4. OPERATIONAL AMPLIFIER COMPARATOR

4.1 OBJECTIVE:

1. Design the comparator for a frequency of 1 KHz sine wave with 5 Vpp at the non-inverting input terminal and apply 1V dc voltage as reference voltage at the inverting terminal of IC741
2. Design a Schmitt Trigger and conduct an experiment to obtain V_{UTP} and V_{LTP} for various values of R_1 and R_2 for the specified design constraint with upper and lower threshold should be ±1V, for the frequency range of 100 Hz to 10KHz.

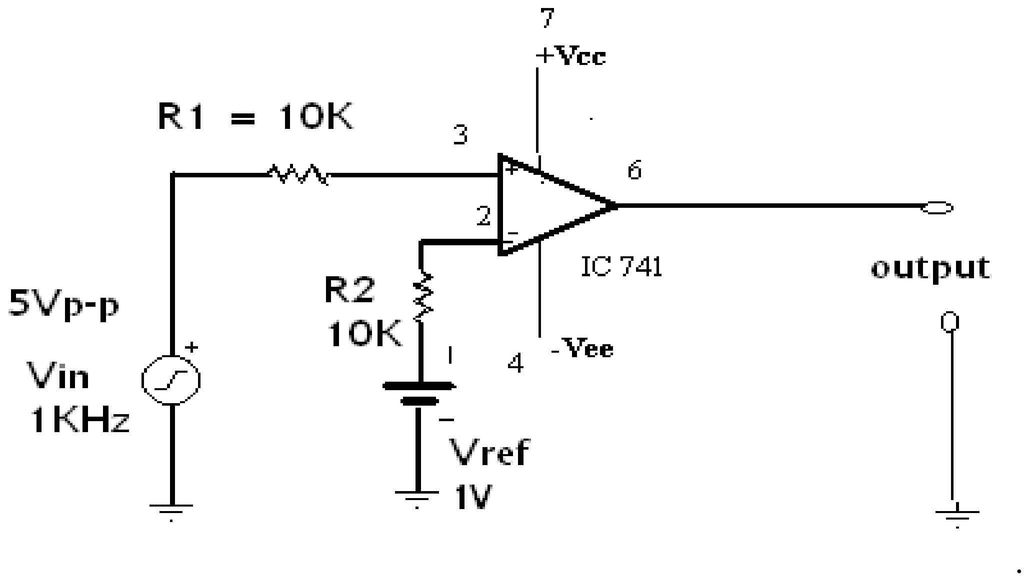
4.2 COMPARATOR

4.2.1 Apparatus required:

S.No	Equipment/Component name	Specifications/Value	Quantity
1	IC 741	Refer data sheet	1
2	Cathode Ray Oscilloscope	(0 – 20MHz) 1	1
3	Multimeter		1
4	Resistors	10 kΩ	2
6	Dual Regulated power supply	(0 -30V), 1A	1

4.2.2 Theory:

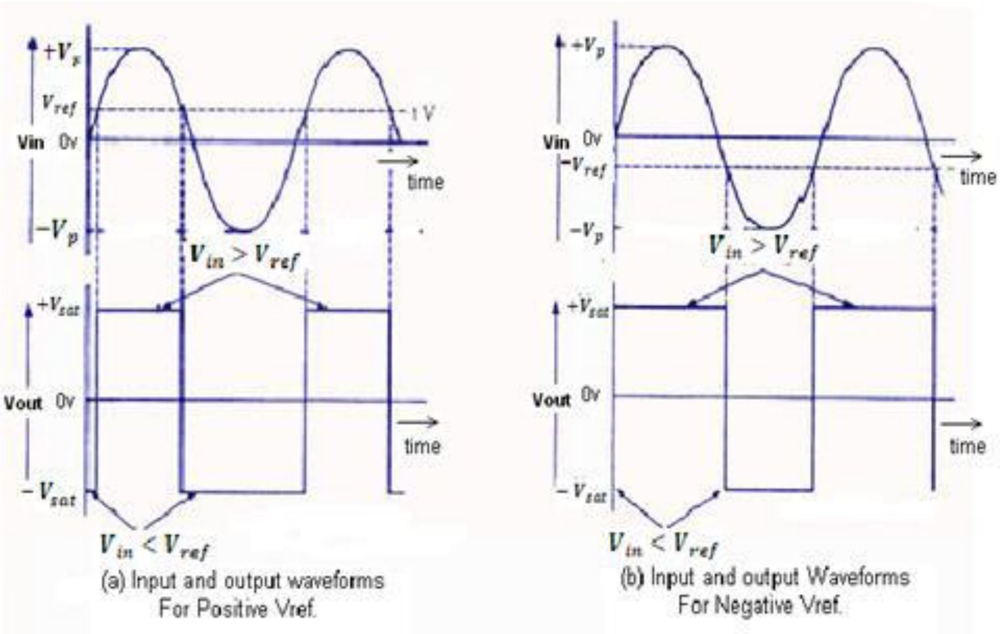
A Comparator is a non-linear signal processor. It is an open loop mode application of Op-amp operated in saturation mode. Comparator compares a signal voltage at one input with a reference voltage at the other input. Here the Op-amp is operated in open loop mode and hence the output is ±Vsat. It is basically classified as inverting and non-inverting comparator. In a non-inverting comparator Vin is given to +ve terminal and Vref to –ve terminal. When Vin < Vref, the output is –Vsat and when Vin > Vref, the output is +Vsat (see expected waveforms). In an inverting comparator input is given to the inverting terminal and reference voltage is given to the non inverting terminal. The output of the inverting comparator is the inverse of the output of non-inverting comparator. The comparator can be used as a zero crossing detector, window detector, time marker generator and phase meter



4.2.3 Experiment

1. Connect the components/equipment as shown in the circuit diagram.
2. Switch ON the power supply.
3. Apply 1 KHz sine wave with 5 Vpp at the non-inverting input terminal of IC741 using a function generator.
4. Apply 1V dc voltage as reference voltage at the inverting terminal of IC741.
5. Connect the channel-1 of CRO at the input terminals and channel-2 of CRO at the output terminals.
6. Observe the input sinusoidal signal at channel-1 and the corresponding output square wave at channel-2 of CRO. Note down their amplitude and time period.
7. Overlap both the input and output waves and note down voltages at positions on sine wave where the output changes its state. These voltages denote the Reference voltage.
8. Plot the output square wave corresponding to the sine input with Vref = 1V.

4.2.4 Expected Waveforms: Comparator Input & Output Waveforms



Observations

Theoretical Reference voltage (From the circuit)	
Practical Reference voltage (From output waveform)	

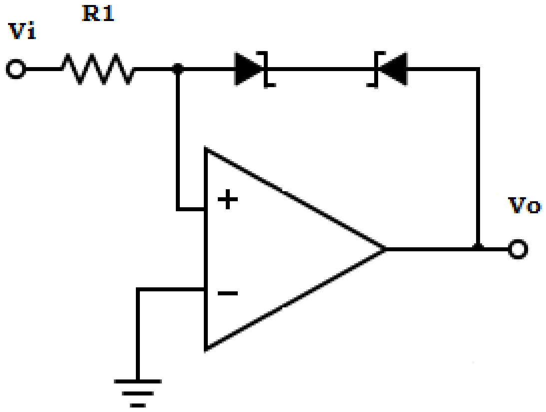
4.2.5 Pre Lab Question:

1. Draw the transfer characteristics of open loop op-amp.
2. How many basic input parameters are required for a comparator?
3. How is *Vo* related to *Vin* and *Vref*?
4. Why this circuit is called a non-inverting comparator?

4.2.6 Post Lab Question:

1. Draw the circuit diagram of a non-inverting comparator and inverting comparator.
2. What do you think is the role of resistors *R1* and *R2*?

3. For the comparator shown below, determine the transfer curves if an ideal op-amp with $V_{Z1}= V_{Z2}=9v$.



4. Draw the circuit of comparator with clamp diodes. Explain the purpose of clamp diodes in comparator circuit.
5. List the application s of comparator.

Result:

4.3 SCHMITT TRIGGER CIRCUITS

4.3.1 Apparatus required:

S.No	Equipment/Component name	Specifications/Value	Quantity
1	IC 741	Refer data sheet	1
2	Cathode Ray Oscilloscope	(0 – 20MHz) 1	1
3	Multimeter		1
4	Resistors	10K Ω 56 K Ω	2 1
5	Dual Regulated power supply	(0 -30V), 1A	1
6`	Function Generator	(0-2) MHz	1

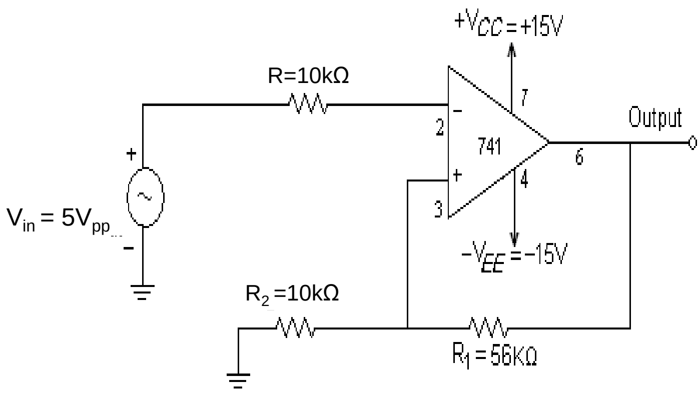
4.3.2 Theory:

Circuit shows an inverting comparator with positive feedback. This circuit converts an irregular shaped waveform to square wave or pulse. This circuit is known as Schmitt trigger or Regenerative comparator or Squaring circuit. The input voltage Vin triggers (changes the state of) the output Vo every time it exceeds certain voltage levels called Upper threshold voltage, V_{UT} and Lower threshold voltage, V_{LT}. The hysteresis width is the difference between these two threshold voltages i.e. $V_{UT} – V_{LT}$. These threshold voltages are calculated as follows.

$$V_{UT} = (R2/R1+R2)\ Vsat \quad \text{when } Vo= Vsat$$

$$V_{LT} = (R2/R1+R2)\ (-Vsat) \quad \text{when } Vo= -Vsat$$

The output of Schmitt trigger is a square wave when the input is sine wave or triangular wave, where as if the input is a saw tooth wave then the output is a pulse wave.



Schmitt trigger circuit using IC 741

Design Equations:

$$V_{UTP} = \frac{R_2}{R_1+R_2}\left(V_{Sat}^{+}\right)$$

$$V_{LTP} = \frac{R_2}{R_1+R_2}\left(V_{Sat}^{-}\right)$$

$$V_{Hyst} = V_{UTP} - V_{LTP} = \frac{R_2}{R_1+R_2}\left(V_{Sat}^{+} - V_{Sat}^{-}\right)$$

4.3.3 Design Constraints

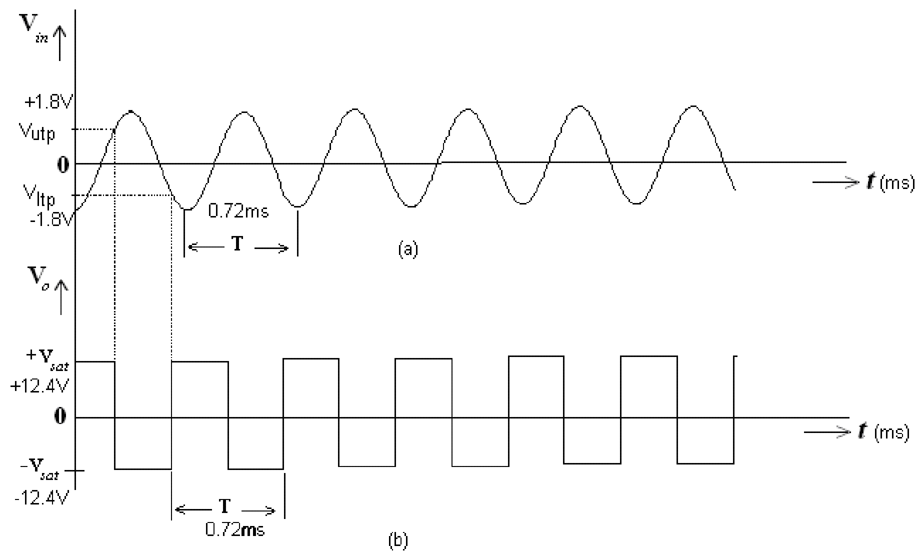
- Minimum Input voltage is 1v and maximum output voltage is 10v.
- Biasing voltage is ±12v
- Frequency range is 100 Hz up to 10kHz

