ENR 510: Nonlinear Dynamics Project 2

Operational Amplifier as Relaxation Oscillator (and Nonlinear Oscillator): Compactor Based Hysteric Oscillator

Course Faculty: Mitaxi Mehta
Submission Date: 21/04/2023
-Aum Trivedi AU2020128
-Meet Vyas AU2040084

Comparator-based hysteretic oscillator a complete description of its working:

➔ **Definition:**

- A comparator-based hysteretic oscillator is a type of oscillator circuit that uses a comparator with hysteresis (a.k.a. Schmitt trigger) to generate a periodic output waveform. The oscillator works by repeatedly charging and discharging a capacitor through a resistor network. The figure 1 shows the Circuit For Compactor based Hysteric Oscillator (made using Op-amp)

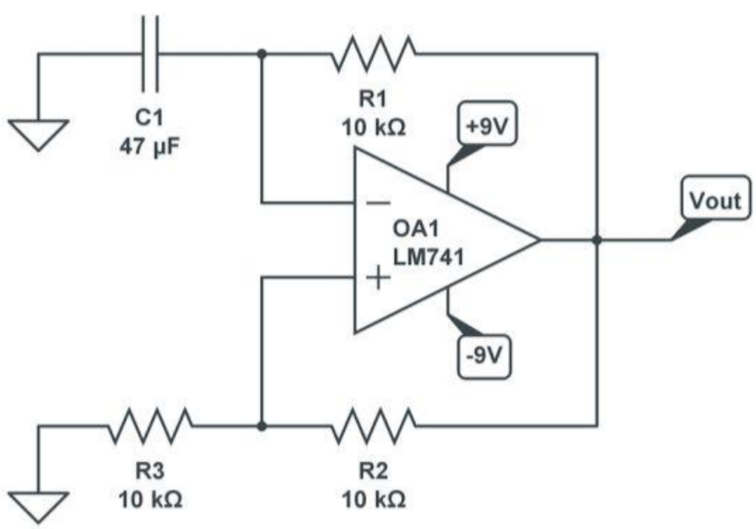

Figure 1a: A comparator-based hysteretic oscillator

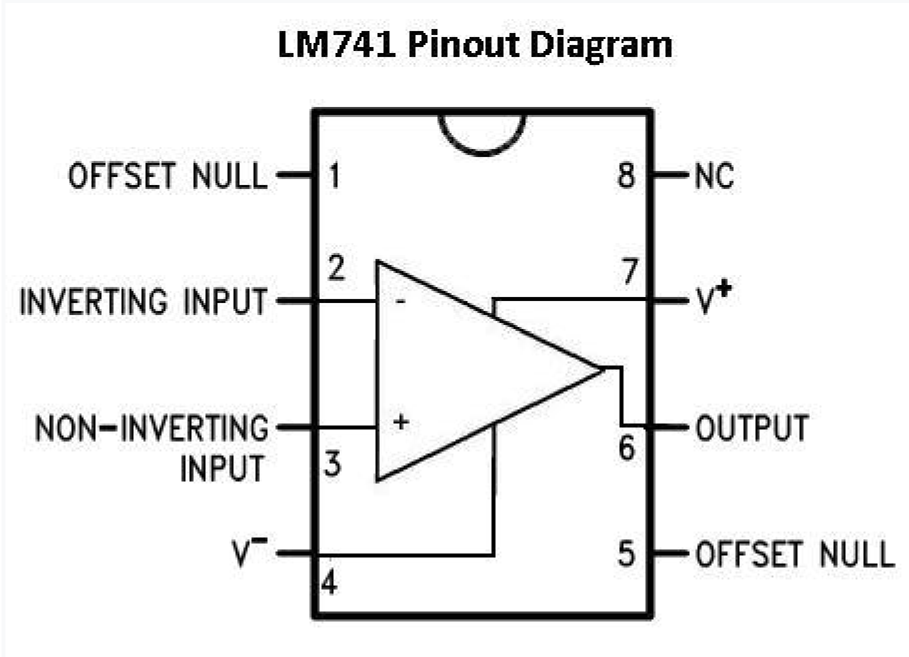

Figure 1b: LM741 Op Amp Pin Layout

➔ **Working:**

1. When the oscillator is powered on, the capacitor starts to charge through a resistor connected to a positive supply voltage.

2. Once the voltage across the capacitor reaches the threshold voltage of the Schmitt trigger's positive input, the output of the comparator switches from low to high.

3. This causes the capacitor to discharge through a resistor connected to the Schmitt trigger's negative input, and the voltage across the capacitor starts to decrease.

4. Once the voltage across the capacitor drops below the threshold voltage of the Schmitt trigger's negative input, the output of the comparator switches from high to low.

5. This causes the capacitor to start charging again, and the cycle repeats, generating a periodic output waveform.

➔ Why is it a Relaxation Oscillator?

- In the context of nonlinear dynamics, a relaxation oscillator is a type of oscillator that uses a slow-changing system variable to drive a fast-changing variable. The slow variable builds up over time until it reaches a threshold, at which point it rapidly resets to its starting value, causing the fast variable to change state. The process then repeats, generating a periodic output waveform.

- The comparator-based hysteretic oscillator is a relaxation oscillator because it uses a capacitor that charges and discharges through a resistor network, which provides a slow-changing variable that drives a fast-changing variable, the output waveform. When the voltage across the capacitor reaches the threshold voltage of the Schmitt trigger's positive input, the output of the comparator switches from low to high, causing the capacitor to discharge through a resistor connected to the Schmitt trigger's negative input, and the voltage across the capacitor starts to decrease. Once the voltage across the capacitor drops below the threshold voltage of the Schmitt trigger's negative input, the output of the comparator switches from high to low, causing the capacitor to start charging again. This process repeats, generating a periodic output waveform.

- Therefore, the comparator-based hysteretic oscillator is a relaxation oscillator because it uses a slow-changing variable (the voltage across the capacitor) to drive a fast-changing variable (the output waveform), similar to other relaxation oscillators.

➔ Why is The comparator-based hysteretic oscillator a nonlinear Oscillator?

- The comparator-based hysteretic oscillator is a non-linear oscillator because it generates a non-sinusoidal output waveform that contains harmonic distortion.

The waveform produced by the oscillator is a square wave with sharp transitions between the high and low states.

- The non-linear behavior of the oscillator is due to the hysteresis added by the Schmitt trigger. The Schmitt trigger has two threshold voltages, one for the positive input and one for the negative input. These threshold voltages create a region of hysteresis, which causes the output to switch between high and low states with a distinct rise and fall time.

- This nonlinear behavior results in harmonic distortion in the output waveform, which means that the waveform contains frequency components that are not present in the fundamental frequency. Harmonic distortion can lead to unwanted noise and interference in the output signal.

- Furthermore, the output waveform of the comparator-based hysteretic oscillator is sensitive to the initial conditions of the circuit and can exhibit complex dynamics, such as chaos, if the circuit is designed to operate near a bifurcation point. This behavior is characteristic of non-linear systems and further confirms that the comparator-based hysteretic oscillator is a non-linear oscillator.

➔ **What does the term Hysteric mean in the Compactor based Hysteric Oscillator?**

- The term "hysteresis" in the comparator-based hysteretic oscillator refers to the characteristic of the Schmitt trigger comparator used in the circuit. Hysteresis is a property of some systems where the output of the system depends not only on the current input but also on the past history of the input.

- In the case of the Schmitt trigger, it has two threshold voltages, one for the positive input and one for the negative input. The threshold voltage for the positive input is higher than the threshold voltage for the negative input, and the difference between the two voltages is known as the hysteresis voltage.

- In summary, the term "hysteric" in the comparator-based hysteretic oscillator refers to the hysteresis characteristic of the Schmitt trigger comparator used in the circuit.

- **Math:**
  - The equations that govern the charging and discharging of the capacitor in a comparator-based hysteretic oscillator are as follows:
  - When the output of the Schmitt trigger comparator is high, the capacitor charges through the resistor network according to the following equation:
  - Vc = Vcc * (1 - e^(-t/RC))
  - where Vc is the voltage across the capacitor, Vcc is the supply voltage, t is time, R is the resistance of the resistor network, and C is the capacitance of the capacitor.
  - When the output of the Schmitt trigger comparator is low, the capacitor discharges through the resistor network according to the following equation:

    $V_{capacitor}$ = Vcc * e^(-t/RC)
  - where Vc is the voltage across the capacitor, Vcc is the supply voltage, t is time, R is the resistance of the resistor network, and C is the capacitance of the capacitor.

- The threshold voltages of the Schmitt trigger comparator can be calculated using the resistor voltage divider network. The upper threshold voltage ($V_{upperthreshold}$) and lower threshold voltage ($V_{lowerthreshold}$) are given by the following equations:

$$V_{upperthreshold} = Vcc * R2 / (R1 + R2)$$

$$V_{lowerthreshold} = Vcc * R1 / (R1 + R2)$$

- where R1 and R2 are the values of the two resistors in the voltage divider network, and Vcc is the supply voltage.

- The time period of the Cycle is given as:

$$T = 2(R1+2*R2)\ C*\ln(V_{upperthreshold}/V_{lowerthreshold})$$

➔ **Data:**

Varying Resistance		
C	**=**	**47uF**
R(Kohm)	**T(ms)**	**V(mV)**
4	20	18
6	20	16
10	20	14.14213562
22	20	8.838834765
68	1.904761905	0.5

Table 1: Varying Resistance

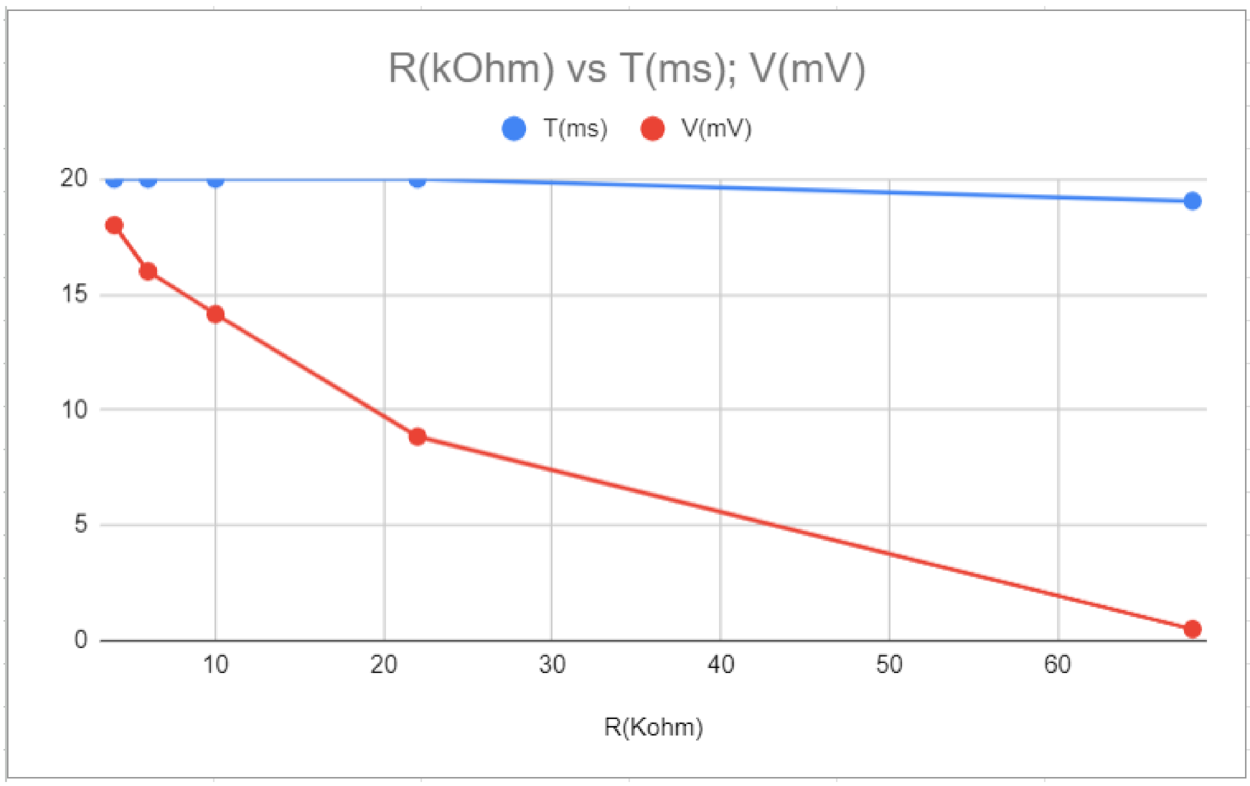

Figure (i): Graph Pertaining to Table 1: Varying Resistance

Varying Capacitance			
R	**=**	**10**	**kOhm**
C(uF)	**Tup(ms)**	**Tdown(ms)**	**V(mV)**
22	15	5	14.14213562
47	10	10	10
100	5	15	4
220	2.5	17.5	2.5

Table 2: Varying Capacitance

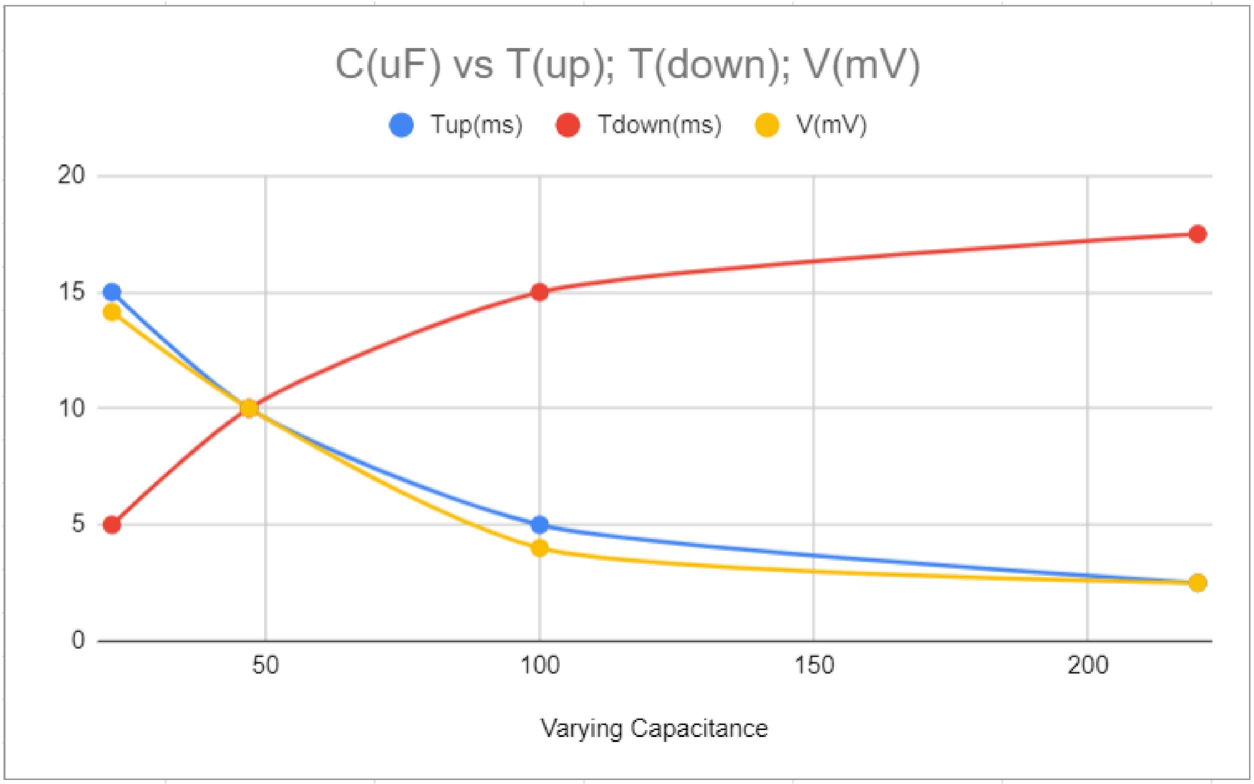

Figure (ii): Graph Pertaining to Table 2: Varying Capacitance

Making of The Compactor Based Hysteric Oscillator:

- **Components Used:**

  - Comparator: This is the main component of the oscillator, which compares the input voltage with the reference voltage and generates a square wave output. The comparator used in this circuit is a Schmitt trigger, which has hysteresis built into its design.
  - Resistors: Two resistors are used to create a voltage divider network that provides a reference voltage to the positive input of the Schmitt trigger.
  - Capacitor: A capacitor is used to provide feedback to the negative input of the Schmitt trigger. The capacitor charges and discharges through the resistor network, providing a slow-changing variable that drives the output waveform.
  - Power supply: A DC power supply is required to provide a constant voltage to the circuit.
  - Ground: The circuit also requires a ground connection to complete the circuit

❖ Image of the Physical Circuit:

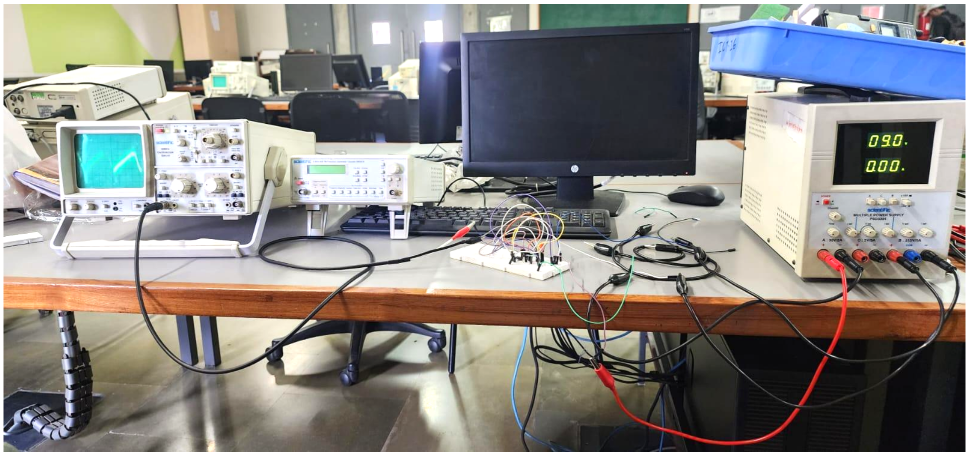

Figure 2a: Shows the Complete Circuit with the Capacitor Cycle

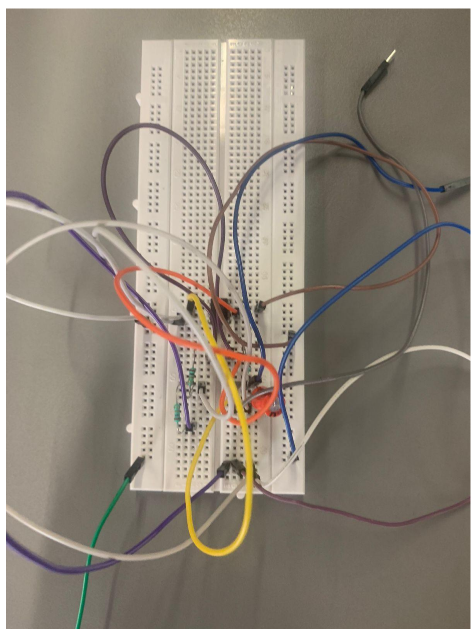

Figure 2b: The actual Circuit based on the Circuit Diagram (Figure 1).

- **Output observed in the Oscilloscope:**
    - Capacitor Charge-Discharge Cycle:

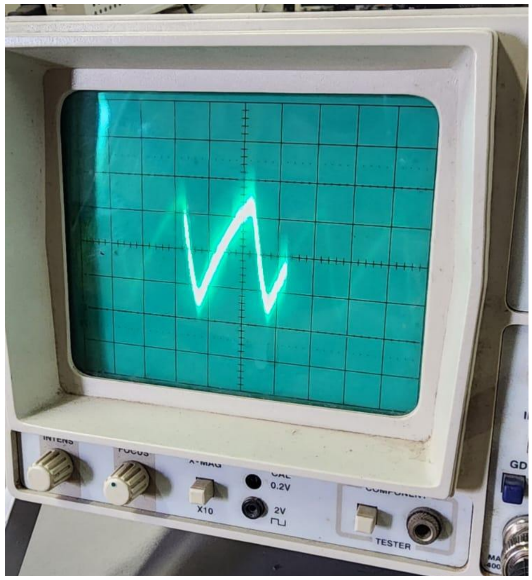

Figure 3a: Capacitor Charge Discharge cycle on the Oscilloscope

- Output Voltage Square wave

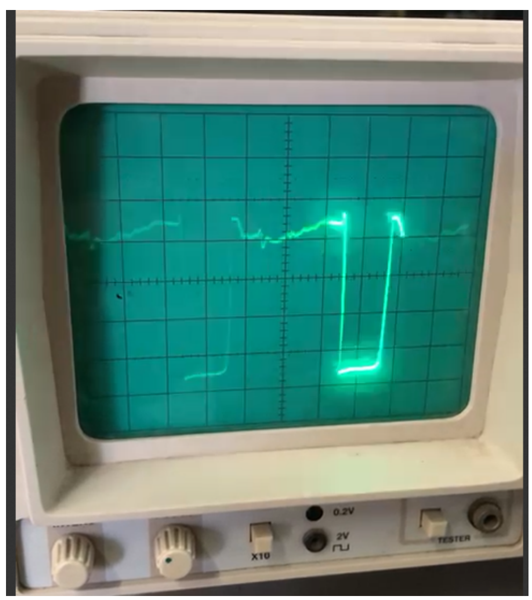

Figure 3b: Output Characteristic Voltage Voltage w.r.t. -9V (Figure 1)