EE230: Experiment 4
Precision Rectifiers

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1 Overview of the experiment

1.1 Aim of the experiment

The goal of this experiment is to analyse/understand the working of different types of rectifiers which are based on the Op-amp and the Diode interconnections and their behaviour at low and high input signal frequencies.

2 Experimental results

2.1 Simple half-wave rectifier

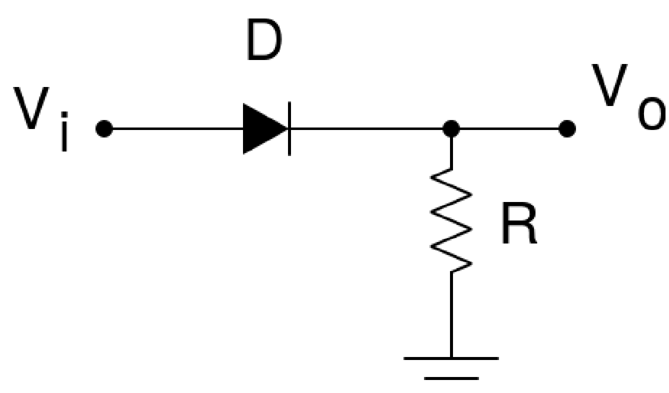

Figure 1: Half-wave rectifier

This is a simple half-wave rectifier with

$$V_o = V_i - V_{ON} \tag{1}$$

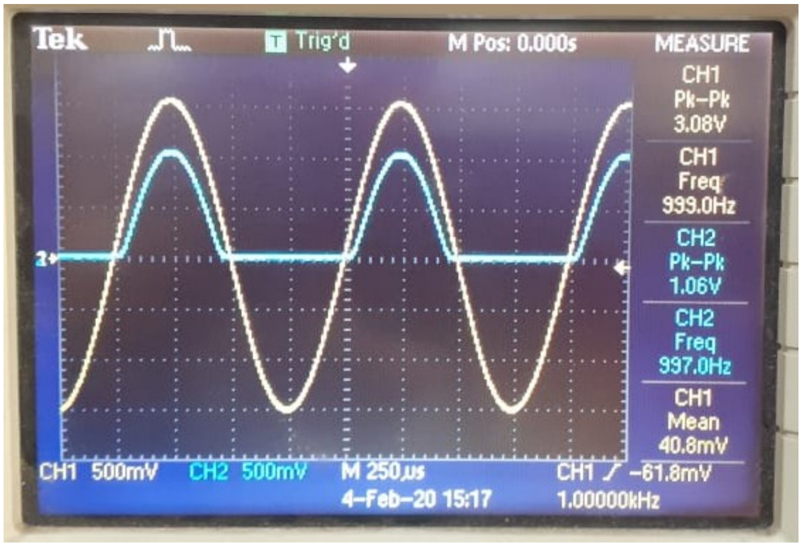

Figure 2: Waveform of simple Half-wave rectifier

From fig. 6, we get $V_o = 1.06V$ peak for $V_i = 1.54V$ peak.

$$\boxed{V_{ON} = 0.48V} \tag{2}$$

Following is the V_o vs V_i plot, the curve follows equation 1.