4.3.4 Experiment:

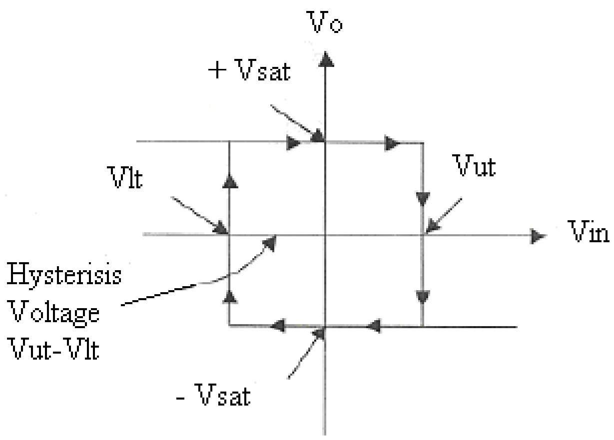
1. Connect the components / equipment as shown in the circuit diagram.
2. Switch ON the power supply.
3. Apply 5 Vpp and 1KHz input sine wave using function generator.
4. Connect the channel - 1 of CRO at the input terminals and Channel-2 at the output terminals.
5. Observe the output square waveform corresponding to input sinusoidal signal.
6. Overlap both the input and output waves and note down voltages at positions on sine wave where output changes its state. These voltages denote the Upper threshold voltage and the Lower threshold voltage (see EXPECTED WAVEFORMS below).

7. Verify that these practical threshold voltages are almost same as the theoretical threshold voltages calculated using formulas given in the THEORY section above.
8. Sketch the waveforms by noting down the amplitude and the time period of the input Vin and the output Vo.

4.3.4 Model output Schmitt trigger input and output Waveforms:



Vo versus Vin plot of Hysterisis Voltage



Observation Table

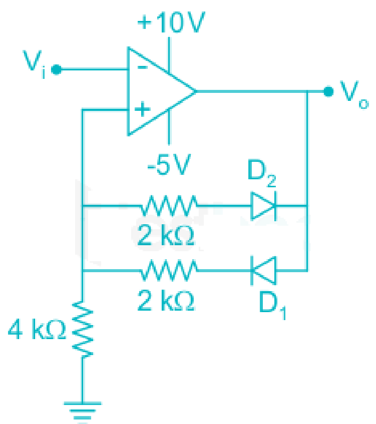
Sl no.	Theoretical Values				Practical Value	
	R_1	R_2	$V_{UTP} = \frac{R_2}{R_1+R_2}(V_{Sat}^{+})$	$V_{LTP} = \frac{R_2}{R_1+R_2}(V_{Sat}^{-})$	V_{UTP}	V_{LTP}
1						
2						
3						

4.3.5 Pre Lab Question:

1. Which is type of comparator called Schmitt trigger using IC741?
2. What is the output wave of Schmitt trigger if the input is sine wave?
3. What type of waveform is obtained when triangular or ramp waveforms are applied to Schmitt trigger circuit?

4.3.6 Post Lab Question:

1. How do you calculate the theoretical values of V_{UT} and V_{LT} in the case of IC741?
2. What is the Hysteresis width?
3. What is the minimum amplitude of the input sine wave in the case of Schmitt trigger using IC741
4. Draw the transfer characteristics of the circuit given below assuming ideal diodes



Result: