ANALOG ELECTRONIC

ULTRA CONCURRENT REMOTE LAB

Contents:

Objectives:

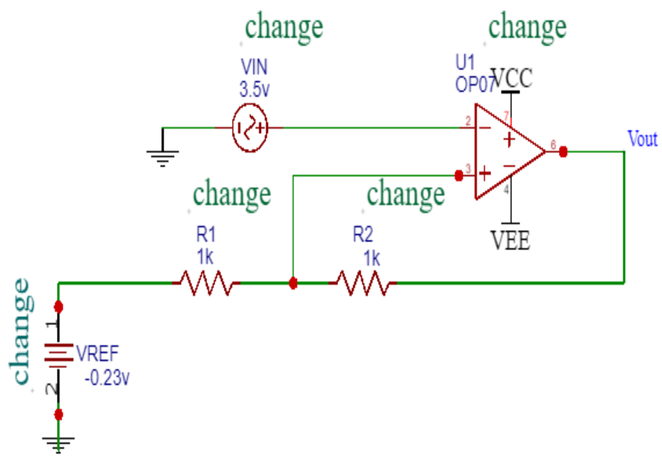
1. Perform frequency response of the circuit and observe the transfer characteristic.

2. Perform parametric variations and observe the impact of the same on the circuit response.

3. Verify the output response with the expected values.

4. Analyze the impact of each parametric variation on the circuit.

Circuit diagram



Design equations

$$V+ = \frac{V_o R_1}{R_1+R_2} + \frac{V_{REF} R_2}{R_1+R_2}$$

When $V_o = +V_{SAT}$, $V+ = \frac{V_o R_1}{R_1+R_2} + \frac{V_{REF} R_2}{R_1+R_2}$ $\quad \beta = \frac{R_1}{R_1+R_2}, \frac{R_2}{R_1+R_2} = (1-\beta)$

$V- = V_{IN}$, V_o will change from $+V_{SAT}$ to $-V_{SAT}$, when

V_{IN} will just exceed V_{TH}, i.e. when $V- > V+$

$$V_{TH} = +V_{SAT}\beta + V_{REF}(1-\beta)$$

When $V_o = -V_{SAT}$, $V+ = \frac{-V_{SAT} R_1}{R_1+R_2} + \frac{V_{REF} R_2}{R_1+R_2}$ $\quad \beta = \frac{R_1}{R_1+R_2}, \frac{R_2}{R_1+R_2} = (1-\beta)$

$V- = V_{IN}$, V_o will change from $-V_{SAT}$ to $+V_{SAT}$, when

V_{IN} will just goes below V_{TL}, i.e. when $V+ > V-$

$$V_{TL} = -V_{SAT}\beta + V_{REF}(1-\beta)$$

$$V_{TH} - V_{TL} = V_{Hysteresis} = \beta\, 2V_{SAT}$$

$$V_{TH} + V_{TL} = (1-\beta)2V_{REF}$$

The Inverting Schmitt Trigger in Ultra concurrent Laboratory has option to vary many circuit components and signal parameters and is listed in the Table 1. Fig.1 shows the schematic of Inverting Schmitt Trigger with variable parameters. The signal frequency is fixed at 100 HZ to obtain the frequency response of the op-amp. However, to realize the frequency response of the Schmitt trigger the input signal frequency is swept from 100 HZ to 10 MHZ

TABLE: 1

Parameter	Variations
R_1	1kΩ, 10kΩ
R_2	1kΩ, 10kΩ
Vin	3.5V, 2.8V
Op-amp	#1, #2, #3

