CSE 350
Digital Electronics and Pulse Techniques

Comparator and Schmitt Trigger

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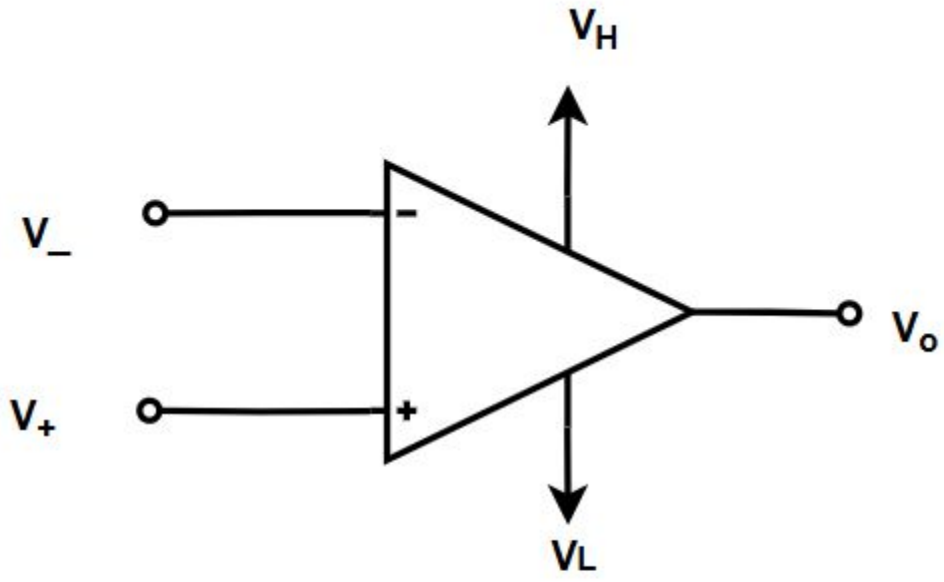
Op-Amp

- Ideal characteristics of Op-Amp

Open loop configuration,

- Input current zero
- If $V_+ > V_-$, $V_o = V_H$
- If $V_+ < V_-$, $V_o = V_L$



Op-Amp Comparator

Comparator can be inverting and non-inverting.

In Inverting Comparator input is connected to the V_- terminal.

In Non-Inverting Comparator input is connected to the V_+ terminal.

Non-Inverting Comparator

Here, $V_+ = V_I$ and $V_- = V_{REF}$

We know when,

$V_+ > V_-$

$\Rightarrow V_I > V_{REF}$

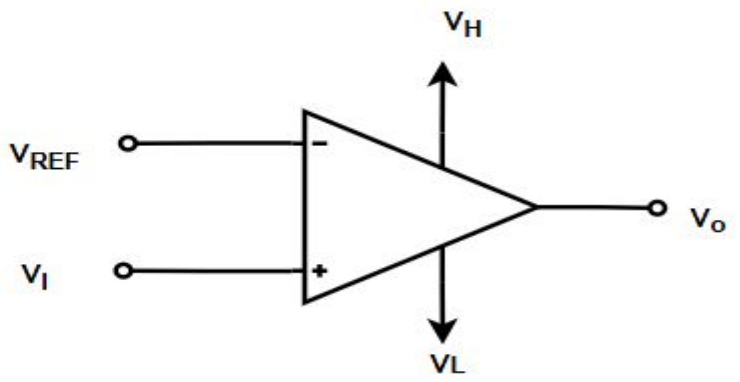
$V_O = V_H$

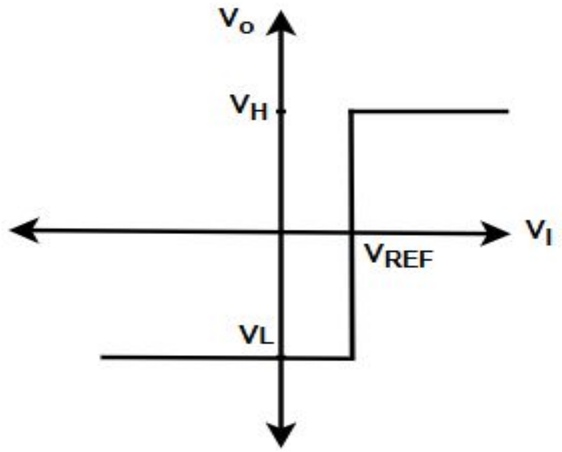
When,

$V_+ < V_-$

$\Rightarrow V_I < V_{REF}$

$V_o = V_L$





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Inverting Comparator

Here, $V_- = V_I$ and $V_+ = V_{REF}$

We know when,

$V_+ > V_-$

$\Rightarrow V_{REF} > V_I$

$\Rightarrow V_I < V_{REF}$

$V_O = V_H$

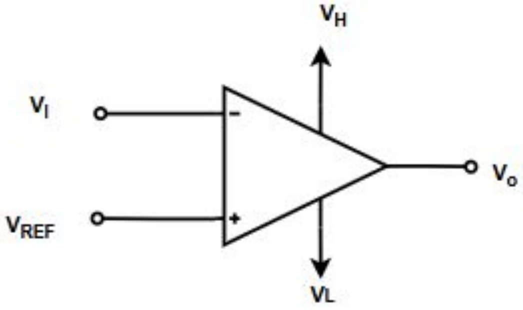
When,

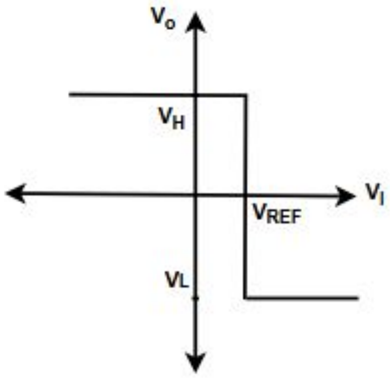
$V_+ < V_-$

$\Rightarrow V_{REF} < V_I$

$\Rightarrow V_I > V_{REF}$

$V_o = V_L$





Non-Inverting Comparator with Divider

Here, $V_{-} = 0\,V$ [As no current is passing through V_{-} terminal]

Node analysis at V_{+} terminal,

$$\frac{V_{+} - V_{REF}}{R_1} + \frac{V_{+} - V_I}{R_2} = 0$$

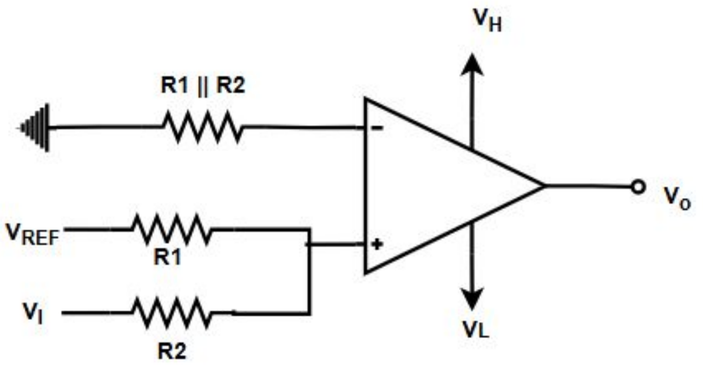
$$\Rightarrow V_{+} = V_I \frac{R_1}{R_1 + R_2} + V_{REF} \frac{R_2}{R_1 + R_2}$$

