Indian Institute of Technology Bombay

Analog Circuits Lab
EE 230

Lab 6
February 17, 2025

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Contents

1 Measurement of Offset voltage and Bias currents

1.1 Measurement of V_{OS}

1.1.1 Aim of the experiment

1. Measure V_{OS} using a circuit that enhances its contribution while minimizing the effects of bias currents.

2. Determine the exact resistor values to accurately calculate V_{OS}.

3. Compare the measured V_{OS} with the value provided in the OpAmp 741 datasheet.

1.1.2 Design

For the measurement of the input offset voltage (V_{OS}), a non-inverting amplifier configuration is used. The circuit consists of an OpAmp 741 powered by a ±15V supply, with two resistors (R_1 = 10Ω and R_2 = 10kΩ) forming the feedback network. The output voltage (V_O) is measured and used to compute V_{OS} using the equation $V_{OS} = \frac{V_O}{1+\frac{R_2}{R_1}}$. The actual resistor values are measured beforehand to ensure accuracy, and the obtained V_{OS} is compared with the typical value provided in the OpAmp 741 datasheet.

$$V_{OS} = \frac{V_O}{1 + \frac{R_2}{R_1}} \approx \frac{V_O}{\frac{R_2}{R_1}} \tag{1}$$

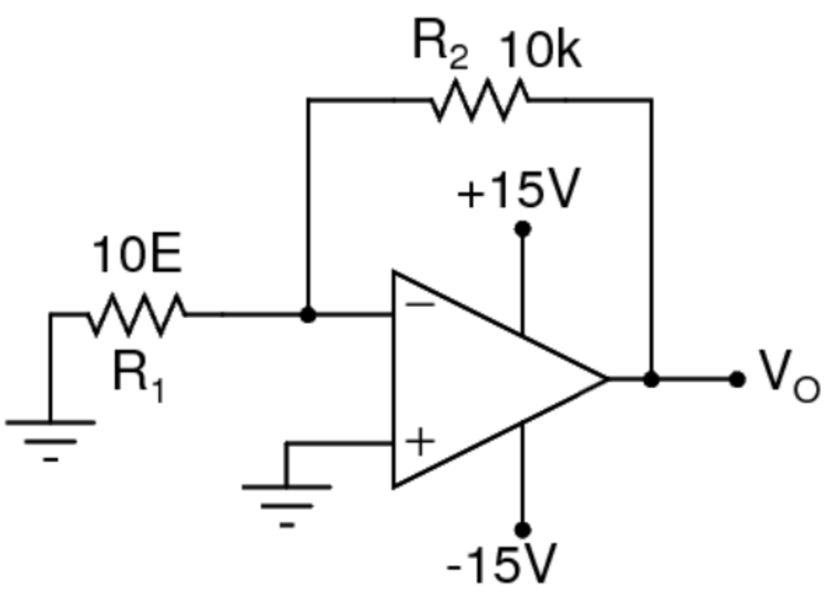

Figure 1: Circuit for measurement of V_{OS}

1.1.3 Experimental results

Sr. No.	Parameter	Value
1	R_1	10.2 Ω
2	R_2	10 kΩ
3	V_O	9 mV
4	V_{OS}	9.18 μ V

1.2 Measurement of bias current I_B^-

1.2.1 Aim of the experiment

1. Measure I_B^- using a circuit where output voltage is primarily influenced by bias current through a high-value resistor.
2. Compare the measured values of bias currents with those from the OpAmp 741 datasheet.

1.2.2 Design

The bias current I_B^- is measured using a configuration where a 10MΩ resistor is placed between the inverting input and ground, ensuring that the output voltage primarily depends on I_B^- . Since the offset voltage component is negligible in comparison, the bias current is determined using $I_B^- = \frac{V_O}{R}$.

