Experiment 01

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Abstract
In Experiment-05, we used an Op-amp to make a weighted summing amplifier circuit, an integrator circuit, and a precision rectifier circuit.

1 Part 1 - Custom Weighted summing and difference amplifier

1.1 Objective

To implement the mathematical functions in an inverting amplifier circuit with properly chosen resistors.

$$V_{out} = 2V_1 + V_2 - V_3$$
$$V_{out} = 2V_1 - V_3$$

1.2 Apparatus

- Op-amp (we used LM358)
- Resistors [$R_1 = R$, $R_2 = 2R$, $R_3 = R$, $R_f = 2R$, where we used $R = 10k\Omega$]
- Oscilloscope
- Two channel function generator
- DC power supply
- Connecting wires and probes

1.3 Theory

A weighted summing amplifier is a circuit that outputs a linear combination of multiple input voltages with different weightings. It is typically implemented using an operational amplifier (op-amp) in the inverting configuration.

An inverting summing amplifier follows the general equation:

$$V_{out} = -R_f \left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} \right) \tag{1}$$

where:

- V_1, V_2, V_3 are the input voltages,
- R_1, R_2, R_3 are the corresponding input resistances,
- R_f is the feedback resistance.

For the given equations:

Circuit for $V_{out} = 2V_1 + V_2 - V_3$
To achieve the required weighting, we select:

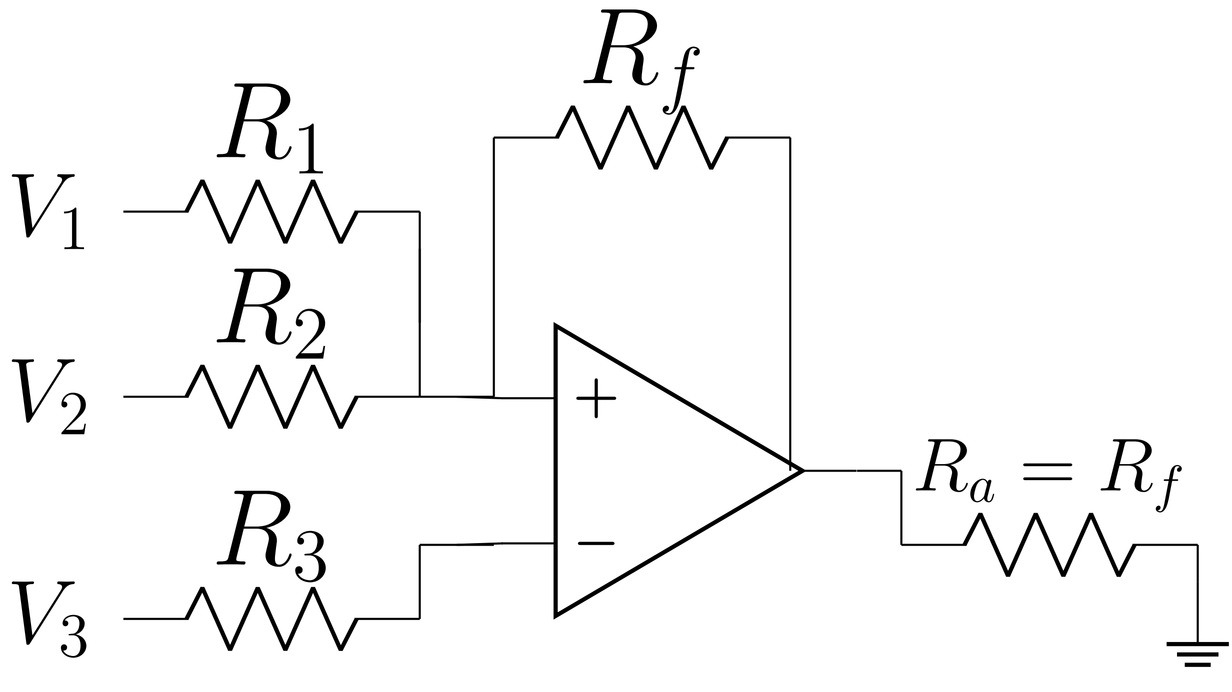
$$R_1 = R, \quad R_2 = 2R, \quad R_3 = R, \quad R_f = 2R. \tag{2}$$

Substituting into the summing amplifier equation:

$$V_{out} = -2V_1 - V_2 + V_3.$$

To correct the sign, we add a second inverting stage to obtain:

$$V_{out} = 2V_1 + V_2 - V_3.$$



Circuit for $V_{out} = 2V_1 - V_3$
For this equation, we use:

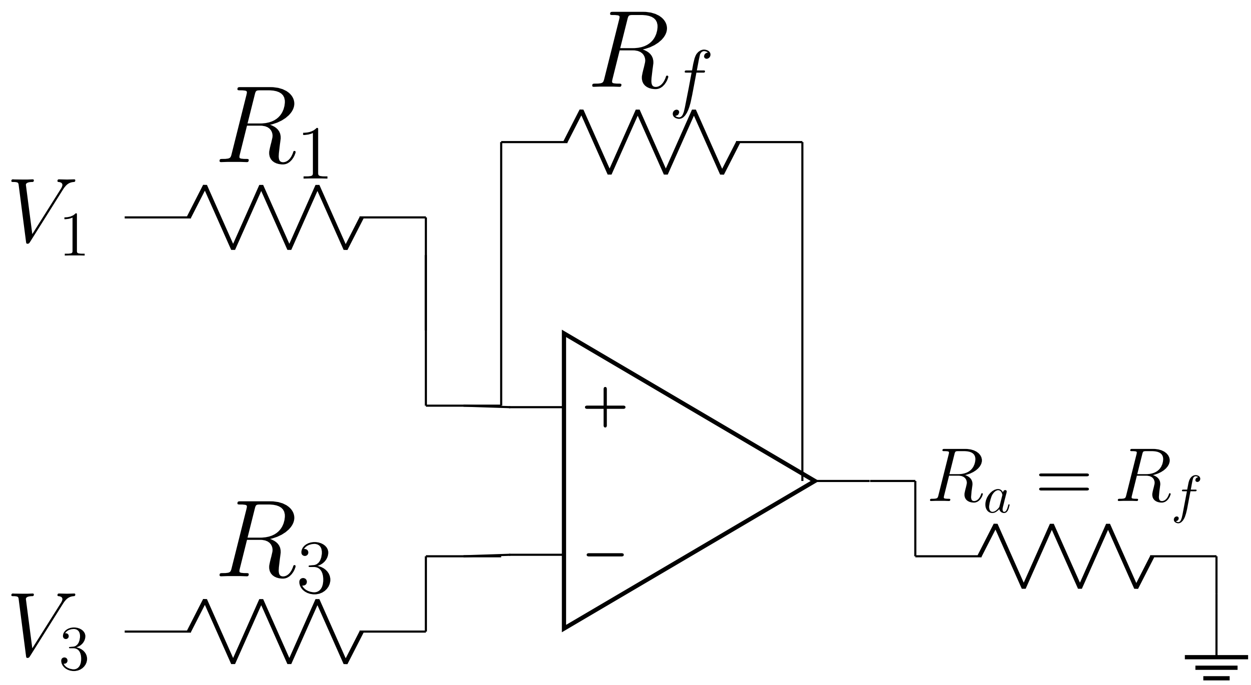
$$R_1 = R, \quad R_3 = R, \quad R_f = 2R. \tag{3}$$

Substituting:

$$V_{out} = -2V_1 + V_3.$$

Adding an additional inverting stage:

$$V_{out} = 2V_1 - V_3.$$



1.4 Procedure

1. IC
   - Use the datasheet of your Op-amp to know the function of its pins and specifications.
   - Ensure the supply voltages V_+ and V_- being provided are within the recommended range in the datasheet, before you turn them onWe used +15V and -15V.
2. Circuit
   - Make the circuits as shown in the theory section using the right pins of the Op-amp, resistors, and connecting wires.
   - Use function generator and DC power supply to make the desired V_1, V_2, and V_3.
   - Apply the voltages and grounds to the circuit to complete it.
3. Oscilloscope: Use the probe to measure voltage at Op-amp output, i.e. across R_a

1.5 Demonstration

Figure 1: $2V_1 + V_2 - V_3$(approximately), V_1, V_2 on the function generator, V_3 from the DC supply(right)

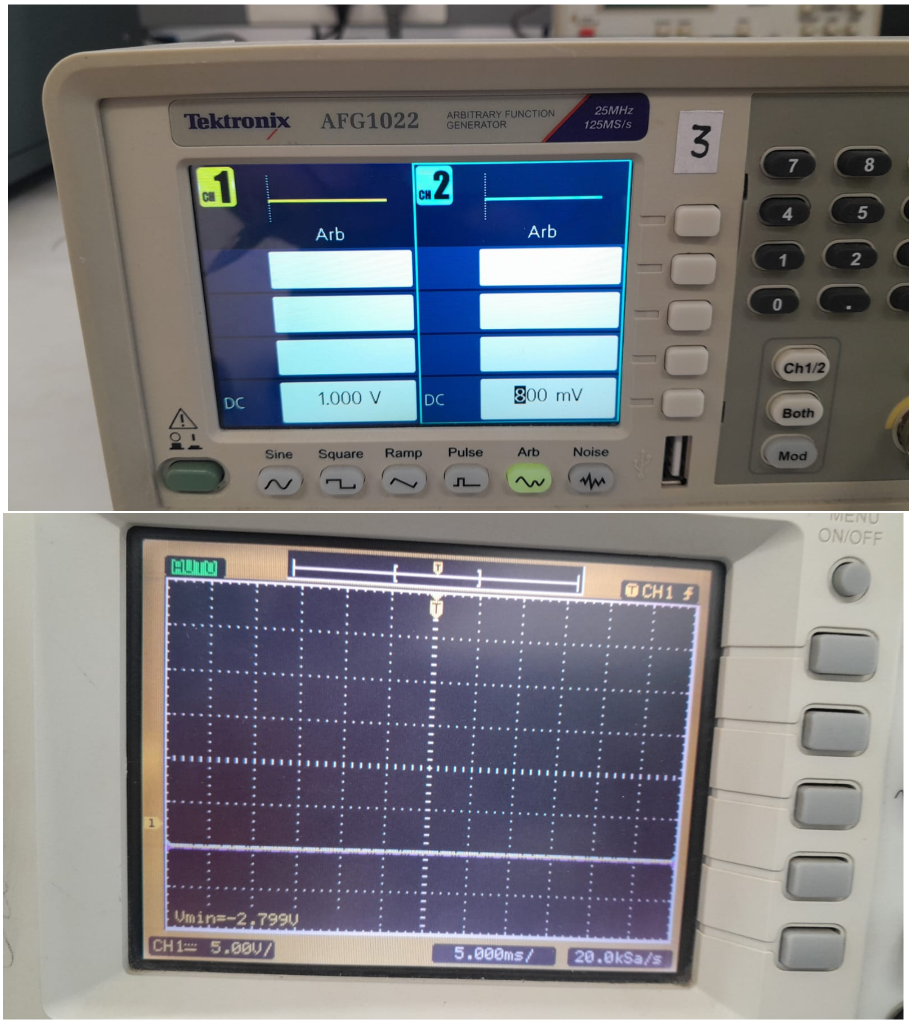


Figure 2: $2V_1 + V_2$, V_1, V_2 on the function generator

1.6 Conclusion

We used an Op-amp inverting amplifier to carry out weighted sums of our desired voltages. Our input voltage ranges were limited by the chosen Op-amp compoment, and the circuit would only work if the output volate was within the supply range.

2 Part 2 - Op-Amp Integrator

2.1 Objective

To design and implement an op-amp integrator circuit that performs mathematical integration of an input voltage signal.

2.2 Apparatus

- Op-amp (we used LM358)
- Resistors R (value to be determined)

- Capacitor C (value to be determined)
- Oscilloscope
- Function generator
- DC power supply
- Connecting wires and probes

2.3 Theory

An op-amp integrator is a circuit that produces an output proportional to the time integral of the input voltage. It is implemented using an operational amplifier with a capacitor in the feedback path and a resistor at the input.

The general equation for an ideal inverting integrator is:

$$V_{out} = -\frac{1}{RC} \int V_{in} dt \tag{4}$$

where:

- V_{in} is the input voltage,
- R is the input resistance,
- C is the feedback capacitance,
- V_{out} is the integrated output voltage.

To design the circuit, we choose appropriate values for R and C to achieve the desired time constant $\tau = RC$.