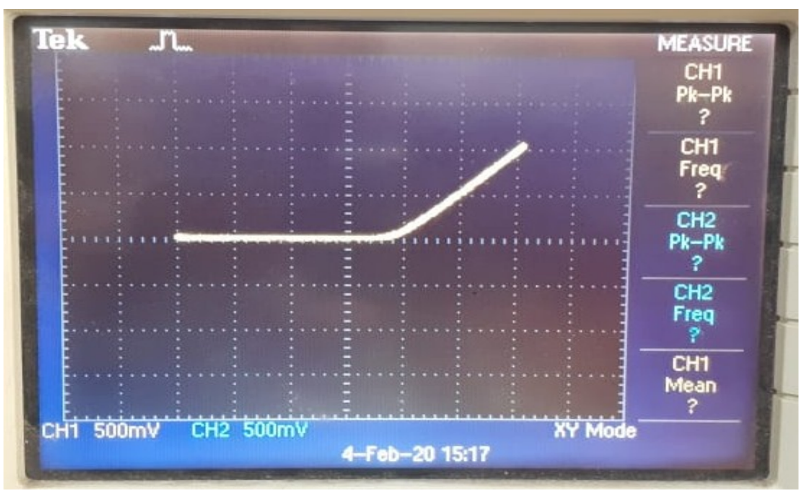

Figure 3: V_o vs V_i relationship

From figure 3, we can see that the value of V_{ON} lies between 0.4V to 0.5V

2.2 Half-wave precision rectifier

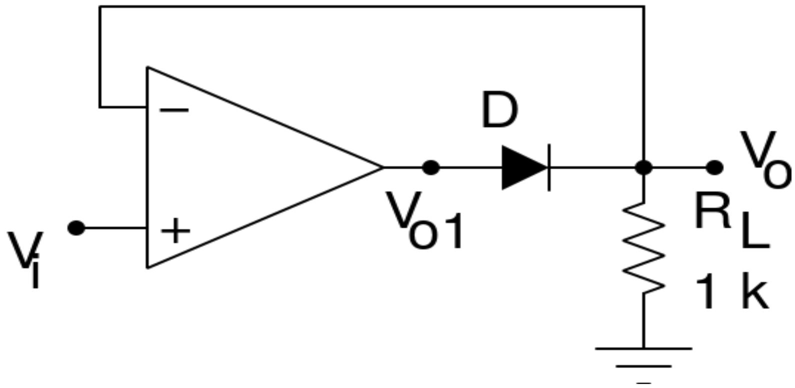

Figure 4: Half-wave precision rectifier

The actual value of resistance R_L is $0.96k\Omega$

(A) With f = 100Hz :

The observed waveform of this rectifier is:

Figure 5: Waveform of Half-wave precision rectifier

V_o vs V_i relationship comes out to be linear for $V_i > 0$, passing through origin.

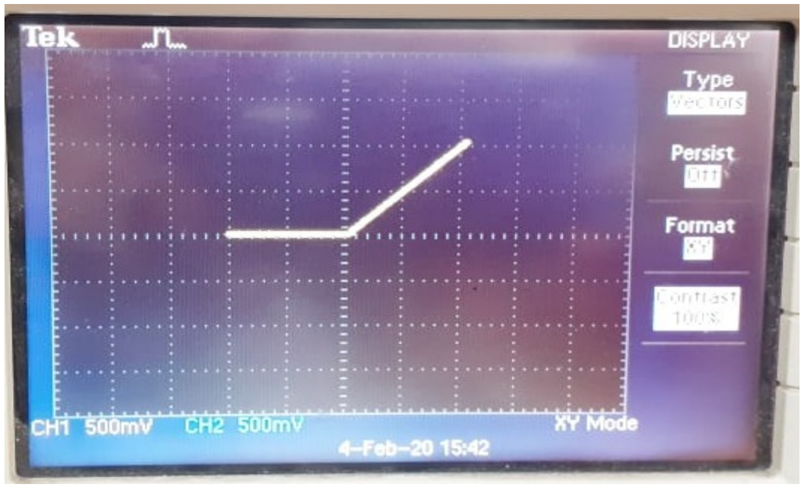

Figure 6: V_o vs V_i relationship

(B) With f = 5kHz :

The observed waveform of this rectifier is:

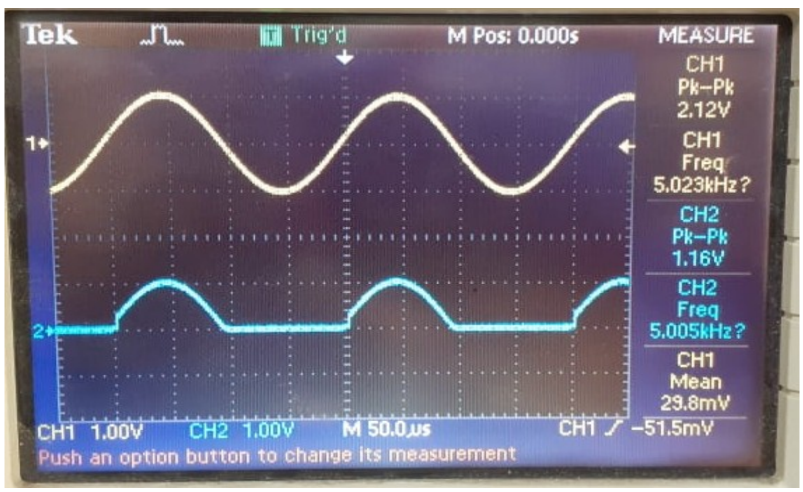

Figure 7: Waveform of Half-wave precision rectifier

The op-amp goes into saturation for $V_i < 0$. Now as $V_i > 0$, the op-amp has to come out of saturation and V_{o1} has to go from $-V_{sat}$ to some V in the linear region. Now, this process is relatively slow and it is limited by the op-amp slew rate and therefore we cannot operate the circuit at higher frequencies. We can look at the above waveform to see that there is distortion in waveform as V_i becomes positive.

2.3 Improved half-wave precision rectifier-A

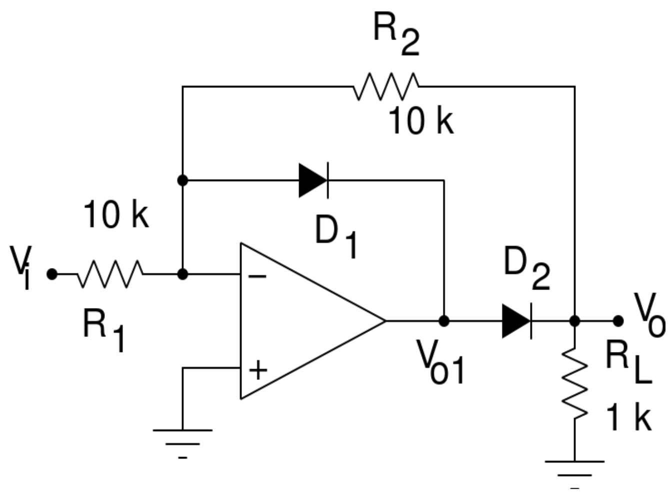

Figure 8: Improved half-wave rectifier-A

The actual resistance of resistors shown in fig 8 are, $R_1 = 9.77$, $R_2 = 9.66k\Omega$, $R_L = 0.96k\Omega$. In this rectifier, the current will flow for $V_i < 0$.

(A) f = 100Hz

The observed waveform of this rectifier is:

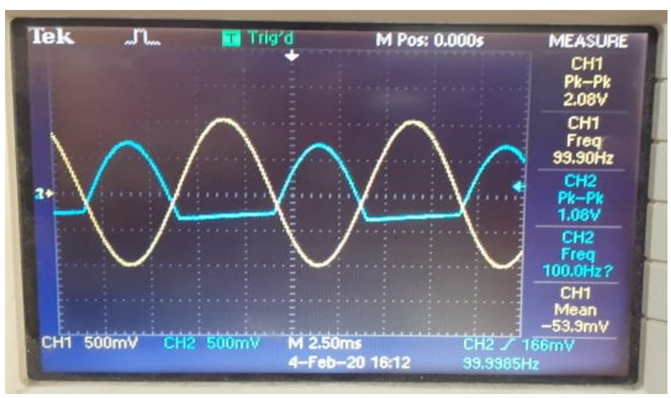

Figure 9: Waveform of Improved half-wave rectifier-A

V_o vs V_i relationship is given by

$$V_o = -\frac{R_2}{R_1} \times V_i \tag{3}$$

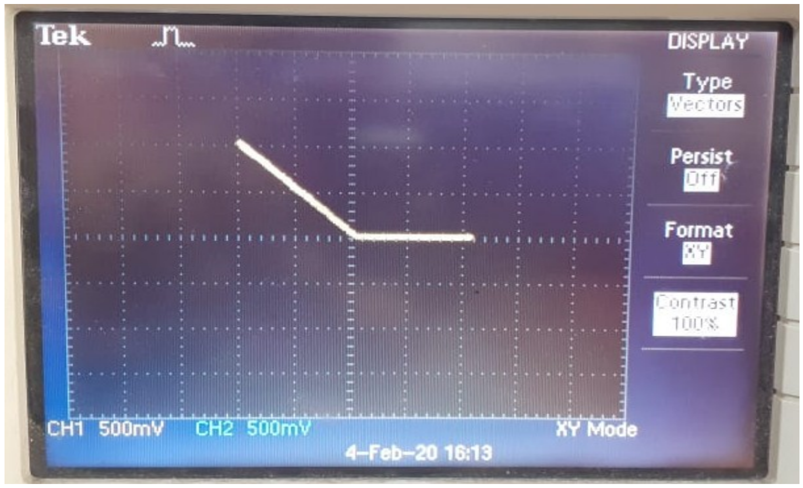

Figure 10: V_o vs V_i relationship

(B) With $\mathbf{f = 5kHz}$:

The observed waveform of this rectifier is:

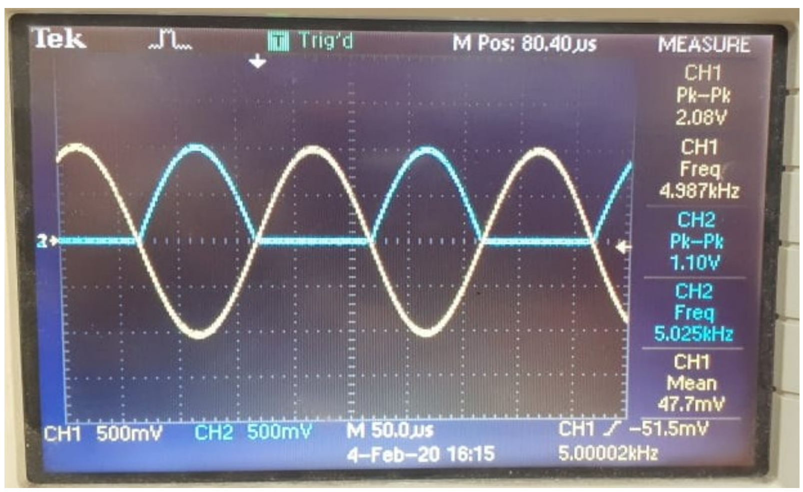

Figure 11: Waveform of Improved half-wave rectifier-A

Here the rectifier conducts for $V_i < 0$. For $V_i > 0$, V_o goes to 0 because at this point the diode D1 conducts and completes the feedback loop not allowing the op-amp to go in saturation. Therefore distortion in the waveform is absent for higher frequencies.

2.4 Improved half-wave precision rectifier-B

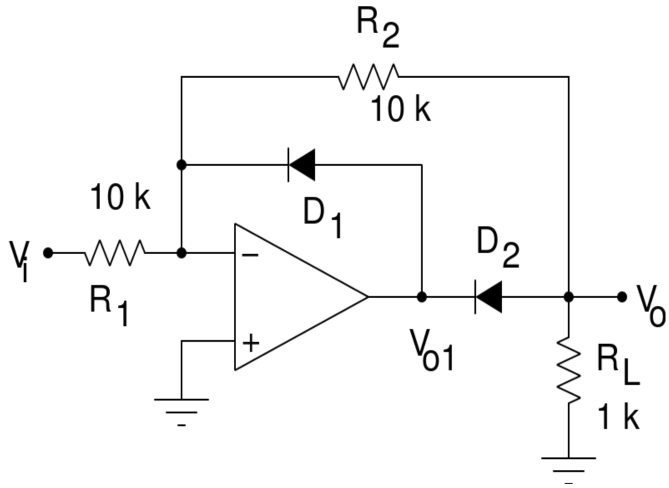

Figure 12: Improved half-wave rectifier-B

The actual resistance of resistors shown in fig 8 are, $R_1 = 9.77$, $R_2 = 9.66k\Omega$, $R_L = 0.96k\Omega$. In this rectifier, the current will flow for $V_i > 0$.