$$I_B^- = \frac{V_O}{R} \tag{2}$$

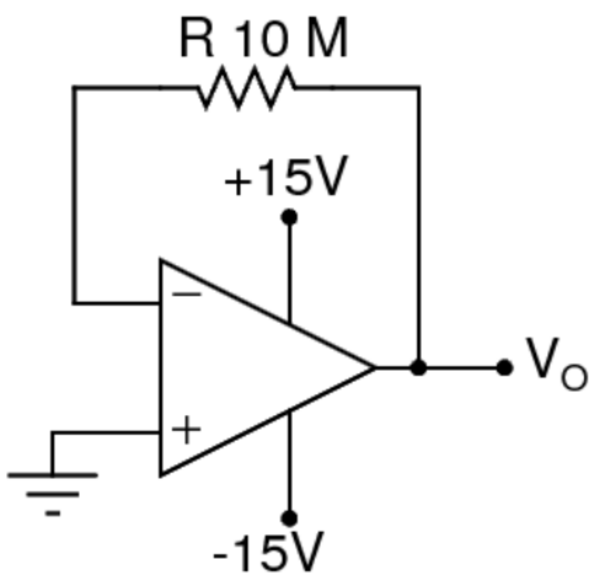

Figure 2: Circuit for measurement of I_B^-

1.2.3 Experimental results

Sr. No.	Parameter	Value
1	R	10 MΩ
2	V_O	0.5 V
3	I_B^-	49.1 nA

1.3 Measurement of bias current I_B^+

1.3.1 Aim of the experiment

1. Measure I_B^+ using a similar circuit where the current flows through a resistor at the non-inverting terminal.
2. Compare the measured values of bias currents with those from the OpAmp 741 datasheet.

1.3.2 Design

I_B^+ is measured using a circuit where a 10MΩ resistor is connected to the non-inverting terminal, causing a voltage drop due to I_B^+, and the current is calculated using the same formula. These values are then compared with the datasheet values of the OpAmp 741.

$$I_B^+ = \frac{V_O}{R} \tag{3}$$

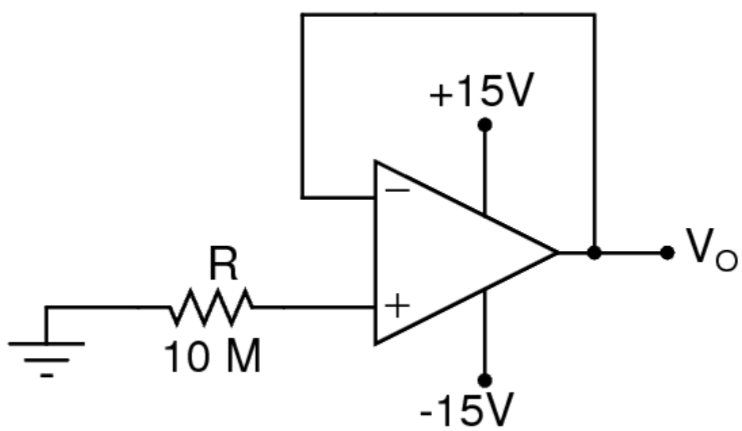

Figure 3: Circuit for measurement of I_B^+

1.3.3 Experimental results

Sr. No.	Parameter	Value
1	R	10 MΩ
2	V_O	-0.5 V
3	I_B^+	-49.1 nA

2 Measurement of Open-loop gain

2.0.1 Aim of the experiment

1. Challenges in Direct Measurement of Open-Loop Gain:
    - Due to the high gain of the OpAmp, direct measurement of AOL is difficult as the amplifier quickly saturates.
    - A method called "False Summing Junction" is used to indirectly measure AOL without saturation.
2. Implementation of Open-Loop Gain Measurement Circuit:
    - Build a circuit where the open-loop gain can be calculated using measurable parameters.
    - Nullify the offset voltage using a potentiometer before taking measurements.
    - Verify circuit operation by applying a DC input and checking expected output.
3. Frequency Response Analysis of AOL:
    - Measure the peak-to-peak voltages at various frequencies to determine AOL as a function of frequency.
    - Plot the magnitude frequency response (Bode Plot) of AOL.
    - Determine the 3-dB bandwidth and the roll-off slope in dB/decade.
    - Identify the number of poles and estimate their frequencies.

