Slide No: 1

COMPARATORS

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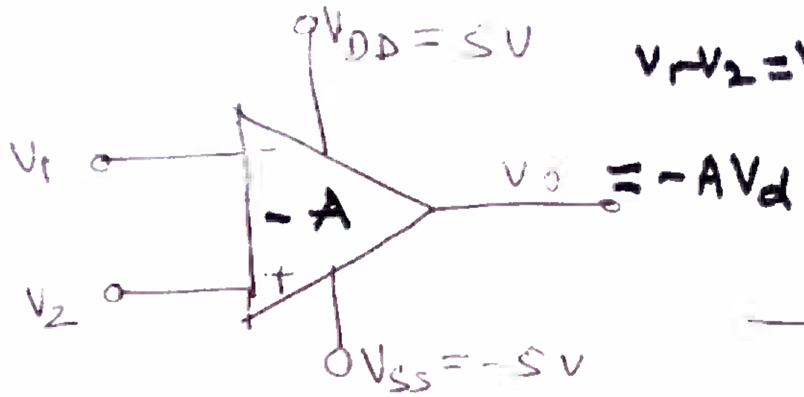
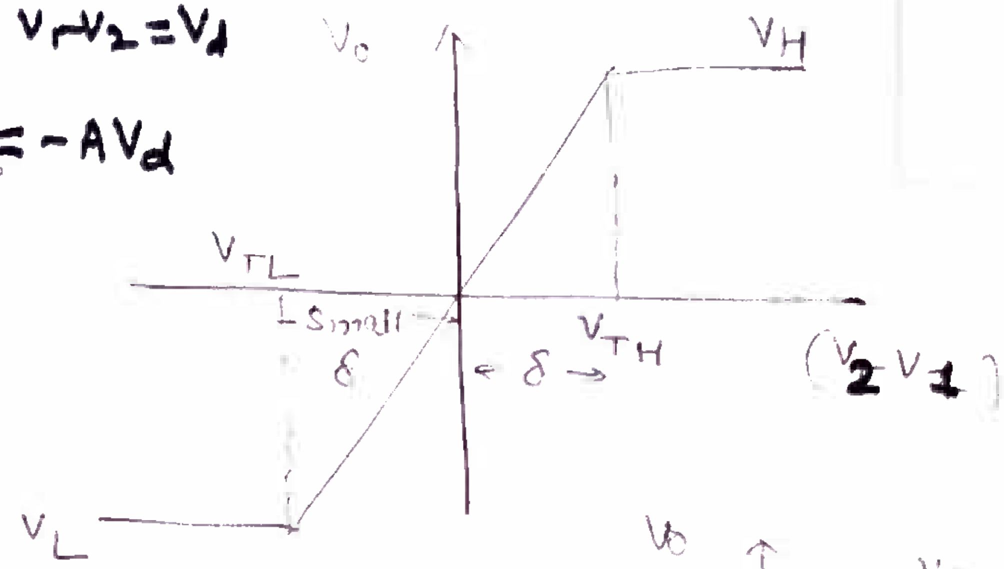
$V_1 - V_2 = V_d$

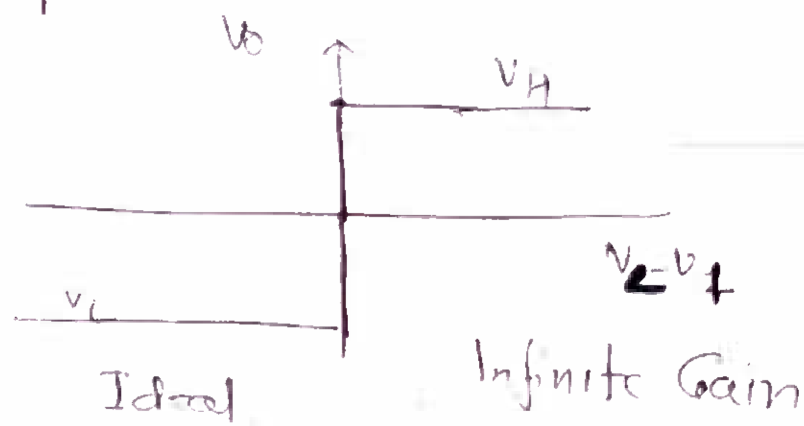




$$\text{Gain} = \frac{dV_o}{dV_{in}} = \frac{V_H - V_L}{2\delta}$$

$$2\delta = \frac{10V}{10^5} = 10^{-4} = 0.1\ mV.$$

$$= 100\ \mu V$$



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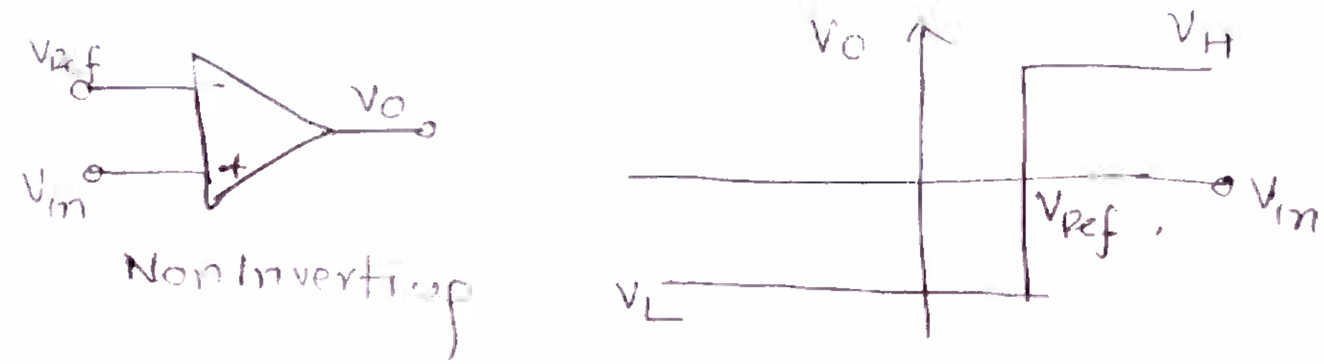

