EE230: Analog Circuits Lab
Lab No. 2

Sravan K Suresh, 22B3936

January 17, 2024

1 OpAmp based Negative feedback circuits

1.1 Aim of the experiment

a) Inverting Amplifier Circuit:

- To analyze the inverting amplifier circuit with resistors $R_1 = 1\text{k}\Omega$ and $R_2 = 10\text{k}\Omega$ by applying a sinusoidal input with a peak of 0.1V and frequency 1kHz. Plot V_i and V_o versus time using a supply voltage of $\pm$15V.
- To vary the input amplitude from 0.1V to 2V and observe the output waveform, explaining the changes in output voltage after a particular value of input voltage.

b) Differentiator Circuit:

- To observe the output waveform of the differentiator circuit with a triangular wave input ($\pm$2V, 2.5kHz) using resistors R = 10kΩ and capacitor C = 0.01µF. Plot the input and output waveforms, and explain the type of output waveform observed.
- To connect a small capacitor (C = 0.001µF) in parallel with R and observe V_o(t), noting any differences in the output waveform compared to (i).

c) Summer Amplifier Circuit:

- To design the values of resistors R_1, R_2, and R_3 for the summer circuit, which is intended to give an output of $V_0 = -2(X_2 + \frac{X_1}{2})$.
- To apply sinusoidal input signals (X_1 and X_2) and observe the output waveform on a Digital Storage Oscilloscope (DSO), noting down the waveform characteristics such as peak-to-peak voltage (V_{pp}) and frequency.

d) Equation Solver

- To design a circuit that performs the mathematical computation $V_0 = -(0.0001\frac{dX_1}{dt} + 2X_2)$.
- To assemble the circuit and apply sinusoidal voltage signals (X_1 and X_2) with specified amplitudes and frequency, and subsequently, to plot the input (X_1) and output (V_0) waveforms.

1.2 Design

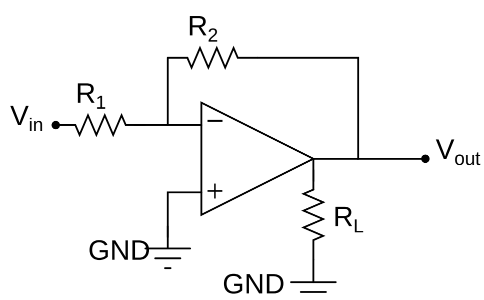

Figure 1: Inverting Amplifier

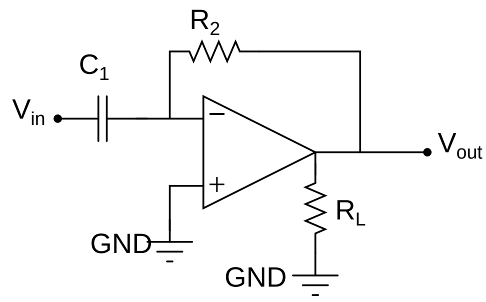

Figure 2: Differentiator

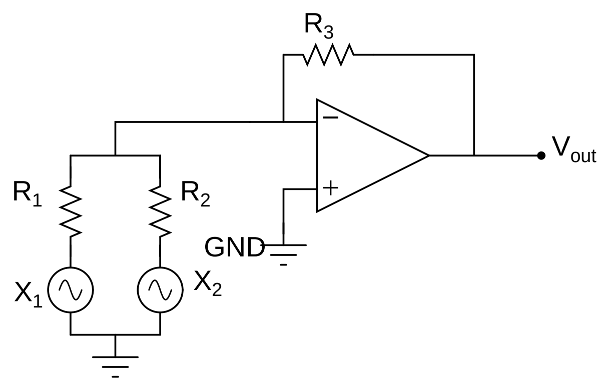

Figure 3: Inverting Summer

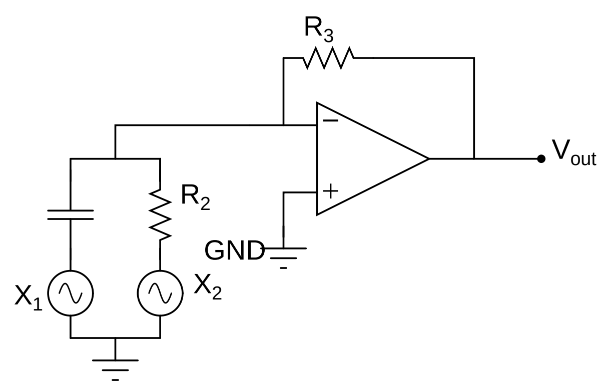

Figure 4: Equation Solver

1.3 Experimental results

Part a:

Upon varying the input voltage from 0.1V to 2V, its amplified output is

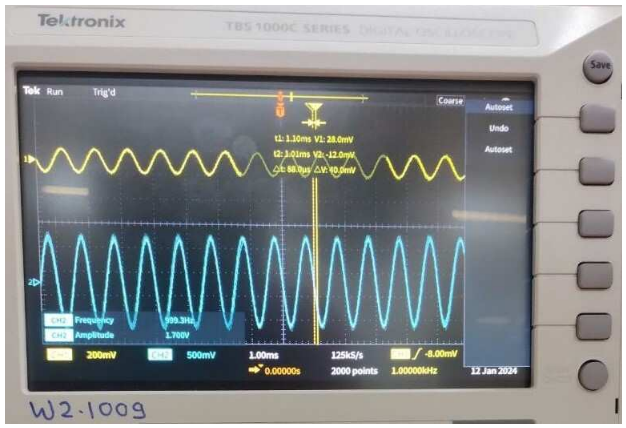

Figure 5: Waveform of Inverting Amplifier

obtained only up till a magnitude of 15V and the waveform gets clipped beyond that threshold.

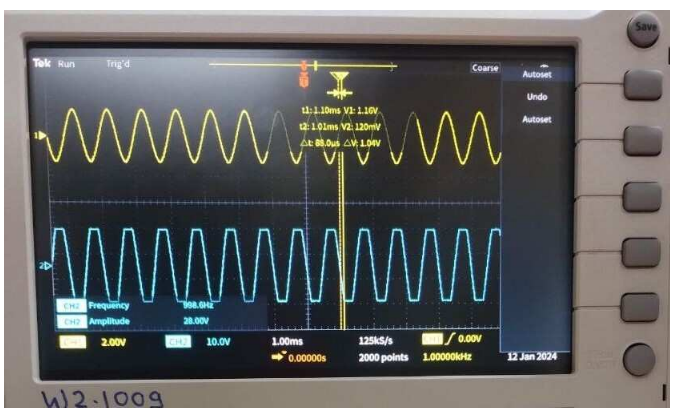

Figure 6: Waveform of Clipped output

Part b:
The triangular waveform fed as input to the circuit gets differentiated into a square wave.

1.4 Conclusion and Inference

Part a)
In the initial phase of the experiment (Part a), where a sinusoidal input with a fixed amplitude of 0.1V and a frequency of 1kHz was applied, the amplifier functioned as expected, exhibiting linear amplification. The output voltage (V_o) followed the input waveform, with the gain determined by the resistor values R_1 and R_2. The amplifier effectively magnified the input signal without distortion.

Upon varying the input amplitude from 0.1V to 2V, an interesting phenomenon emerged. While the amplifier initially maintained linear amplification, a critical point was reached where the output voltage started to saturate. This saturation effect became more prominent as the input amplitude increased beyond a certain threshold.

The saturation observed in the output waveform indicates a limitation in the amplifier's ability to provide further voltage swing. This behavior is inherent to operational amplifiers in non-inverting amplifier configurations and occurs when the output voltage reaches the maximum or minimum values defined by the power supply voltage (±15 V in this case). As a result, the output waveform becomes "clipped", leading to distortion in the signal. Thus, the experiment revealed that while the non-inverting amplifier provides linear amplification within its operational limits, there is a point at which further increases in input amplitude lead to output saturation and distortion.

Part b)
In the first scenario, where the differentiator circuit is connected with a triangular wave input (±2V, 2.5kHz), and with resistor R = 10kΩ and capacitor C = 0.01µF, the output waveform is expected to exhibit characteristics of a square wave. This is because the differentiator circuit amplifies the high-frequency components of the input signal, leading to sharp transitions at the peaks and troughs of the triangular wave.

Upon connecting a small capacitor (C = 0.001µF) in parallel with the resistor, we can anticipate a change in the output waveform. The addition of the capacitor alters the circuit's response, affecting the differentiation process. The smaller capacitor allows more high-frequency components to pass through, modifying the behavior of the differentiator.

Upon observing the output waveform $V_o(t)$ in this modified setup, we may observe a waveform with less pronounced edges or smoother transitions compared to the scenario without the additional capacitor. The modification should influence the differentiation process, and the output waveform may exhibit a slower rise and fall time.

In conclusion, the experiment demonstrates the impact of circuit modifications on the output waveform of a differentiator circuit. The addition of a capacitor affects the differentiation process, leading to observable changes in the shape and characteristics of the output waveform.

Part c) the experiment aims to validate the functionality of the op-amp circuit as a summer, and the plotted waveforms should confirm whether the circuit behaves as expected. Any deviations from the expected behavior can be analyzed to understand the performance of the circuit.

1.5 Experiment completion status

Sections completed in lab:

- Part a)
- Part b)
- Part c)
- Part d)

Hence, status of completion: **100%**

2 OpAmp based positive feedback circuits

2.1 Aim of the experiment

The primary aim of this laboratory experiment is to explore the behavior and characteristics of Schmitt trigger circuits. In the first part, a conventional Schmitt trigger circuit is designed to achieve specific upper (V_{TH}) and lower (V_{TL}) threshold values using an operational amplifier (Op-amp 741) and a dual supply of ±15V, considering $V_a = 0$V (GND). The circuit's response is then observed by applying a sinusoidal input signal (10V_{pp}, 1kHz), and the resulting output waveform ($V_o(t)$) is analyzed. Subsequently, the threshold voltages are compared between the observed values and the design specifications. The experiment is extended by recalculating the threshold values for a different virtual ground voltage ($V_a = 2$V) and repeating the observations and comparisons. Additionally, the robustness of the Schmitt trigger circuit is evaluated to assess its ability to maintain stable threshold values despite variations in the Op-amp characteristics. In the second part of the experiment, a modified Schmitt trigger circuit featuring a Zener diode is investigated. The role of resistor R' is explored, and the effects of setting R' to zero are considered. The modified circuit is connected as per the provided diagram, and the response to a sinusoidal input (10V_{pp}, 1kHz) is observed. The threshold voltages are then compared with the expected theoretical values to analyze the effectiveness of the modified design. Overall, this experiment aims to provide a comprehensive understanding of Schmitt trigger circuits, covering design considerations, practical implications, and the impact of modifications on circuit behavior.

2.2 Design

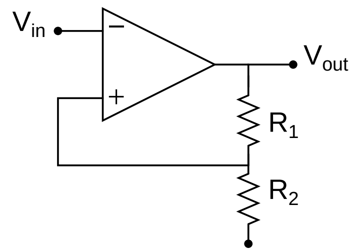

Figure 7: Schidt Trigger

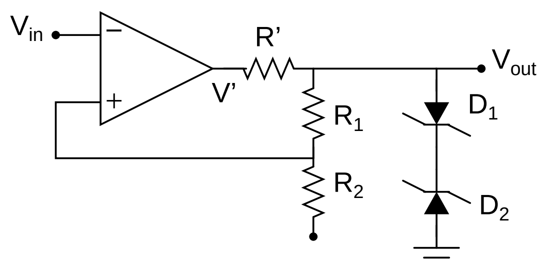

Figure 8: Modified Schmidt Trigger

2.3 Experimental results

Part a:

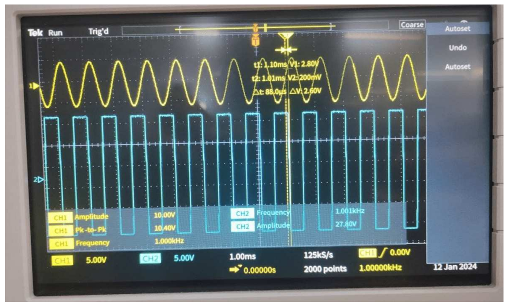

Figure 9: Waveform of Schmidt Trigger

Part b:

The purpose of R' is to limit the current that may pass through the Zener diodes.

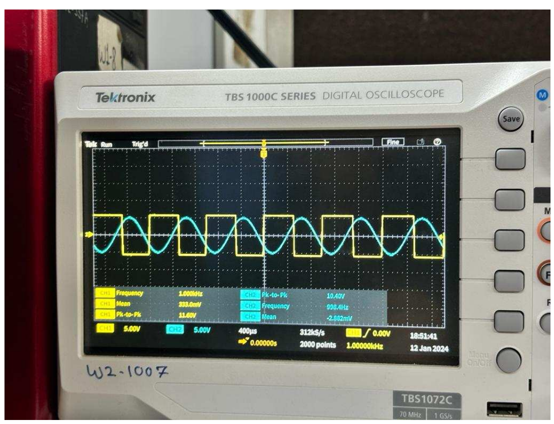

Figure 10: Waveform of Modified Schmidt Trigger

2.4 Conclusion and Inference

In this laboratory experiment, the exploration of Schmitt trigger circuits provided valuable insights into their design and performance characteristics. For the conventional Schmitt trigger circuit, the successful achievement of upper (V_{TH}) and lower (V_{TL}) threshold values of 2.5V and -2.5V, respectively, demonstrated the effectiveness of the design. The observed output waveform, generated by applying a sinusoidal input signal (10V_{pp}, 1kHz), exhibited the anticipated hysteresis behavior, confirming the circuit's functionality.

