Indian Institute of Technology Bombay

Analog Circuits Lab
EE 230

Lab 2
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Mridul Choudhary
23B3933

Contents

1 OpAmp based Negative Feedback Circuits

1.1 Inverting Amplifier circuit

1.1.1 Aim of the experiment

To study the operation of an inverting amplifier circuit and analyze its input (V_i) and output (V_o) waveforms under varying input conditions. Specifically, to observe the linear amplification behavior and understand the saturation effects of the amplifier when the input amplitude is increased.

1.1.2 Design

The experiment utilizes an operational amplifier configured as an inverting amplifier powered by a ±15V dual supply. Key components include resistors $R_1 = 1\text{k}\Omega$ and $R_2 = 10\text{k}\Omega$, a signal generator to provide a sinusoidal input signal with an initial peak amplitude of 0.1V at a frequency of 1kHz, and a digital storage oscilloscope (DSO) for plotting the input (V_i) and output (V_o) waveforms. The DSO serves as the load for output voltage measurement. The input amplitude is varied from 0.1V to 2V to analyze the amplifier's behavior, including its linear region and the point at which output saturation occurs.

$$V_o = \frac{-V_i R_2}{R_1} \tag{1}$$

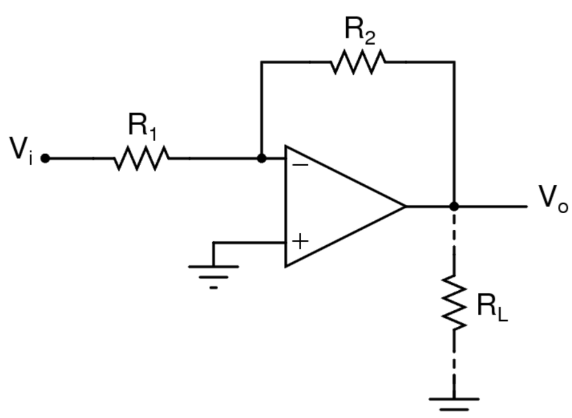

Figure 1: Inverting Amplifier

1.1.3 Conclusion and Inference

After the input voltage reaches a threshold of 15V, the amplifier gets saturated and outputs a constant voltage of 15V.

1.1.4 Experimental results

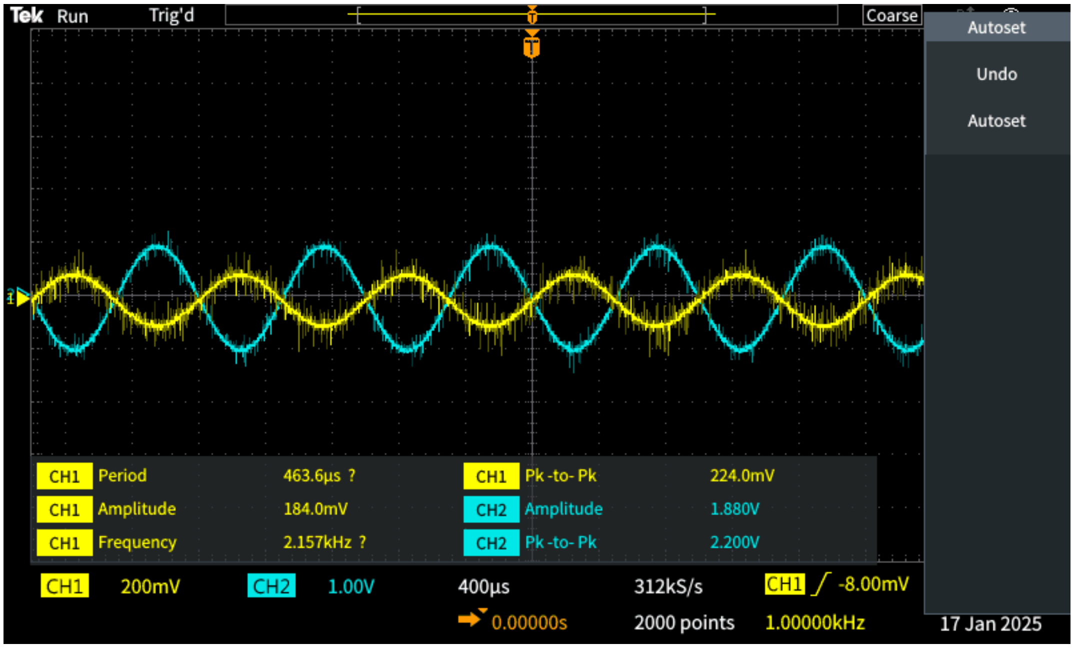

Figure 2: Input and Output of an Inverting Amplifier

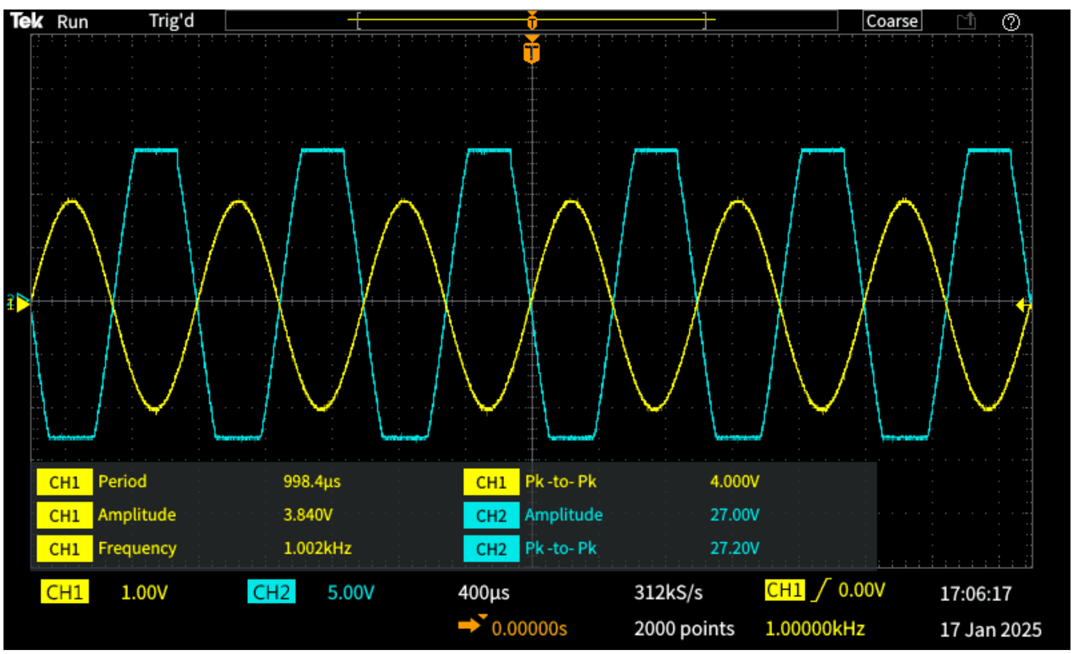

Figure 3: Saturation Characteristics of an Inverting Amplifier

1.2 Differentiator

1.2.1 Aim of the experiment

To analyze the operation of a differentiator circuit by observing the input and output waveforms for a triangular wave input and study the effect of adding a small capacitor in parallel with the resistor on the output waveform.

1.2.2 Design

The experiment uses a differentiator circuit built with an operational amplifier, powered by a suitable DC supply. Key components include a resistor R = 10kΩ, a capacitor C = 0.01μF, a signal generator to provide a triangular wave input with an amplitude of $\pm$2V at a frequency of 2.5kHz, and a DSO to observe and plot the input (V_i) and output (V_o) waveforms. In the second part of the experiment, a small capacitor C = 0.001μF is connected in parallel with R, and the resulting output waveform is observed and compared with the output from the initial setup to analyze the effect of the modification.

$$V_o = -RC\frac{\mathrm{d}V_i}{\mathrm{d}t} \tag{2}$$

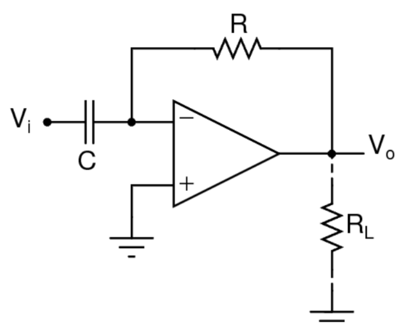

Figure 4: Differentiator

1.2.3 Conclusion and Inference

1. The output waveform has ripples because of the Gibb's phenomenon due to the presence of C which differentiates its input.
2. The ripples in the second case have smoothen themselves because of the presence of a parallel filter capacitor.

1.2.4 Experimental results

Figure 5: Input and Output of a Differentiator

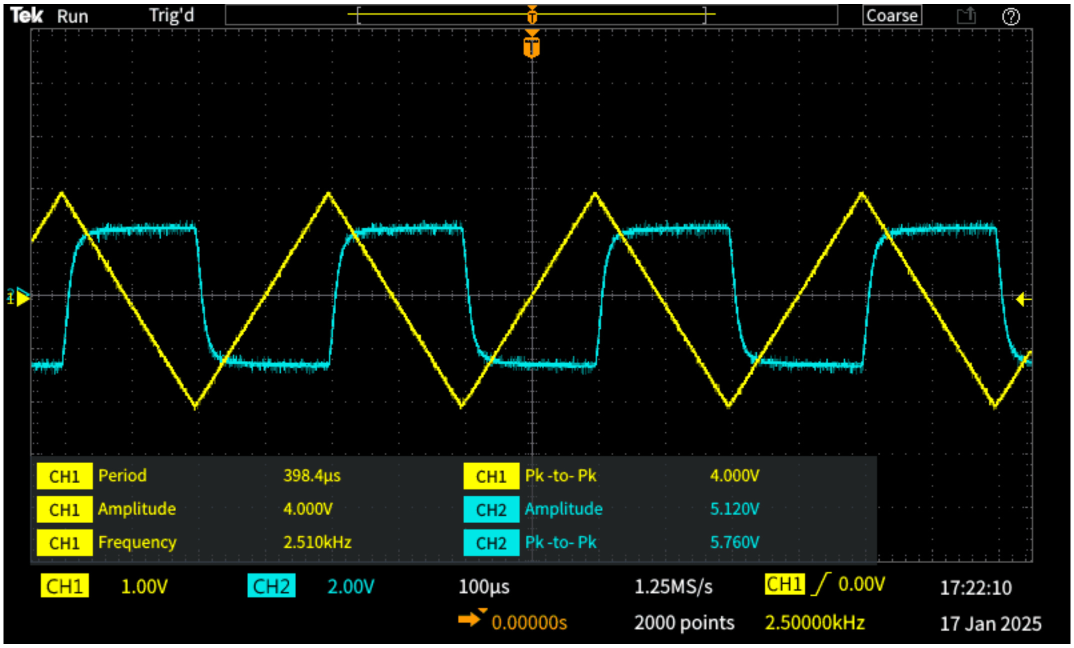

Figure 6: Input and Output of a Differentiator with a parallel C

1.3 Summer Amplifier Circuit

1.3.1 Aim of the experiment

To design, assemble, and analyze an Op-Amp based summing amplifier that computes the output voltage V_o, and to observe the input (V_i) and output (V_o) waveforms.

1.3.2 Design

The experiment uses an operational amplifier powered by a suitable DC supply to configure a summing amplifier circuit. The key components include resistors, whose values are designed to satisfy the equation $V_o = -2(X_2 + \frac{X_1}{2})$. An input of 4V V_{pp} and 500Hz and the other input of 1V DC are applied to the circuit. The DSO is used to observe and plot the input waveforms (X_1 and X_2) and output (V_o).

$$V_o = -2(X_2 + \frac{X_1}{2}) \tag{3}$$

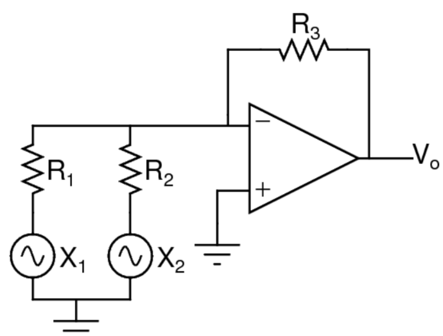

Figure 7: Summer Circuit Using Op-Amp

1.3.3 Conclusion and Inference

The output waveform is similar to that of an Inverting Amplifier.

1.3.4 Experimental results

Sr. No.	Parameter	Value
1	R_1	20kΩ
2	R_2	10kΩ
3	R_3	20kΩ
4	V_o	4V AC

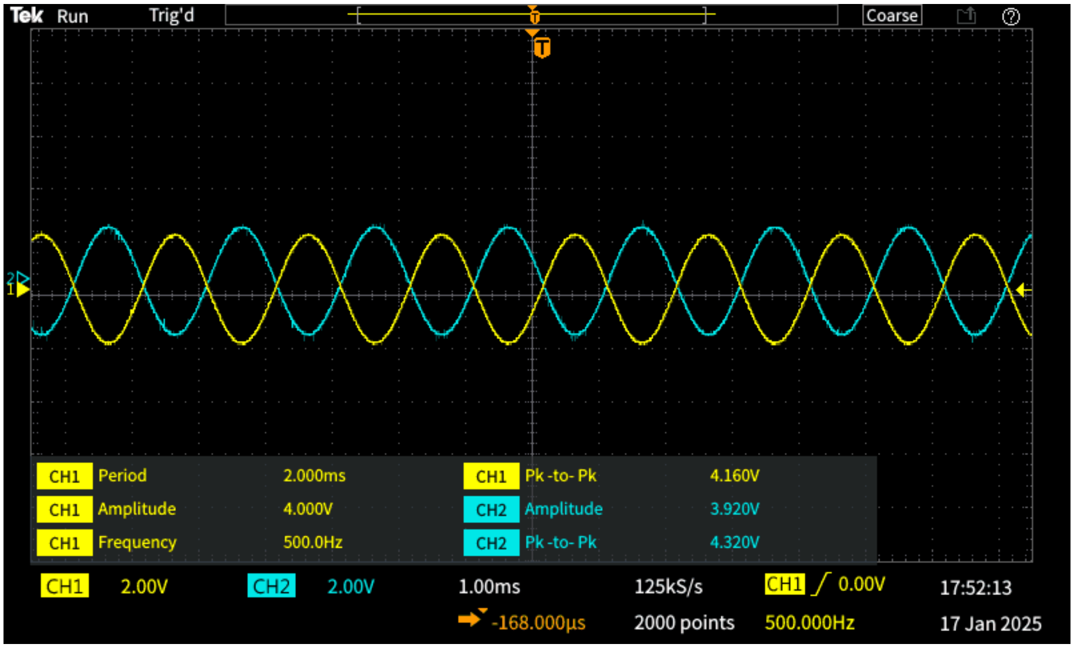

Figure 8: Output waveform of a Summer Amplifier Circuit

1.4 Equation Solver

1.4.1 Aim of the experiment

To design, implement, and analyze an Op-Amp based circuit that computes the output voltage $V_o = -(0.0001\frac{\mathrm{d}X_1}{\mathrm{d}t} + 2X_2)$, and to observe and measure the output waveform (V_o) .

1.4.2 Design

The experiment uses an operational amplifier configured as a differentiation-summing amplifier. The key components include resistors and capacitors chosen to achieve the desired gain and differentiation factor. Specifically:

$$V_o = -(0.0001\frac{\mathrm{d}X_1}{\mathrm{d}t} + 2X_2) \tag{4}$$

$$V_o = -(RC\frac{\mathrm{d}X_1}{\mathrm{d}t} + \frac{R_o}{R_i}X_2) \tag{5}$$

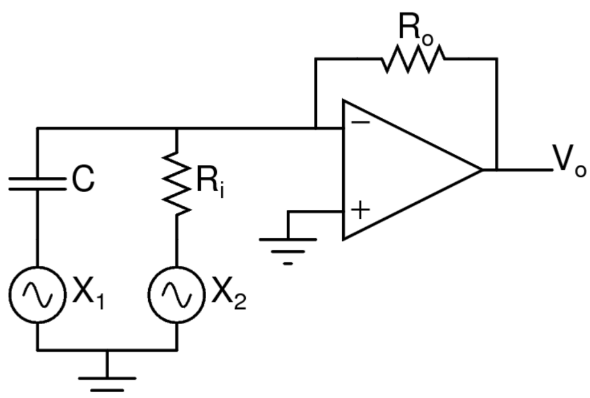

Figure 9: Differentiator Summer Amplifier

1.4.3 Experimental results

Sr. No,	Parameter	Value
1	R_i	5kΩ
2	R_o	10kΩ
3	C	10nF
4	V_{pp}	20.2V
5	Frequency	500Hz

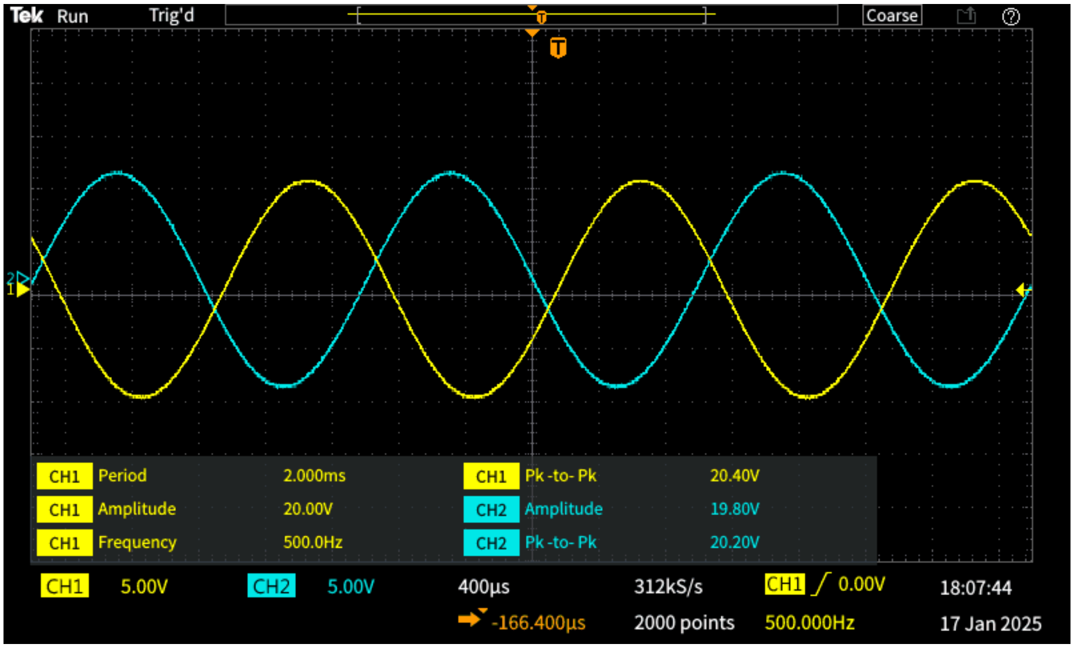

Figure 10: Input and Output Waveform

2 OpAmp Based Positive Feedback Circuits

2.1 Schmitt Trigger Circuit

2.1.1 Aim of the experiment

To design and analyze a Schmitt trigger circuit with specified upper (V_{TH}) and lower (V_{TL}) threshold voltages of ±2.5 V using an Op-Amp, observe its output response to a sinusoidal input, and evaluate the design's robustness against variations.

2.1.2 Design

The circuit utilizes an OpAmp (741) powered by a dual ±15 V supply, configured as a Schmitt trigger. Resistors are selected to achieve V_{TH} = 2.5V and V_{TL} = -2.5V, with the reference voltage V_a = 0V (GND). A sinusoidal input of 10V V_{pp} at 1kHz is applied to the circuit, and the output (V_o) waveform is observed on a DSO. The observed threshold voltages are compared with the design specifications. The reference voltage is then changed to V_a = 2V, and the new threshold values are calculated and verified experimentally. The circuit's performance is evaluated for robustness by considering the impact of Op-Amp variations on the threshold voltages.

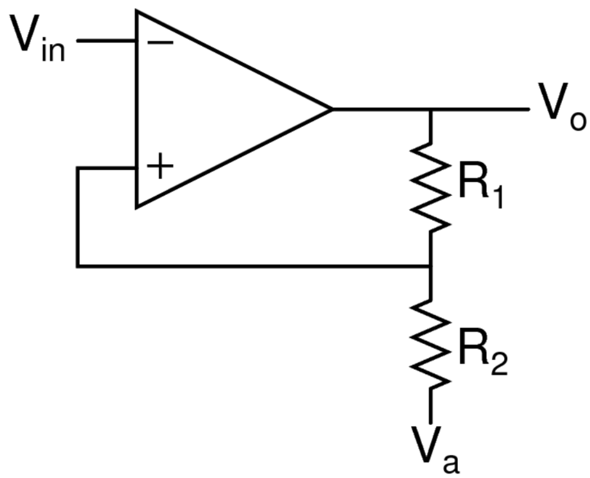

Figure 11: Schmitt Trigger

2.1.3 Experimental results

Sr. No.	Parameter	Value	V_a
1	R_1	1kΩ	0V
2	R_1	5kΩ	0V
3	V_{TH} (measured)	2.6V	0V
4	V_{TH} (calculated)	2.5V	0V
5	V_{TH} (measured)	4.32V	2V
6	V_{TH} (calculated)	4.5V	2V

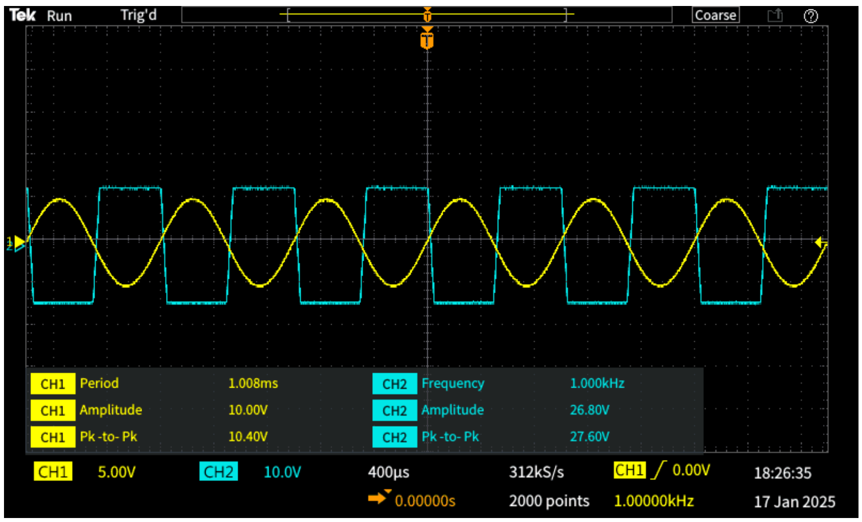

Figure 12: Output characteristics of Schmitt trigger

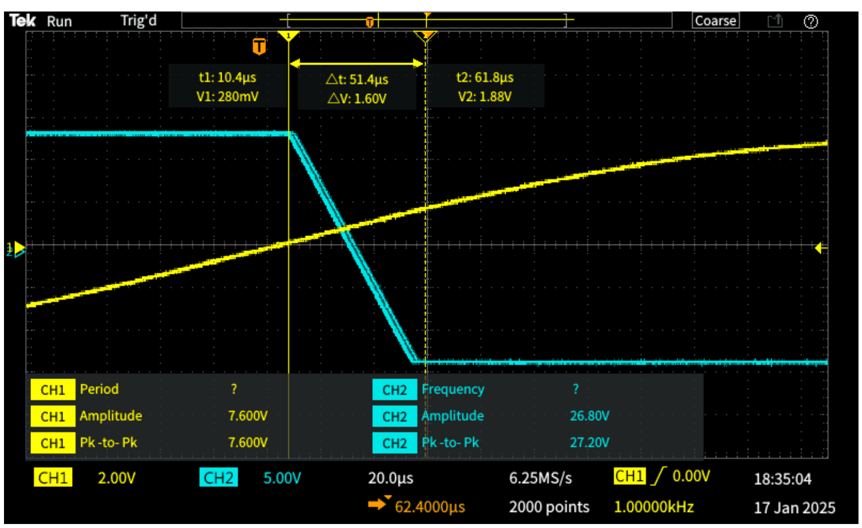

Figure 13: V_{TL} for $V_a = 0\text{V}$

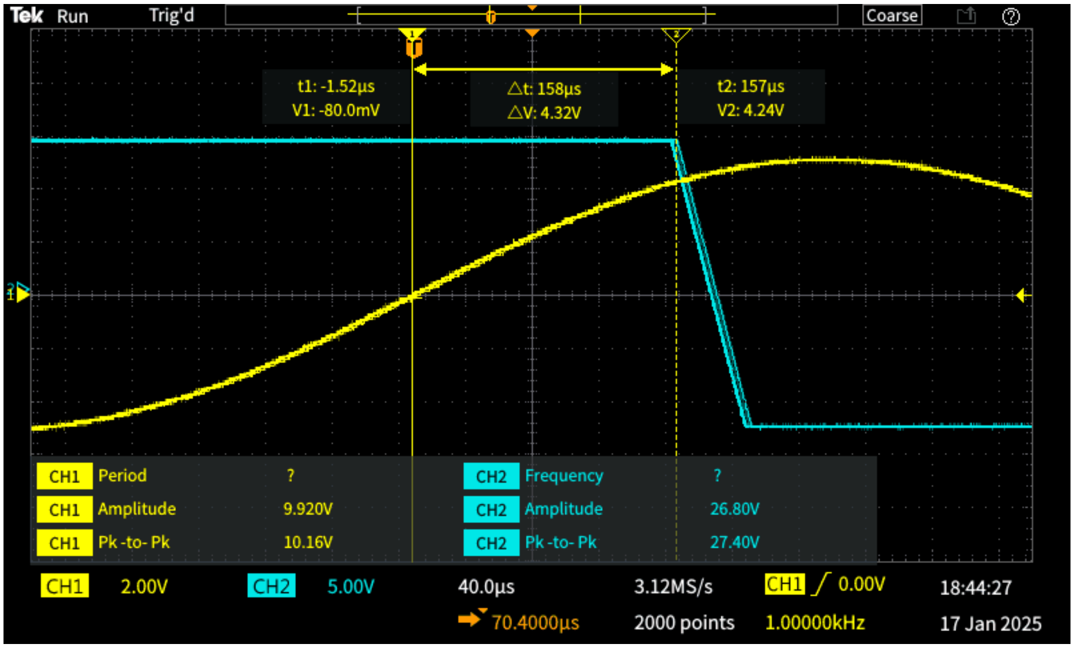

Figure 14: V_{TL} for $V_a = 2$V

2.1.4 Conclusion and Inference

1. The difference in the values of V_{TH} (measured) and V_{TL} (calculated) is due to the internal errors and the non-ideal behaviour of the OpAmp.
2. No, in this type of circuit, the values of V_{TH} and V_{TL} change and are not fixed.

2.2 Modified Schmitt Trigger Circuit

2.2.1 Aim of the experiment

To analyze the operation of a modified Schmitt trigger circuit with Zener diodes for clamping, study the purpose of the resistor R', observe the output waveform for a sinusoidal input, and compare the observed threshold voltages V_{TH} and V_{TL} with theoretical values.

2.2.2 Design

The circuit is a Schmitt trigger with modifications including two 4.7V Zener diodes D_1 and D_2 for clamping the output voltage. The key components include resistors $R_1 = 10\text{k}\Omega$ and $R_2 = 10\text{k}\Omega$ with $R' = 1\text{k}\Omega$ influencing the feedback path. The input signal is a sinusoidal waveform with an amplitude of 10V V_{pp} and a frequency of 1kHz. The Op-Amp is powered by a dual ±15V supply. The circuit is first analyzed theoretically to determine the impact of R', including the case when $R' = 0\text{k}\Omega$. The circuit is then assembled, and the output waveform (V_o) is observed on a DSO for $V_a = 0$V (GND). The threshold voltages and V_{TH} and V_{TL} are calculated and compared with experimental results to verify the circuit's behavior.

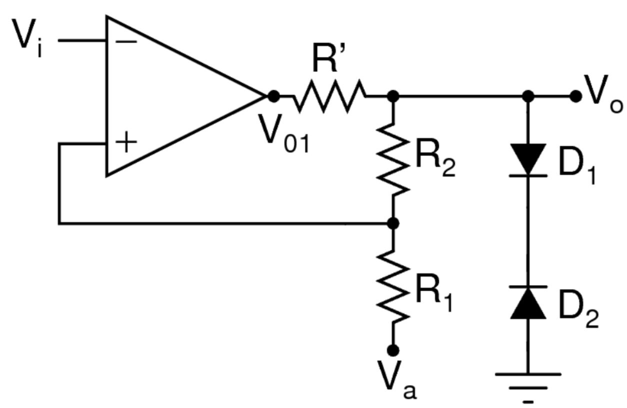

Figure 15: Schmitt Trigger with Zener Diode at output

2.2.3 Experimental results

Sr. No.	Parameter	Value
1	V_{TH} (measured)	3.2V
2	V_{TL} (measured)	-3.2V

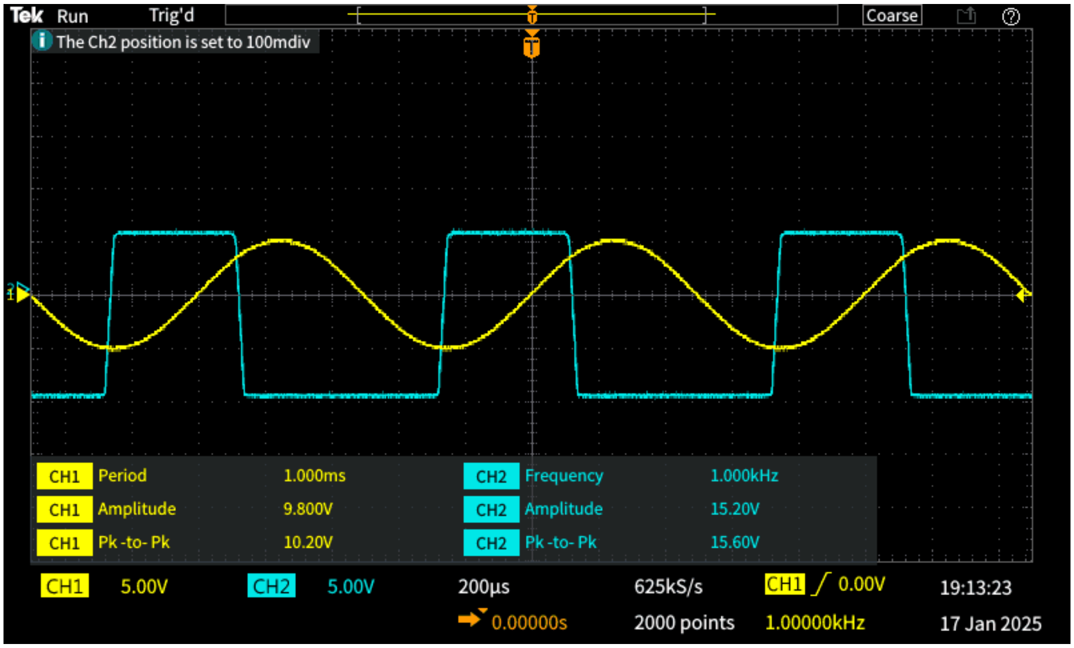

Figure 16: Output characteristics of the modified Schmitt trigger

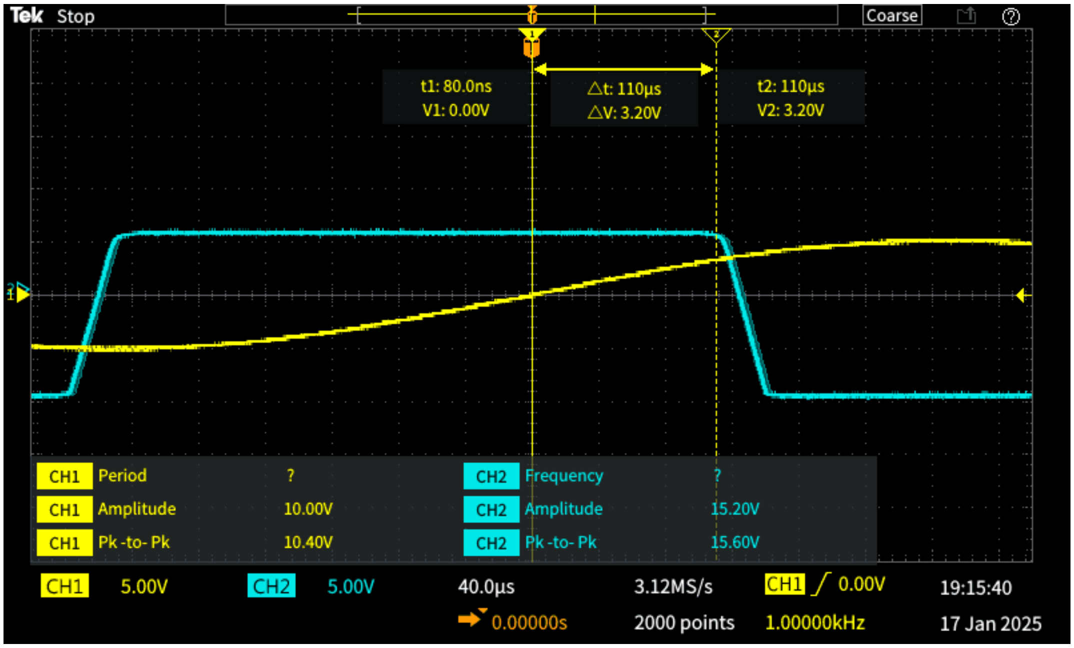

Figure 17: Measuring the value of V_{TH} and V_{TL}

2.2.4 Conclusion and Inference

R' limits the current through the Zener diode when they clamp the circuit. When R' is removed, a high current might flow, damaging the circuit.

3 OpAmp Based Feedback circuit

3.1 Howland Current Source

3.1.1 Aim of the experiment

To analyze the operation of two OpAmp based feedback circuits with different resistor configurations, determine the type of feedback implemented, and observe the input (V_i) and output (V_o) waveforms for a sinusoidal input signal. V_i V_o V_i V_o Ω μ

3.1.2 Design

The experiment involves two op-amp feedback circuits powered by a ±15 V supply. For the first circuit, resistors $R_1 = 1\text{k}\Omega$, $R_2 = 10\text{k}\Omega$, $R_3 = 100\text{k}\Omega$, and $R_4 = 1\text{k}\Omega$ are used. In the second circuit, the resistor configuration changes to $R_1 = 1\text{k}\Omega$, $R_2 = 100\text{k}\Omega$, $R_3 = 10\text{k}\Omega$, and $R_1 = 1\text{k}\Omega$. A sinusoidal input signal with a peak amplitude of 0.1V and a frequency of 1kHz is applied to both circuits. The input (V_i) and output (V_o) waveforms are observed and plotted using a digital storage oscilloscope (DSO). The type of feedback in each circuit is identified and explained based on the resistor arrangement and the observed behavior of the output signal.

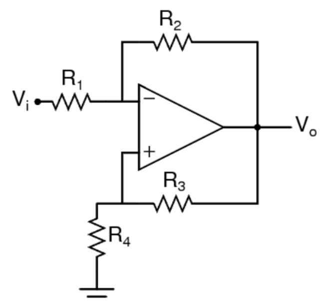

Figure 18: OpAmp based feedback circuits

3.1.3 Conclusion and Inference

1. The circuit in the first case is a negative feedback amplifier.
2. The circuit in the second case is a positive feedback amplifier.

3.1.4 Experimental results

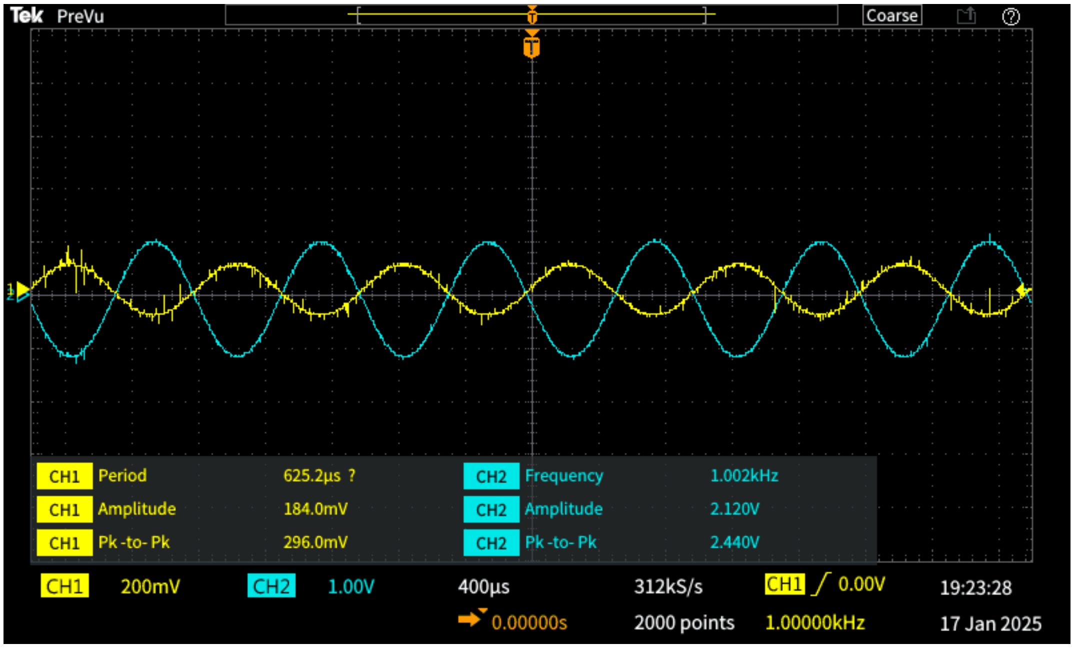

Figure 19: Output waveform in first case

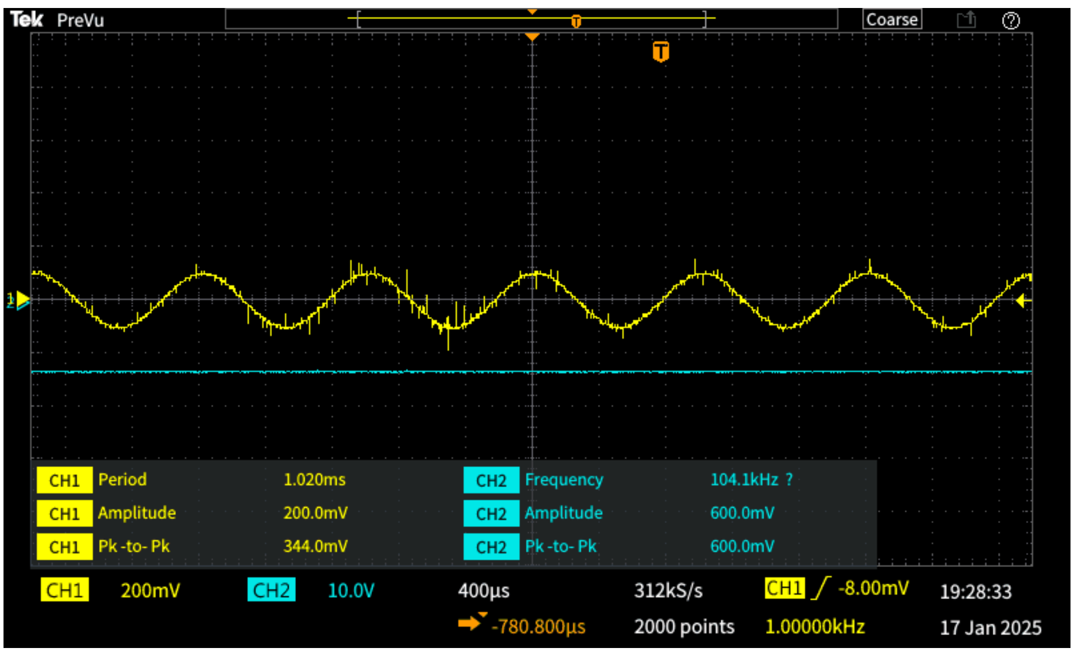

Figure 20: Output waveform in second case

4 Experiment Status

The complete experiment was conducted in the lab itself in the presence of the beloved TA.