2.0.2 Design

The measurement of the open-loop gain (A_{OL}) presents challenges due to the extremely high gain of the OpAmp, which causes immediate saturation. To overcome this, the "False Summing Junction" method is used. In this method, a resistive feedback network is introduced to control the gain, allowing measurement without driving the OpAmp into saturation. The circuit includes an OpAmp 741 with resistors ($R_{in} = 5\text{k}\Omega$, $R_{FB} = 5\text{k}\Omega$, $R_1 = 100\text{k}\Omega$, $R_2 = 100\Omega$), which ensures proper feedback control. A sine wave input with a peak-to-peak voltage of 15V is applied at various frequencies ranging from 1Hz to 10kHz, and the output voltage (V_O) and reference voltage (V_R) are measured. The open-loop gain is then calculated using the formula $A_{OL} = \frac{|V_O|}{|V_R|}\frac{R_1+R_2}{R_2}$. The frequency response of A_{OL} is plotted to determine the 3-dB bandwidth and the roll-off slope, identifying the dominant poles in the system.

Each of these circuits is designed to ensure precise measurement of OpAmp characteristics while accounting for real-world variations in component values. The step-by-step experimental procedure ensures that results are reliable and comparable with theoretical expectations from the OpAmp 741 datasheet.

$$A_{OL} = \frac{|V_O|}{|V_R|} \frac{R_1 + R_2}{R_2} \tag{4}$$

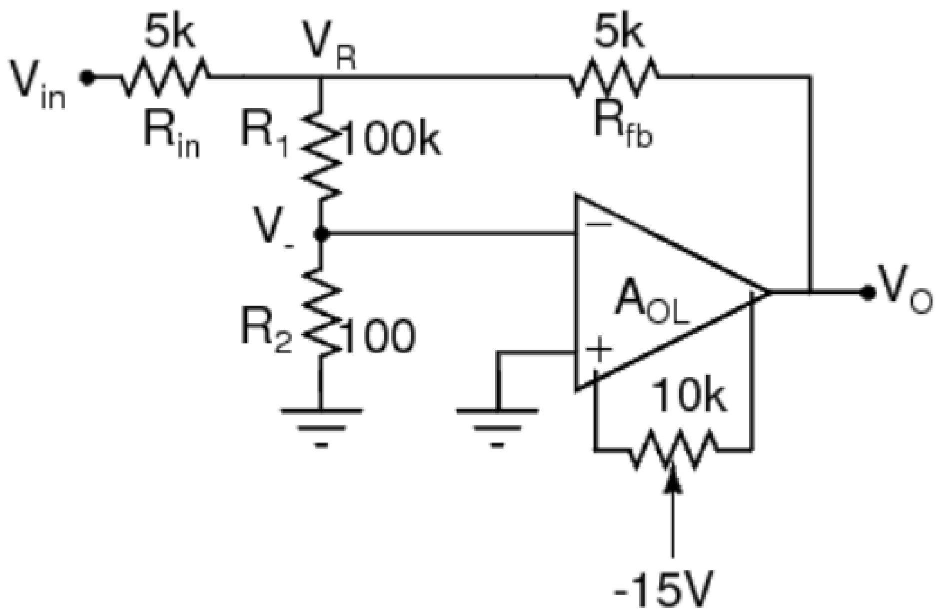

Figure 4: Measurement of open-loop gain A_{OL}

2.0.3 Experimental results

Sr. No.	Parameter	Value
1	R_{in}	5 kΩ
2	R_{fb}	5 kΩ
3	R_1	100 kΩ
4	R_2	100 Ω

Sr. No.	Frequency	V_O (V_{PP})	V_R (mV_{PP})	A_{OL}
1	10 kHz	100 mV_{PP}	8 V_{PP}	12.5125
2	1 kHz	800 mV_{PP}	6.6 V_{PP}	121.33
3	500 Hz	1.2	4.92 V_{PP}	244.1463
4	100 Hz	1.56	1.32 V_{PP}	1183
5	20 Hz	1.56	280	5577
6	10 Hz	1.52	200	7607.6
7	9 Hz	1.56	200	7807.8
8	8 Hz	1.56	200	7807.8
9	7 Hz	1.56	160	9759.75
10	6 Hz	1.56	108	13717.4074
11	5 Hz	1.56	100	15615.6
12	4 Hz	1.56	80	19019
13	3 Hz	1.52	80	19019
14	2 Hz	1.52	76	20020
15	1 Hz	1.52	72	21132.22

