Analog Electronic Circuits Lab - 2

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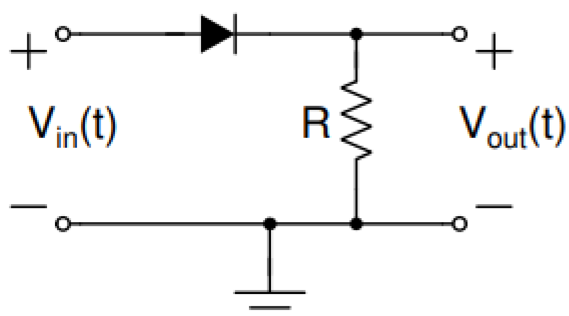
Lab-2: Diode Characterization and Applications

Materials Required:

1. Lab Notebook
2. USB Drive/Camera
3. Calculator
4. Digital Multimeter
5. Breadboard
6. Connecting Wires
7. Oscilloscope (Keysight EDUX1052G DSO)
8. Function Generator
9. Resistors (R = 1 kΩ)
10. Capacitors (47 µF, 100 µF)
11. Diodes
12. Power Supply
13. Probes (1x, 10x)

1. Diode Characteristics

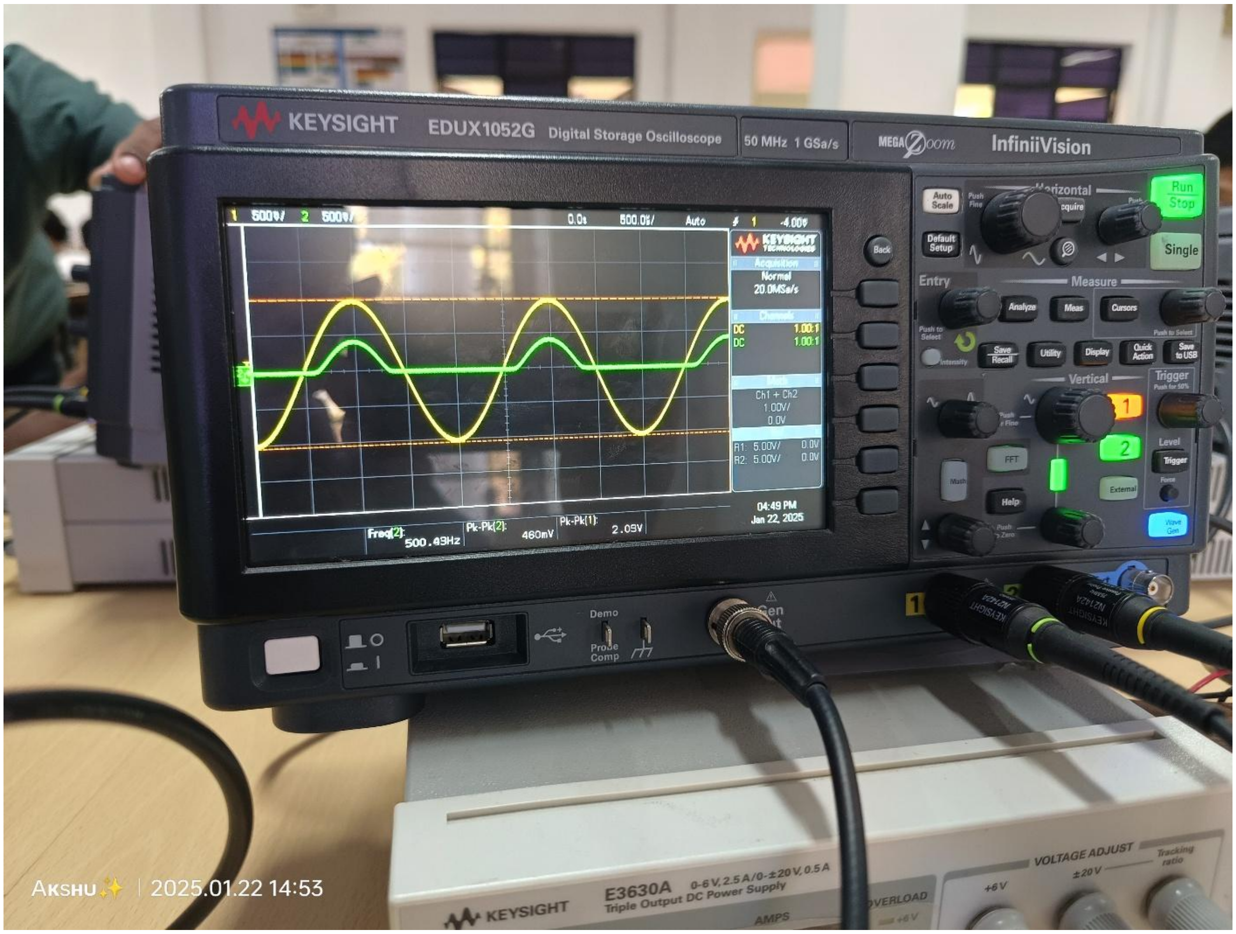
Connect the diode in forward bias as shown in Pic. Use R = 1 kΩ.



Apply a sinusoidal input signal (Vin) with amplitude 1 V

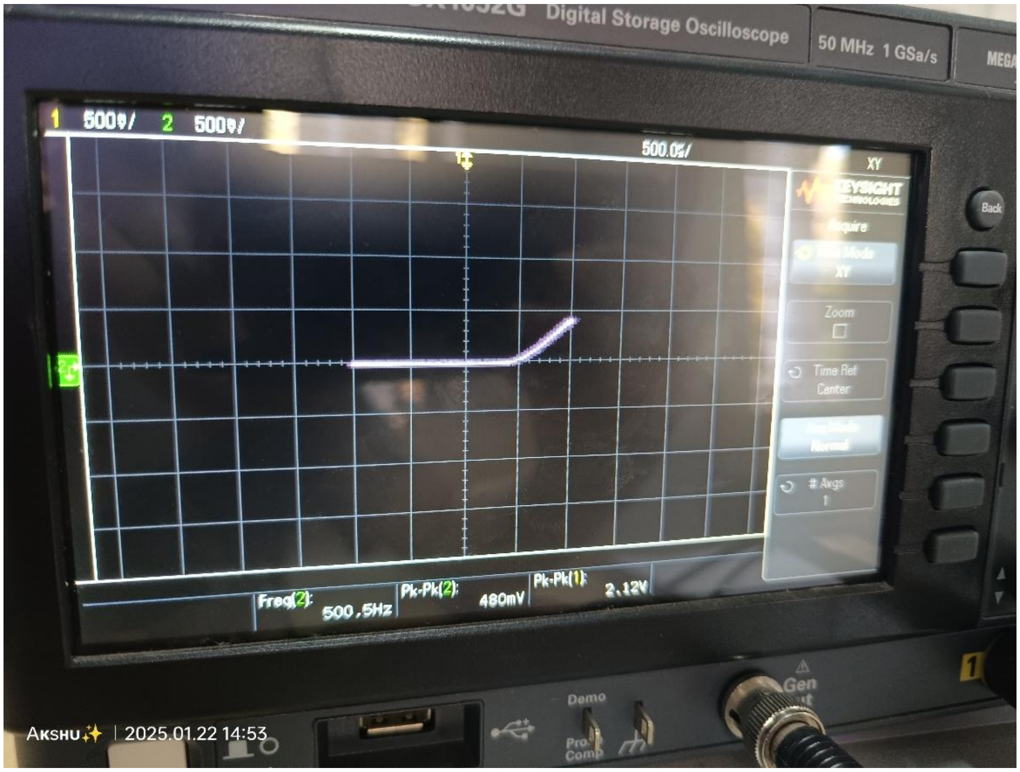
a) Half-Wave Rectification:

- The circuit behaved as a half-wave rectifier.
- Output (Vout) remained zero until Vin exceeded Vcut-in.
- For Vin > Vcut-in: $V_{out} = V_{in} - I * R$



b) Voltage Transfer Characteristics:

- X-Y mode was used to plot Vout versus Vin.
- Cut-in voltage measured using the cursor: $V_{cut-in} = 462.1mV$



c) To measure the V cut in accurately, the input and the output signal were pushed to zero by pressing the push to zero button.

Now from the V(out) vs Vin graph,

The Vin from zero at which the V(out) just starts to rise is the cut in voltage of the diode. We use cursors to find the exact/appropriate value of cut-in Voltage.

As we can see in above plot x2[V cut-in] = 462.1mV.

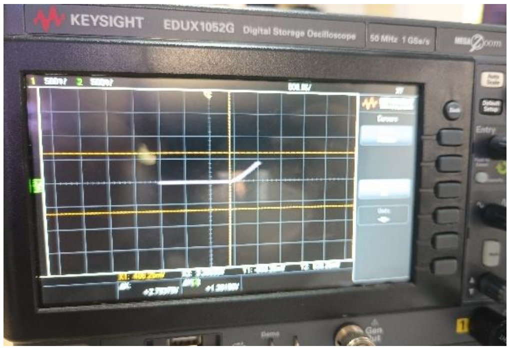
As after when vin becomes greater than Cut-in voltage then only current increases suddenly.

d) Internal Resistance (R):

Calculated as:

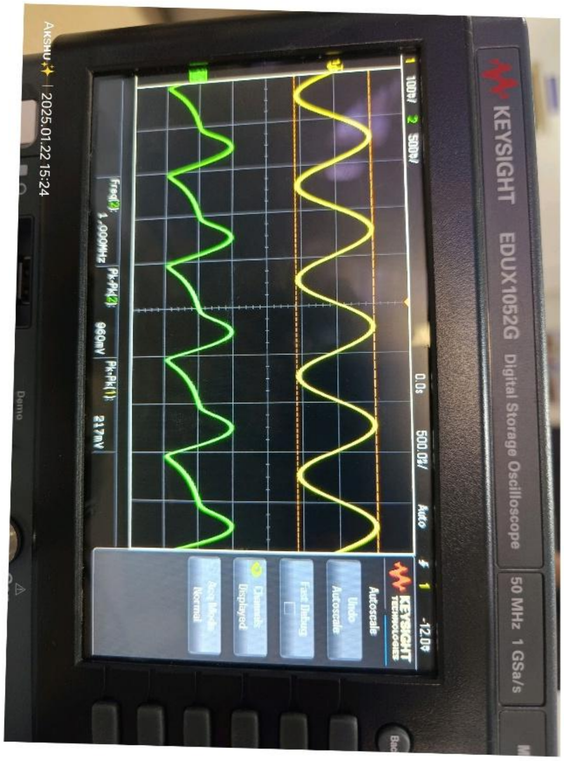
$R=R*(Vin-Vcutin-Vout)/Vout$

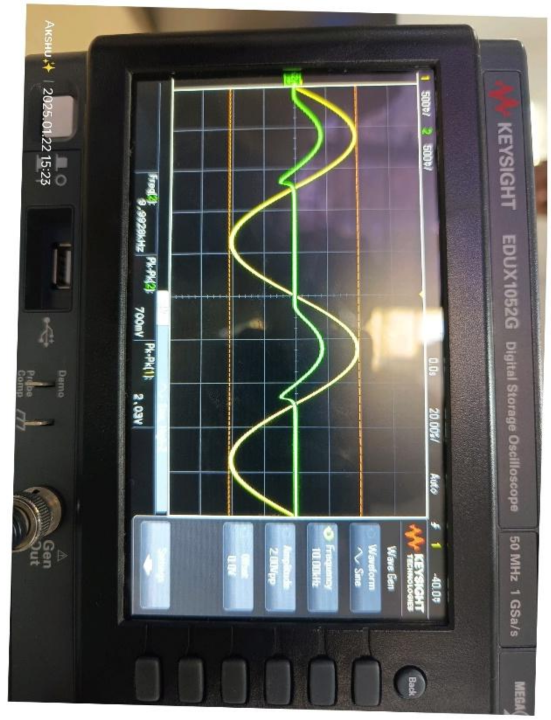
Vin (V)	Vout (V)	R (Ω)
0.55	0.09	5100
1.8	1.25	440
2.0	1.57	500

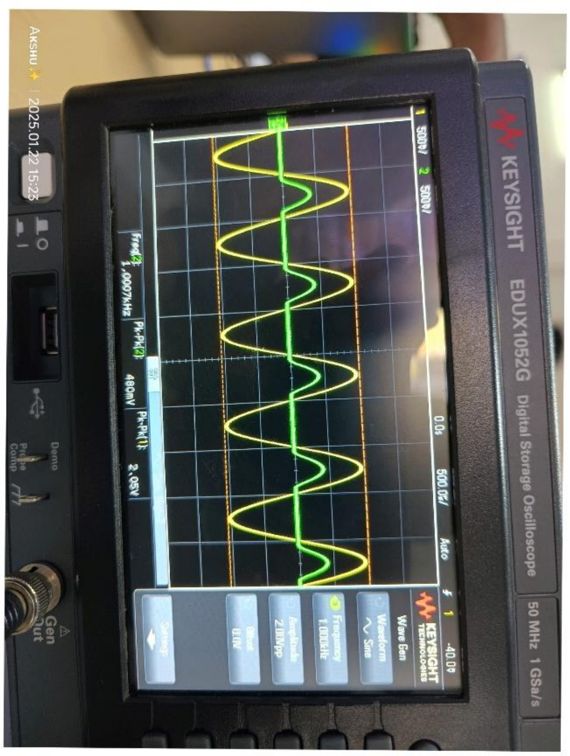


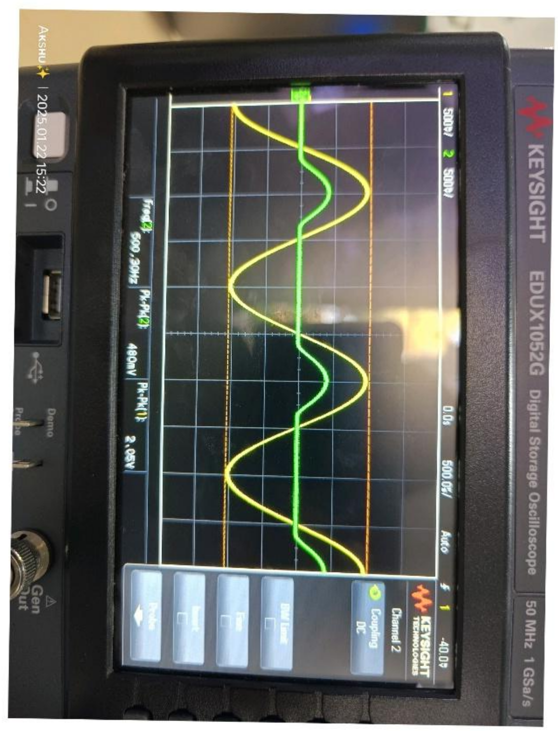
e) Transient Response:

- Observed output distortion at higher frequencies (10 kHz and above) due to diode capacitance.
- Low-frequency signals showed proper rectification.







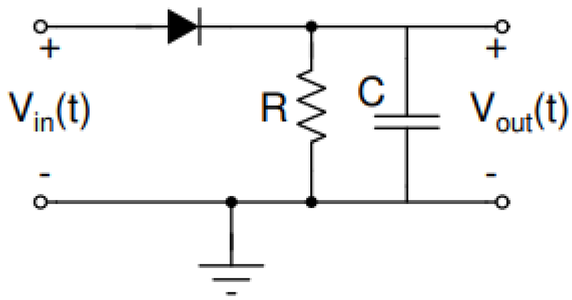


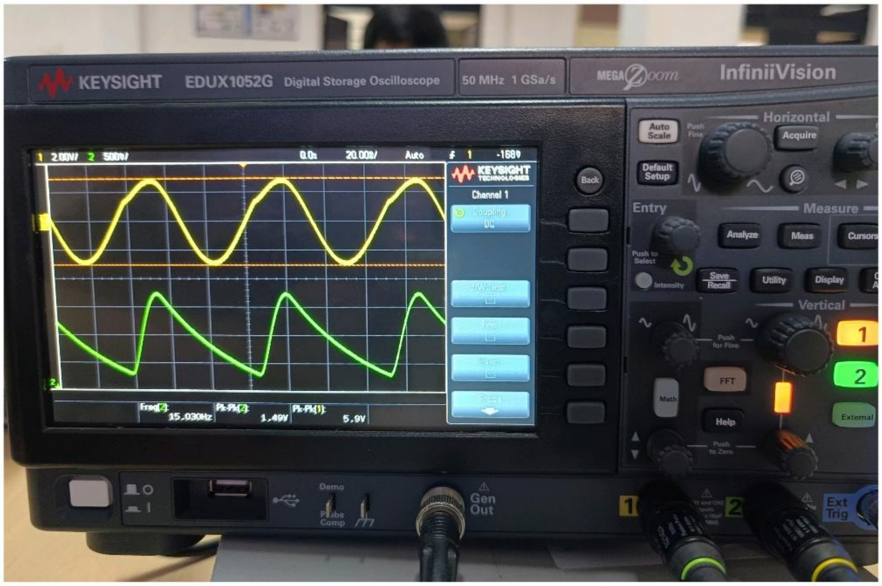
- 500 Hz: The output waveform closely followed the input signal with minimal distortion.
- 1000 Hz: The output still followed the input, though slight distortion began to appear.

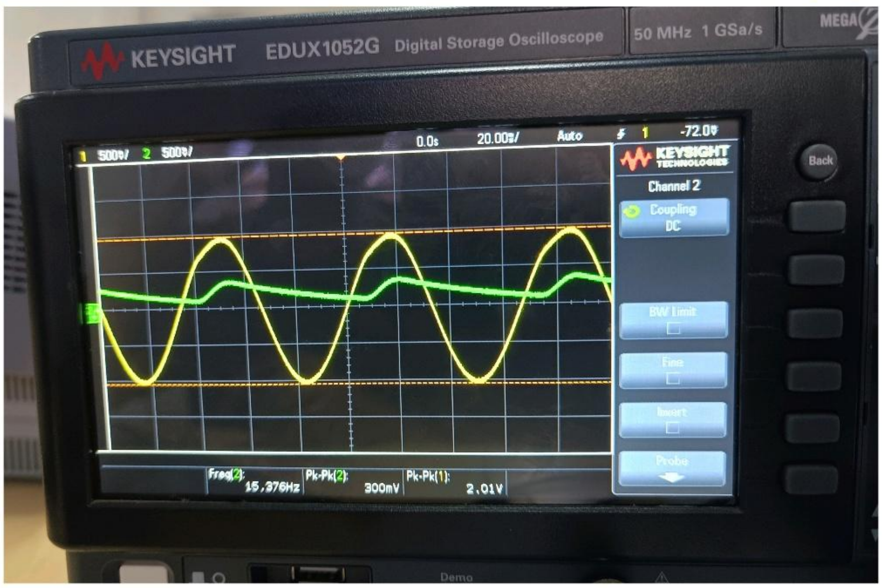
- 10 kHz: At this frequency, the output started showing more noticeable distortion due to the diode's inability to switch quickly enough.

- 1 MHz: At such a high frequency, the output became heavily distorted. This is due to the diode's internal capacitance preventing it from switching instantaneously, leading to flattened peaks in the output waveform.

f) Effect of Capacitor:







- Effect of capacitor on output voltage:

- The above two graphs are for 47 µF and 100 µF. When the input increases upto its peak value in its half period V(out) also increases proportionally to Vin. Now when Vin is peak capacitor is fully charged so as soon as Vin comes below of its peak voltage diode will be in reverse bias now. So no current flow in circuit now, and the capacitor itself discharges until the diode comes in forward bias again.
- Now if time constant is very greater than time period of input signal then only less charge is lost, i.e we can see almost a straight line while capacitor is discharging.
- Therefore by using a capacitor and connecting as shown above we will get an output which is close to a constant voltage i.e DC output.

  - Output approximated a DC voltage due to capacitor discharge during reverse bias

2. Clipper Circuits

Clipping circuits are used to limit the amplitude of an input signal to a predefined range. These circuits are essential in various applications such as waveform shaping, signal protection, and signal conditioning. The main components in a clipping circuit are diodes, which conduct when the input signal exceeds a certain threshold. In this experiment, two clipping circuits are analyzed: one with two diodes connected in parallel but opposite directions with a DC bias voltage, and another circuit using a resistor and diode with varying bias voltage.

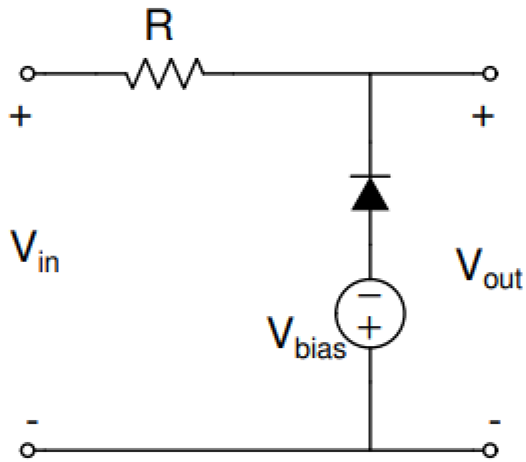


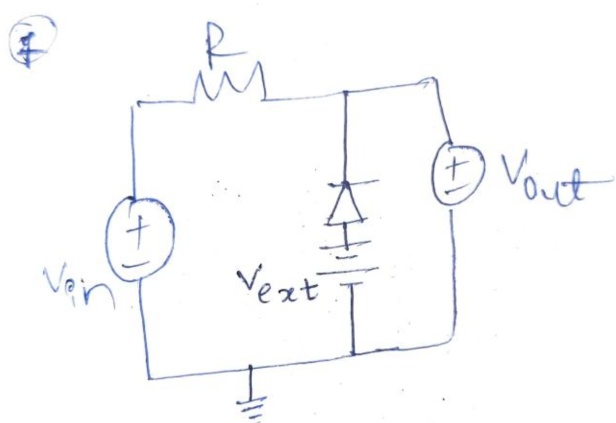
Figure 7: Negative Bias

A) **. Circuit Description**

In this modified configuration:

- The positions of the resistor and diode are swapped compared to the previous circuit.
- VbiasV_{bias}Vbias: A DC bias voltage is applied using a power supply. This bias voltage determines the clipping level.
- The input voltage (VinV_{in}Vin) is applied across the resistor and diode, and the output voltage (VoutV_{out}Vout) is measured across the diode.

B).



$$V_{out} = \begin{cases} V_{in} \text{ if } & V_{in} < V_{ext} \\ V_{ext} \text{ if } & V_{in} \geq V_{ext} \end{cases}$$

When we send a sine wave into the circuit through the WaveGen, we observe that depending on the direction of the applied external voltage and the diode’s direction a certain part of the input signal gets clipped, we derive equations for each and every case below

When the resistor and diode are switched in the circuit:

1. **Effect of Varying Bias Voltage:**
   - By adjusting the external bias voltage using the DC power supply, the diode conducts only when the input voltage exceeds the external bias.
   - Positive or negative bias voltage causes clipping of the input signal's half-cycle depending on the diode's direction and the applied bias voltage**.**
2. **Clipping Behavior:**
   - For positive bias, the upper half-cycle is clipped.
   - For negative bias, the lower half-cycle is clipped.
3. **Transfer Characteristics:**
   - The output voltage follows the input voltage until the input exceeds the bias voltage, after which clipping occurs.
   - The transfer function is validated by comparing the input-output relationship, which is consistent with the previously derived expression.
4. **Verification with Oscilloscope:**
   - The transfer characteristics can be verified using the XY mode on the oscilloscope by varying the DC bias voltage and observing the output waveforms.

