Comparator :-

The Comparator is one of the non-linear application of operational amplifier.

A comparator is a circuit which compares a signal voltage applied at one input of an op-amp with a known reference voltage at the other input. it is basically an open-loop op-amp with output $\pm V_{sat}$ ($\cong V_{cc}$).

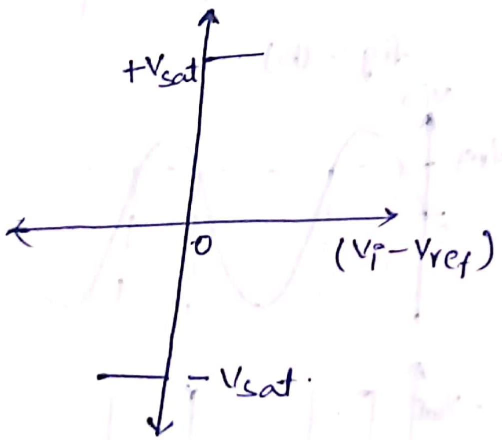


fig (a)

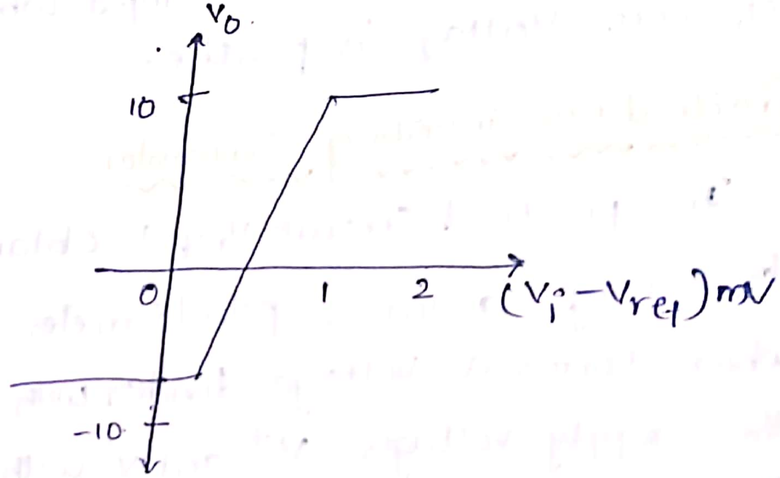


fig (b)

Transfer characteristics
(a) ideal comparator
(b) Practical Comparator.

if input voltage $V_i < V_{ref}$ then output is $-V_{sat}$.
if input voltage $V_i > V_{ref}$ then output is $+V_{sat}$
if input voltage $V_i = V_{ref}$ then O/P is '0'

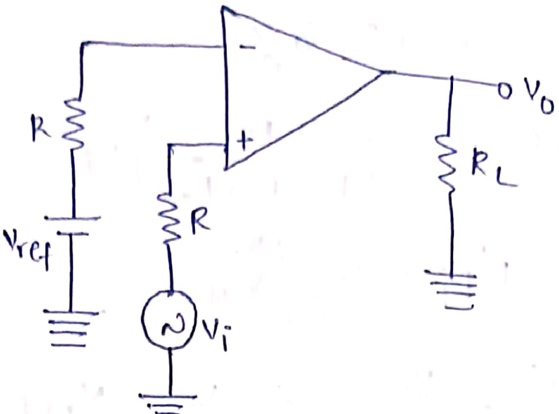
2 types of comparators:-

(i) Non - inverting comparator

(ii) inverting comparator.

(i) Non- inverting Comparator :-

The circuit represents a Non- inverting Comparator in which reference Voltage is connected across inverting terminal and input Voltage at non-inverting terminal.



if $V_i < V_{ref}$ so we get $V_0 = -V_{sat}$.

$V_i > V_{ref}$ $\qquad V_0 = +V_{sat}$.

