EE230: Analog Circuits Lab
Lab No. 1

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1 Title of the experiment 1

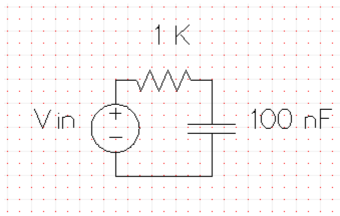
Recap And Familiarization of RC circuits, diode-based and Op-Amp-based simple circuits

1.1 Aim of the experiment

In this experiment, we design a simple RC-based low pass filter and measure the frequency and time response. Then we make a positive and a negative diode-based half wave rectifier, followed by basics of probing circuits, and end with an Op-Amp-based Non-Inverting Amplifier.

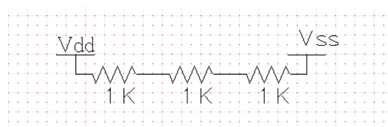
1.2 Design

To make the RC-low pass filter, we connect the supply across an RC-network and measure the voltage across the capacitor. The output gives us a low-pass filtered version of the input.In an RC circuit, the voltage across the capacitor (V_C) is given by the formula $V_C(t) = V_{\text{in}} \left(1 - e^{-\frac{t}{RC}}\right)$. As time ($t$) approaches infinity, the exponential term tends to zero, and the capacitor voltage reaches the input voltage. This behavior defines the capacitor as a low-pass filter, allowing DC components to pass through while attenuating AC components during the transient phase.

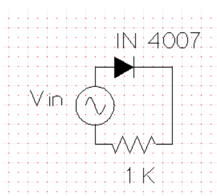


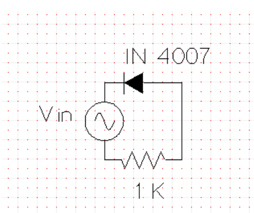
Following instructions, we created a basic voltage divider circuit with probes:

$$V_{\text{out}} = V_{\text{in}} \times \frac{R_2}{R_1 + R_2 + R_3}$$

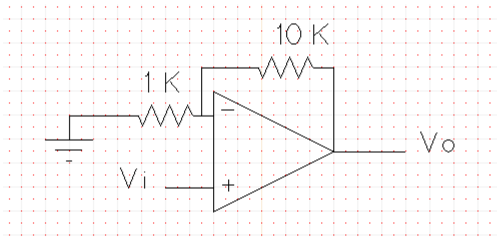


Later, we implemented a half-wave rectifier by incorporating a diode and resistor into the input circuit. This configuration cancels the negative side of the input signal when the diode is in reverse bias. For a change in the direction of half-wave rectification, we reversed the orientation of the diode.





The last part was to make the Op-Amp-based negative amplifier. We followed the diagram given in the handout and made the circuit accordingly.



1.3 Experimental results

1.3.1 Time response of the RC circuits- PART 1

Values of the components used here are:
Resistance = 1kΩ
$Capacitance = 1nF$

1a] The time constant of the circuit was obtained using the DSO cursor to be **68 us**. The waveform was nearly a square wave but the capacitor being charged and discharged continually was visible on the same.So, we get a periodically oscillating distorted square wave as the output
1b] The measured bandwidth is 2.33 KHz, while the calculated one was simply $\frac{1}{RC}$, which turned out to be 10000 rad/s or simply 1.59 KHz.
The reason for the discrepancies is the following:
1. The resistance was not 100% accurate and had a tolerance of 10 %
2. The DSO and its probes have internal resistance/capacitance or inductance which might change the values.
3. The breadboard itself has an internal capacitance which changes the overall capacitance of the circuit
All of these cause a difference in the practical and theoretical values.

1c] The rise and fall times measured and calculated are as follows:

Table 1: Calculated using DSO vs Cursor

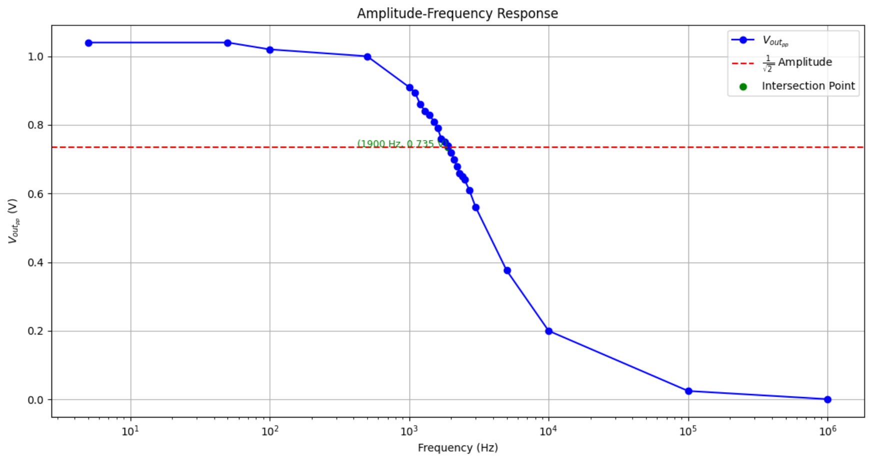
Sr. No.	Rise Time	Fall Time
Cursor	132 us	129.5 us
DSO	164 us	150 us

1.3.2 Frequency response of the RC circuits- PART 2

2 a]

Table 2: frequency response

Sr. No.	Frequency(Hz)	Amplitude(V)
1	5	1.04
2	50	1.04
3	100	1.02
4	500	1.00
5	1000	0.910
6	1100	0.895
7	1200	0.860
8	1300	0.840
5	1400	0.830
5	1500	0.810
5	1600	0.790
5	1700	0.760
5	1800	0.750
5	1900	0.740
5	2000	0.720
5	2100	0.700
5	2200	0.680
5	2300	0.660
5	2400	0.650
5	2500	0.640
5	2700	0.610
5	3000	0.560
5	5000	0.376
5	10000	0.200
5	100000	0.0248
5	1000000	0.0010



2 b] Analyzing the graph, the frequency corresponding to the point where the amplitude reaches $\frac{1}{\sqrt{2}}$ of the maximum value is identified as 1.9 kHz. Consequently, the measured bandwidth is determined to be 1.9 kHz.

2 c] The measured bandwidth at 1.9 kHz differed from the expected values of 1.6 kHz (calculated using formulas) and 2.3 kHz (from time-domain calculations). Discrepancies may arise from errors such as signal distortions, instrument inaccuracies, non-ideal filter responses, noise interference, transient effects, calibration issues, and inadequate sampling rates in digital systems. Real-world complexities and deviations from ideal conditions contribute to variations, highlighting the importance of thoroughly considering these factors when interpreting bandwidth measurements.

1.3.3 Basics of probing the circuit

3a] The voltage drop measured across R3 using probe1 was **9.92** V and this closely matched the expected value of **10 V.**

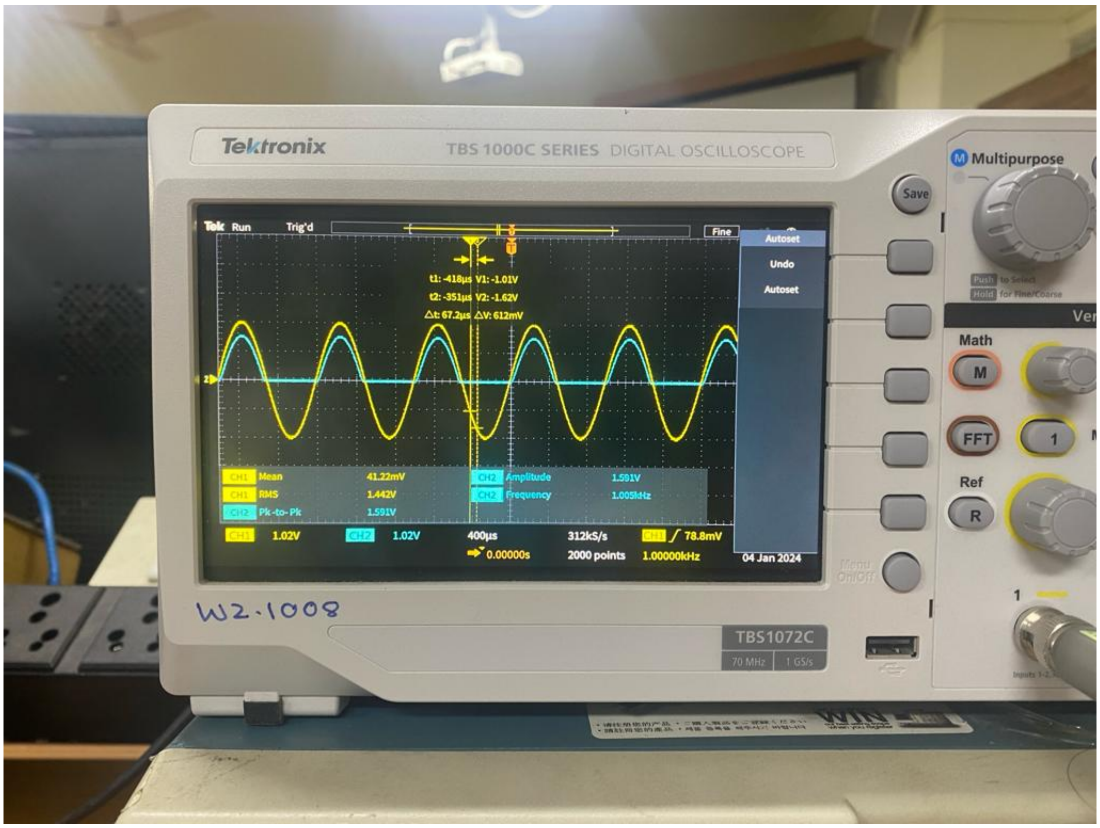
3b] The voltage drop measured across R2 using probe2(while keeping probe-1 connected) was **14.95 V** and this differed from the expected value of 10 V. The error occurred due to the internal shorting of the grounds of probe 1 and probe 2 of the DSO. This shorting caused nodes B and Vss to be shorted, leaving only resistors R1 and R2 connected in the circuit, resulting in a potential drop of around 15 V instead of the expected 10 V, since the voltage is now divided in only two resistors instead of 3.

3c] To avoid this error, a **digital multimeter(DMM)** can be used. A DSO

with isolated grounds can also be used for the same.
3d] The recorded outcome of the **2.5V** sine wave (5/2) deviated from the anticipated **1.65V** sine wave(5/3) due to a short circuit between the probe ground, function generator ground, and the earth ground. Consequently, resistor R3 is shorted, directing the entire current through R1 and R2 and resulting in a voltage drop with an amplitude of 2.5V. To rectify this issue, it is crucial to ensure the isolation of the probe and function generator grounds from the earth's ground. This can be achieved using techniques such as differential inputs or isolating transformers to prevent unintended ground loops.

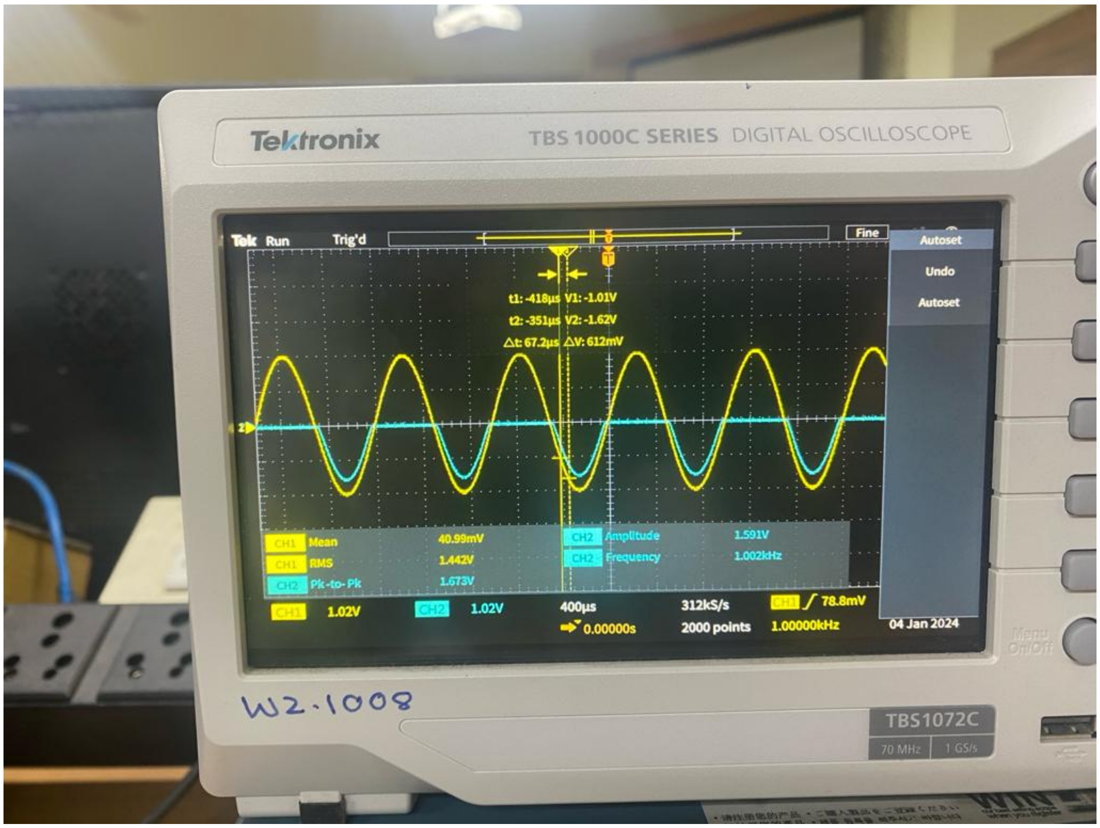
1.3.4 Half wave Rectifier

4 a]