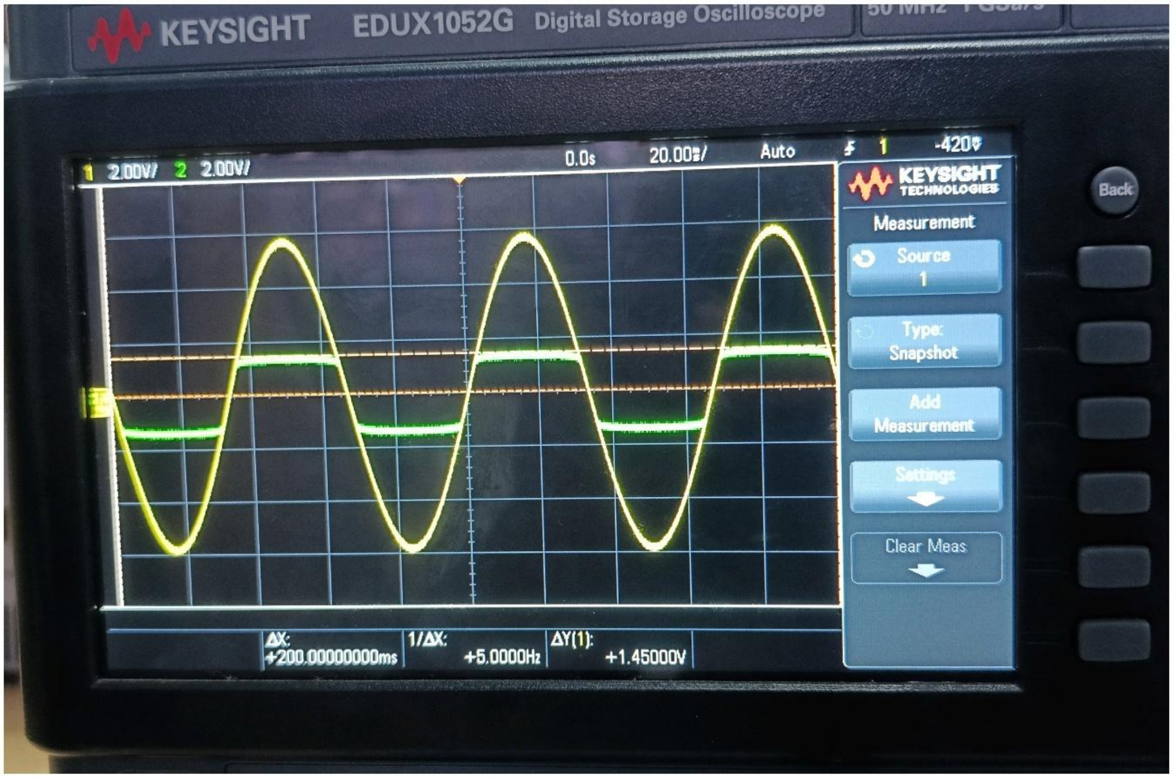
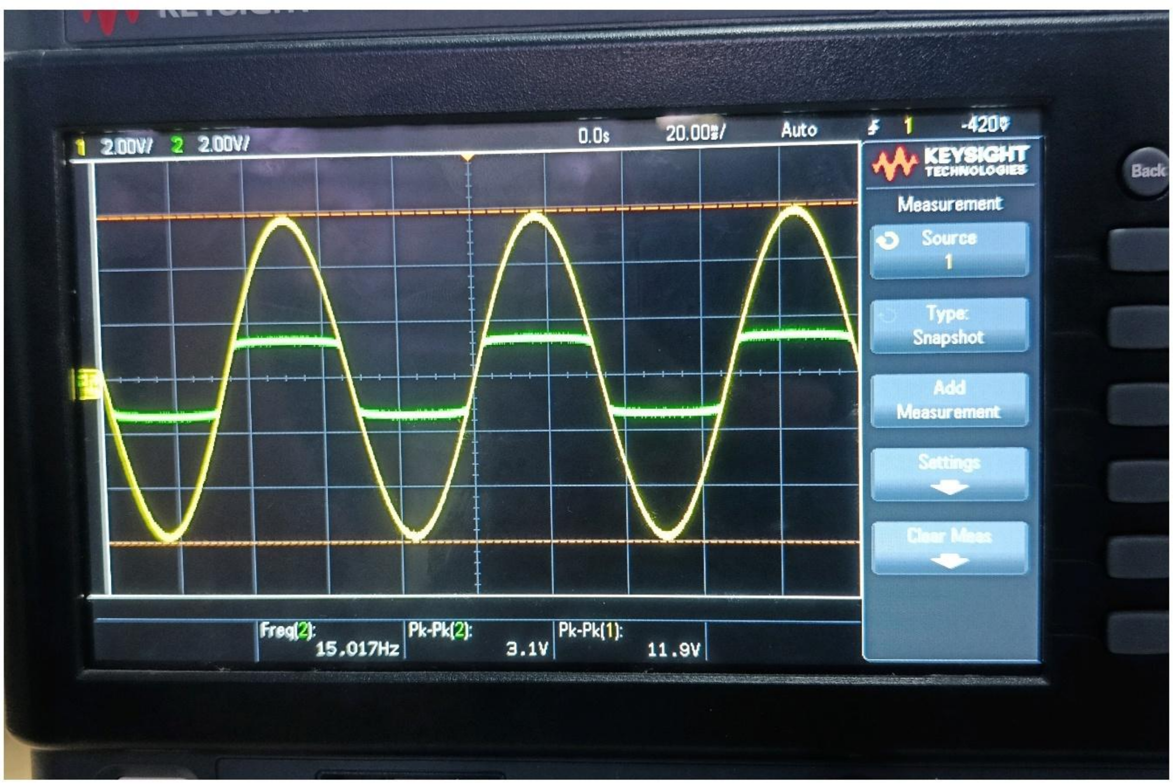
C)