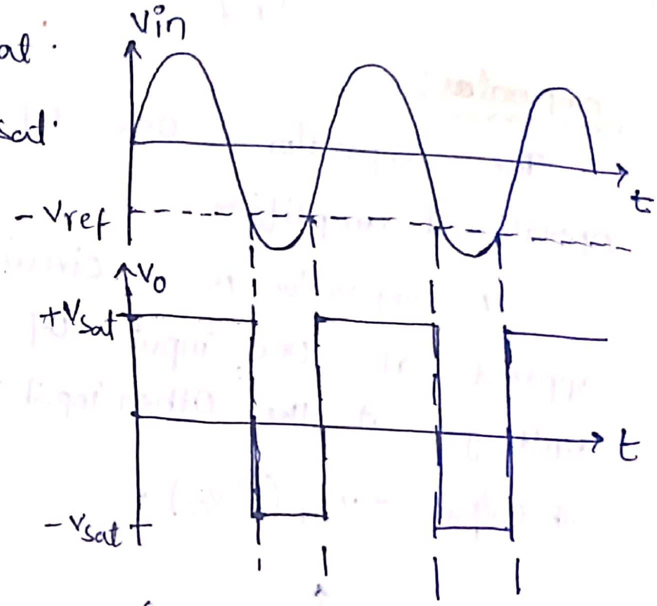


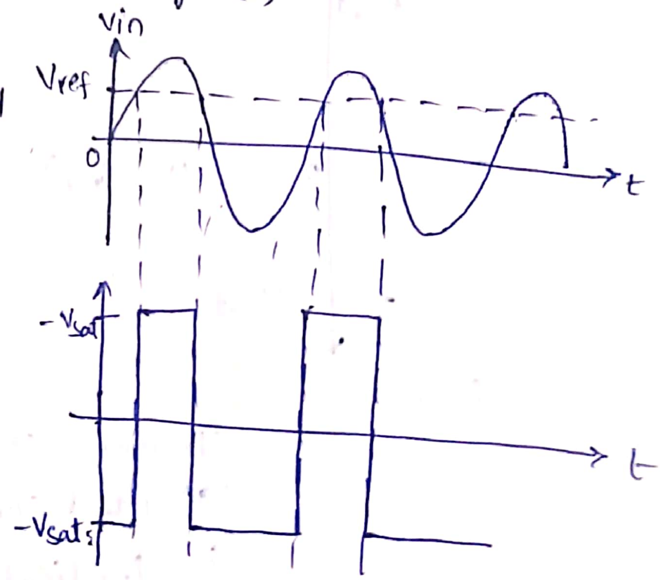
fig :- (b)

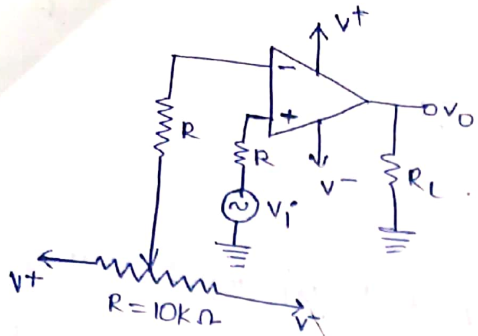
fig(b) represents an output waveform for a sinusoidal input when reference Voltage is negative.

fig(c) represents an input and output waveform for a sine wave input when reference Voltage is positive.

Practical non-inverting Comparator :-

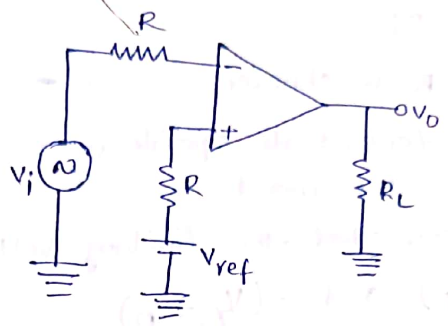
In practical Circuit V_{ref} is obtained by using a $10k\Omega$ potentiometer which forms a Voltage divider with the supply voltages V^+ and V^- with the wiper Connected to (-) input terminal Thus V_{ref} of desired amplitude and Polarity Can be obtained by simply adjusting the $10k\Omega$ potentiometer.