Recalculation of threshold values with a different virtual ground voltage ($V_a = 2V$) further highlighted the circuit's adaptability to variations. The subsequent observation of the output waveform and comparison of threshold voltages revealed insights into the circuit's response to changes in operating conditions.

Moving to the modified Schmidt trigger circuit, the introduction of resistor R' was found to play a crucial role. The experiment explored the effects of setting R' to zero, emphasizing the importance of this resistor in the circuit's functionality.

When applying a sinusoidal input signal (10V_{pp}, 1kHz) to the modified circuit, the observed output waveform and the comparison of threshold voltages with theoretical expectations provided a comprehensive understanding of the modified design. This analysis allowed for the assessment of the effectiveness of the modification in achieving the desired circuit behavior.

In conclusion, this experiment not only affirmed the successful implementation of Schmitt trigger circuits but also offered valuable insights into their adaptability to variations and the impact of modifications. The exploration of conventional and modified designs contributes to a deeper understanding of the practical considerations involved in the application of Schmitt trigger circuits in electronic systems.

2.5 Experiment completion status

Sections completed in lab:

- Part a)
- Part b)

- Part c)
- Part d)

Hence, status of completion: **100%**

3 OpAmp based feedback circuits

3.1 Aim of the experiment

The aim of this laboratory experiment is to investigate and characterize the behavior of operational amplifier (OpAmp) based feedback circuits. Two different feedback circuit configurations, as depicted in Fig. [6], are studied, each with specific resistor values. The primary objectives are to identify the type of feedback circuit in each configuration, analyze their responses to sinusoidal inputs, and observe the relationship between the input (V_i) and output (V_o) waveforms. In the first part, where $R_1 = 1k\Omega$, $R_2 = 10k\Omega$, $R_3 = 100k\Omega$, and $R_4 = 1k\Omega$, the experiment aims to determine the type of feedback circuit and observe the dynamic behavior under a sinusoidal input with a peak of 0.1V and a frequency of 1kHz. The second part involves a different resistor configuration ($R_1 = 1k\Omega$, $R_2 = 100k\Omega$, $R_3 = 10k\Omega$, $R_4 = 1k\Omega$), requiring a similar investigation into the feedback type and response characteristics to a sinusoidal input. By conducting these experiments, the goal is to enhance understanding regarding the impact of feedback resistor values on circuit behavior and to gain insights into the operational principles of OpAmp-based feedback circuits.

3.2 Design

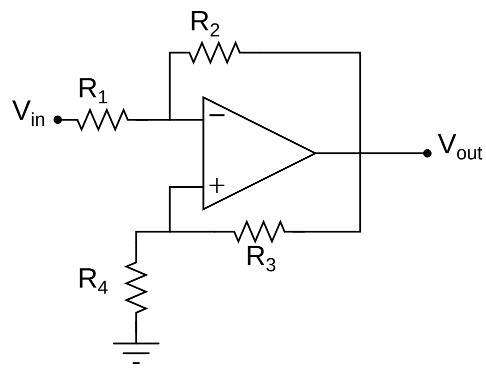

Figure 11: Feedback Circuit

3.3 Experimental Results

The circuit is in negative feedback for the first circuit and in positive feedback for the second one.

3.4 Conclusion and Inference

In conclusion, through the exploration of two distinct operational amplifier (OpAmp) based feedback circuits, valuable insights into their behavior were gained. In the first configuration with resistor values $R_1 = 1k\Omega$, $R_2 = 10k\Omega$, $R_3 = 100k\Omega$, and $R_4 = 1k\Omega$, the feedback circuit was identified as a voltage divider. The observed responses, particularly the relationship between the input (V_i) and output (V_o) waveforms under a sinusoidal input with a peak of 0.1V and a frequency of 1kHz, provided a comprehensive understanding of its dynamic behavior.

Moving to the second configuration with $R_1 = 1k\Omega$, $R_2 = 100k\Omega$, $R_3 = 10k\Omega$, and $R_4 = 1k\Omega$, the circuit type was further explored. The experiment aimed to discern any variations in feedback behavior and response characteristics. Similar to the first part, applying a sinusoidal input allowed for the observation of V_i and V_o waveforms, shedding light on the unique characteristics of this feedback configuration.

In both cases, the experiment provided valuable insights into the influence of feedback resistor values on circuit dynamics. The findings contribute to a broader comprehension of OpAmp-based feedback circuits, offering practical knowledge applicable to electronic circuit design and analysis

3.5 Experiment completion status

Sections completed in lab:

- Part a)
- Part b)
- Part c)
- Part d)

Hence, status of completion: **100%**