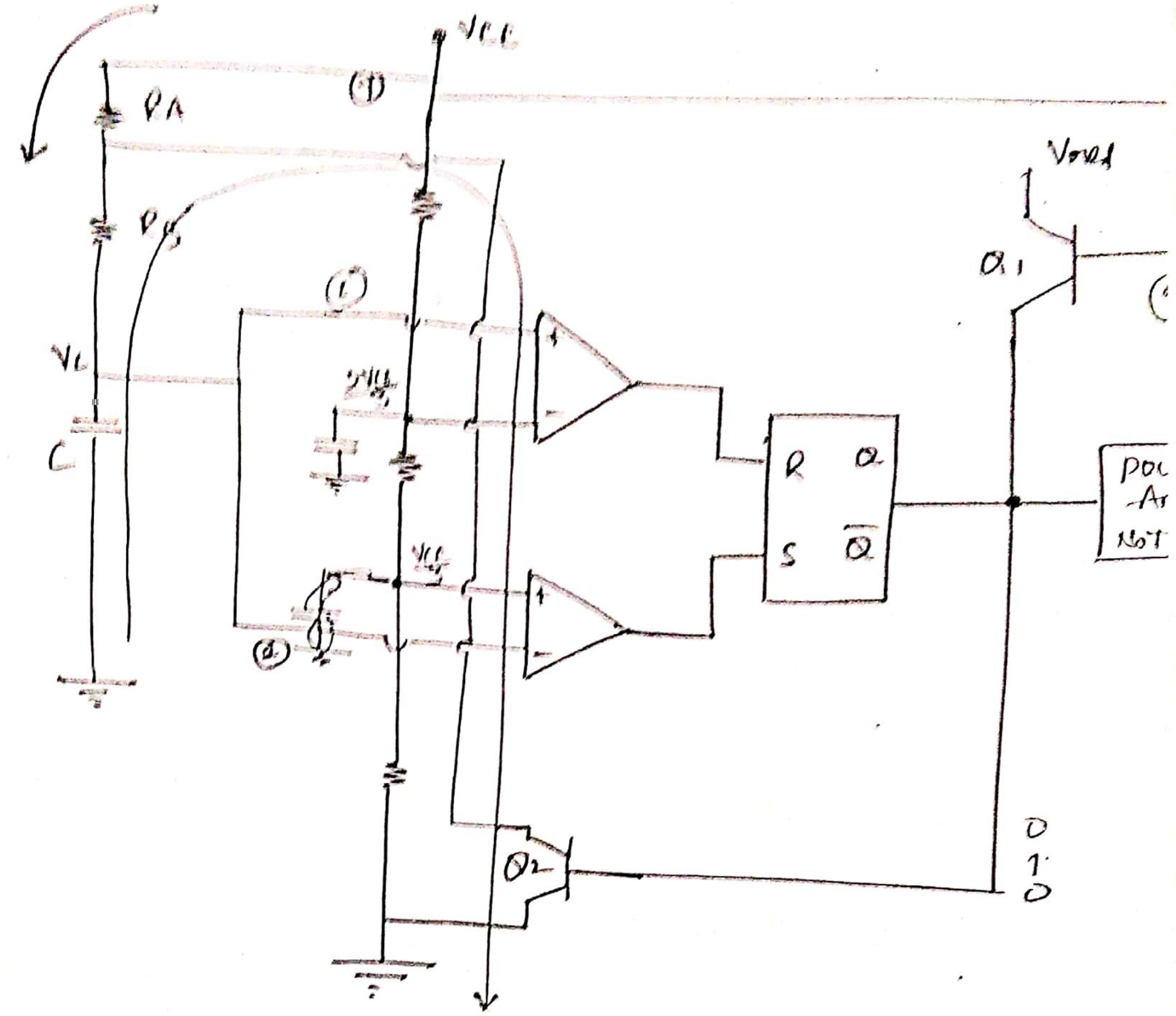
$V_x < 0$: $V_{o1} = -V_{sat}$

→ Thus V_{o1} is a square wave form.

→ 2nd op Amp behaves as integractor.

$$V_o = \frac{-1}{R_1 C_1} \int_t V_{o1}\, dt.$$

→ When $V_{o1} = +V_{sat}$. Integrator generates negative ramp ... $V_{o1} = -V_{sat}$ integrator generates positive ramp thus V_o beco... triangular wave.