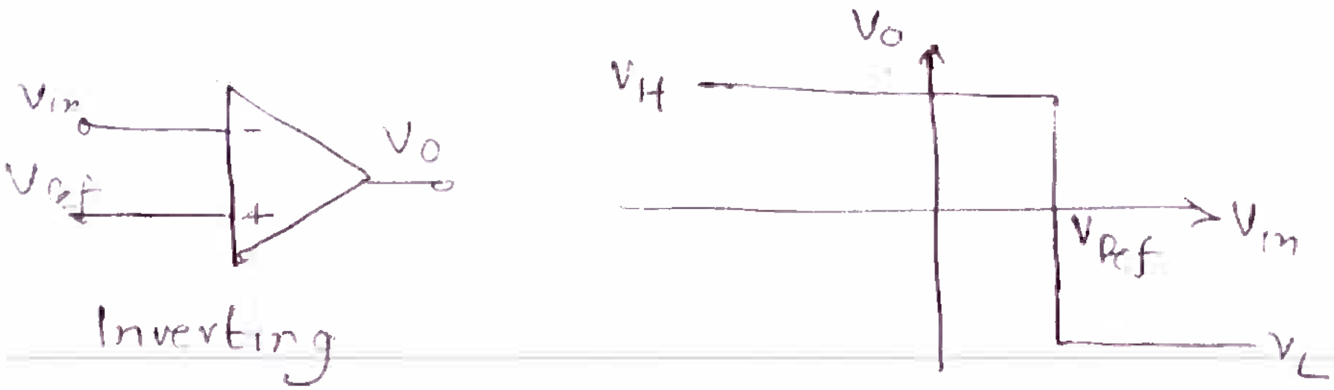

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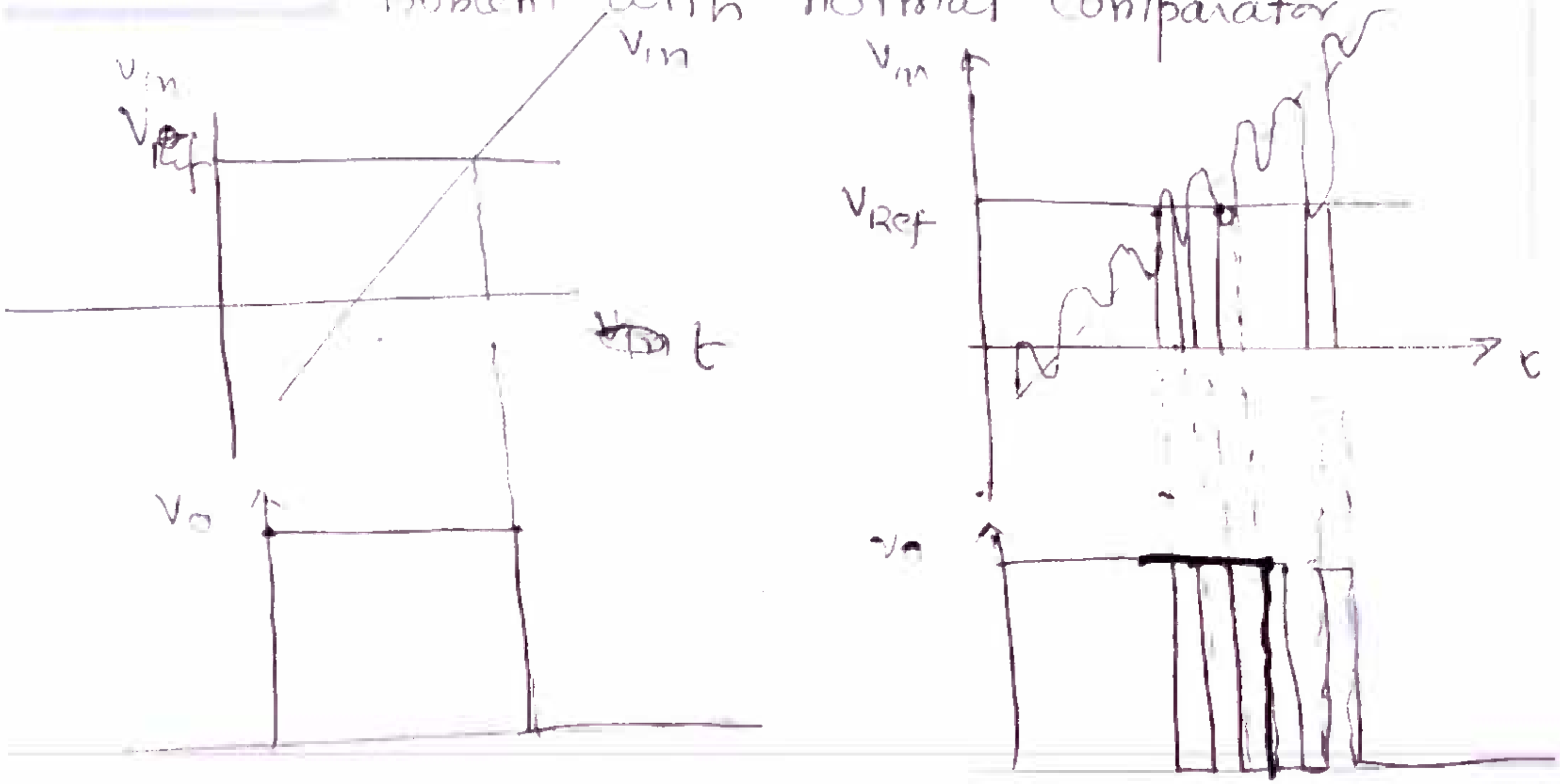
Problem with normal Comparator



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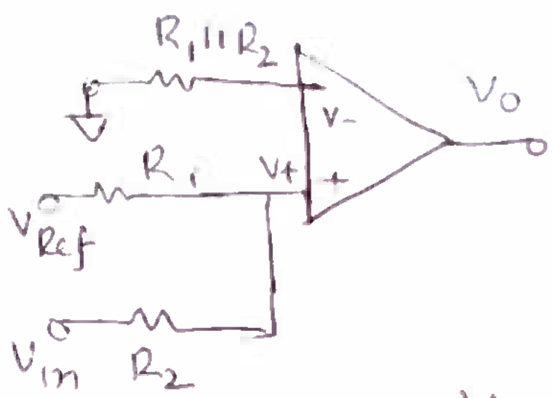

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V_o switches when V_+ crosses V_- (0 V here) i.e. at $V_+ = 0$

Crossover exists.