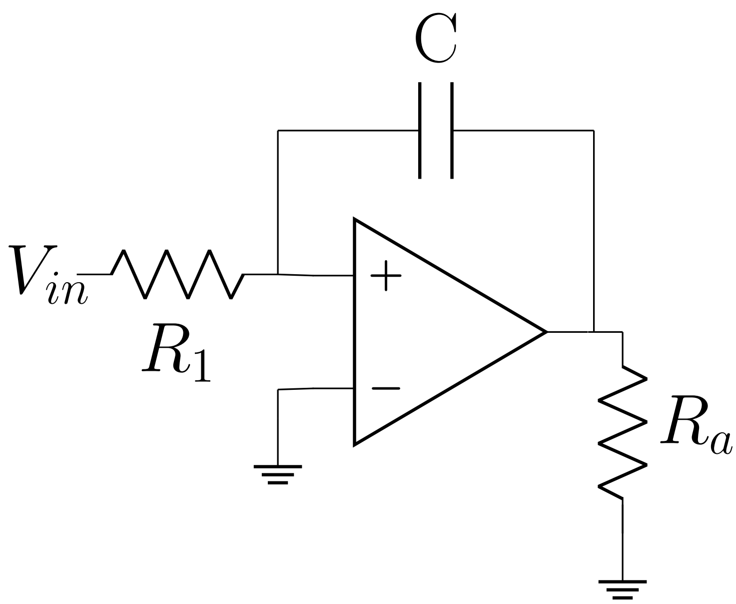
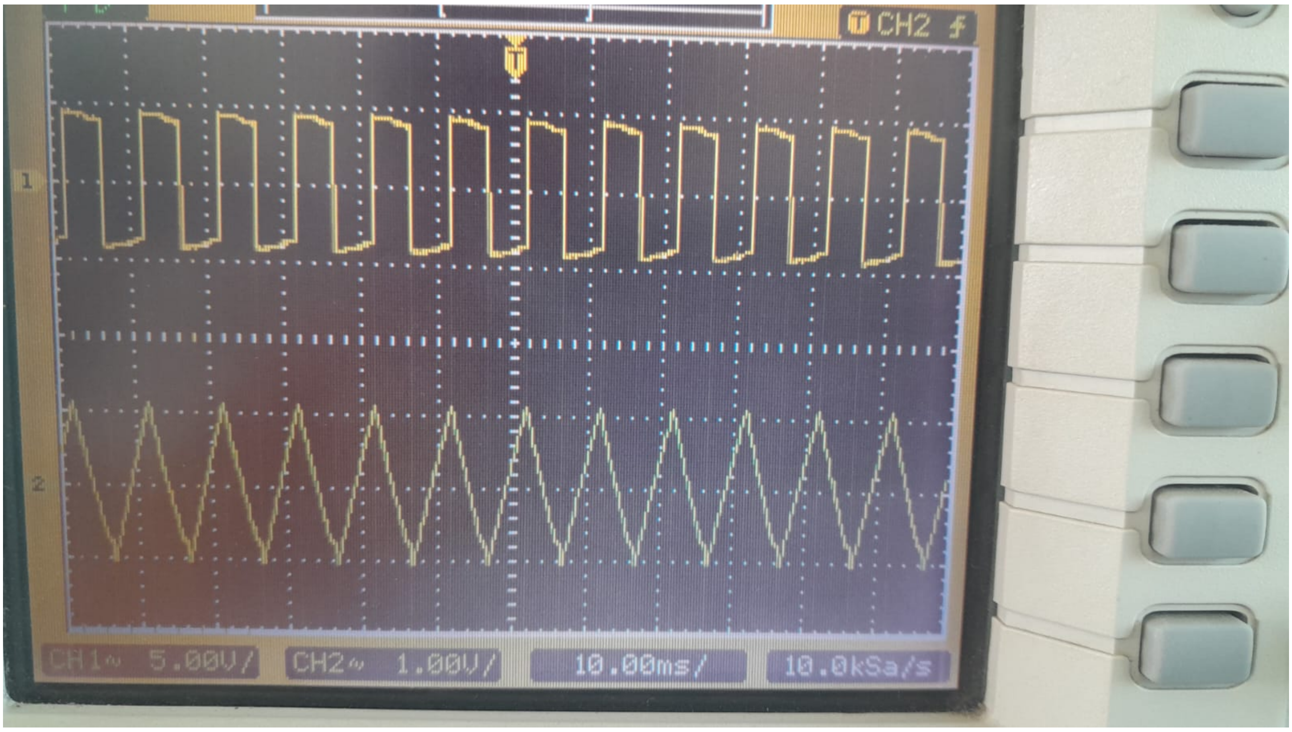


Figure 3: Op-amp Integrator circuit

2.4 Procedure

1. **IC Setup**
   - Refer to the Op-amp datasheet to identify pin functions and electrical characteristics.
   - Ensure the power supply voltages V_+ and V_- are within the recommended range (we used +15V and -15V).
2. **Circuit Assembly**
   - Connect the circuit as shown in the diagram using appropriate resistor R and capacitor C values (we used $R = 1\mu F$ and $C = 10k\Omega$).
   - Apply a known input signal V_{in} using a function generator (e.g., a square wave).
   - Connect the oscilloscope to measure V_{out}.
3. **Oscilloscope Measurement**
   - Observe the output waveform to verify integration behavior.
   - Compare with the expected theoretical response.

2.5 Demonstration



For a square wave input:

- Assume a square wave of amplitude A and period T, given by:

$$V_{in}(t) = \begin{cases} A, & 0 \le t < \frac{T}{2} \\ -A, & \frac{T}{2} \le t < T \end{cases} \tag{5}$$

- Integrating V_{in} over time:
$$V_{out}(t) = -\frac{1}{RC}\int V_{in}(t)dt \tag{6}$$

- For $0 \leq t < \frac{T}{2}$:
$$V_{out}(t) = -\frac{A}{RC}t + V_{out}(0) \tag{7}$$

- For $\frac{T}{2} \leq t < T$:
$$V_{out}(t) = \frac{A}{RC}(t - T/2) + V_{out}(T/2) \tag{8}$$

Thus, the output is a triangular wave with a slope of $\pm A/RC$, confirming that an op-amp integrator converts a square wave input into a triangular wave output.

2.6 Conclusion

The op-amp integrator successfully performed mathematical integration, converting an input square wave into a triangular wave. The response was dependent on the values of R and C, confirming the theoretical integration formula. The circuit functioned correctly within the op-amp's operational limits.

3 Part 3 - Rectifier

3.1 Objective

To study the response of a series RLC circuit with a precharged capacitor.

3.2 Apparatus

- LM 358
- Two $10k\Omega$ resistors
- Two PN - junction diodes
- Oscilloscope
- Function Generator

3.3 Theory

The half wave rectifier implemented with a series connection of a resistor and a PN-junction diode is suboptimal in its working due to the threshold voltage required for the flow of current in the positive half cycle of the input wave.

To implement a better half wave rectifer free from the above mentioned problem we use the following circuit which makes use of an op-amp and a couple of diodes commonly known as a precision half wave rectifier or a superdiode.

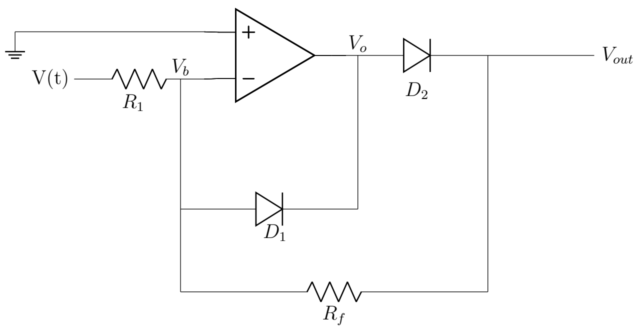


Figure 4: Precision Rectifier

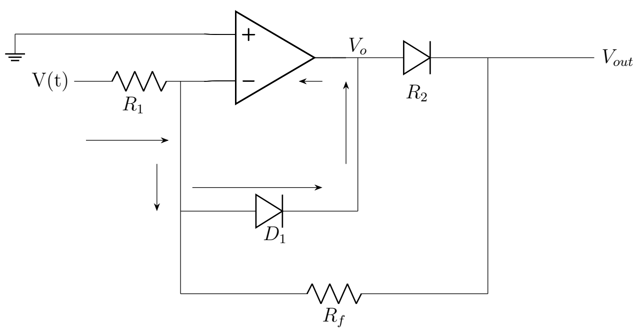


Figure 5: Current flow for positive half cycle

Initially all voltages are at 0V. When $V(t) > 0$, V_o will also become positive. Thus, the flow of current will be as shown:

It is evident that the voltage at the V_{out} is zero since the voltages at $t = 0$ were all zero. When the input voltage is negative, the flow of current will be as follows:

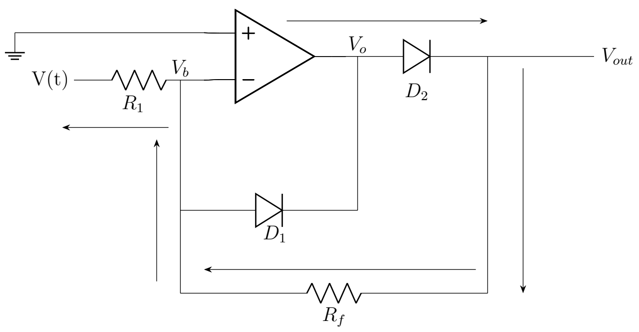


Figure 6: Current flow for negative half cycle

The voltage at V_{out} will approximately be equal to

$$V_{out} \approx \frac{-R_f}{R_1} V(t) \tag{9}$$

The advantage of the superdiode is that for the current to start flowing, the input voltage need to be close to ratio of threshold voltage and open loop gain(a very large number)

$$V(t) \approx \frac{V_{th}}{A}, \text{where A = open loop gain} \tag{10}$$

as opposed to the threshold voltage in the resistor-diode-only approach. Thus a superdiode can be used to rectify signals of amplitude $\approx 100mV$.

3.4 Procedure

1. Connections
   - Connect the circuit as shown in Figure 1.
   - Connect V_+ to $15V$ and V_- to $-15V$
   - Connect the probe of the oscilloscope across the common ground and output pin of the LM358.

3.5 Response captured

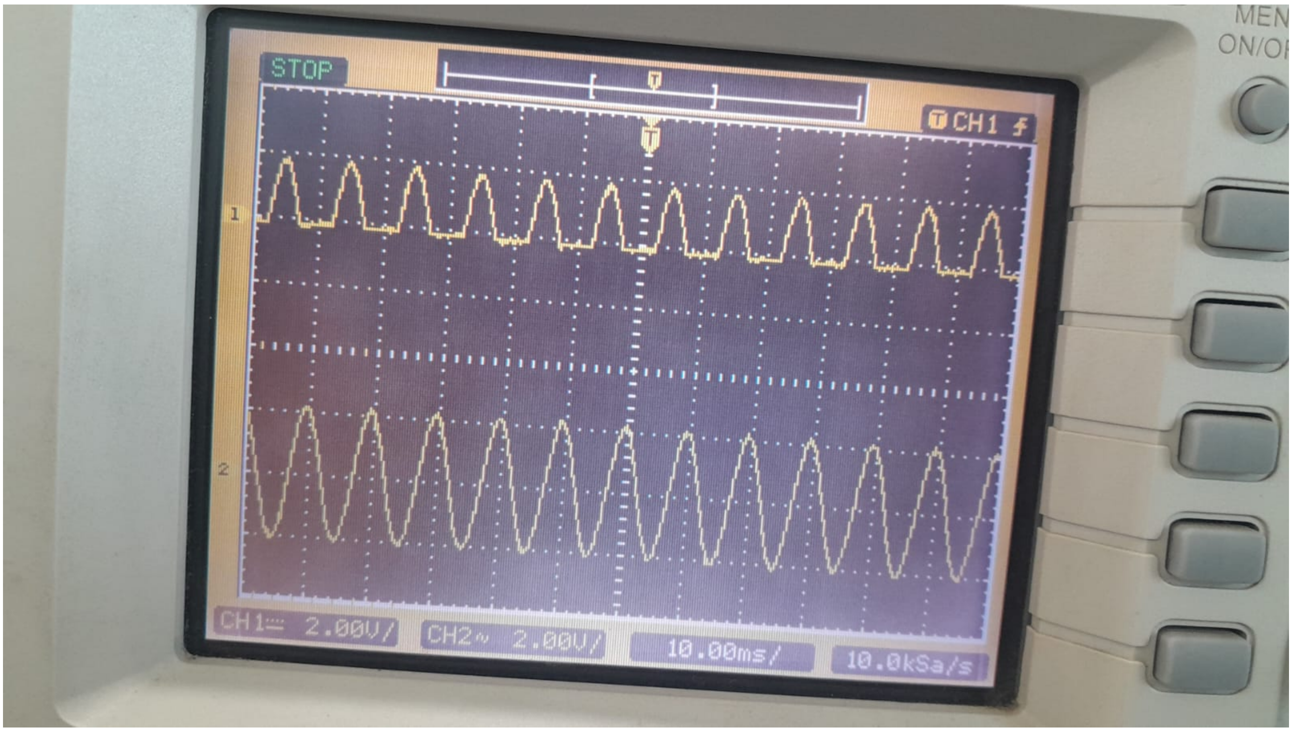


Figure 7: Response for resitor-diode-only circuit

Figure 8: Response for superdiode circuit