→ Vo has two quasi stable states '1' & '0'

Operation:

(I) Let Vo = '1'

→ $\overline{Q}$ = 0 ⇒ Q_2 − OFF

→ C − cannot discharge and 'C' starts charging throu

→ Vc increases upto $\frac{2V_{cc}}{3}$.

→ If Vc becomes just greater than $\frac{2V_{cc}}{3}$, the output comparator becomes '1'

i.e, R = 1

⇒ Q = 0, $\overline{Q}$ = 1 & Vo = 0

Thus Vo changes from 1 to '0'.

(II) Let Vo = '0'

$\overline{Q}$ = 1 Q_2 = ON ' C starts discharging through

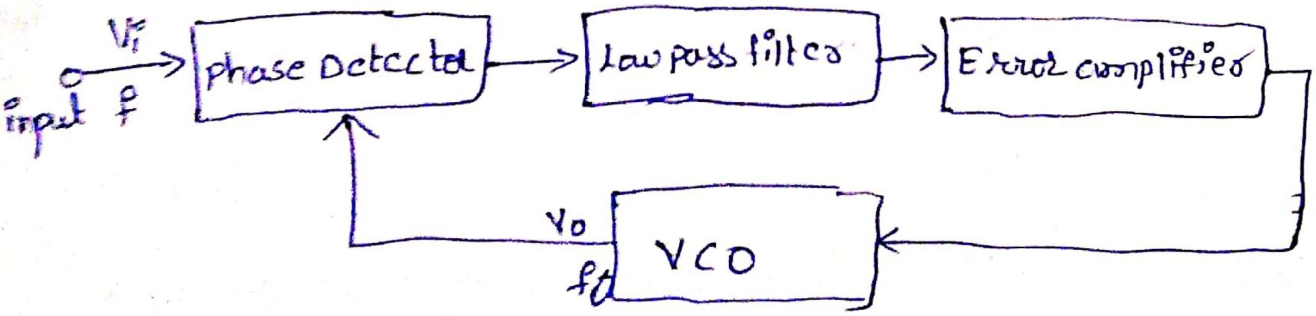
...oduction to phase locked loop (PLL) :-

→ The phase locked loop, generally abbreviated as PLL, is very widely used in radio communication systems for various applications such as frequency modulation, demodulation, frequency synthesis, AM detection, as tracking filter, tone detector etc.

→ Basically PLL is a closed loop system which is designed to lock the output frequency and phase to the frequency and phase of the input signal.

Basic principles of PLL :-

The block diagram representation of a phase locked loop:-



→ PLL mainly consists of a phase detector, a low-pass filter, an error amplifier and a voltage controlled oscillator.

→ The function of the phase detector is to compare the frequency of the input signal f_i with the frequency of the VCO output fo.

→ The difference between the phase of the input signal and the phase of the feedback signal, and this is basically a DC voltage mixed with high frequency noise.

→ The output of the phase detector is next applied to a low pass filter.

→ The main function of LPF is to remove the high frequency noise voltages associated with the DC output of the detector. (The LPF may be either an active filter or a passive filter.

→ The output of the low-pass filter is termed as error voltage and this forms the control voltage of the VCO.

→ The output frequency of the VCO depends upon the control voltage. When the control voltage is zero, its output frequency is termed as centre frequency, and it is denoted as fo. With zero control voltage, the VCO is said to be free running mode.

→ output frequency of the VCO from fo to f.

fo and f are related as,

$$f = f_0 + K_V V_C$$

where,

V_C = output voltage of the VCO.

K_V = voltage to frequency transfer co-efficient of the VCO.

Important Definitions Related to PLL :-

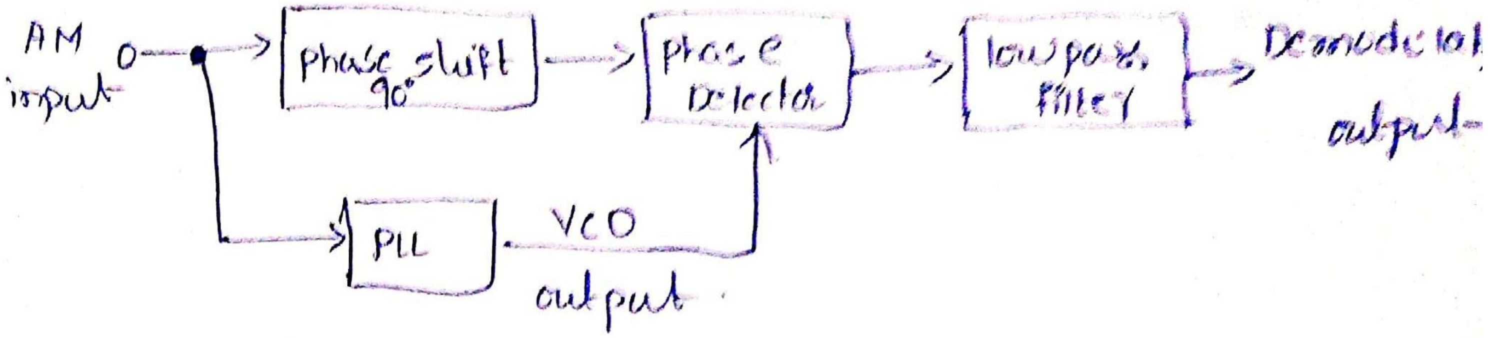
1) **Lock Range :-** When PLL is locked, it can track the changes in frequency of the incoming signal. The range of frequency over which the PLL can maintain the lock with the incoming signal is called the lock range or tracking range of the PLL.