Inverting comparator:-

The circuit represents an inverting comparator in which input is connected at inverting terminal and reference voltage at non-inverting terminal.



When $V_i < V_{ref}$ then $V_o = +V_{sat}$.

$V_i > V_{ref}$ then $V_o = -V_{sat}$.

fig (b) represents the i/p & o/p waveforms when known reference voltage is positive.

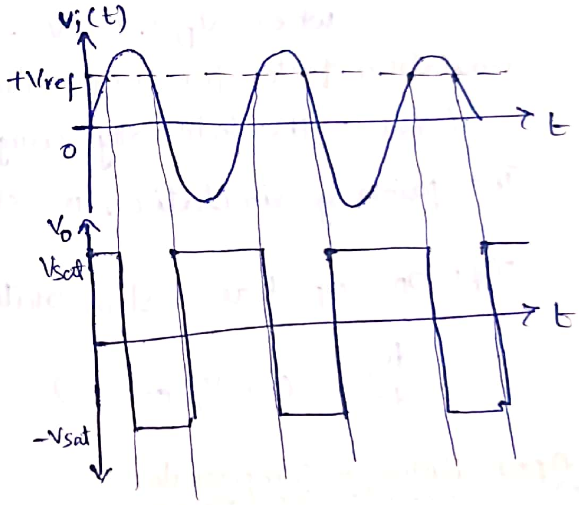
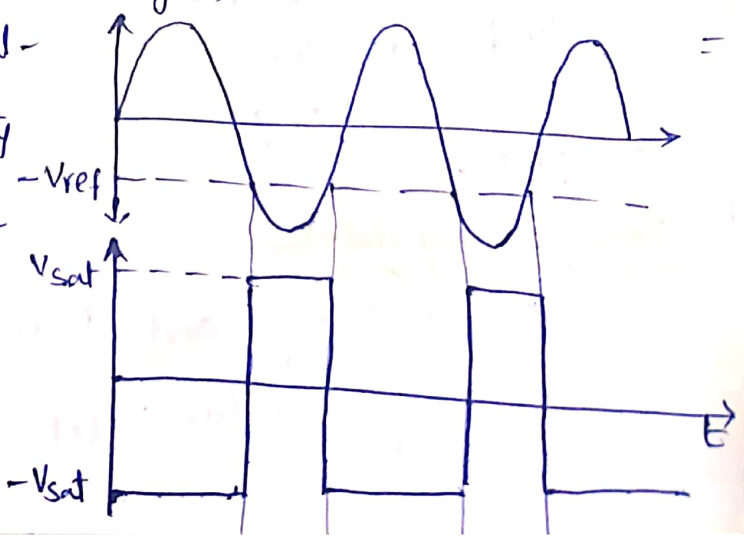
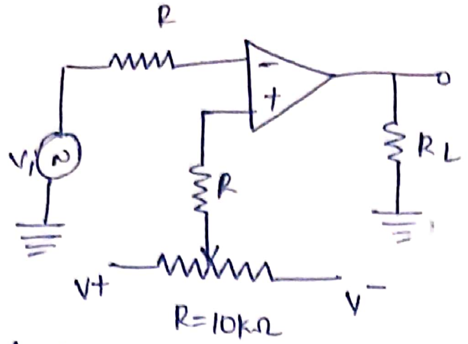


fig (b)

Practical Inverting comparator:-

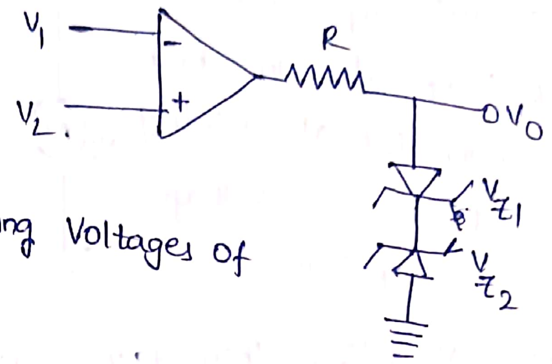
In practical circuit Vref is obtained by using a 10kΩ potentiometer which forms a voltage divider with the supply voltages V^+ and V^- with the wiper connected to (+) input terminal. Thus a desired amplitude and polarity of Vref can obtained by adjusting 10kΩ potentiometer.