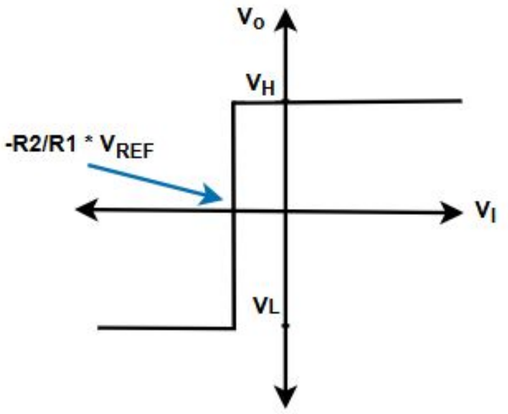
When, $V_{+} > V_{-} \Rightarrow V_I > \; -\frac{R_2}{R_1} V_{REF}$

$V_o = V_H$

And,

$V_I < -\frac{R_2}{R_1} V_{REF}$,,,, $V_0 = V_L$





Inverting Comparator with Divider

Here, $V_{+} = 0\ V$ [As no current is passing through V_{+} terminal]

Node analysis at V_{-} terminal,

$$\frac{V_{-} - V_{REF}}{R_1} + \frac{V_{-} - V_I}{R_2} = 0$$

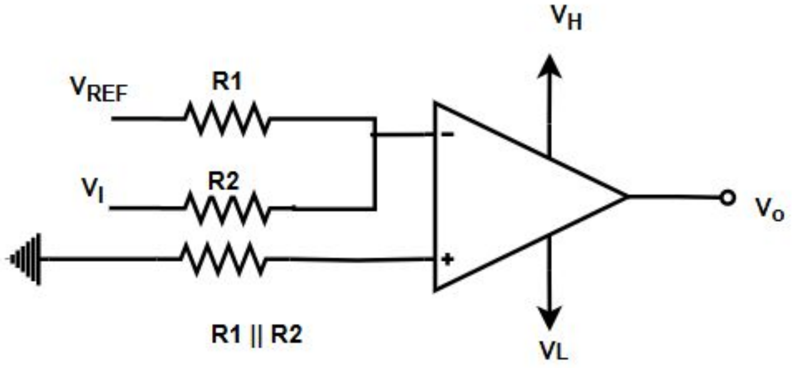
$$\Rightarrow V_{-} = V_I \frac{R_1}{R_1 + R_2} + V_{REF} \frac{R_2}{R_1 + R_2}$$

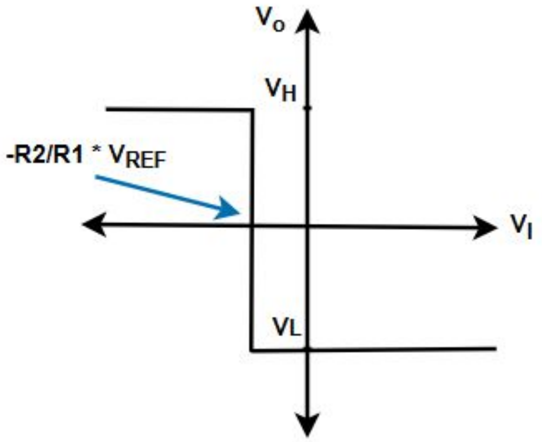
When, $V_{+} > V_{-} \Rightarrow \boldsymbol{V_I < -\frac{R_2}{R_1} V_{REF}}$

$\boldsymbol{V_o = V_H}$

And,

$$\boldsymbol{V_I > -\frac{R_2}{R_1} V_{REF}, V_0 = V_L}$$

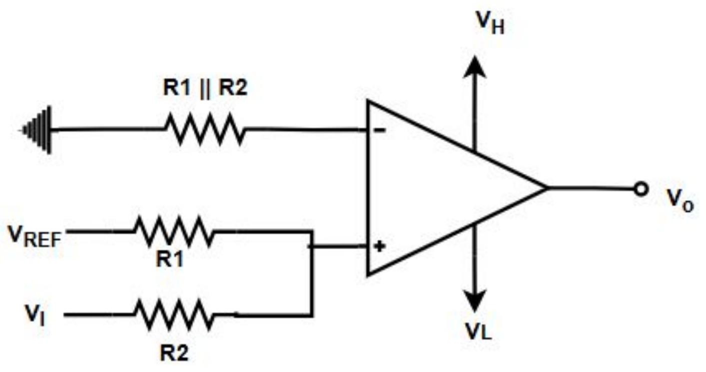


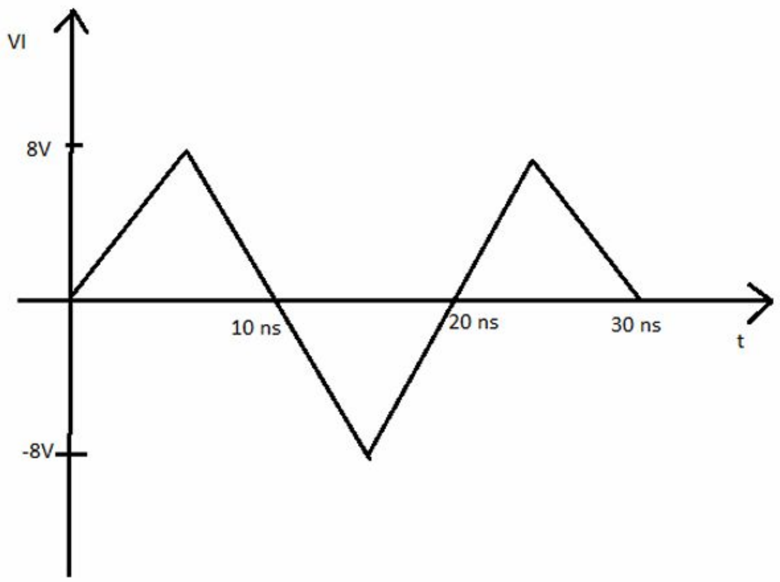


Exercise

- The wave is connected as input of the given circuit. Find the output waveform of the circuit.