2) **capture range :-** The range of frequencies over which the PLL can acquire lock with an input signal.

3) **Pull in Time :-** The capture of an input signal does not take place as soon as the signal is applied, but it takes some finite time. The total time taken by the PLL to establish a lock is called pull in time.

Applications of PLL :-

1) **AM Detector :-** The PLL can be used for the detection of an Amplitude modulated (A.M) signal.



→ The AM signal to be demodulated is applied to the 90° phase shifting network as well as the PLL. The PLL is locked to the carrier frequency of the AM signal.

→ Therefore, the VCO output frequency is same as the unmodulated carrier.

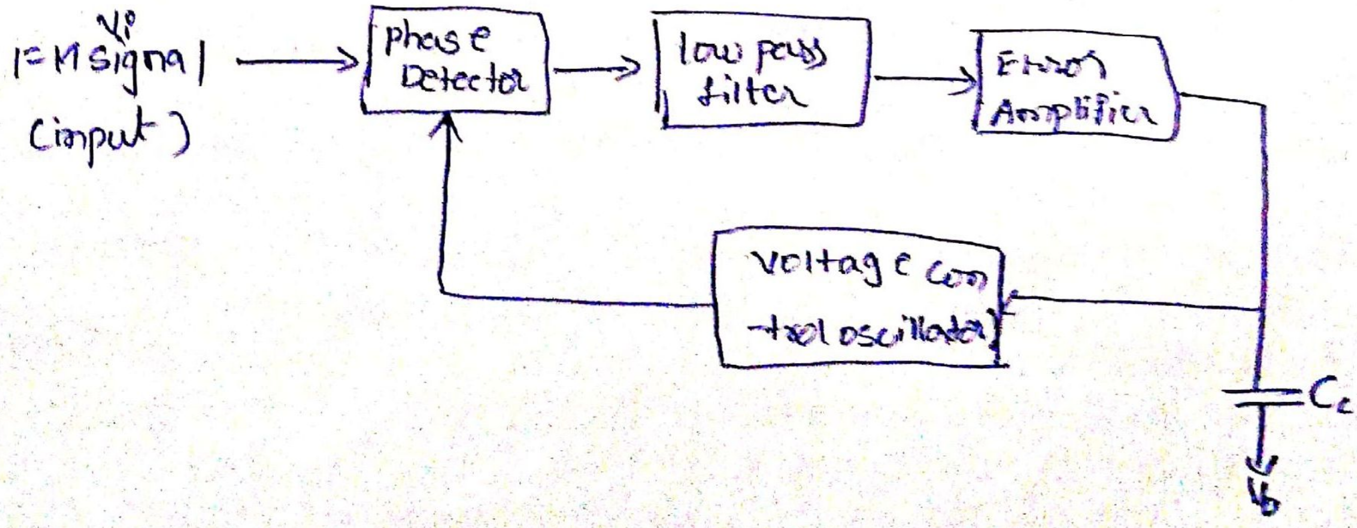
→ When the VCO output is locked with AM signal perfectly the phase shift b/w the two is 90°. In order to nullify this phase shift, the AM signal is phase shifted by 90°.

→ This will bring both the inputs to the phase detector in phase.

phase detector circuit is basically a multiplier which will produce both sum and difference components of frequency or at its output. The low pass filter will allow only those frequency components which are close to carrier and lower than it.

→ The advantage of using the AM detector using PLL is its high noise immunity.

FM Detector:- FM stands for frequency modulation, and detector means demodulator. The PLL can be used as demodulator for extracting the modulating signal from a frequency modulated RF carrier.