To get output voltage independent of input voltage by choosing using a resistor R and two back to back Zener diodes at the o/p of op-amp.

The value of R is choosen such that the Zener diode operate at the recommended current.



it can be seen that the limiting voltages of V_o are $(V_{Z_1}+V_D)$ and $-(V_{Z_2}+V_D)$

where $V_D \simeq 0.7V$.

Limitation factor for comparator:-

if 741; the internally compensated op-amp is used as comparator, The primary limitation is slew rate.

741 op-amp has slew rate $0.5V/\mu sec$.

$$\frac{dv_o}{dt} = 0.5V/sec \Rightarrow dt = \frac{dv_o}{0.5} = \frac{2 \times V_{sat}}{0.5} = \frac{2 \times 15}{0.5} = 60 \mu sec.$$

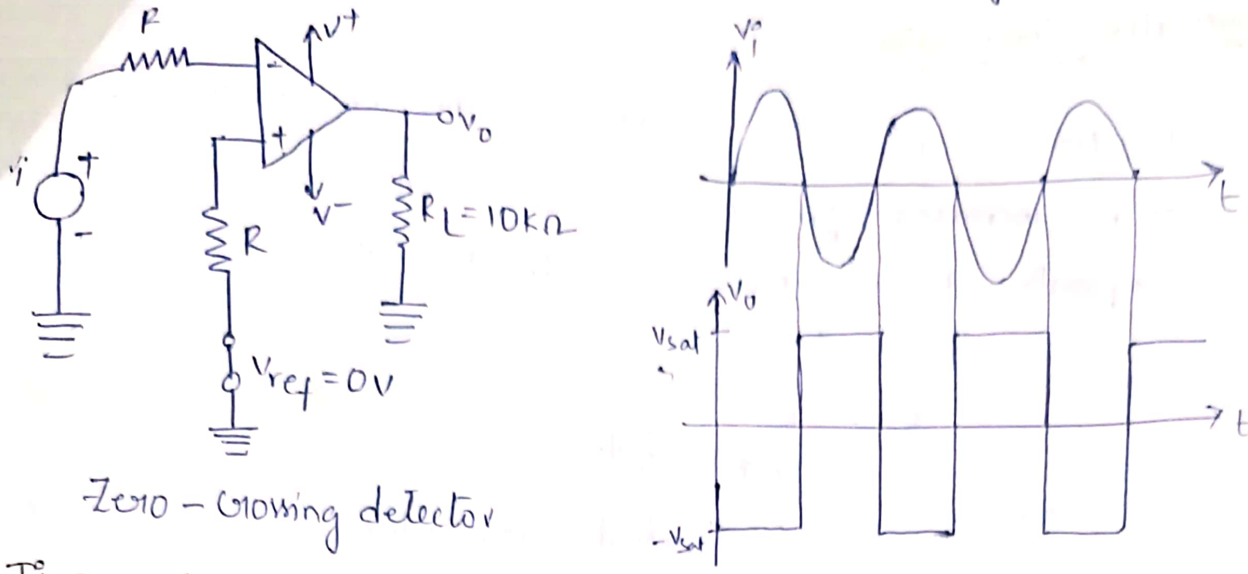
$(\because V_{sat} \simeq V_{cc} = 15V)$

Applications of comparator:-

→ Zero crossing detector.
→ Window detector
→ Time marker generator.
→ phase meter.

Zero crossing detector:-

Both inverting and non-inverting comparators are used as zero crossing detector. Let us consider an inverting comparator provided that V_{ref} is set to zero. The output is shown is also known as "Sine to square wave generator".

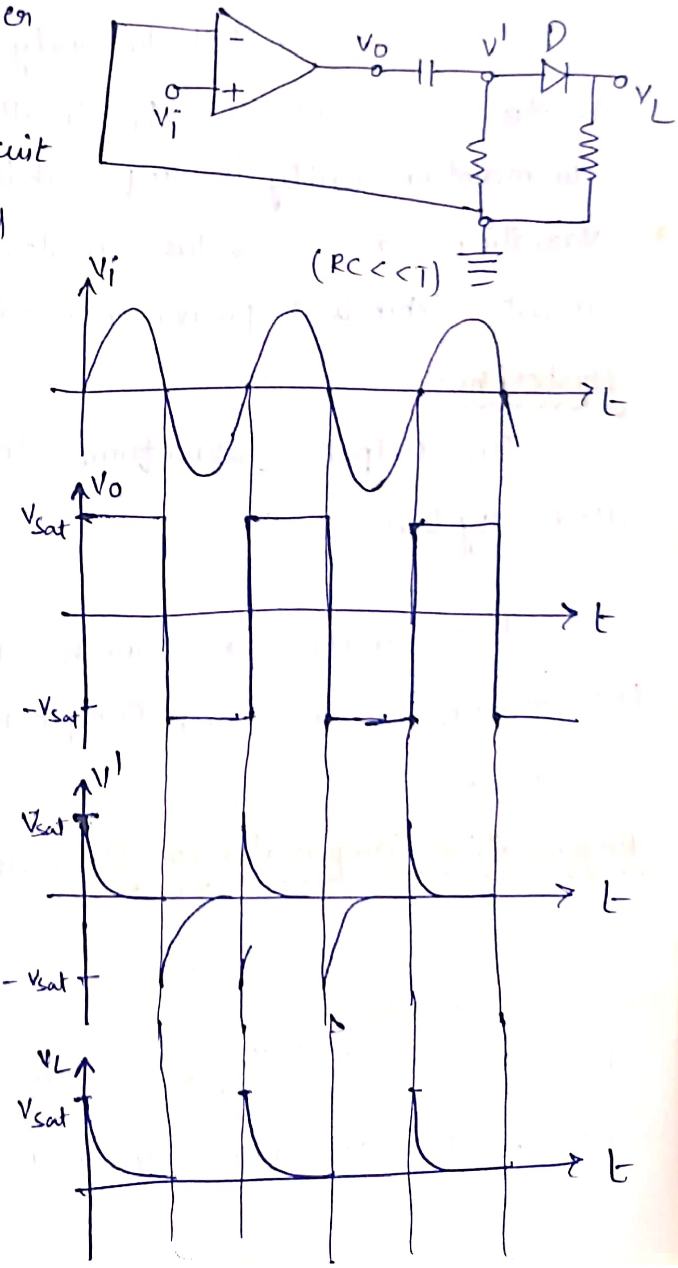


Zero-Crossing detector

Time marker generator :-

The circuit represents a Time marker generator. The output of zero crossing detector is differentiated by RC circuit so, that V' is series of positive and negative pulses. The negative portion is clipped when it passed through a Diode D and the output waveform V_L is shown.

So, with the help of this ckt Sinusoid has been converted into a train of positive pulses of spacing T which may used for triggering the monoshots, SCR, Sweep Voltage of CRT etc.



Phase detector :-

The phase angle between two Voltages can also be measured using the Time marker generator.

The time interval is proportional to the phase differ... measure phase angles from 0 to 360° with such a circuit.

Regenerative Comparator

if positive feedback is added to the Comparator circ.. gain can be increased greatly. Consequently, the transfer curve of Comparator becomes more close to ideal curve

$$\vartheta_o = A_{OL}\uparrow \vartheta_i$$

$$\vartheta_i = \frac{\vartheta_o}{A_{OL}\uparrow} \Rightarrow \vartheta_i \downarrow$$

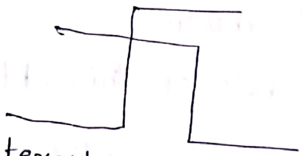
then it is similar to ideal characteristics.

closed loop gain $A_{cl} = \frac{A_{OL}}{1+A_{OL}\beta} = \frac{A_{OL}}{1-(-A_{OL}\beta)}$.

$-\beta A_{OL}$ is adjusted to unity, then the gain with feedback, A_{cl} ~~Acl~~ becomes infinite. Practically circuits, loop gain Exactly to maintain unity is impossible, due to supply voltage & temperature variations. so, a value greater than unity is choosen. then the circuit Exhibits a phenomenon called hyteresis.

Hysteresis:-

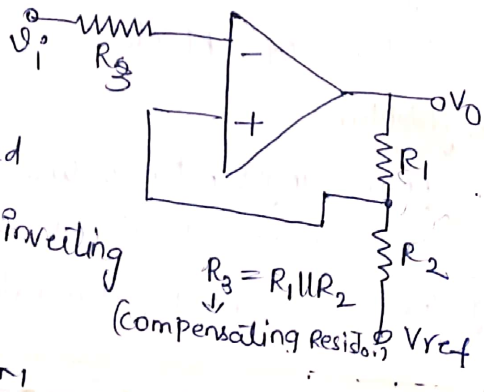
In output waveform some discontinous Exists it is called Hysteresis.



The circuit in which Hysteresis (or) Black slash Phenomenon Exists. Such Comparators are known as Regenerative Comparators.

Regenerative Comparator (or) Schmitt trigger:-

The figure shows a regenerative Comparator in which input is applied at inverting terminal. and feed back is connected to non-inverting



voltage V_i triggers the o/p V_o everytime it exceeds ...age levels. Those voltage levels are knowns as ...threshold voltage (V_{UT}) & lower threshold voltage (V_{LT}). (38)

...esis width :- The difference between these two threshold voltages i.e., $V_{UT} - V_{LT}$.

Suppose output $V_o = +V_{sat}$

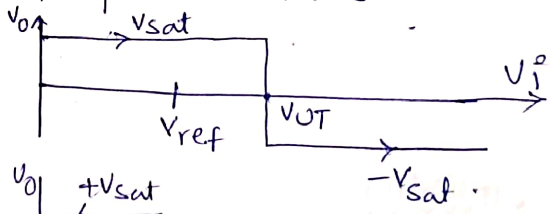
. The voltage at (+) input terminal can be obtained by using superposition theorem.

$$V_{UT} = \frac{V_{ref} R_1}{(R_1+R_2)} + \frac{R_2 V_{sat}}{(R_1+R_2)}$$ (This voltage is upper threshold vol)

As long as V_i is less than V_{UT}, the output V_o remains constant at $+V_{sat}$. When, V_i greater than $+V_{UT}$, the o/p regeneratively switches to $-V_{sat}$ and remains at this level as long as $V_i > V_{UT}$.

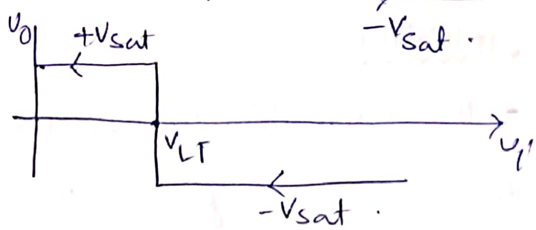
for $V_o = -V_{sat}$ the voltage at (+) input terminal is

$$V_{LT} = \frac{V_{ref} R_1}{R_1+R_2} - \frac{R_2 V_{sat}}{R_1+R_2}$$



$V_i > V_{LT} \Rightarrow -V_{sat}$

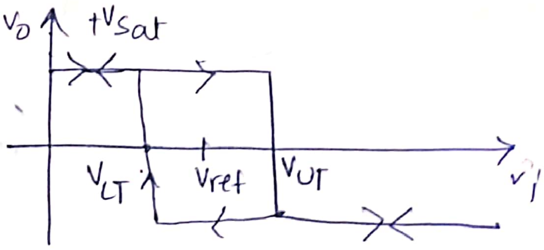
$V_i < V_{LT} \Rightarrow +V_{sat}$



$V_H = V_{UT} - V_{LT}$

$$V_H = \frac{\cancel{V_{ref} R_1}}{(R_1+R_2)} + \frac{R_2 V_{sat}}{R_1+R_2} - \frac{\cancel{V_{ref} R_1}}{R_1+R_2} + \frac{R_2 V_{sat}}{R_1+R_2}$$

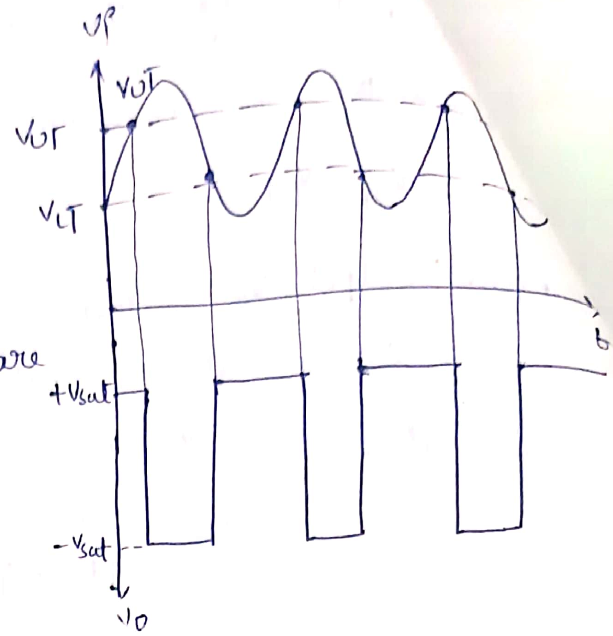
$$\boxed{V_H = \frac{2 R_2 V_{sat}}{R_1+R_2}}$$



> Hysteresis circuit triggers output voltage to the high volt for ~~decreasing~~ Increasing signals than for decreasing ones

→ if peak to peak input voltage less than V_H then o/p c..

Suppose consider sinusoidal signal :-



If $V_i < V_{UT}$ then $V_o = +V_{sat}$

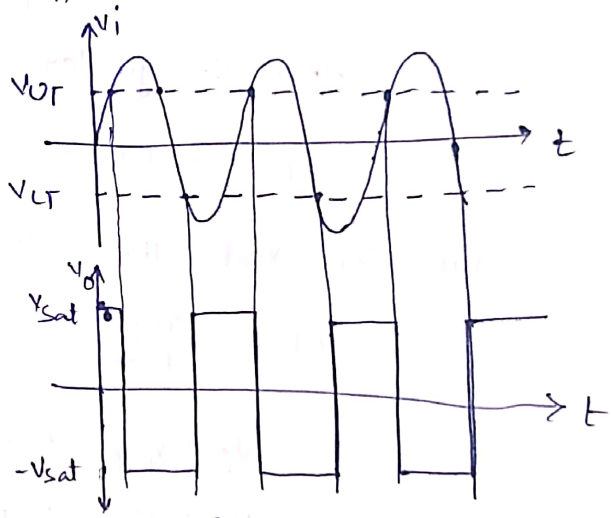
if $V_i > V_{LT}$ then $V_o = -V_{sat}$.

We obtain an unsymmetrical square wave.

To get symmetrical square wave.

the reference voltage is set to '0' volts and frequence $f = 1/T$ and $V_{UT} = V_m \sin\theta$.

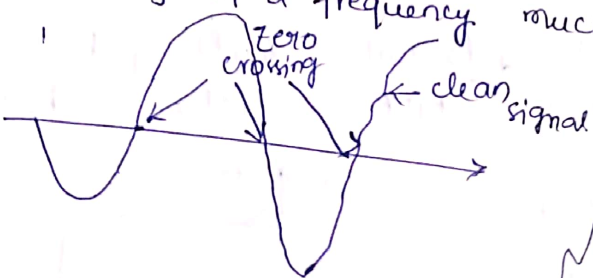
with shifted an phase angle of 'θ'.

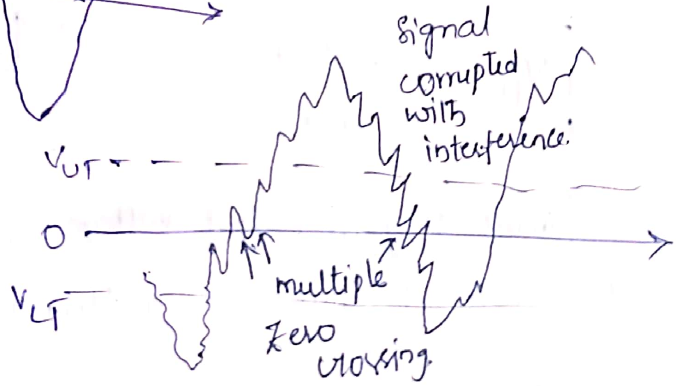


Symmetrical square wave,

Application :-

→ The application of hysteresis is in the detection and counting of the zero crossing of an arbitary waveform if it is superimposed with interference say of a frequency much higher than the signal





...chmitt trigger circuit $R_2 = 100\,\Omega$, $R_1 = 50K\Omega$, $V_{ref} = 0V$, sine wave and saturation voltage $= \pm 14V$. Determine voltage V_{UT} & V_{LT}.

$V_{ref} = 0V$.

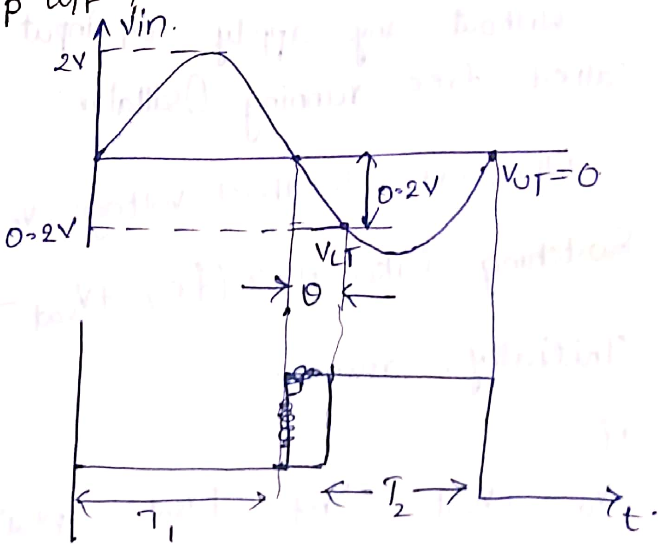
$$V_{UT} = \frac{R_1 V_{ref}}{R_1+R_2} + \frac{R_2 V_{sat}}{R_1+R_2}$$

$$= 0 + \frac{100(+14)}{100+50K} \Rightarrow \boxed{V_{UT} = 27mV}$$

$\boxed{V_{LT} = -27mV}$ since $V_{UT} = -V_{LT}$ when $V_{ref} = 0V$.

Q) A schmitt trigger with the upper threshold level $V_{UT} = 0V$ and hysteresis width $V_H = 0.2V$ converts a 1KHz sine wave of amplitude 4Vp-p into a square wave. Calculate the time duration of the negative and +ve portion of the o/p w/f ?

Sol).



Given $V_{UT} = 0V$

$V_{LT} = -0.2V$

$V_{UT} = V_m \sin\theta$.

$V_{LT} = V_m \sin(180+\theta)$.

$-0.2 = -2\sin\theta$

$\sin\theta = 0.1$

Time period $T = \frac{1}{f} = \frac{1}{10^3} = 1msec$

$\sin\theta = \frac{0.1}{2\pi}$

$\sin\theta = 0.015$.

$T_1 = 0.5 + 0.015$ $\qquad$ $T_2 = 0.5 - 0.015$

$T_1 = 0.516ms$ $\qquad$ $T_2 = 0.485\,msec$