(A) f = 100Hz

The observed waveform of this rectifier is:

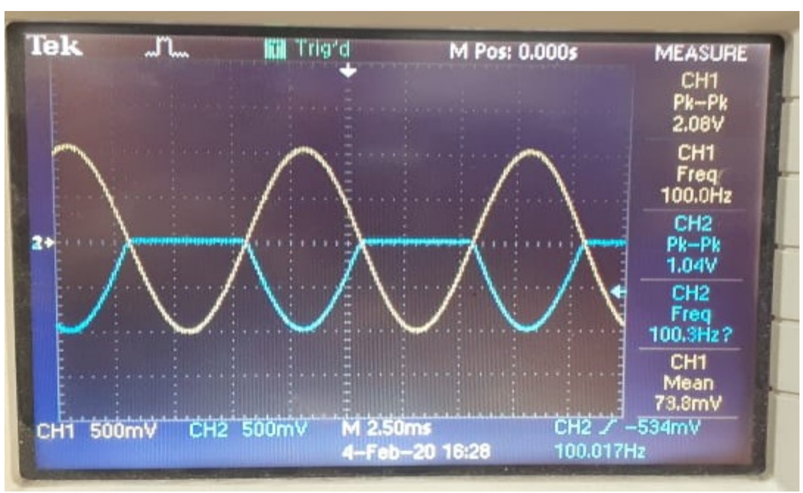

Figure 13: Waveform of Improved half-wave rectifier-B

V_o vs V_i relationship is given by

$$V_o = -\frac{R_2}{R_1} V_i \tag{4}$$

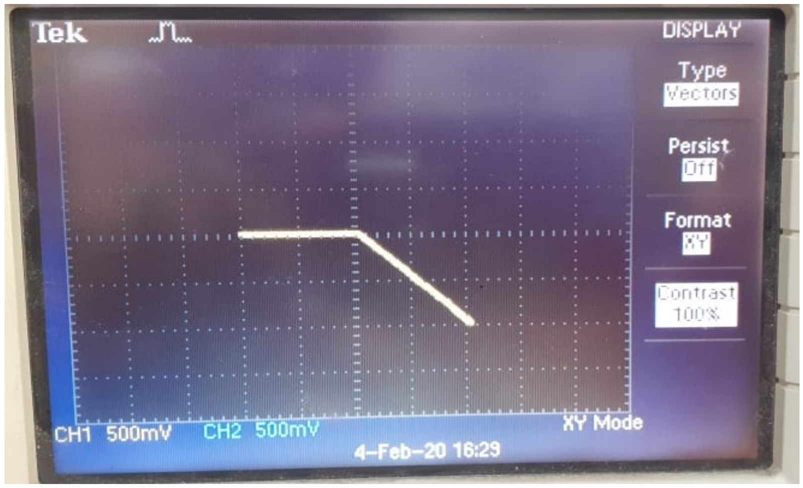

Figure 14: V_o vs V_i relationship

(B) With f = 5kHz :

The observed waveform of this rectifier is:

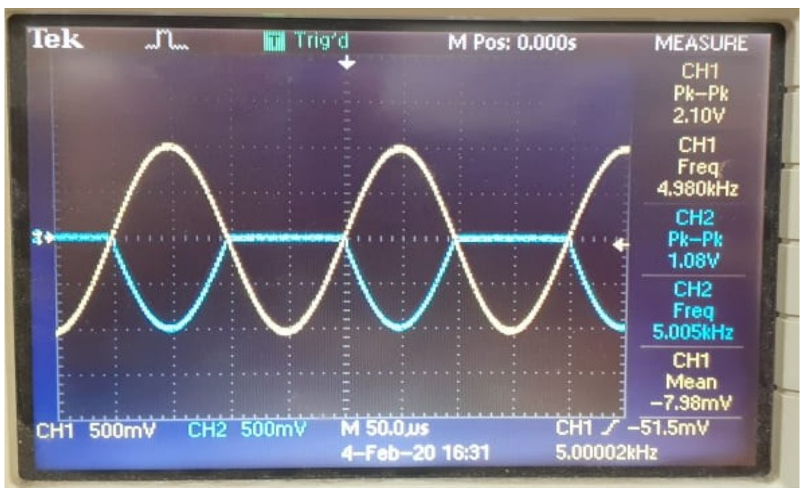

Figure 15: Waveform of Improved half-wave rectifier-B

Similar, to rectifier-A.

Here the rectifier conducts for $V_i > 0$. For $V_i < 0$, V_o goes to 0 because at this point the diode D1 conducts and completes the feedback loop not allowing the op-amp to go in saturation. Therefore distortion in the waveform is absent for higher frequencies.