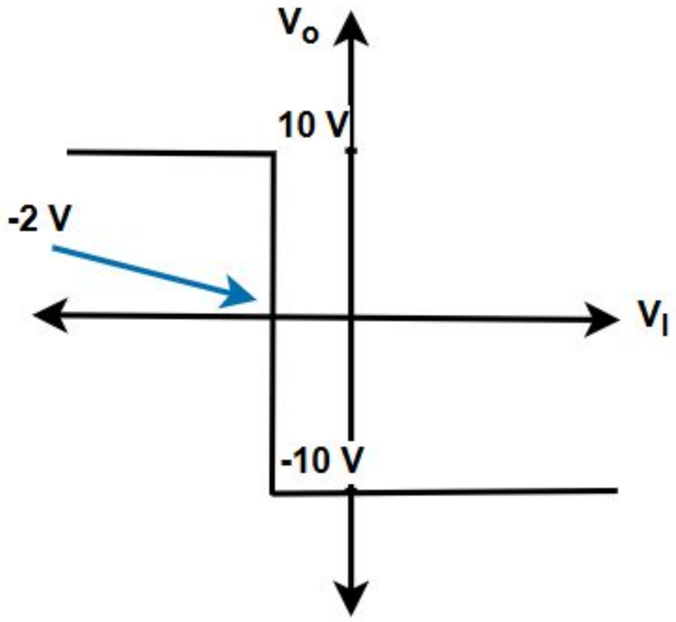
Given, $V_H = 15\text{ V}, V_L = -15\ V, R1 = R2 = 10k, V_{REF} = 4\ V$





Exercise

Design a comparator circuit that will show the given transfer curve. You need to use 5 V as reference voltage.



Exercise

Design a comparator for street light control system. The photodetector detect light intensity and outputs a corresponding voltage. The detector output is 0 V when intensity of light is 0% of Max intensity and 5 V when the intensity of light Maximum. Design the comparator such that it can turn on the street light when the intensity is below 15% of the Max Light intensity.

You must satisfy all the mentioned criteria, and assume any component values accordingly.

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Schmitt Trigger circuit

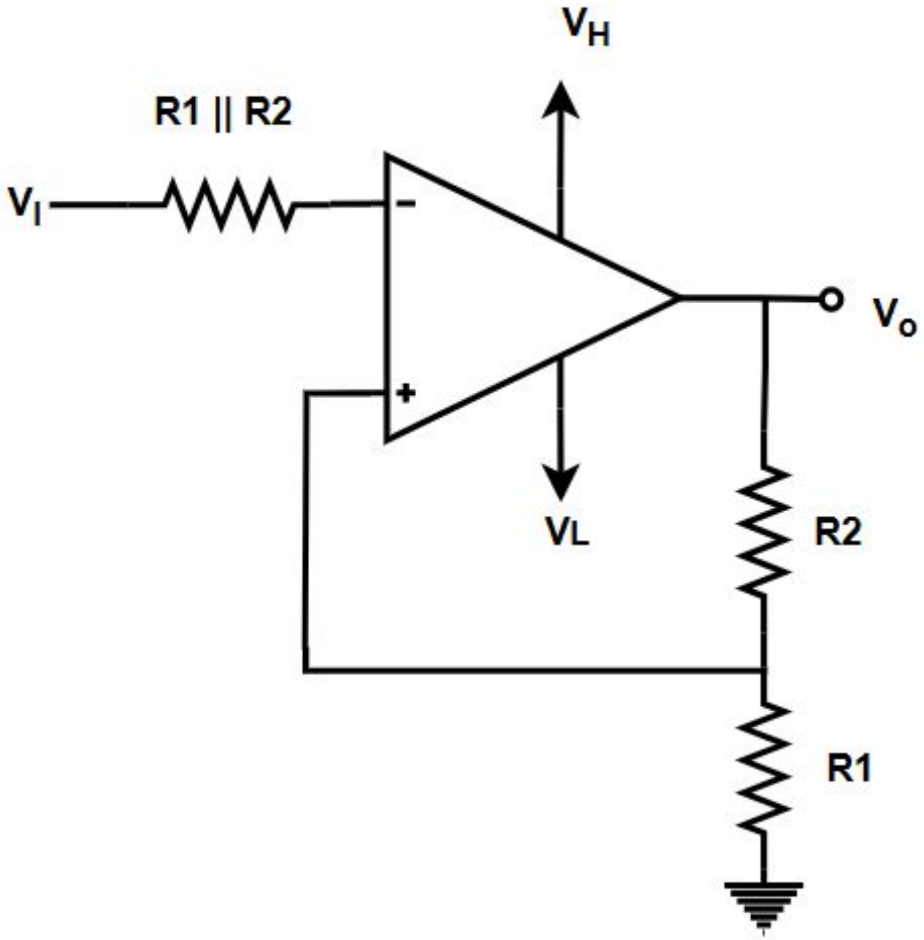
We will study 4 types of Schmitt Trigger circuit

1. Inverting ST
2. Non-inverting ST
3. Inverting ST with Ref
4. Non-inverting with Ref

Inverting ST

- Here, $V_{-} = V_I \ , V_{+} = V_o \frac{R_1}{R_1+R_2}$

  We need to know previous output for calculating the next output.



Inverting ST

Case 01:

$$If\ V_I\ large\ positive, no\ doubt\ V_- > V_+$$

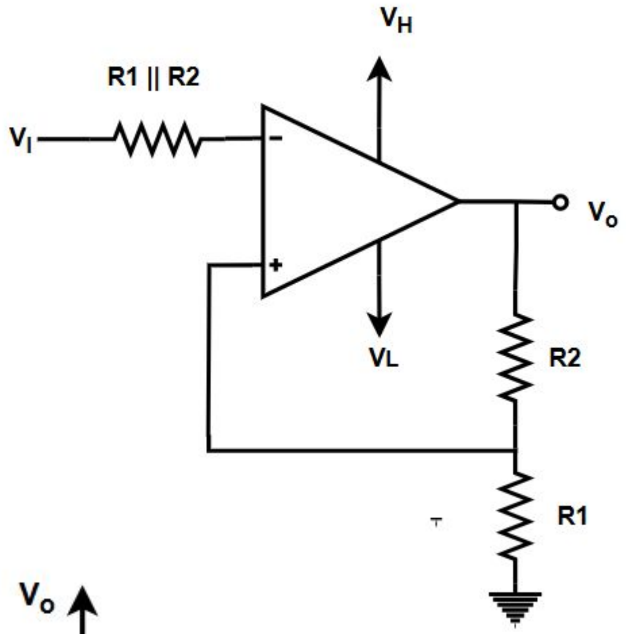
$$V_o = V_L$$

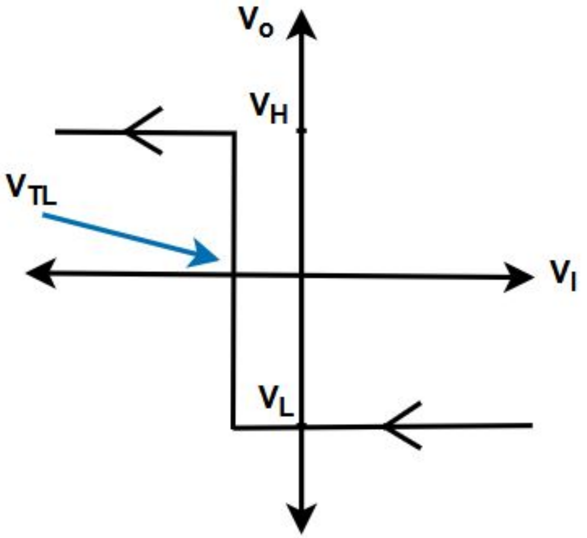
For sustaining, $V_o = V_L$

$$V_- > V_+$$

$$V_I > V_L \frac{R_1}{R_1 + R_2}$$

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





Inverting ST

Case 02:

$If\ V_I\ large\ negative, no\ doubt\ V_- < V_+$

$V_o = V_H$

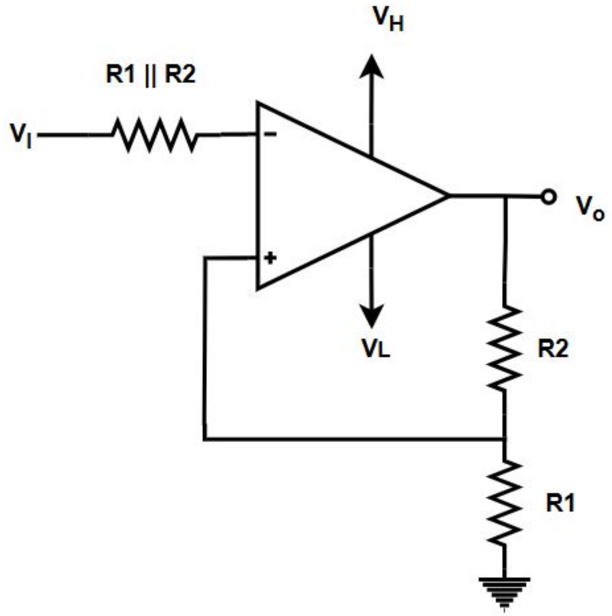
For sustaining, $V_o = V_H$

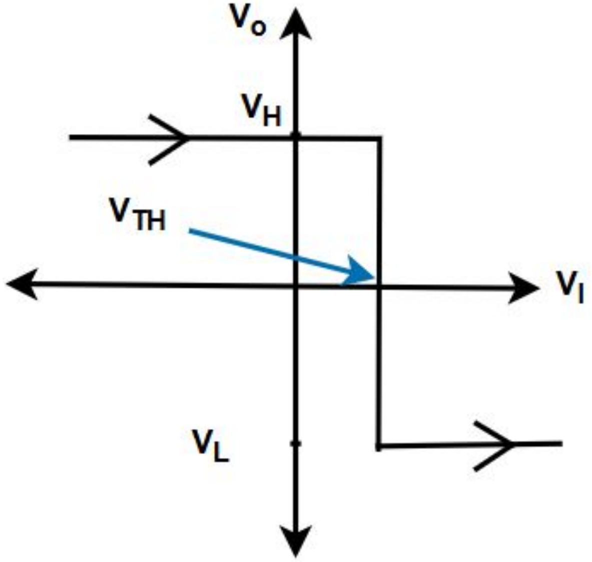
$V_+ > V_-$

$V_H \dfrac{R_1}{R_1 + R_2} > V_I$

$V_I < V_H \dfrac{R_1}{R_1 + R_2}$

$\therefore V_{TH} = V_H \dfrac{R_1}{R_1 + R_2}$





Inverting ST

V_{TH} = Upper Threshold

V_{TL} = Lower Threshold

V_S = Center voltage

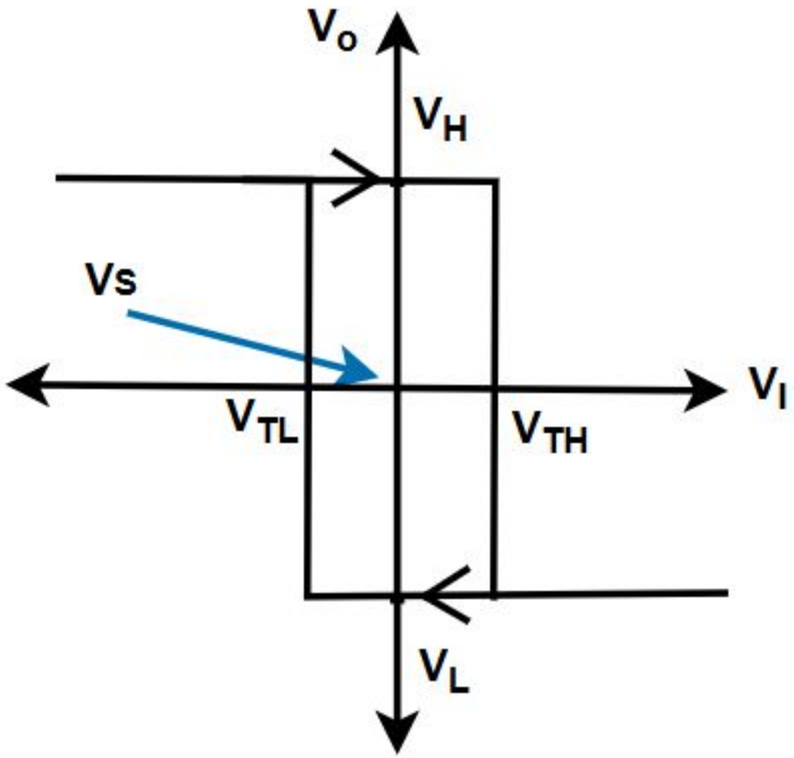
V_{HW} = Hysteresis width

$$V_s = \frac{V_{TH} + V_{TL}}{2}$$

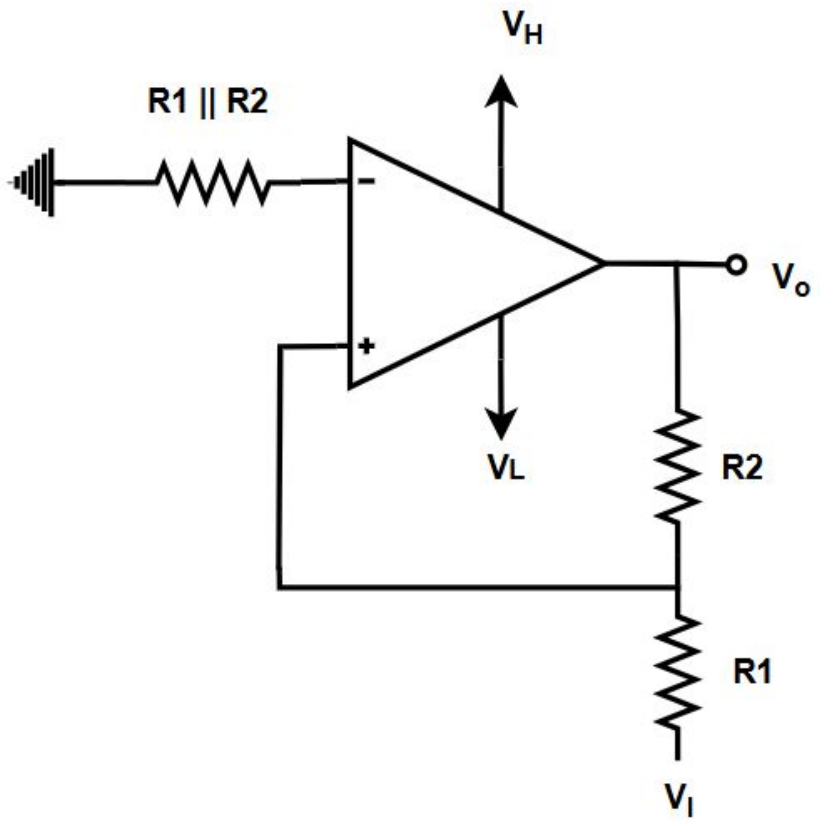
$$V_{HW} = V_{TH} - V_{TL}$$

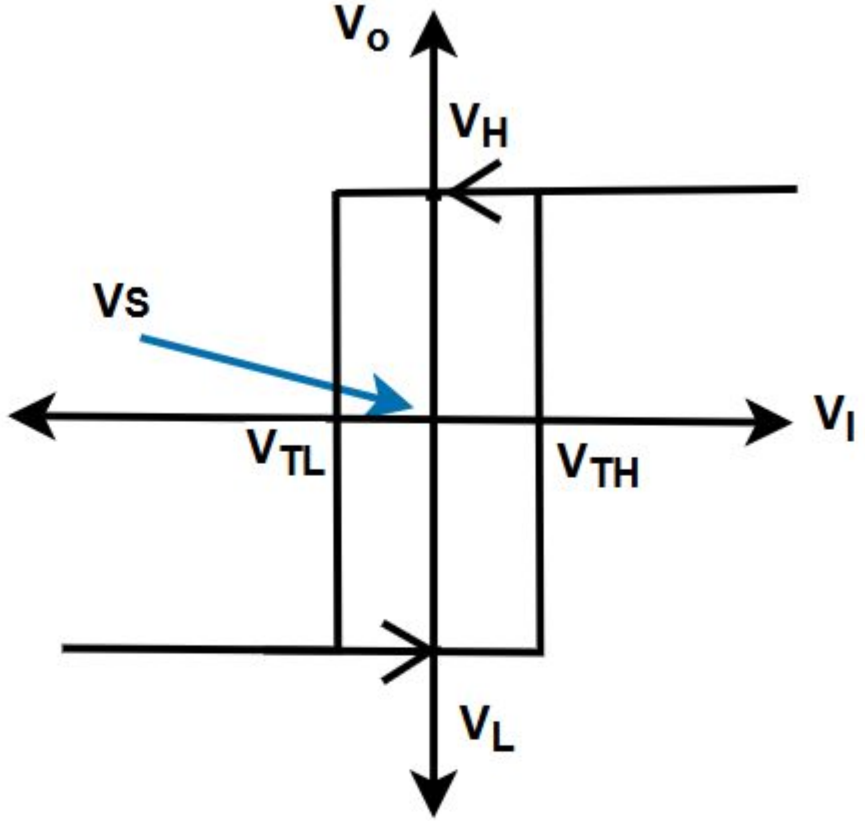
If $V_L = -V_H \, , V_S = 0$

$$and\ V_{HW} = 2 * V_H * \frac{R_1}{R_1 + R_2}$$



Non-inverting ST





Non-inverting ST

Formula,

$$V_{TH} = -\frac{R_1}{R_2} V_L$$

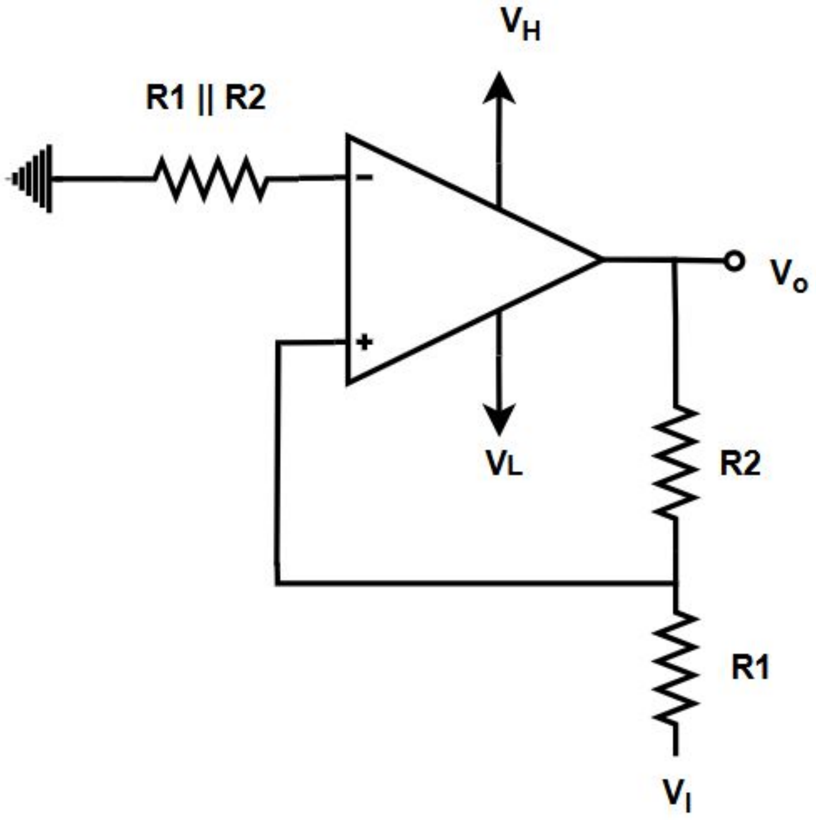
$$V_{TL} = -\frac{R_1}{R_2} V_H$$

$$V_s = \frac{V_{TH} + V_{TL}}{2}$$

$$V_{HW} = V_{TH} - V_{TL}$$

IF $V_L = -V_H$

$$V_S = 0, V_{HW} = 2V_H \frac{R_1}{R_2}$$



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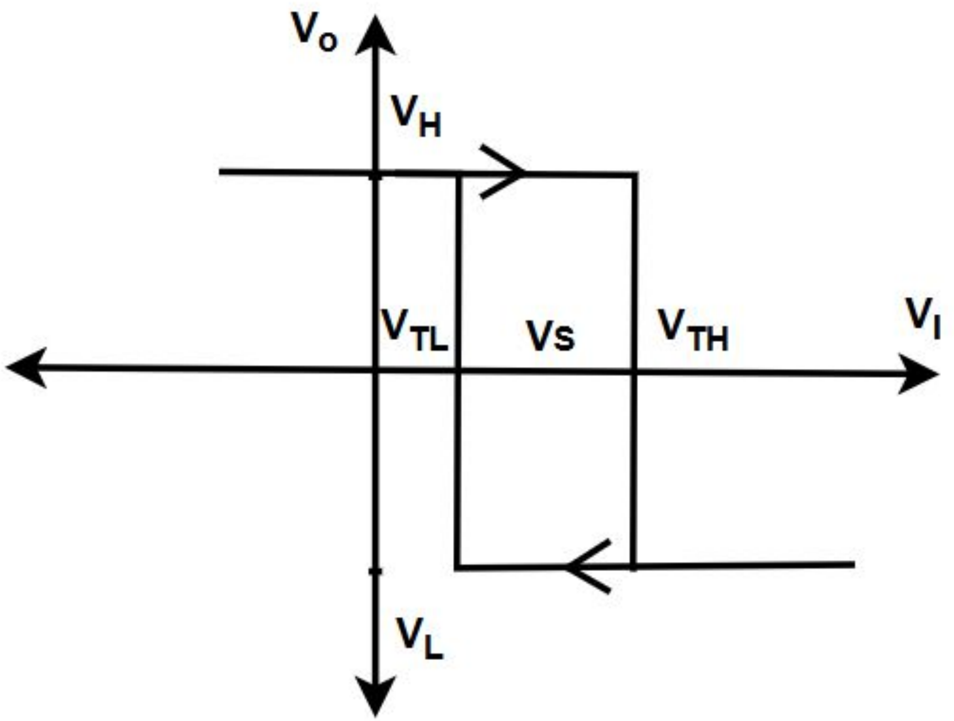
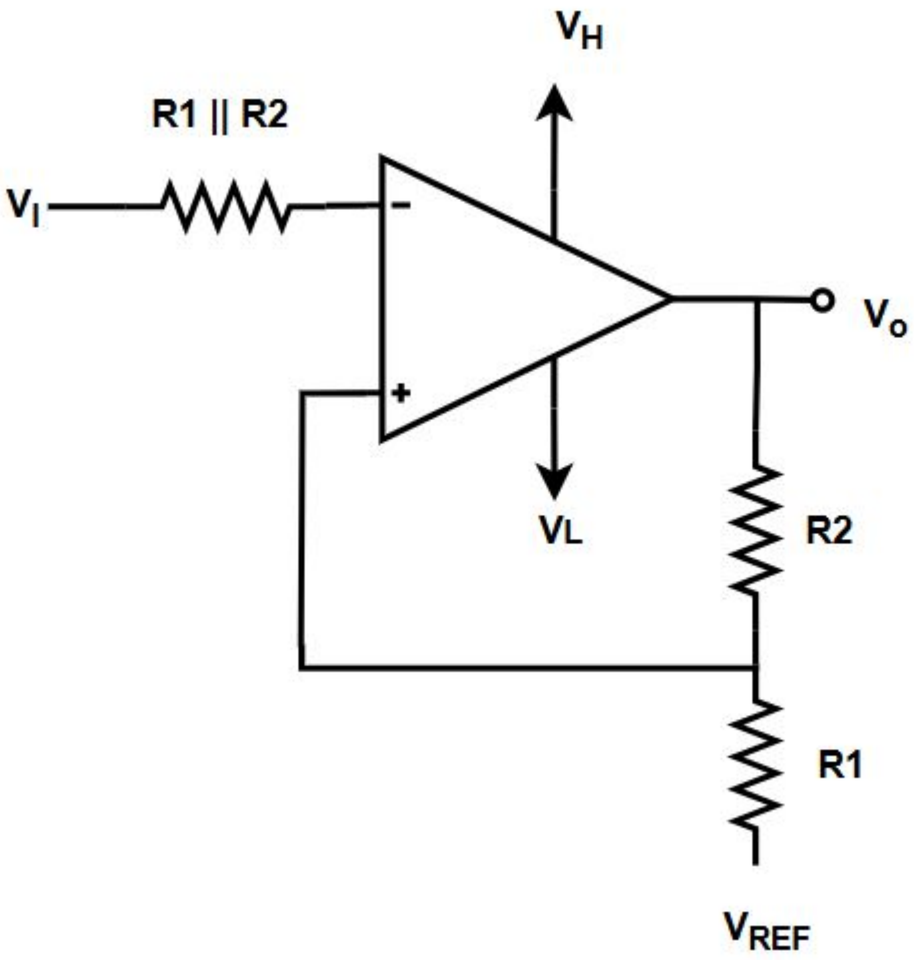
Inverting ST with Ref





Inverting ST with Ref

Formula,

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

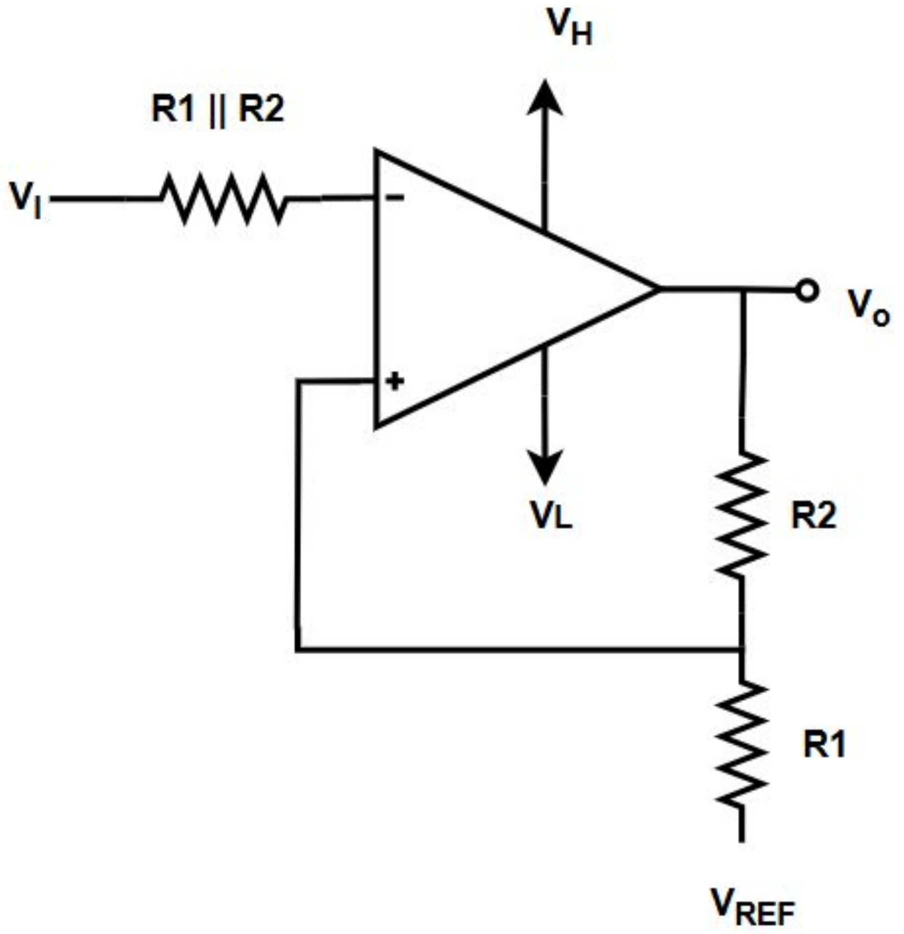
$$V_{TL} = V_{REF}\frac{R_2}{R_1 + R_2} + V_L\frac{R_1}{R_1 + R_2}$$

$$V_s = \frac{V_{TH} + V_{TL}}{2}$$

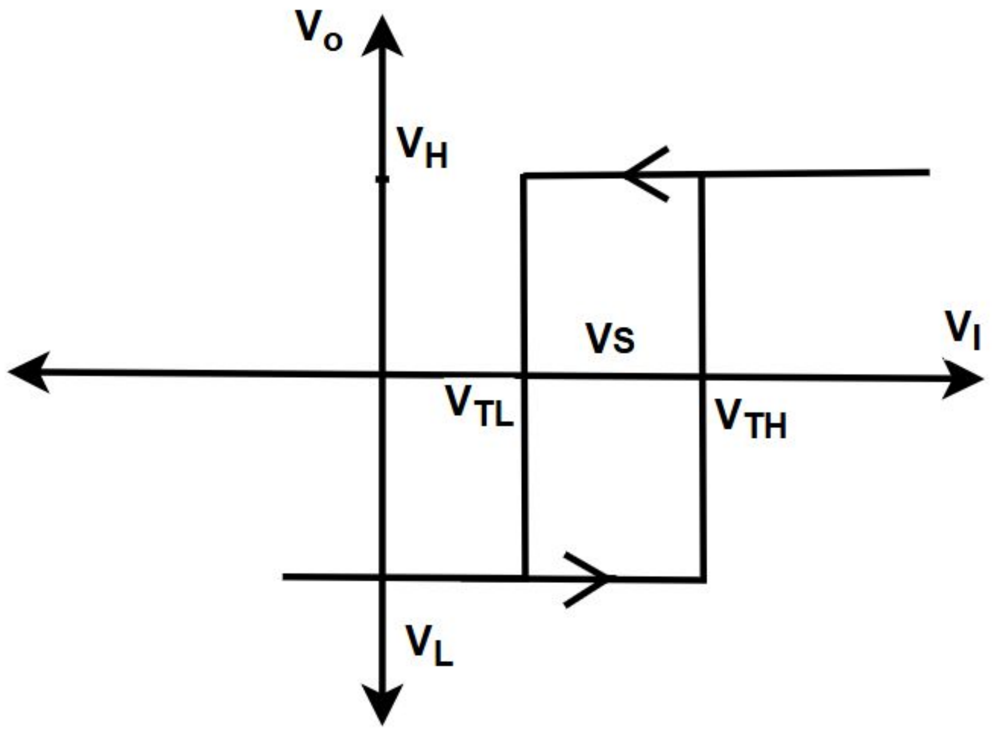
$$V_{HW} = V_{TH} - V_{TL}$$

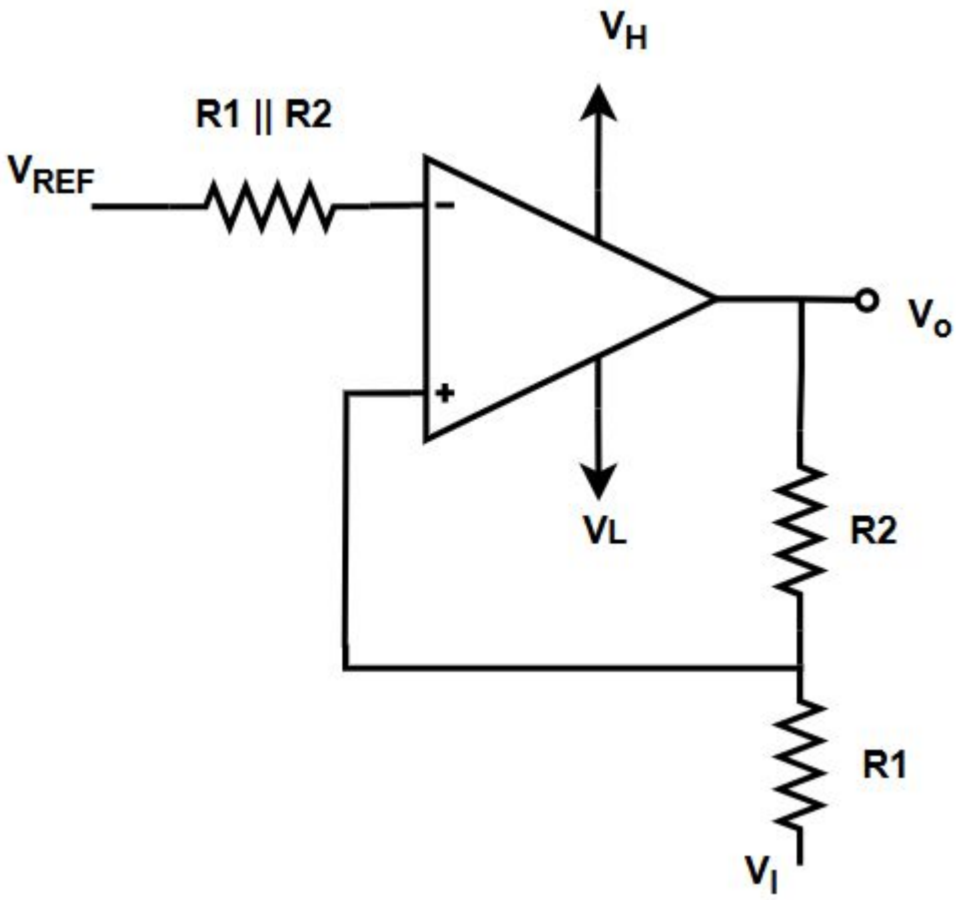
IF $V_H = -V_L$

$$V_S = V_{REF}\frac{R_2}{R_1 + R_2} \ and\ V_{HW} = 2V_H\frac{R_1}{R_1 + R_2}$$



Non-inverting ST with Ref





Non-inverting ST with ref

$$V_{TH} = \frac{R_1 + R_2}{R_2} V_{REF} - \frac{R_1}{R_2} V_L$$

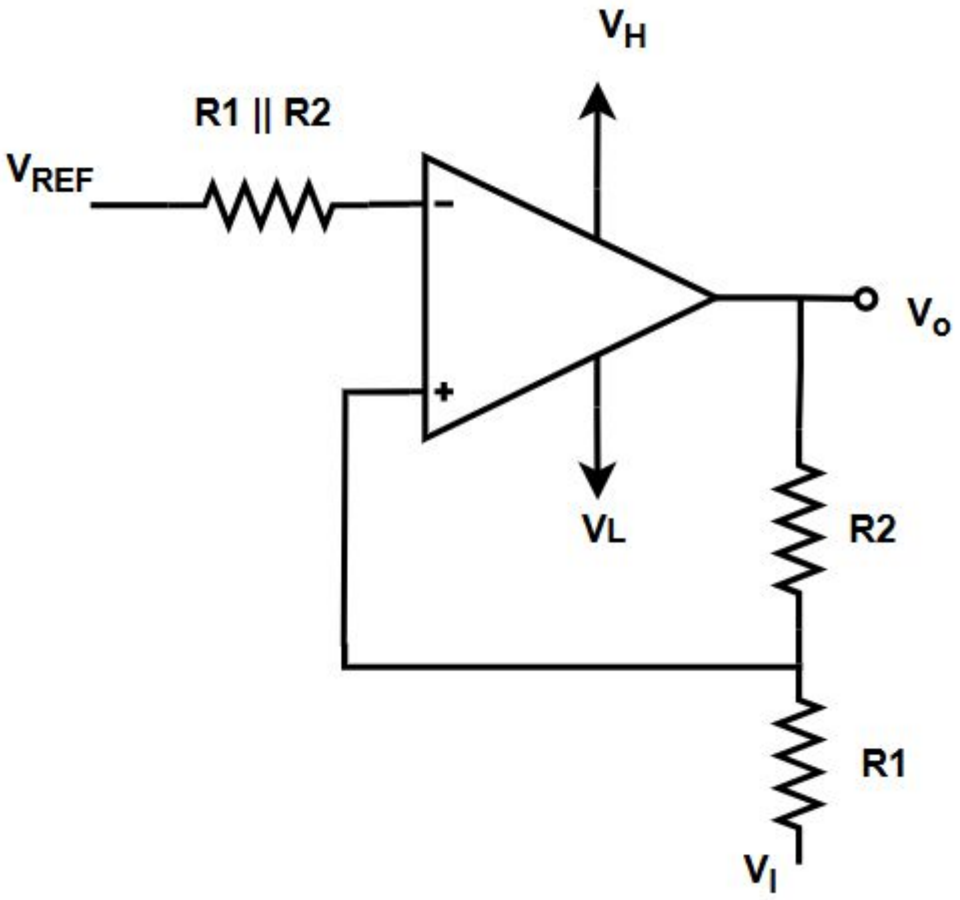
$$V_{TL} = \frac{R_1 + R_2}{R_2} V_{REF} - \frac{R_1}{R_2} V_H$$

$$V_s = \frac{V_{TH} + V_{TL}}{2}$$

$$V_{HW} = V_{TH} - V_{TL}$$

IF $V_L = -V_L$

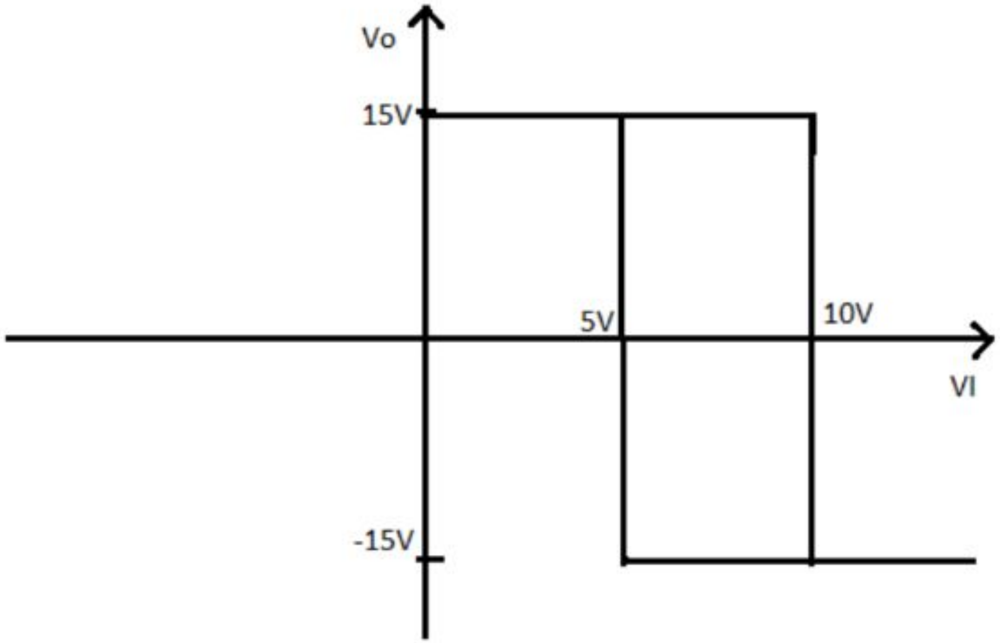
$$V_S = \frac{R_1 + R_2}{R_2} V_{REF}, V_{HW} = 2V_H \frac{R_1}{R_2}$$



Exercise:

a. Design a Schmitt trigger that will produce the same VTC.

b. IF the input signal of the Schmitt trigger is $x(t) = 12\cos 2\pi f t$, find the output of the Schmitt trigger circuit.



Exercise:

Suppose you want to design a street light controller. You have a sensor that gives output as voltage as proportional to the light intensity. You need to switch off the light when the output of the sensor is above 5V. You need to switch on the light when the sensor output is below the 5V. There is a noise source of 1V peak-peak. Your instructor has told you to use a Schmitt trigger circuit to improve performance. (You can assume the VH and VL value)

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