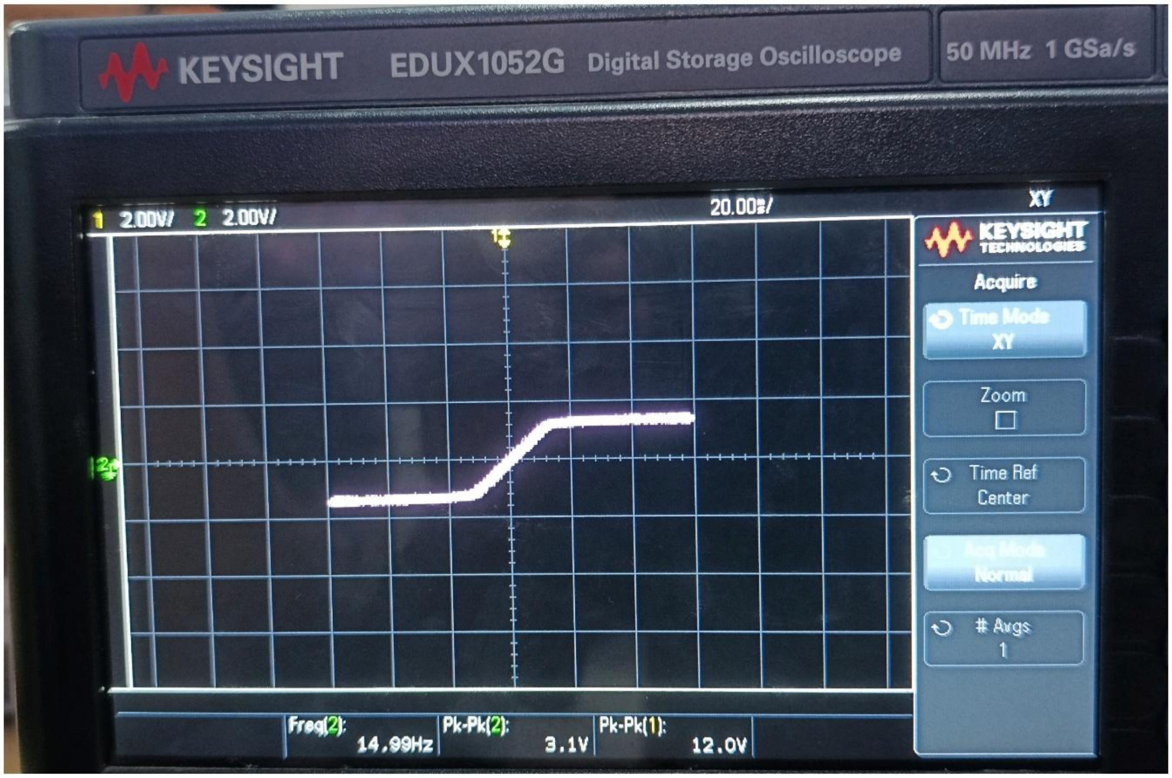
2. **Deriving Transfer Characteristics:**
   - Observed the waveform in Figure 9.
   - Derived transfer characteristics for clipping at ±1.5 V.
3. **Circuit Modification:**
   - Modified the circuit in Figure 7 by adding zener diodes to clip both positive and negative half cycles.
   - Ensured clipping levels were set at ±1.5 V using appropriate zener diodes.
4. **Circuit Description:**
   - Two diodes are connected in opposite directions with bias voltages of ±1.5 V.
   - The input Vin(pp)=12 V is applied, and the circuit clips both the positive and negative peaks.
5. **Observation:**
   - The **positive half-cycle** is clipped at +1.5 V.
   - The **negative half-cycle** is clipped at −1.5 V.

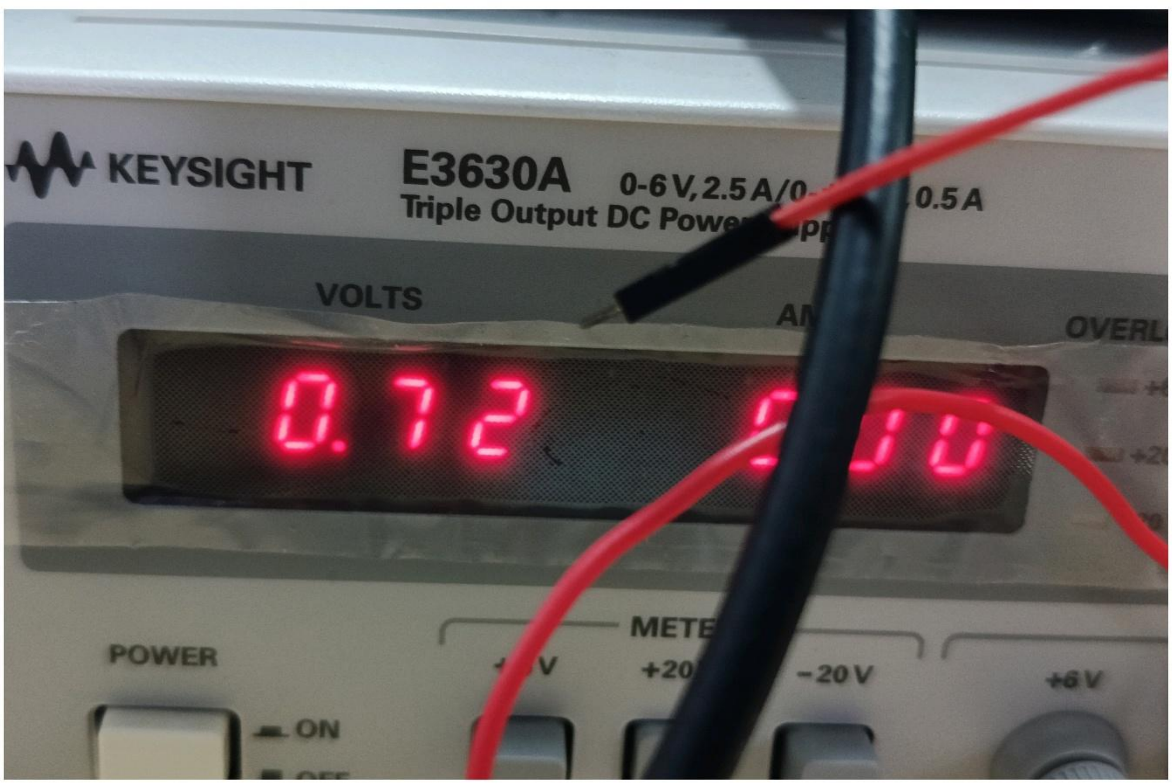
6. **Expression for Transfer Characteristics:**

Vout =

$\{+1.5\ V == \text{if } Vin>1.5\ V\ ,\ Vin == \text{if } -1.5\ V \le Vin \le 1.5V\ ,\ -1.5\ V==\text{if } Vin<-1.5\ V.\}$


KEYSIGHT
EDUX1052G Digital Storage Oscilloscope
1 2.00V/ 2 2.00V/
0.0s
Auto
-420
Measurement
Source 1
Type: Snapshot
Add Measurement
Settings
Clear Meas
Back
ΔX: +200.00000000ms
1/ΔX: +5.0000Hz
ΔY(1): +1.45000V

1 2.00V/ 2 2.00V/
0.0s
Auto
-420
Measurement
Source 1
Type: Snapshot
Add Measurement
Settings
Clear Meas
Back
Freq(2): 15.017Hz
Pk-Pk(2): 3.1V
Pk-Pk(1): 11.9V


KEYSIGHT
EDUX1052G Digital Storage Oscilloscope
50 MHz 1 GSa/s
1 2.00V/ 2 2.00V/
XY
KEYSIGHT TECHNOLOGIES
Acquire
Time Mode XY
Zoom
Time Ref Center
Acq Mode Normal
Avgs 1
Freq(2): 14.99Hz
Pk-Pk(2): 3.1V
Pk-Pk(1): 12.0V

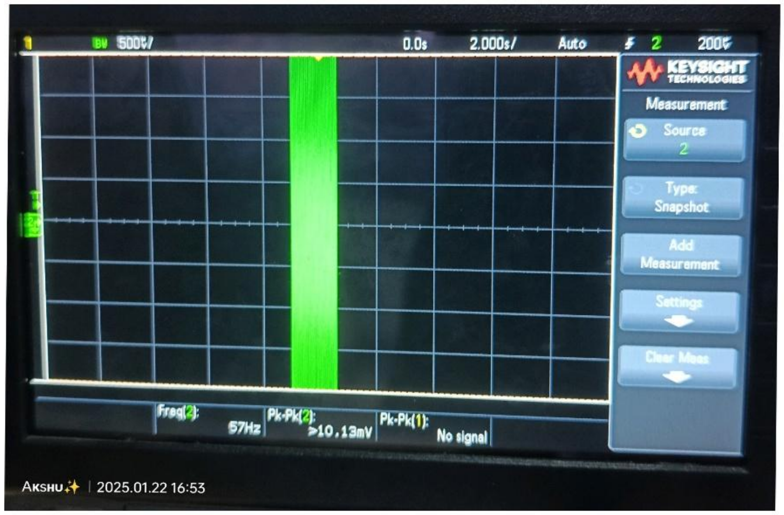

KEYSIGHT
E3630A
VOLTS
0.72
POWER
ON
-20 V
+6V

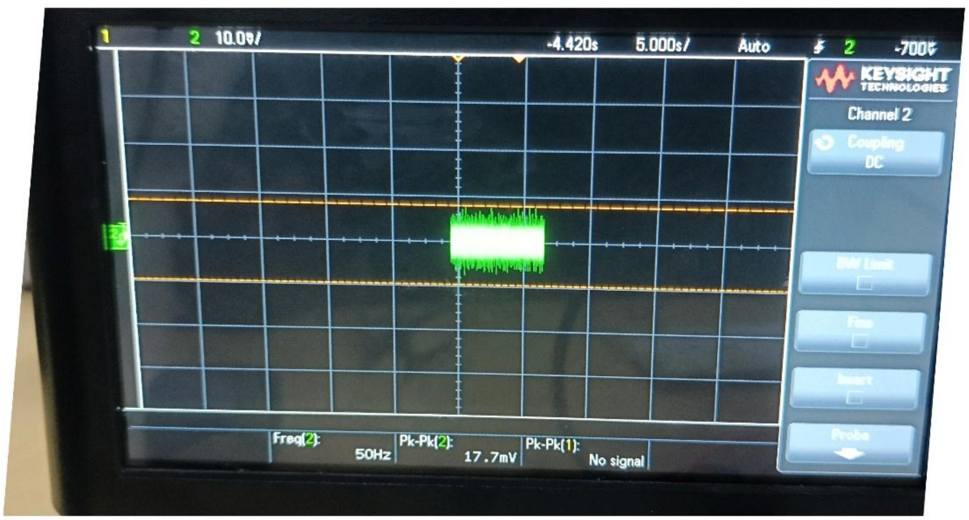
3. Application of Diode in Energy Harvesting

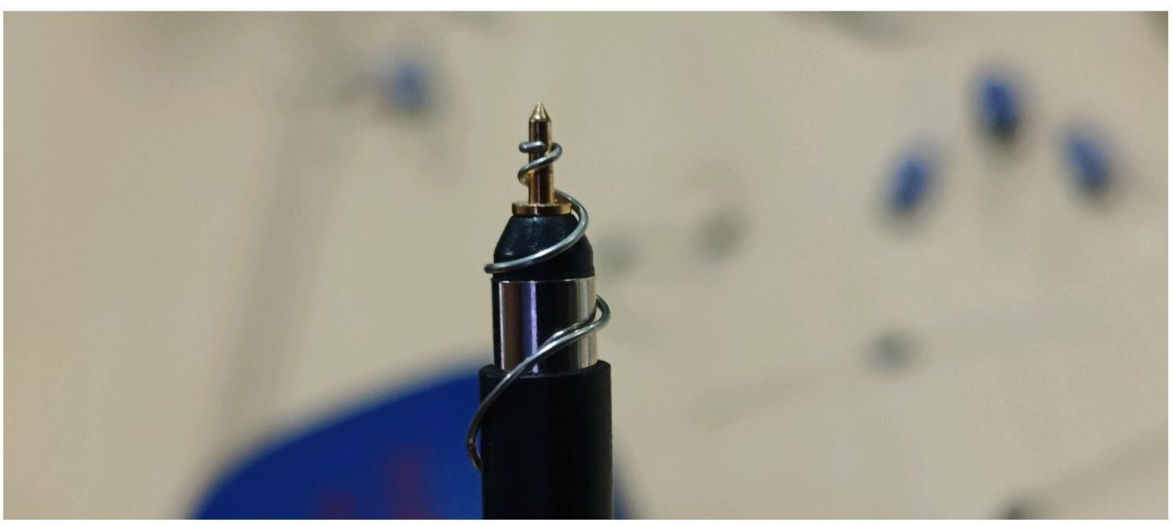
• Measure the amplitude and frequency of a 50 Hz noise signal using an oscilloscope.