2.5 Full-wave precision rectifier

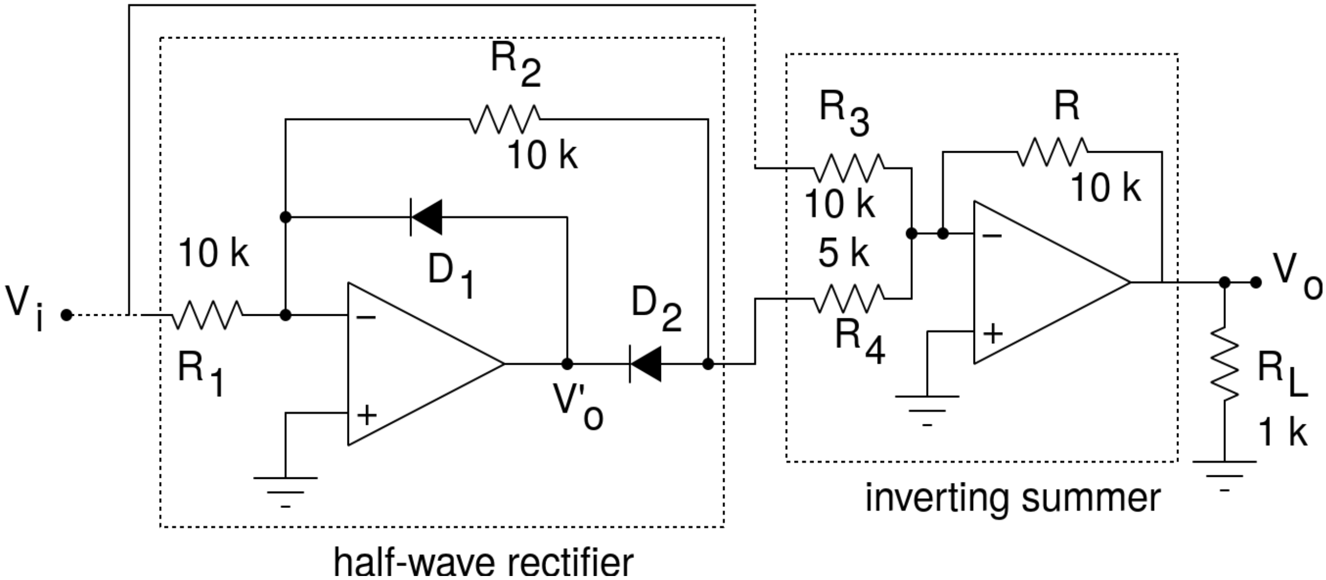

Figure 16: Full-wave precision rectifier

The full-wave rectifier is implemented by suitably combining the circuits of half-wave precision rectifier-B and of an inverting summer.

The actual resistance of resistors shown in fig 8 are, $R_1 = 9.77$, $R_2 = 9.66k\Omega$, $R_2 = 9.66k\Omega$, $R_3 = 9.88k\Omega$, $R_4 = 5.03k\Omega$, $R_L = 0.96k\Omega$.

(A) f = 100Hz

The observed waveform of this rectifier at different frequencies are:

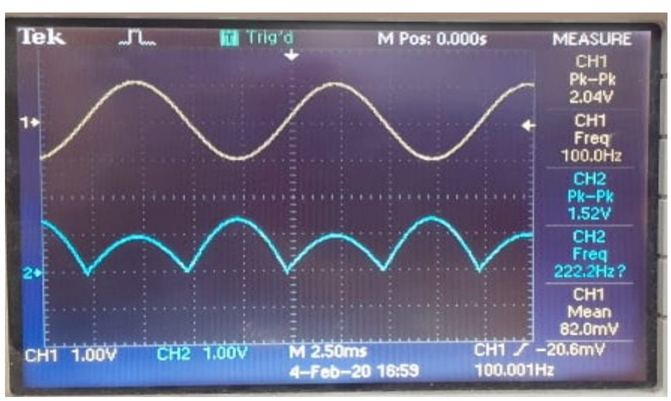

Figure 17: Waveform of Full-wave precision rectifier for f = 100Hz

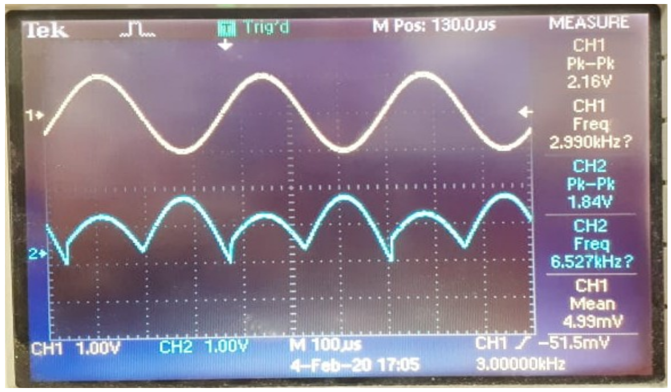

Figure 18: Waveform of Full-wave precision rectifier for f = 3kHz

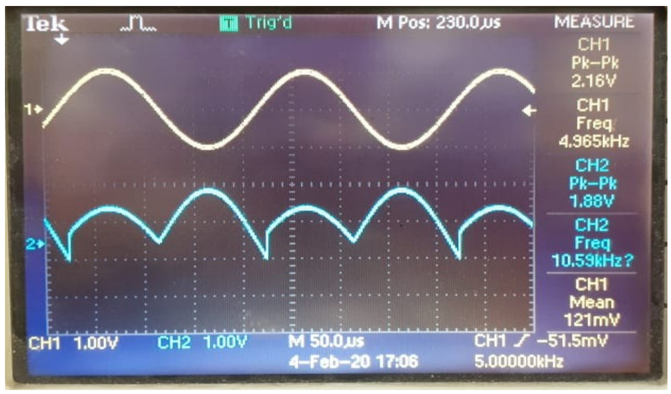

Figure 19: Waveform of Full-wave precision rectifier for f = 5kHz

V_o vs V_i relationship is given by

$$V_o = -(\frac{R}{R_3}V_i + \frac{R}{R_4}V_{o1}) \tag{5}$$

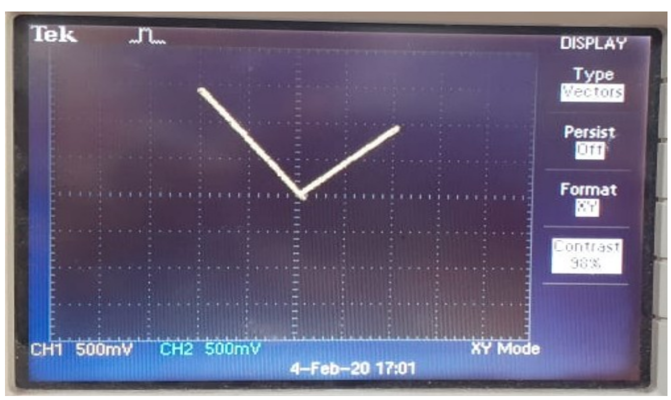

Figure 20: V_o vs V_i relationship

Ideally, R_3 and R_4 are equal to R, so the V_o vs V_i relationship comes out to be symmetric along y-axis. Since here the practical values of resistors are not same, we see unequal weightage given to V_i and V_{o1} in the inverting summer.

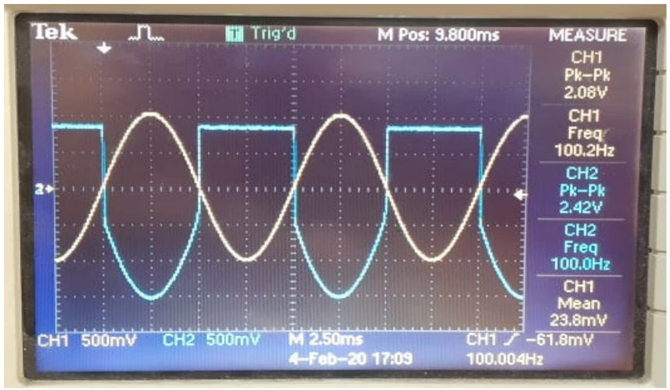

Figure 21: waveform of V_o' and V_i

The full-wave precision rectifier is in saturation region for $V_i < 0$ and is in linear region for $V_i > 0$ as is evident from the above figure.

References

[1] Rectifier supporting document
`http://wel.ee.iitb.ac.in/teaching_labs/WEL%20Site/ee230/Labsheets-2020/supporting_documents/Rectifier%20circuits.pdf`