Table 1: Frequency v/s loop gain Amplitude

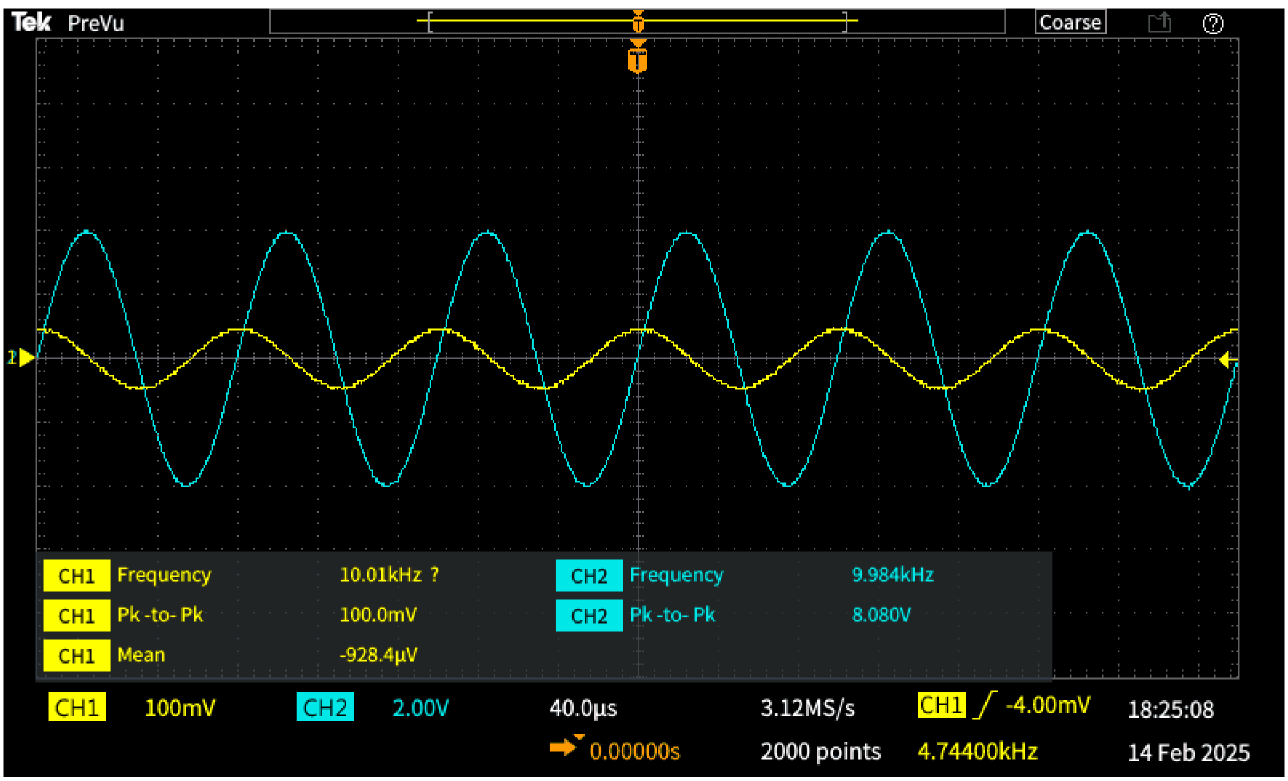

Figure 5: Waveform at 10 kHz

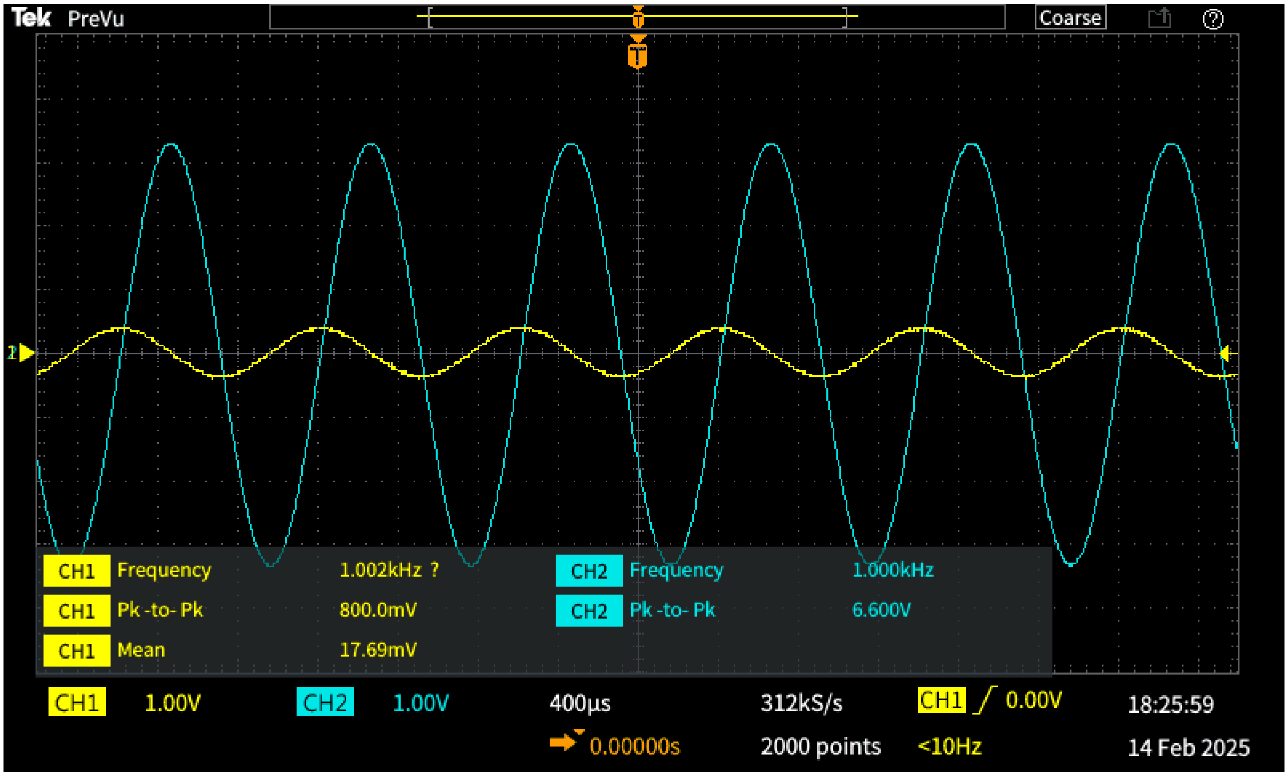