→ During normal operation, when the PLL is in phase-locked mode, it is evident that the VCO output frequency follows the instantaneous frequency of the input signal.

→ The error voltage the VCO control voltage is proportional to the difference b/w the input frequency and the centre frequency of the VCO

→ Therefore, the AC component of the error voltage must be an exact replica (or) mirror image of the modulating image.

→ The coupling capacitor blocks DC component and allows only the AC components of the error voltage, and hence V_0 is a true replica of the modulating voltage. Thus the PLL operates as FM detector.

Voltage Controlled Oscillator (VCO):-

A voltage controlled oscillator (VCO) is an oscillator circuit in which the frequency of oscillations can be controlled by an externally applied voltage.

→ The control of frequency with help of control voltage is also known as voltage to frequency conversion.

→ Therefore, VCO is also known as voltage to frequency converter.

→ practically, VCO is used to produce square and triangular waveform whose frequency is controlled by control voltage.

→ practically, VCO is available in IC form.

→ Commonly used VCO ICs are NE/SE 566, LM 566 etc.

Voltage controlled oscillator IC 566:-

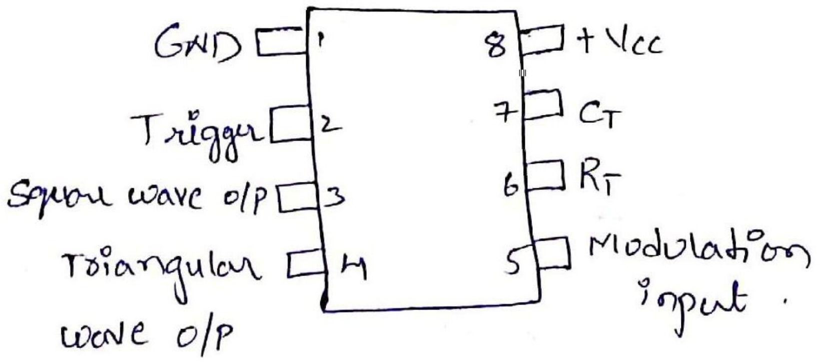
→ A free running multivibrator is used as a voltage controlled oscillator. It operates at a set frequency "fo" called free running frequency.

→ This frequency is determined by an external timing capacitor & external resistor.

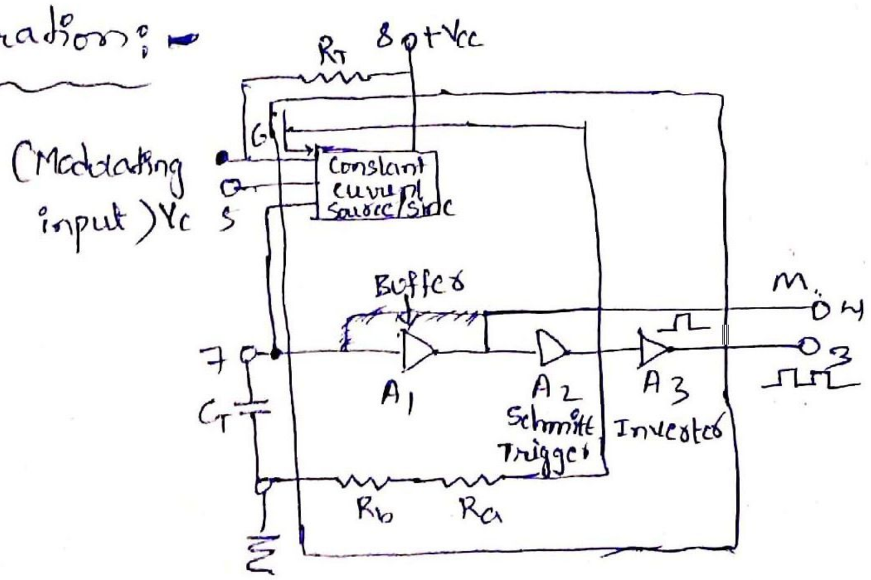
→ The frequency can also be shifted by applying a DC control voltage V_{cc} to an appropriate terminal of the integrated circuit.

→ The deviation in frequency is directly proportional to the DC control voltage and so it is called "VCO"

→ It's important feature is that it provides both square wave and triangular wave outputs at a time which are the functions of input.



Operation:-



Timing capacitor C_T is charged linearly or it is discharged by a constant current source/sink

-> The value of current can be controlled in two ways either by changing the control voltage Vcc at a given modulating input pin(5) (or) by varying the timing resistor R_T connected externally to the pin 6 of the IC.