• Build a simple energy harvester circuit using a diode and capacitor.

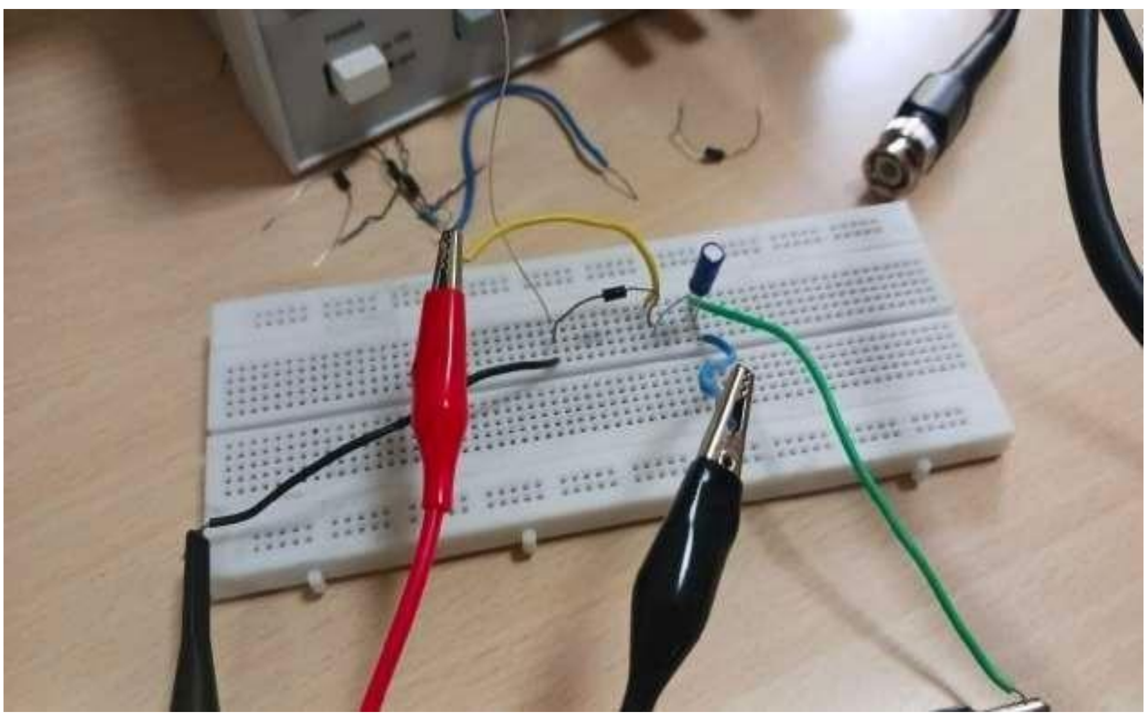
• Record and observe changes in Vout as the circuit stores and discharges energy.







Probe when set coiled :



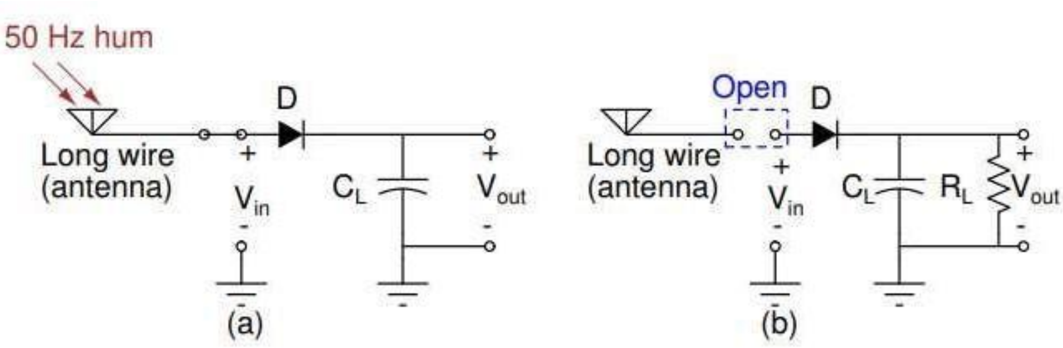


Figure 6

Connect a diode and a capacitor of capacitance CL = 47 μF. Short both terminals of the capacitor to ground to discharge it.

Connect an oscillator probe at the output and observe that the voltage is zero. Connect a large wire to the circuit and measure the amplitude of the 50 Hz signal using another channel of the oscilloscope.

Connect the large wire (antenna) to the input of the circuit as shown in Fig. 6(a). Observe V(out), which should rise as energy is harvested from the environment. When V(out) reaches 400 mV, disconnect the long wire (antenna) from the input as shown in Fig. 6(b).

The capacitor CL should hold this value for some time as energy is stored in it from the environment, but it will slowly start reducing due to leakage.

Once the voltage drops to 300 mV, connect a resistance RL = 1 kΩ to the circuit. Observe how V(out) changes now and what its final value is.

We can observe a gradual decay of the capacitor voltage while the current flows through the load. By doing so, we have effectively stored energy harvested from the environment and employed it as a source of power similar to that of a battery.