Figure 6: Waveform at 1 kHz

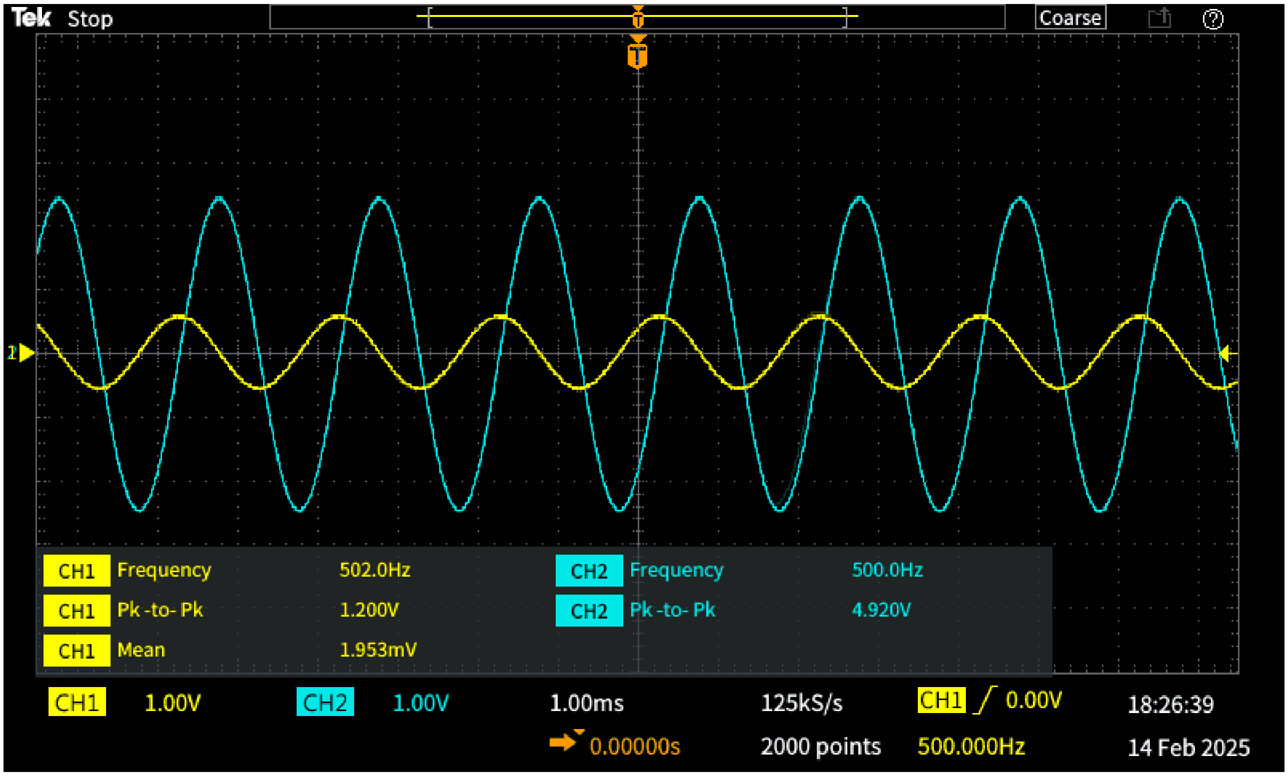

Figure 7: Waveform at 500 Hz

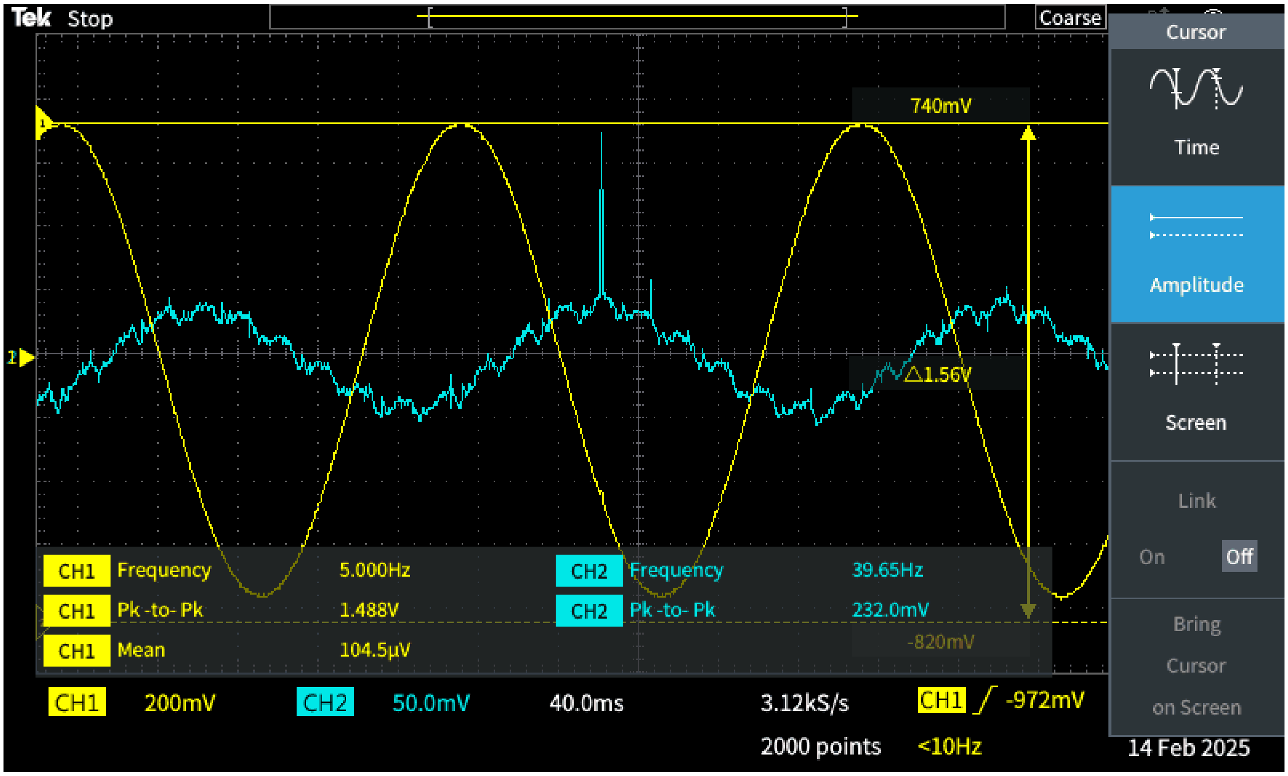