We find relationship between V_+ & V_{in} & V_{Ref} now

$$V_+ = \frac{R_2}{R_1+R_2} V_{Ref} + \frac{R_1}{R_1+R_2} V_{in}$$

Here

$V_{in} < V_{in}' \rightarrow V_o = \text{Low}$

$V_{in} > V_{in}' \rightarrow V_o = \text{High}$.

For Cross Over $V_+ \rightarrow 0$

or $R_2 V_{Ref} = R_1 V_{in}$ or $V_{in}' = -\frac{R_2}{R_1} V_{Ref}$ is Cross Over

For Inverting case too cross over occurs at same value.

But Vo goes from High to Low

Slide No: 5

Basic Schmitt Trigger

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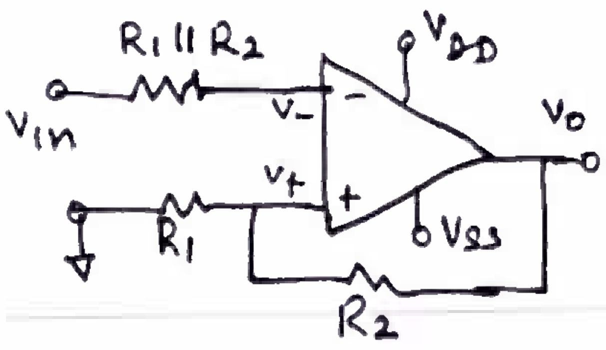
Schmitt Trigger is modified Comparator with Positive feedback. This results in a circuit which has TWO stable states (Bi Stable Multivibrator) of Oscillator



Now $V_+ = \dfrac{R_1}{R_1+R_2} \cdot V_o$

Since $V_o = f(V_{in})$, hence V_+ is time-varying function

Depending upon whether $V_+ > V_-$ or $V_- > V_+$, V_o can be +tive (V_{DD}) or −ve (V_{SS})

As $V_- = V_{in}$, V_o could be +tive or −ve depending upon V_{in} value & polarity.

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We say $V_o = V_H$ (Could be V_{DD})

or $V_o = V_L$ (could be V_{SS})

When $V_o = V_H$, obiviously $V_- < V_+$

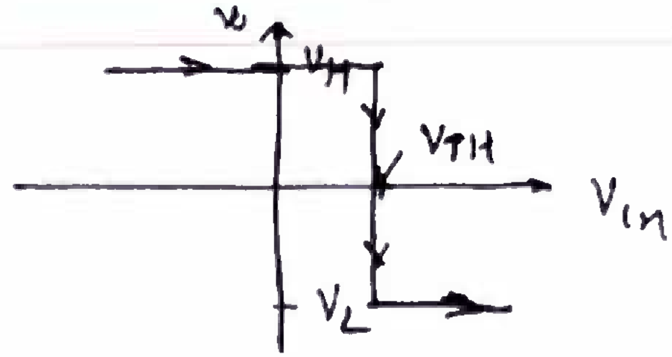
where $V_+ = \frac{R_1}{R_1+R_2} V_H$

As long as $V_- < V_+$ $V_o = V_H$. (i.e. $V_{in} < V_+$ condition)

However if $V_{in} > V_+$ (or $V_- > V_+$), $V_o = V_L$

At $V_{in} = \frac{R_1}{R_1+R_2} V_H$ cross over from $V_o = V_H$ to $V_o = V_L$ occures

Then V_{in} => called Cross-Over Voltage V_{TH}.



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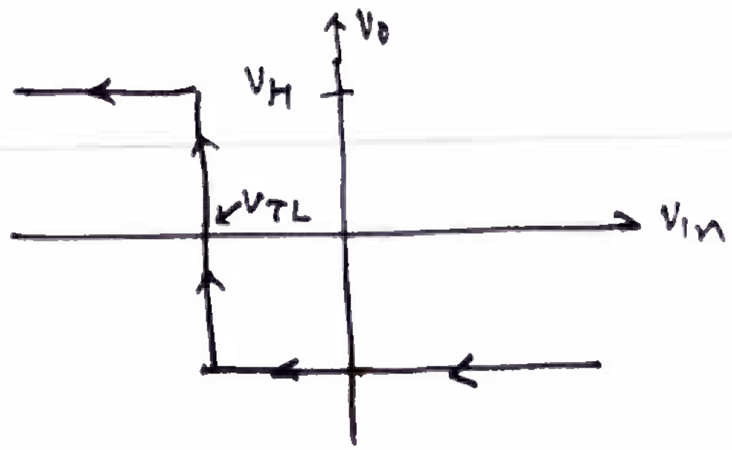
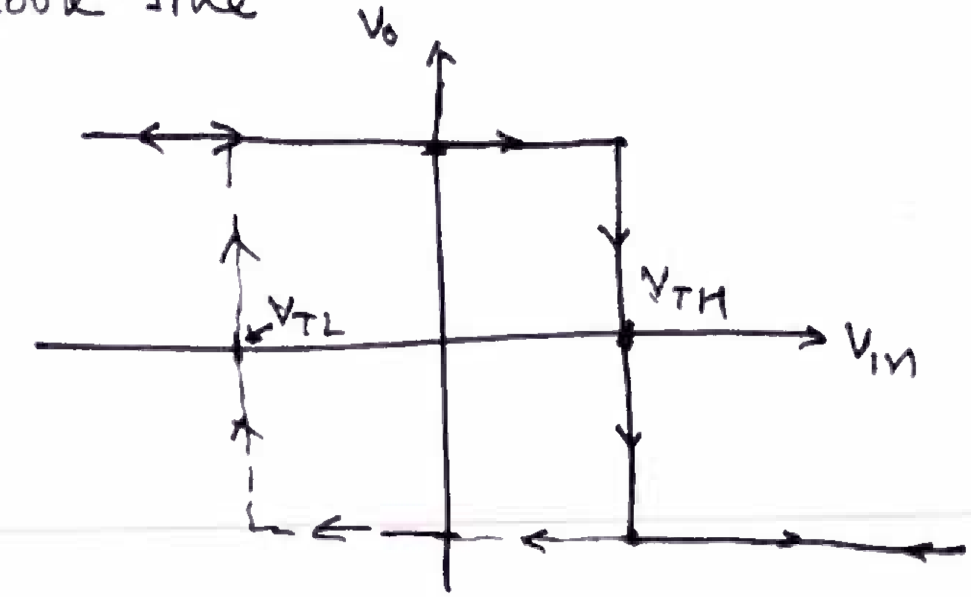
Now let us say we have $V_o = V_L$ (-ve) value, then $V_- > V_+$ or $V_{in} > V_+$ or $V_{in} > V_{TH}$

$$\therefore \quad V_+ = \frac{R_1}{R_1 + R_2} \cdot V_L = V_{TL}$$

If we now reduce V_{in} (Hence V_-), We see that till $V_{in} > V_{TL}$, $V_o = V_L$, but once $V_{in} \leq V_{TL}$ V_o switches due to comparator action to +tive V_H and remains V_H till $V_{in} < V_{TL}$ ($V_- < V_+$).



If V_{in} goes from $-ve$ value ($< V_{TL}$) to $+$tive value ($> V_{TH}$) and returns back, the Transfer Characteristics will look like



Clearly cross over points V_{TH} & V_{TL} occur when V_{in} crosses V_{TH} and later $V_{in} < V_{TL}$

We thus see Hysteresis Effect.

Width of Hysteresis $= V_{TH} - V_{TL}$

Example: If $V_{TH} = |V_{TL}| = 10V$ Evaluate R_1 for $V_{TH} = -V_{TL} = 2V$ if $R_2 = 20K$

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We have

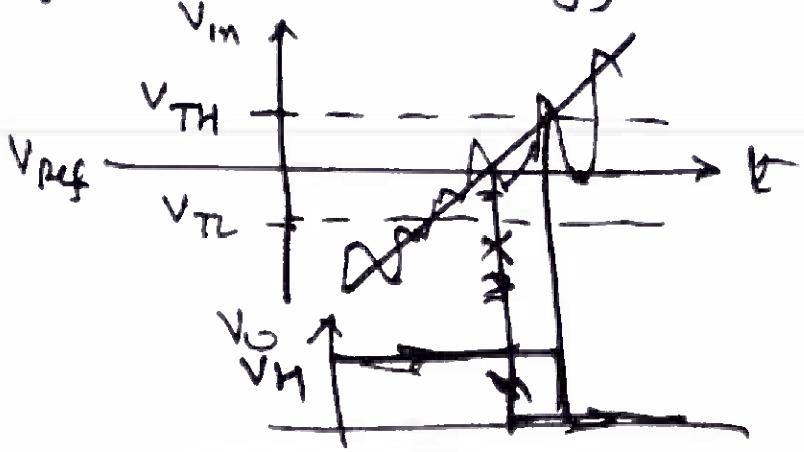
$$V_{TH} = 2\,V = \frac{R_1}{R_1 + R_2} V_H = \frac{1}{\left(1+\frac{20}{R_1}\right)} \cdot 10$$

or $\quad 2\left(1+\frac{20}{R_1}\right) = 10 \quad$ or $10 R_1 = 42$

or $R_1 = 4.2\,K$

Similarly $V_{TL} = -2V = \frac{1}{1+\frac{20}{R_1}}(-10)$, which gives $R_1 = 4.2K$

Advantages of Schmitt Trigger



Schmitt Trigger with V_{REF}.

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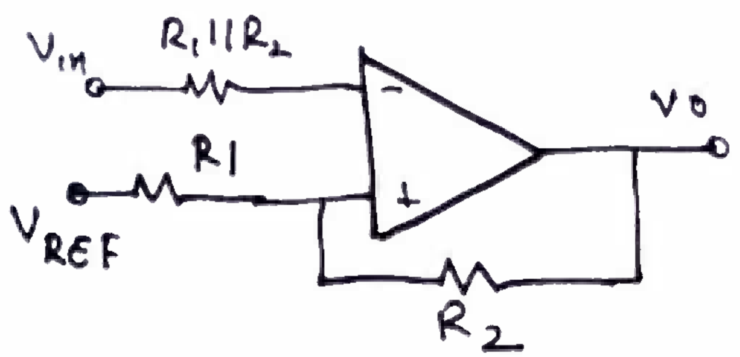


We define voltage

$$V_S = \frac{V_{TH} - V_{TL}}{2}$$

(Symmetric cross-over)

V_s is called Switching Voltage

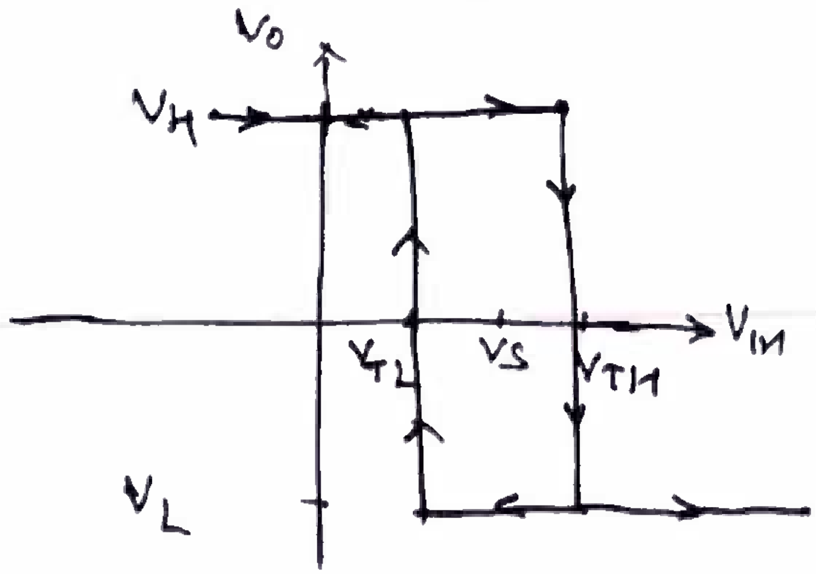
If $V_H = -V_L$ then

$$V_S = \frac{R_2}{R_1 + R_2} \cdot V_{REF}$$

&

$$V_{TH} = V_S + \frac{R_1}{R_1 + R_2} V_H$$

$$V_{TL} = V_S + \frac{R_1}{R_1 + R_2} V_L$$



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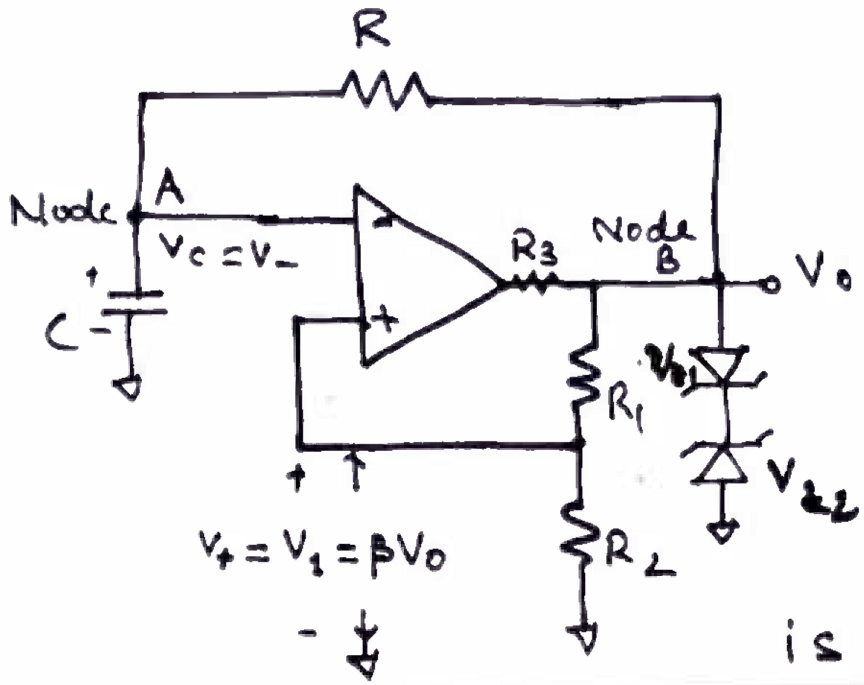
Schmitt Trigger Oscillator



Inverting Schmitt Trigger with 'Limiters' can be used to create Free-Running Squarewave Generator, Also known as Astable Multivibrator

We know Capacitor Charging Transient is $V_c(t) = V_0 \left[1 - e^{-t/RC}\right]$ where RC is time constant

In Astable Multivibrator, whenever V_c crosses thresholds of Comparator Switching Occures leading to Square Wave Generation.

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At $t = \frac{T}{2}$, $V_c(t) = +\beta V_0$

Then $\beta V_0 = V_0 \left[1 - (1+\beta)\, e^{-T/2RC}\right]$

$= V_0 - (1+\beta) V_0\, e^{-T/2RC}$

or $(1+\beta)\, e^{-T/2RC} = 1 - \beta$

or $T = 2RC \ln\left(\frac{1+\beta}{1-\beta}\right) = 2RC \ln\left[1 + \frac{2R_2}{R_1}\right]$

Observe $T \neq f(V_0)$

Frequency Range 10 Hz to 10 KHz (why?)

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For v. high gain Comparator case we have

(Theory) $v_o = V_z + V_D = V_o$ (Limiter limits V_H & V_L)

if $v_{id} < 0$

$(v_- < v_+)$

& $v_o = -V_o$ if $v_{id} > 0$

We start at an instant $t=0$, where $v_{id} < 0$ $(V_- < V_+)$

Then $v_c(t) = V_o' = -\beta V_o$ (Initial Cond^n)

As $v_c(t)$ starts rising (capacitor starts charging) towards V_o with time constant $R \cdot C$, then

$$v_c(t) = V_o\left[1 - (1+\beta)e^{-t/RC}\right]$$

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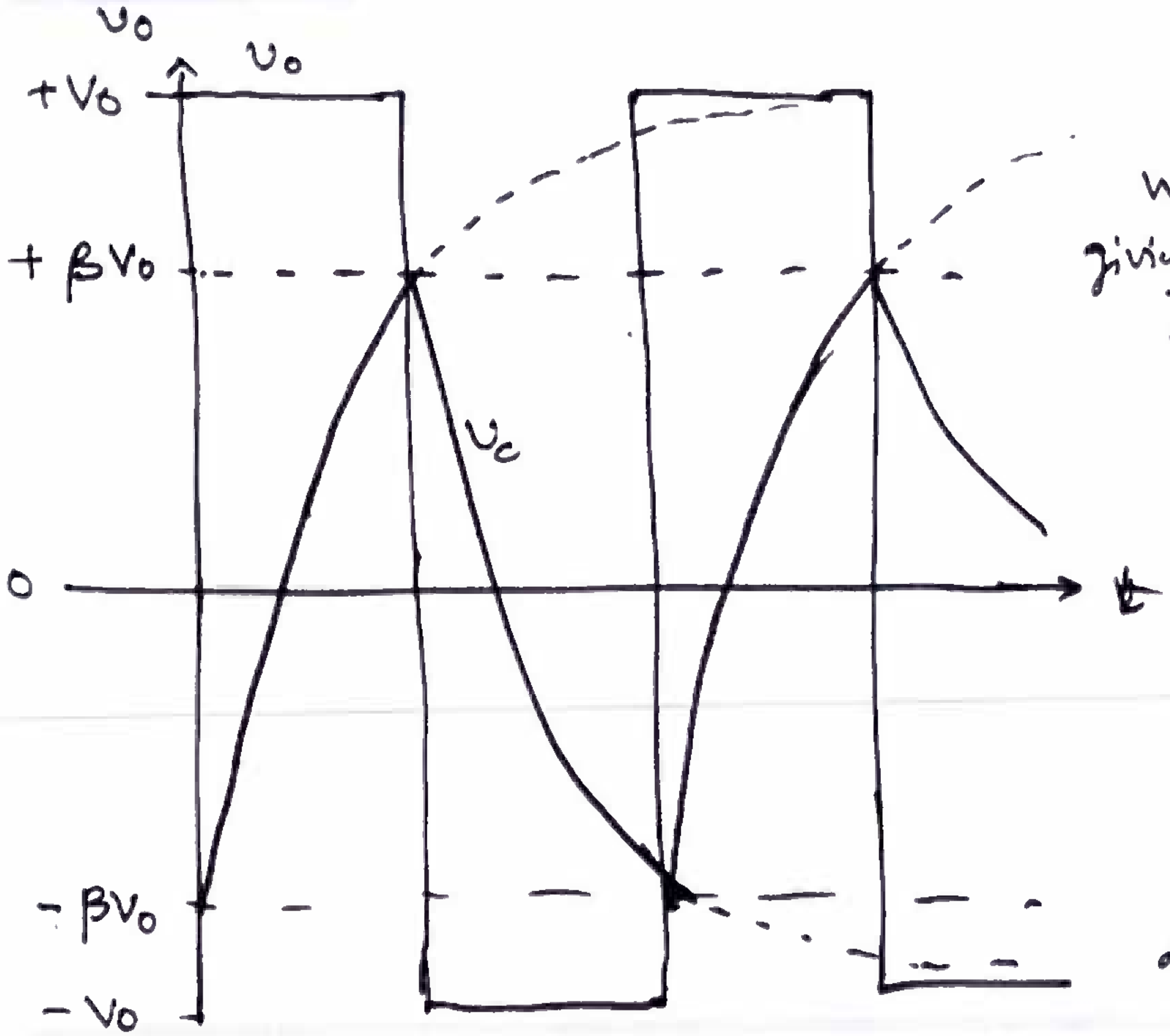
Waveforms in SC oscillator



We have feedback giving as $\frac{R_2}{R_1+R_2} \cdot V_0 = \beta V_0$

Then Difference signal input is

$$V_{id} = V_- - V_+$$

$$= V_c - V_+$$

But $V_+ = \frac{R_2}{R_1+R_2} V_0$

$$\therefore V_{id} = V_c - \frac{R_2}{R_1+R_2} V_0$$

or $V_{id} = V_c - \beta V_0$

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