-> The voltage available at pin 6 is same as that of pin 5

-> Let the modulating voltage at pin 5 be increased, the voltage at pin 6 also gets increased.

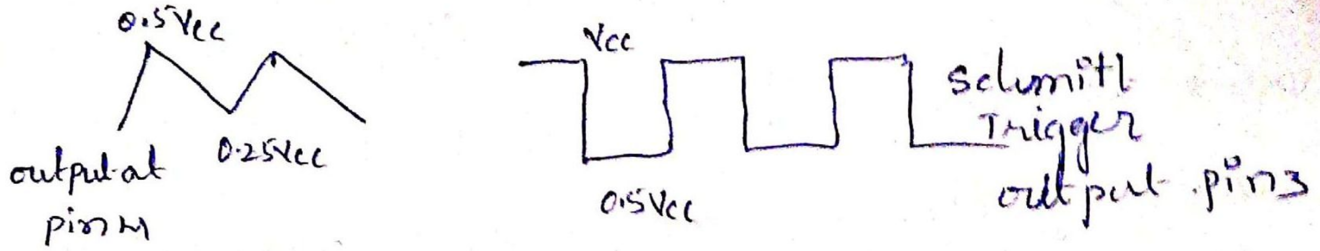
-> It causes in less voltage across R_T and there by decreasing C_T is provided to the inverting terminal of Schmitt trigger A_2 through buffer amplifier A_1.

-> The schmitt triger is designed to swing b/w Vcc and 0.5Vcc

-> For the case, $R_a = R_b$, in the +ve feedback loop, the voltage at non-inverting input terminal of A_2 swings b/w 0.5Vcc and 0.5Vcc

-> When the voltage on capacitor C_T exceeds 0.5Vcc during charging period

→ The output of schmitt trigger becomes low ...



→ As the capacitor discharges and reaches 0.25Vcc, the output of the schmitt trigger becomes high (Vcc).

→ The source & sink currents are equal.

→ Therefore the capacitor gets charged and discharged for same amount of time.

The frequency of the voltage control oscillator can be calculated as following.

ΔV = Difference voltage

$$\Delta V = 0.5V_{cc} - 0.25V_{cc} = 0.25V_{cc}$$

A constant current source charges the capacitor.

Now

$$\frac{\Delta V}{\Delta t} = \frac{i}{C_T}$$

$$\frac{0.25V_{cc}}{\Delta t} = \frac{i}{C_T}$$

$$\Delta t = \frac{0.25V_{cc}C_T}{i}$$

(3)

The period "T" of the triangular waveform = $2\Delta t$

$\therefore f_0$ = oscillator frequency.

$$f_0 = \frac{1}{T}$$

$$= \frac{1}{2\Delta t} \quad (\because T = 2\Delta t)$$

$$= \frac{1}{2\left(\frac{0.25 V_{cc} C_T}{i}\right)} \quad \left(\because \Delta t = \frac{0.25 V_{cc} C_T}{i}\right)$$

$$= \frac{i}{0.5 V_{cc} C_T}$$

Multiply & Divide the above equation with "2" we get

$$f_0 = \frac{2i}{V_{cc} C_T} \longrightarrow (1)$$

But $i = \frac{V_{cc} - V_c}{R_T}$ [V_c = Voltage at pin 5]

Substitute "i" value in eq (1)

$$f_0 = \frac{2\left(\frac{V_{cc} - V_c}{R_T}\right)}{V_{cc} C_T}$$

$$f_0 = 2\left\{\frac{(V_{cc} - V_c)}{(V_{cc} C_T R_T)}\right\}$$

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→ From the above equation can intepret that output frequency can be varied by changing the value of R_T, value of C_T & the voltage "V_c" at pin 5 of the IC

→ If Modulating input voltage changed from $0.75V_{cc}$ to V_{cc} then frequency variation changed from 10 to 1.

→ If we donot apply modulating input at pin 5, the 'vco' output frequency is given by.

$$f_0 = \frac{2\left[V_{cc} - \left(\frac{7}{8}\right)V_{cc}\right]}{C_T R_T V_{cc}}$$

$$= \frac{2V_{cc} - 2\left(\frac{7}{8}\right)V_{cc}}{C_T R_T V_{cc}}$$

$$= \frac{2V_{cc} - \frac{7}{4}V_{cc}}{C_T R_T V_{cc}}$$

$$= \frac{2V_{cc} - 1.75V_{cc}}{C_T R_T V_{cc}} \Rightarrow \frac{0.25V_{cc}}{C_T R_T V_{cc}}$$

$$\boxed{f_0 = \frac{0.25}{R_T C_T}}$$

c) frequency conversion factor:-

The voltage to frequency conversion factor can be defined as the ratio of change in the "VCO" output frequency under no modulating input signal to the swing in the controlled voltage.

$$K_v = \frac{\Delta f_o}{\Delta V_c}$$

where

Δf_o = The change in output frequency.