Figure 8: Waveform at 5 Hz

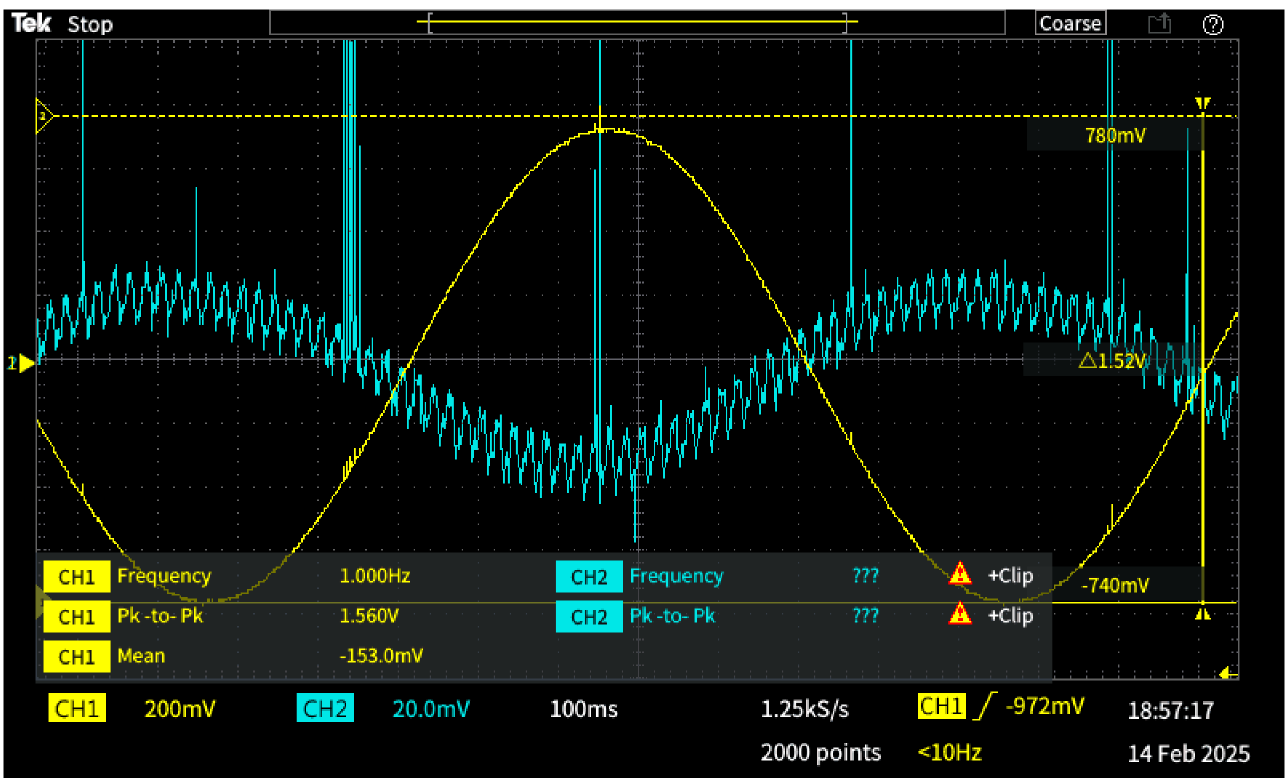

Figure 9: Waveform at 1 Hz

2.0.4 Conclusion and Inference

1. The roll-off slope of A_{OL} w.r.t. frequency in dB/dec is estimated using the five highest frequencies and their corresponding amplitudes which comes around -19.63 dB/decade.