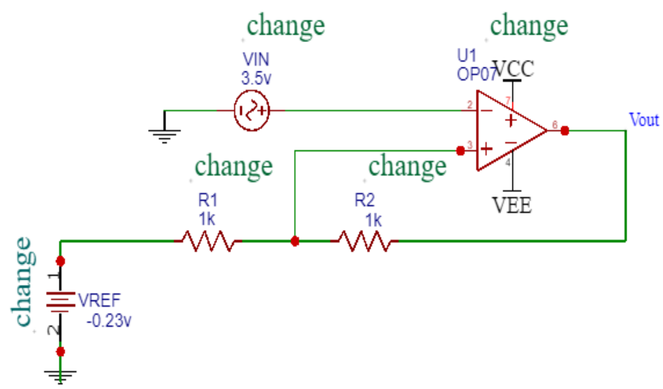


Fig. 1: Schematic of Inverting Schmitt Trigger with variable options

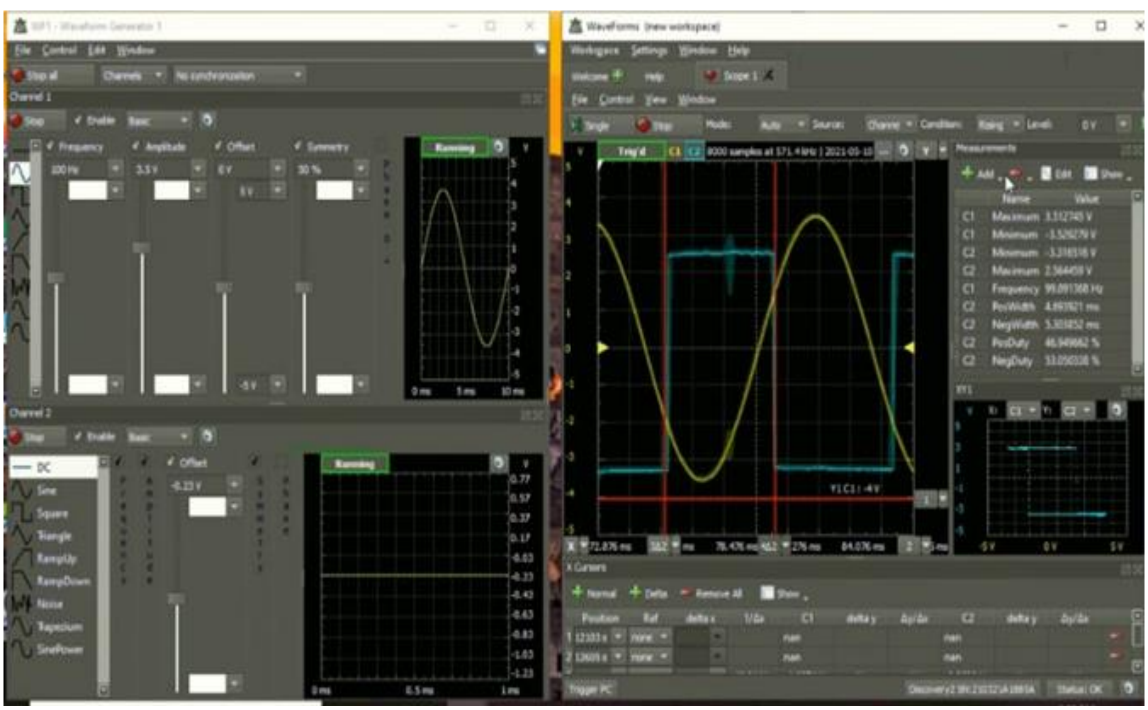


Fig. 2: Various view of the Inverting Schmitt Trigger output response

The laboratory has three important views to give real-time feeling during the conduction of the experiment. Fig.1 shows the circuit view and parameters to be changed.Fig.2 shows the scope of the waveform application that has input sine wave, dc voltage, frequency, amplitude, offset voltage, output response and transfer characteristics.

1. Effect of parametric variations on the circuit performances

As there are many variations are possible in the Inverting Schmitt Trigger circuit, let's see the impact of each one on the circuit performance in detail.

1. Impact of reference voltage(V_{REF}) on the Inverting Schmitt Trigger Circuit:

In the Inverting Schmitt trigger schematic it is possible to modify the value of V_{REF} voltage.

From the set of design equations shown above it can be verified that as $V_{REF}\uparrow \longrightarrow$

$V_{TH}\uparrow \longrightarrow V_{TL}\downarrow$. If R1 > R2 or R2> R1 and V_{REF} is kept constant, VTH and VTL remains the same.