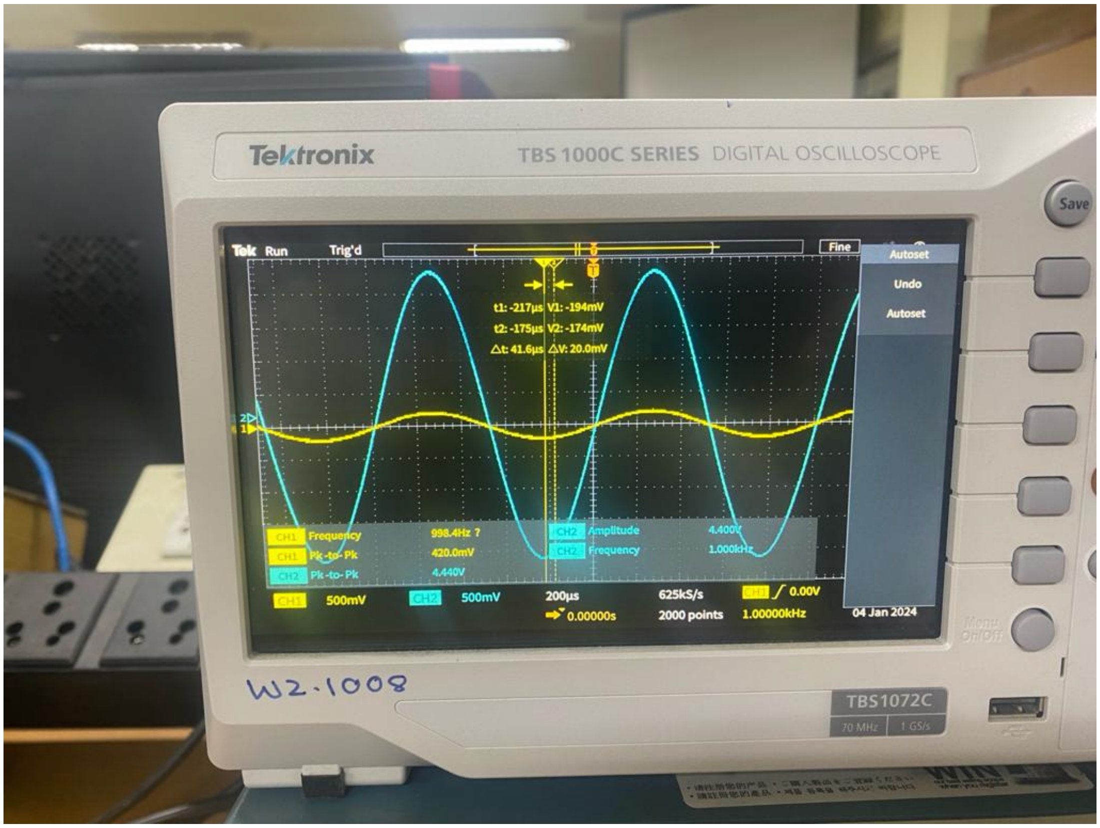
4 b] The Diode drop of approximately 0.7 V, which is the forward bias voltage, leads to the reduction in the peak amplitude between the input and the output voltage.

4 c] As the direction of the diode is reversed, only the negative input voltages pass instead of the positive voltages and hence the plot gets inverted, with the negative peaks coming and the positive ones being rectified.

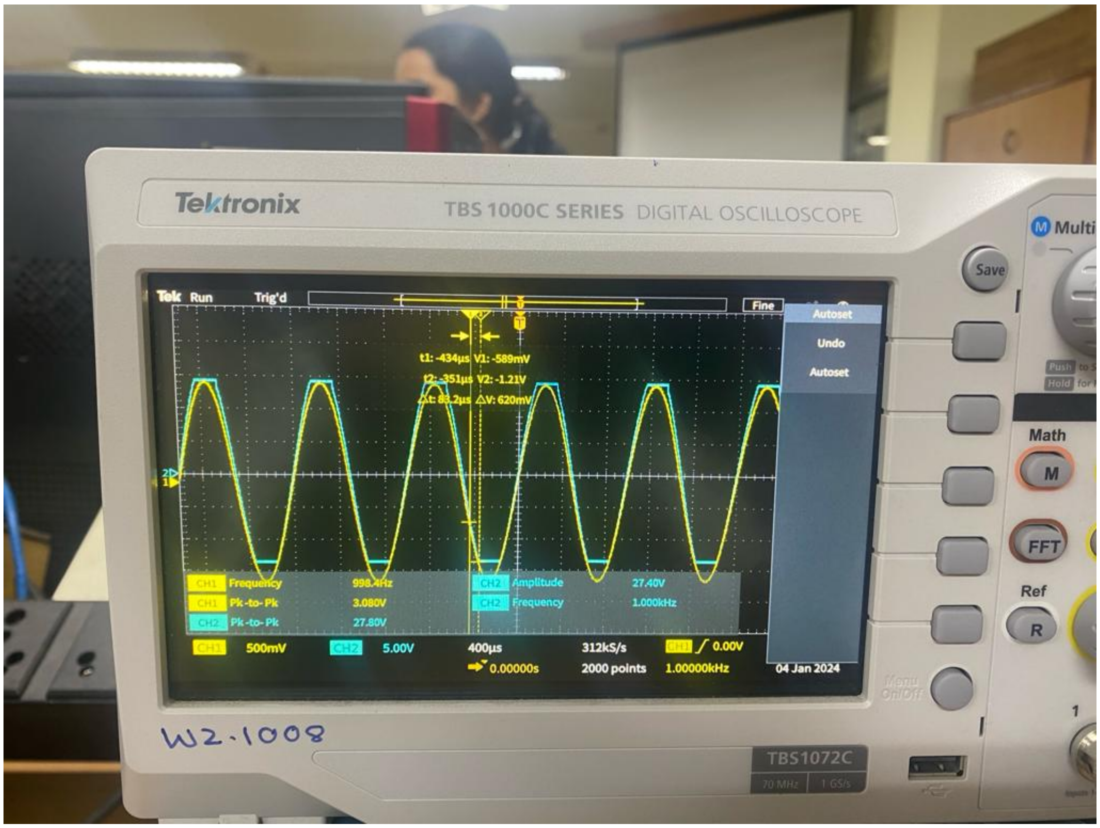


1.3.5 OpAmp based Negative feedback circuits - Non Inverting Amplifier

5 a] Input Voltage is connected to Channel 1 whereas Output Voltage is connected to Channel 2



5 b] After a particular value of input voltage, the output voltage gets clipped as it starts exceeding Vcc(Supply Voltage), due to which the OpAmp gets saturated.



1.4 Conclusion

The experiment aimed to familiarize us with RC circuits, diode-based, and Op-Amp-based simple circuits. We successfully designed an RC-based low-pass filter, observed its time and frequency response, and implemented diode-based half-wave rectifiers. Additionally, we constructed an Op-Amp-based Non-Inverting Amplifier.

The RC circuit exhibited a periodic oscillating distorted square wave in its time response, with a measured bandwidth of 2.33 kHz(time-domain) with a calculated value of 1.59 kHz(theoretical). Discrepancies in bandwidth values were attributed to inaccuracies in resistor tolerance, internal resistance/capacitance of the DSO and probes, and the internal capacitance of the breadboard.

In the frequency response, analysis revealed a measured bandwidth of 1.9 kHz, differing from calculated values due to various sources of error. The importance of considering real-world complexities in interpreting bandwidth measurements was emphasized.

The probing of the circuit demonstrated the significance of avoiding ground-related errors, and the half-wave rectifier showcased the impact of diode direction on signal rectification. The Op-Amp-based amplifier exhibited saturation beyond a certain input voltage, a natural characteristic of any Op Amp which does not allow the output to go beyond the supply, and clips the output if it tries to.

In summary, the experiment provided hands-on experience with various circuits, emphasizing the practical challenges and considerations involved in circuit design and measurement.

1.5 Inference

The experimental results highlighted the critical role of accurate component values, instrument calibration, and consideration of real-world factors in achieving precise measurements. Discrepancies between the measured and calculated values underscored the impact of resistor tolerance, internal instrument characteristics, and breadboard capacitance on circuit behavior.

Additionally, the analysis of the frequency response emphasized the need to account for potential sources of error in bandwidth measurements. Ground-related errors in probing, diode characteristics in rectification, and Op-Amp saturation limitations further demonstrated the intricacies involved in practical circuit implementations.

1.6 Experiment completion status

We successfully completed all 5 sections of the experiment on time.