2. f_{-3dB} can be found where gain drops by 3dB from its DC value which comes around 100 Hz.

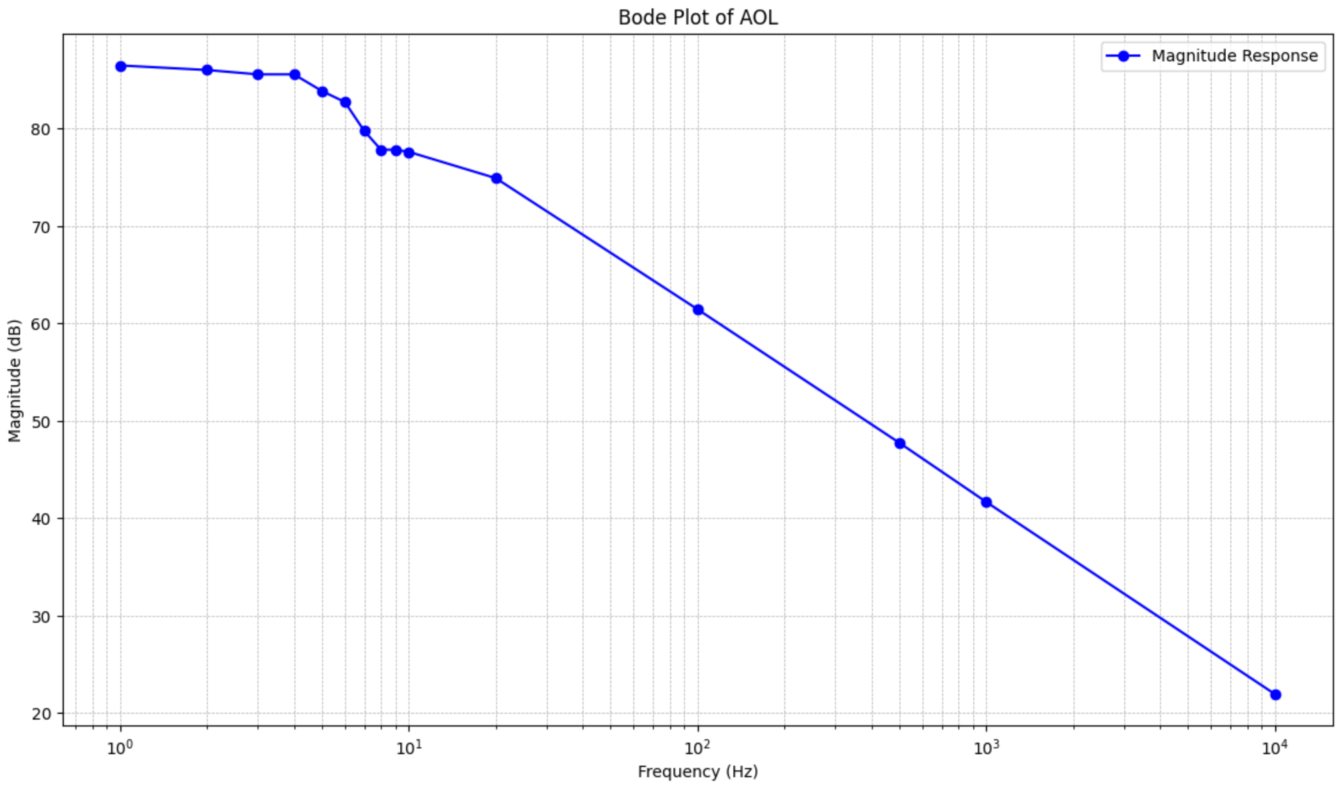

Figure 10: The Bode Plot

3 Experiment completion status

The complete experiment was performed in front of the TA in the lab itself.