In order to verify the effect of reference voltage change the DC voltage to 1v. We can notice the shift in the threshold voltages (V_{TH} and V_{TL}). We have two threshold voltages i.e. Higher Threshold Voltage V_{TH} and Lower Threshold Voltage V_{TL} which is given by

$V_{TH} = +V_{SAT}\beta + V_{REF}(1 - \beta)$ V_{TL}

$= -V_{SAT}\beta + V_{REF}(1 - \beta)$

$$\beta = \frac{R1}{R1+R2}$$

Various output parameters of the Inverting Schmitt Trigger circuit noted from the different views for the changes in V_{REF} are recorded and tabulated in TABLE: 2

TABLE: 2

V_{REF}	R_1 kΩ	R_2 kΩ	VTH	VTL	R_1 kΩ	F Hz	V Hysteresis
-0.23v	1 kΩ	1 kΩ	1.135v	-1.815v	1 kΩ	100	3v
0.72v	1 kΩ	1kΩ	0.89v	-1.96v	1 kΩ	130	3.64v
-1.03v	1 kΩ	1 kΩ	0.735v	-2.115v	10 kΩ	150	5.44v
-1.03v	1 kΩ	10 kΩ	-0.709v	-1.25v	10 kΩ	200	0.5v
Remarks	Specification	Specification	Evaluation	Evaluation	Specification	Almost constant	

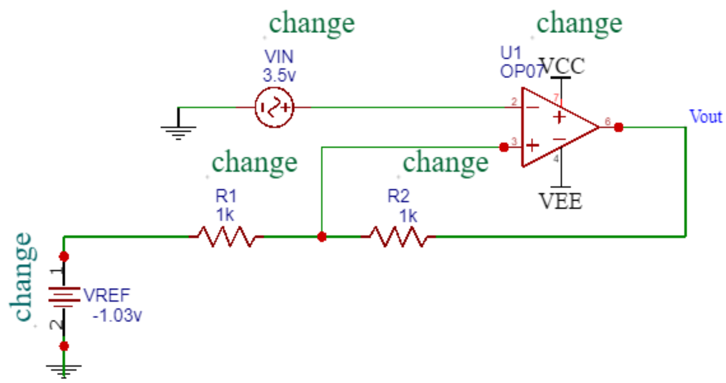


Fig. 3.View of Inverting Schmitt Trigger circuit for variation in V_{REF} value

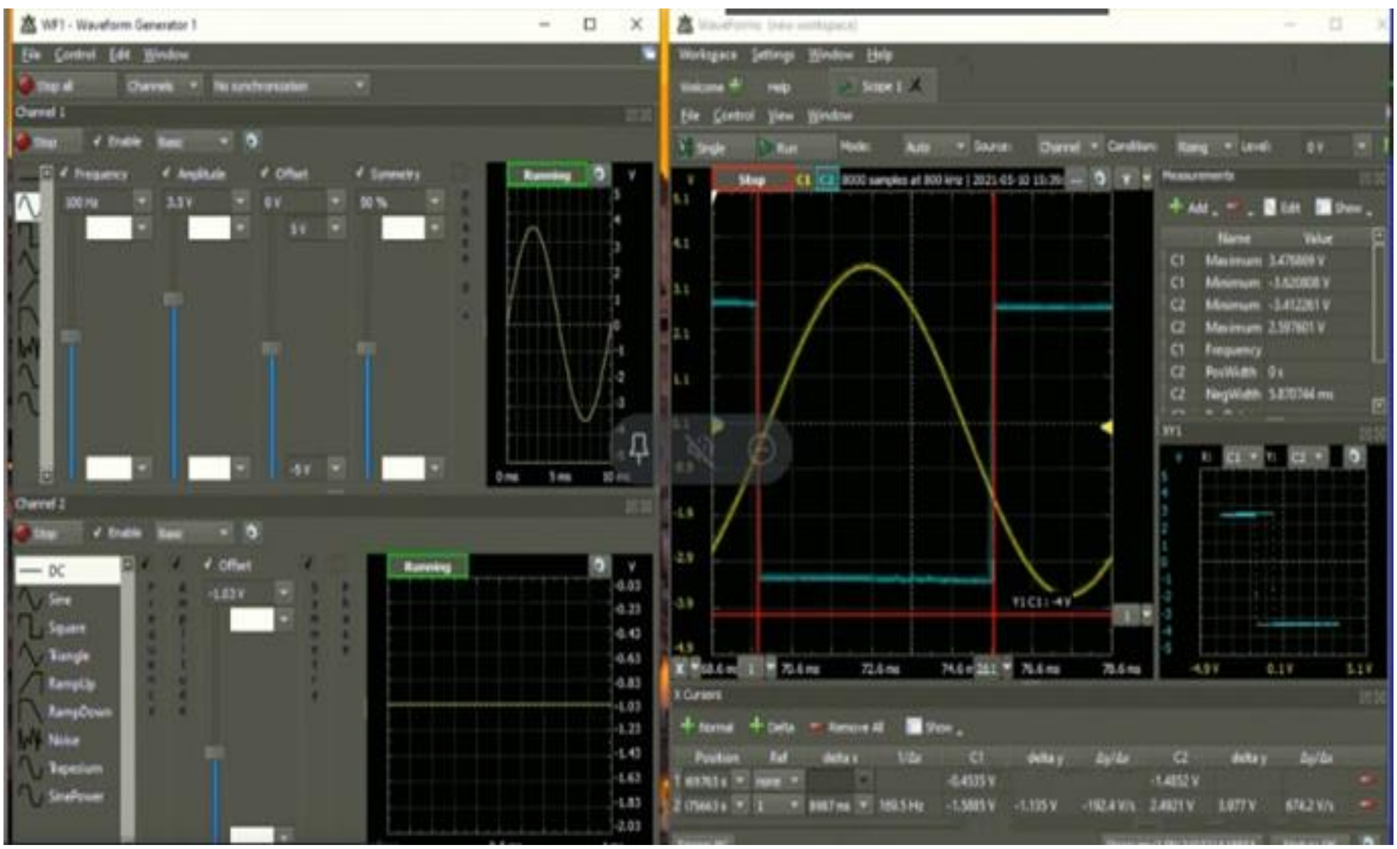


Fig. 4.View of Inverting Schmitt Trigger response for variation in V_{REF} value

Similar analysis is done by changing the choosing different combinations of constant parameter of V_{IN}.

2. Impact of R_1 on the Inverting Schmitt Trigger:

In the Inverting Schmitt Trigger schematic it is possible to modify the value of R_1 from 1 kΩ to 10 kΩ. To understand the effect of change in resistor R1. Observe the change in the threshold voltages as per the new value of resistor R1 from the set of design equations shown above it can be verified that as R1 ↑ ⟶ VTH ↑ ⟶ VTL↓. When V_{REF} kept constant. Various output parameters of the Inverting Schmitt Trigger Circuit noted from the different views for the changes in R_1 are recorded and tabulated in TABLE: 3 .

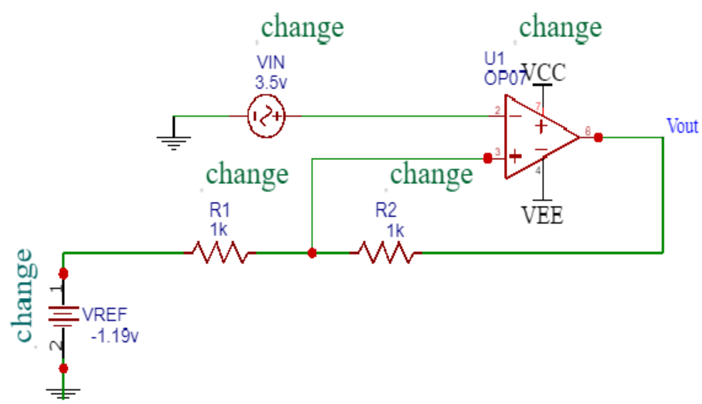


Fig. 5.Views of Inverting Schmitt Trigger circuit for variation in R_1 value

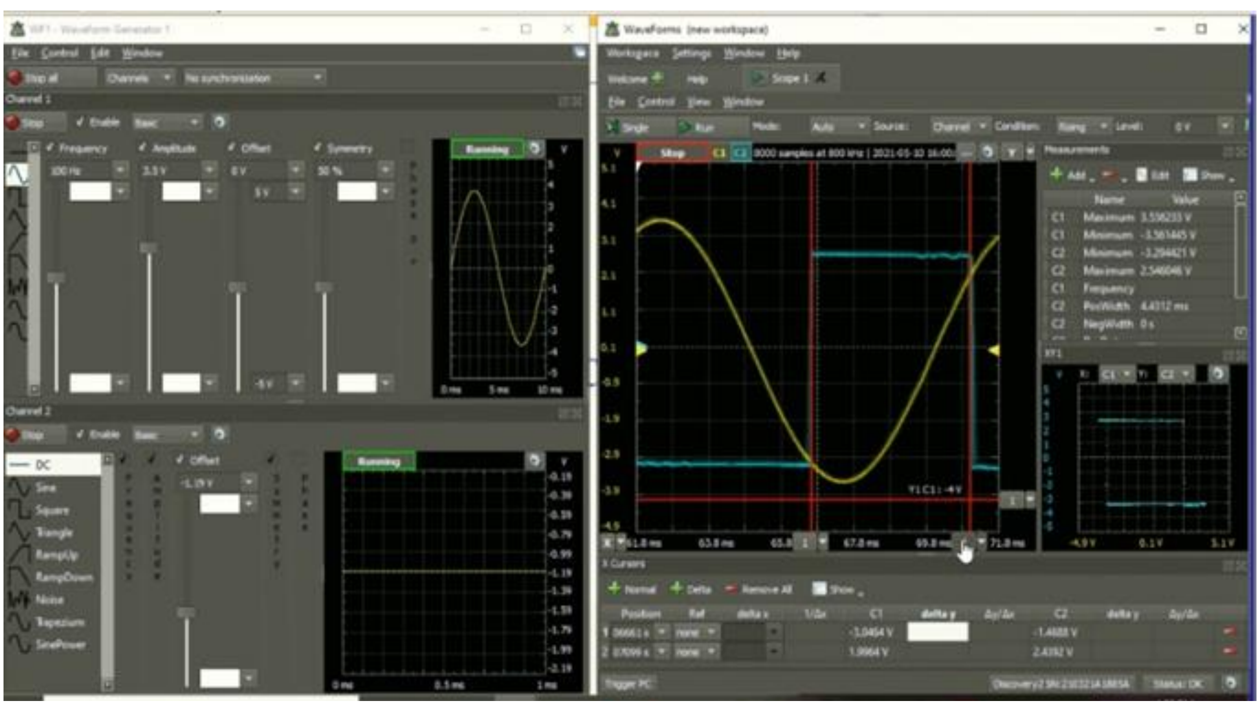


Fig. 5.View of Inverting Schmitt Trigger response for variation in R_1 value

TABLE: 3

R_1 kΩ	V_{REF}	V_{TH}	V_{TL}	F Hz	V Hysteresis
1 kΩ	-1.03v	-0.709v	-1.25v	100	0.541v
1 kΩ	-1.19v	0.86v	-1.36v	120	2.22v
10 kΩ	0v	1.4v	-1.6v	100	3v
10 kΩ	-1v	1.75v	-1v	160	2.75v
Remarks		Expected Change	Expected Change	Almost constant	

Note: R_2 = 10 kΩ

Similar analysis is done by choosing different combinations of constant parameters of R_2 and V_{IN}.

3. Impact of R_2 on the Inverting Schmitt Trigger:

In the Inverting Schmitt Trigger schematic it is possible to modify the value of R_2 from 1 k Ω to 10 k Ω. To understand the effect of change in resistor R_2 . Observe the change in the threshold voltages as per the new value of resistor R_2.

From the set of design equations shown above it can be verified that as R2 ↑ ⟶

V_{REF}↑ ⟶ Threshold voltage↑ . When R1 is kept constant. If V_{REF} is kept constant the value of V_{TH} will get slightly changed.

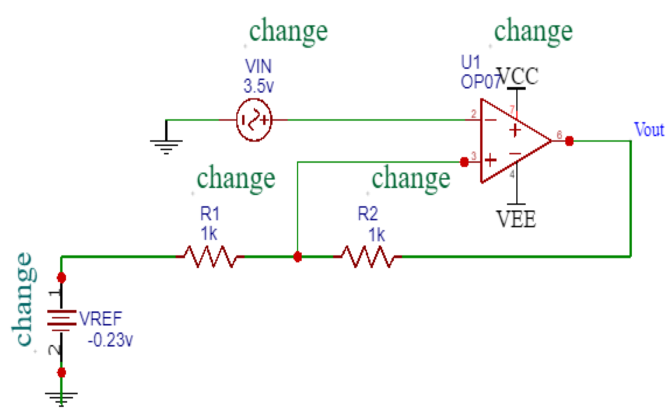


Fig. 5.View of Inverting Schmitt Trigger circuit for variation in R_2 value

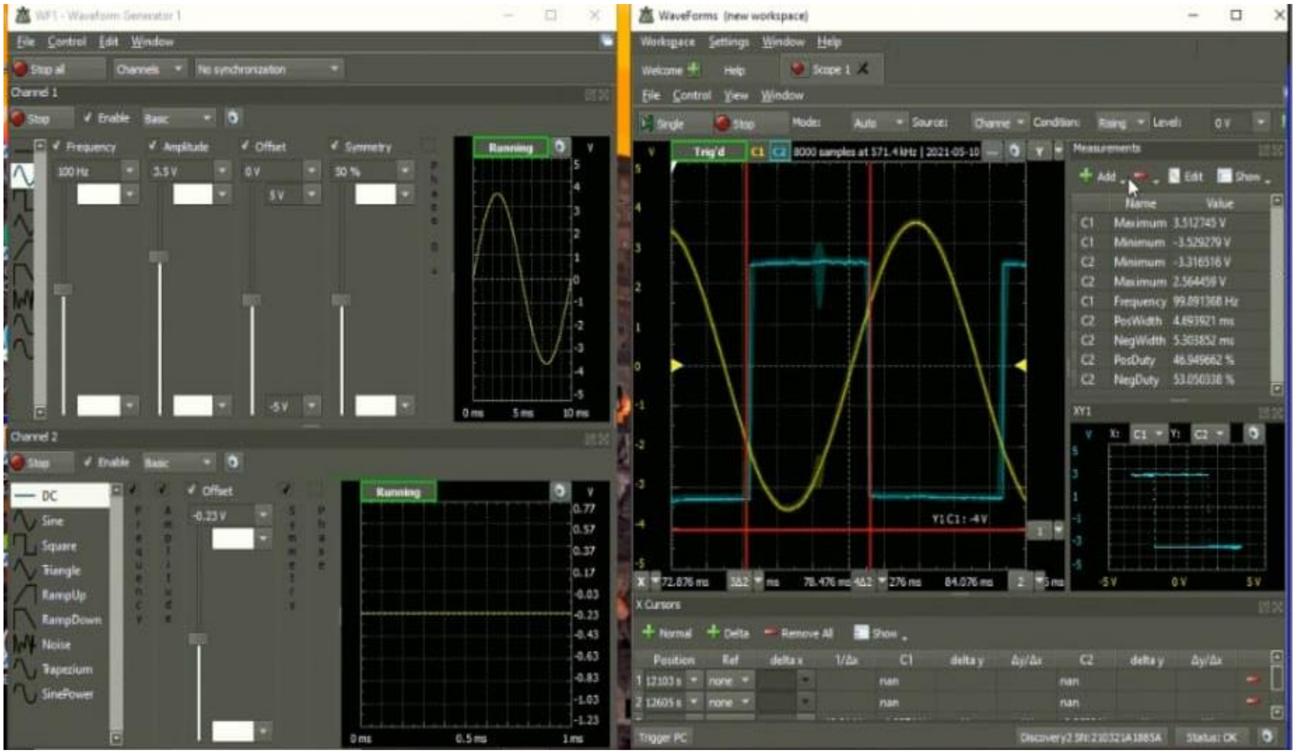


Fig. 6.View of Inverting Schmitt Trigger response for variation in R_2 value

TABLE: 4

R_2 kΩ	V_{REF}	V_{TH}	V_{TL}	F Hz	V Hysteresis
1 kΩ	-0.23v	1.135v	-1.815v	100	2.95v
1 kΩ	0.72v	0.89v	-1.96v	160	2.85v
1 kΩ	-1.03v	0.735v	-2.115v	150	2.85v
10 kΩ	2.06v	2.1v	-1.585v	100	3.685v
Remarks	Expected Change	Expected Change	Expected Change	Almost constant	

Note: R_1 = 1 kΩ

Similar analysis is done by choosing different combinations of constant parameters of R_1, V_{IN} .

4. Impact of V_{IN} on the Inverting Schmitt Trigger:

In the Inverting Schmitt Trigger schematic it is possible to modify the value of V_{IN} from 3.5v to 2.8v.

To know the importance of amplitude of the input signal reduce the amplitude of the input sine wave to 1v.Notice the output either at $+V_{SAT}$ or $-V_{SAT}$.

Figure: 5 shows the transfer characteristics of Inverting Schmitt Trigger. As shown in the figure when the input voltage is zero and if it starts exceeding the input voltage will be less than V_{TH} .When input voltage crosses beyond V_{TH} output makes a transition from $+V_{SAT}$ to $–V_{SAT}$ .Output remains in $– V_{SAT}$ for input voltage more than $V_{TH.}$ Then input voltage starts reducing in the negative direction output voltage remains in $–V_{SAT}$. If input voltage goes below V_{TL} output voltage makes a transition from $–V_{SAT}$ to $+V_{SAT}$. It remains there in $+V_{SAT}$ till input voltage exceed $V_{TH.}$

TABLE: 5

$V- = V_{IN}$	
V+	**Vo**
+βVcc	**+Vcc**
-βVcc	**-Vcc**

TABLE: 6

V+ (Initial)	V-	Vo	V+ (After)
+βVcc	**+βVcc**	+Vcc	**+βVcc**
+βVcc	**+βVcc**	-Vcc	**-βVcc**
-βVcc	**-βVcc**	-Vcc	**-βVcc**
-βVcc	**-βVcc**	+Vcc	**+βVcc**

From TABLE: 5 and TABLE: 6, we can see β is a factor indicates how much voltage at the output voltage(Vo) will be available at the non – inverting terminal(V+) .Depending on whether the output voltage is +VCC or –VCC we will have voltage at non – inverting terminal (V+) , +βVcc, -βVcc.

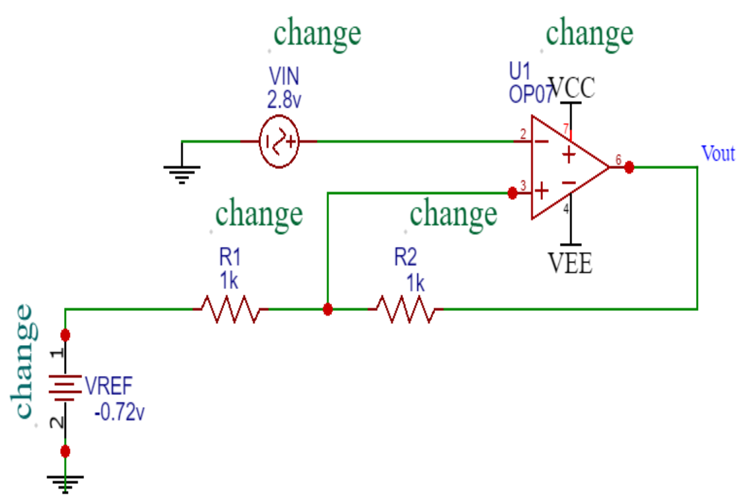


Fig. 6.View of Inverting Schmitt Trigger circuit for variation in V_{IN} value

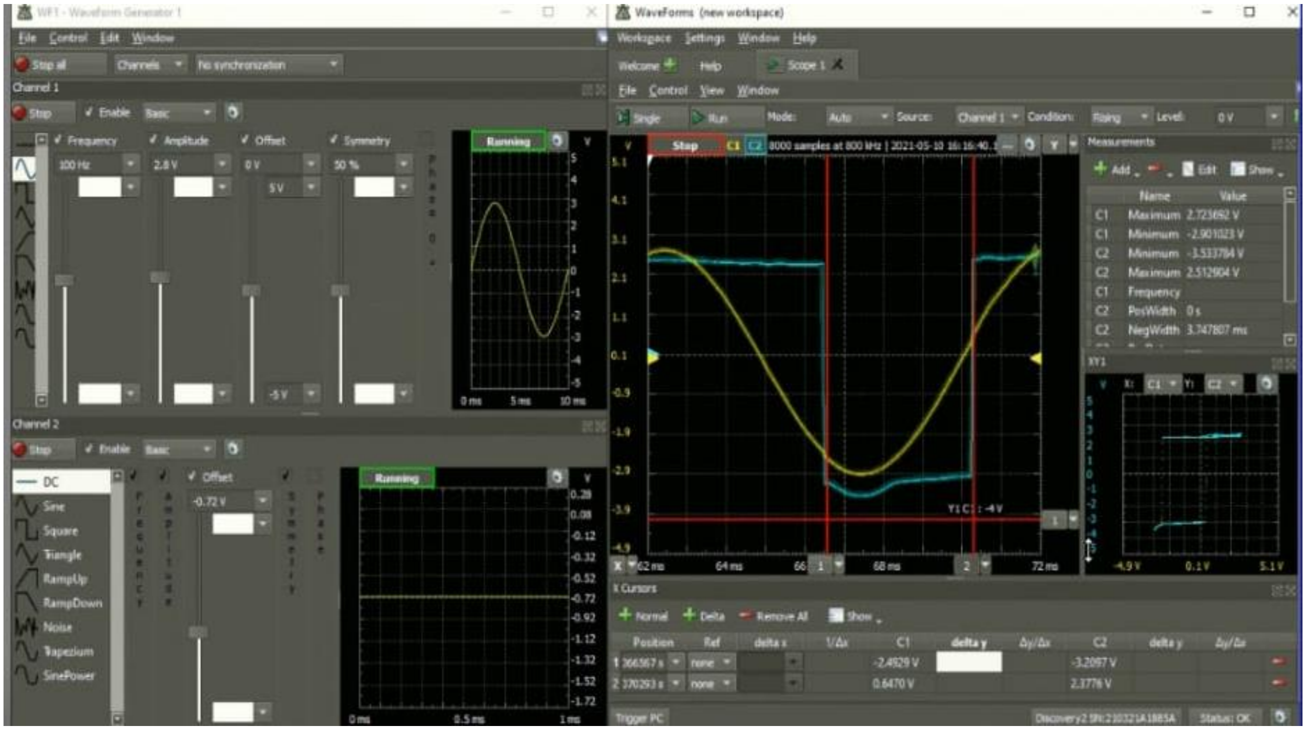


Fig. 7.View of Inverting Schmitt Trigger responses for variation in V_{IN} value

In this experiment it is also possible to measure the slew rate of the op-amp. By observing slope of the output waveform.

Summary of the impact of components on the Schmitt response

TABLE: 7

	Circuit Response						
Parameter	R_1 kΩ	R_2 kΩ	$+V_{CC}$	$-V_{CC}$	V_{TH}	V_{TL}	V_{REF}
V_{REF}	✓	✓	X	X	✓	✓	✓
R_1	✓	✓	X	X	✓	✓	✓
R_2	✓	✓	X	X	✓	✓	✓
V_{IN}	X	X	✓	✓	✓	✓	✓

✓ **Impact** X **No impact** Tabular column in the TABLE:8 is used to record various output response for different variation can be entered for further analysis. Op-amp 741 , Vin=5v

TABLE: 8

Sl. No.	R_1 kΩ	R_2 kΩ	V_{REF}	V_{TH}	V_{TL}	V Hysteresis	V_{TH} (measured)	V_{TL} (measured)
1.	1k	1k	-0.23v	1.135v	-1.815v	2.95v		
2.	1K	1k	0.72v	0.89v	-1.96v	2.85v		
3.	1k	1k	-1.03v	0.735v	-2.115v	2.85v		
4.	1k	10k	-1.03v	-0.709v	-1.25v	0.541v		
5.	1k	10k	2.06v	2.1v	-1.585v	3.685v		
6.	1k	10k	-1.19v	0.86v	-1.36v	2.22v		
7.	10k	1k	0v	2.18v	-3v	5.18v		
8.	10k	1k	1.6v	2.32v	-2.85v	5.17v		
9.	10k	1k	-1.03v	2.08v	-3.11v	5.19v		
10.	10K	10k	0v	1.4v	-1.6v	3v		
11.	10k	10k	+1	0.9v	-2.1v	3v		
12.	10k	10k	-1v	1.75v	-1v	2.75v		