ΔV_c = The change in the control voltage.

$$\Delta f_o = f_1 - f_o.$$

where

f_o = original frequency

f_1 = New frequency.

$$\Delta f_o = \frac{2[V_{cc} - V_c + \Delta V_c]}{C_T R_T V_{cc}} - \frac{2[V_{cc} - V_c]}{C_T R_T V_{cc}}$$

$$\Delta f_o = \frac{2[V_{cc} - V_c + \Delta V_c - V_{cc} + V_c]}{C_T R_T V_{cc}}$$

$$\Delta f_o = \frac{2\Delta V_c}{C_T R_T V_{cc}} \Rightarrow \frac{\Delta f_o}{\Delta V_c} = \frac{2}{C_T R_T V_{cc}}$$

Hence $K_V = \frac{2}{C_T R_T V_{cc}}$ —— (2) $\left(\because K_V = \frac{\Delta f_0}{\Delta V_c} \right)$

We know that

$$f_0 = \frac{0.25}{C_T R_T}$$

$$C_T R_T = \frac{0.25}{f_0}$$

$$C_T R_T = \frac{1}{4 f_0}$$

Substitute $C_T R_T$ value in eq (2) we get.

$$K_V = \frac{2}{\frac{1}{4f_0} V_{cc}}$$

$$K_V = \frac{8 f_0}{V_{cc}}$$

Features of 566 VCO:-

→ Wide supply voltage range 10V to 24V.

→ Very linear modulation characteristics.

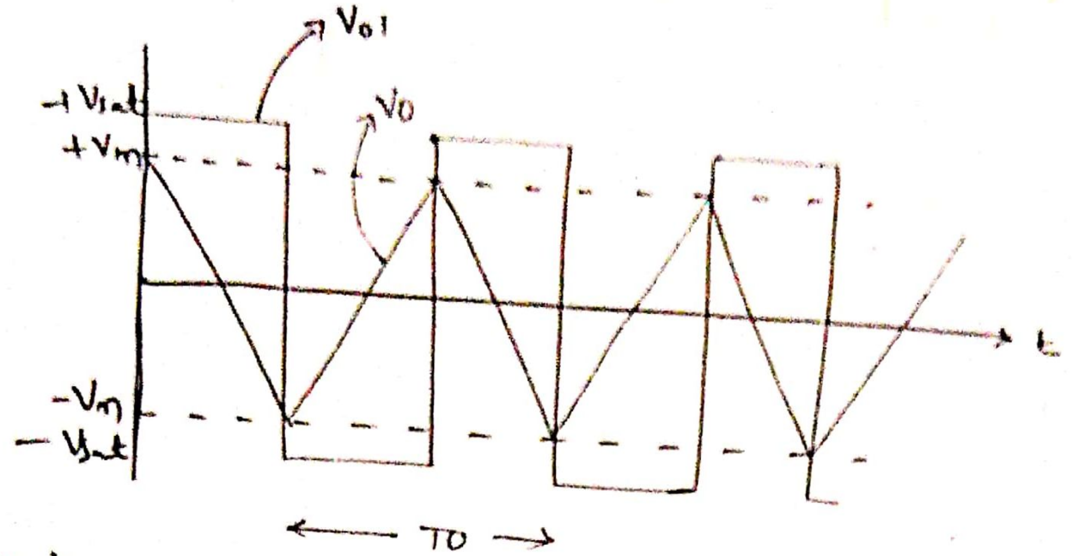
→ High temperature stability

Applications of 566 VCO:-

→ FM modulation

→ Signal generation

→ Function generation.



→ peak output voltage is given by $V_m = \frac{R_2}{R_3} \times V_{sat}$

→ Time period of output wave-form is given by

$$T_O = \frac{4 R_1 R_2 C_1}{R_3}$$

⇒ $f_O = \frac{1}{T_O}$ → frequency

Note ⇝

Traingular waveform can also be generated by cascade astable multivibrator and an integrator.

IC - 555 :

→ It is called timer IC

→ It is used to generate pulse and square wave-forms

Internal structure: