Experiment 8
First Order Circuits

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Contents

1 Introduction

In this experiment, as students, we are expected to experiment with first order circuits by completing the steps described in the eight experiment laboratory manual. The simple RC and RL circuit structures are expected to be learned throughout the first step. The output versus input characteristics ,and τ value are obtained by connecting the signal generator to the oscilloscope and the circuit . Then, characteristics of variable τ value is expected to be expressed and experimented. The results of the steps are recorded and plotted for further comments.

2 Experimental Results

In this section, the results of Experiment 8 are discussed.

2.1 Step 1

In this step, circuit shown in the Figure 1 is constructed.

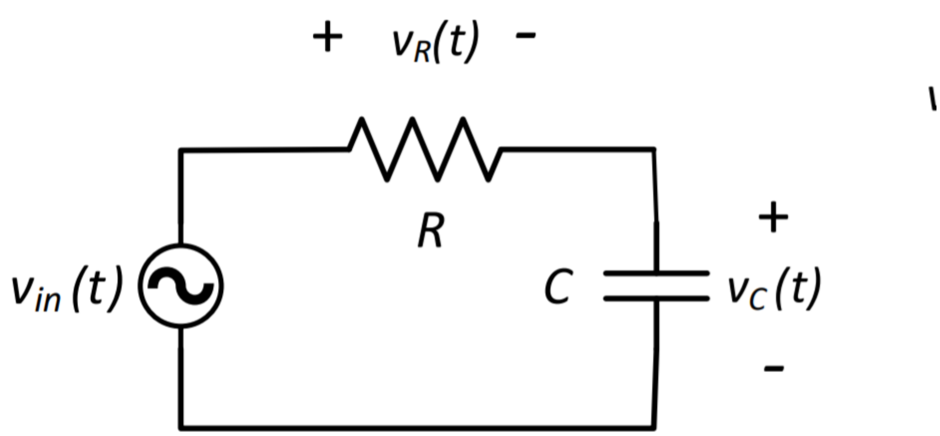

Figure 1: Circuit schematic for the step 1

The square waveform generator is adjusted as given in Figure 2.

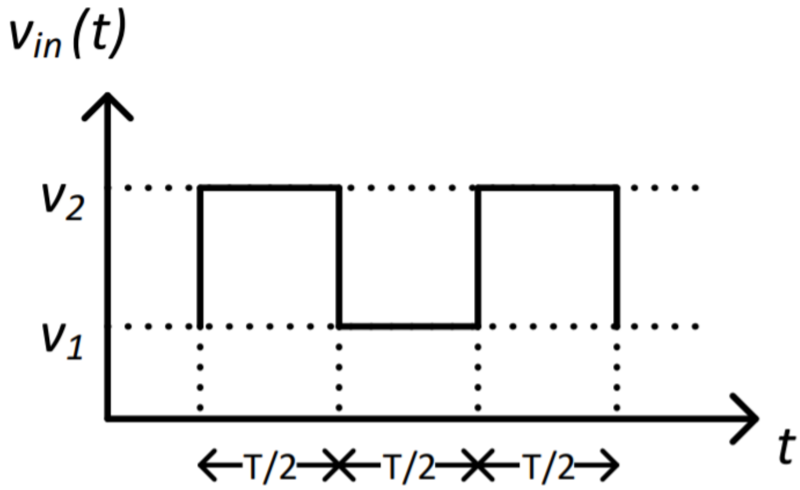

Figure 2: Waveform for the step 1

2.1.1 a)

The set of data given in Table 1 is used for the measurements.

Table 1: RC circuit parameters

f (kHz)	R (kΩ)	C (nF)	Theoretical Calculation τ (μ sec)
2	3.3	4.7	15.51
2	68	10	680

The theoretical calculation of τ is obtained from the general time constant equation of RC circuits;

$$\tau = R \times C$$

The result of the circuit with parameters of first row is given in Figure 3.

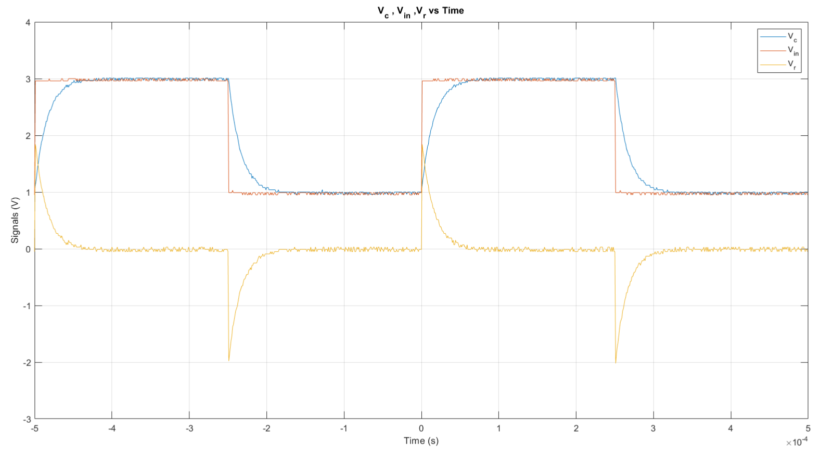

Figure 3: Waveform for the step 1

To measure time constant experimentally following data is obtained from the plot.

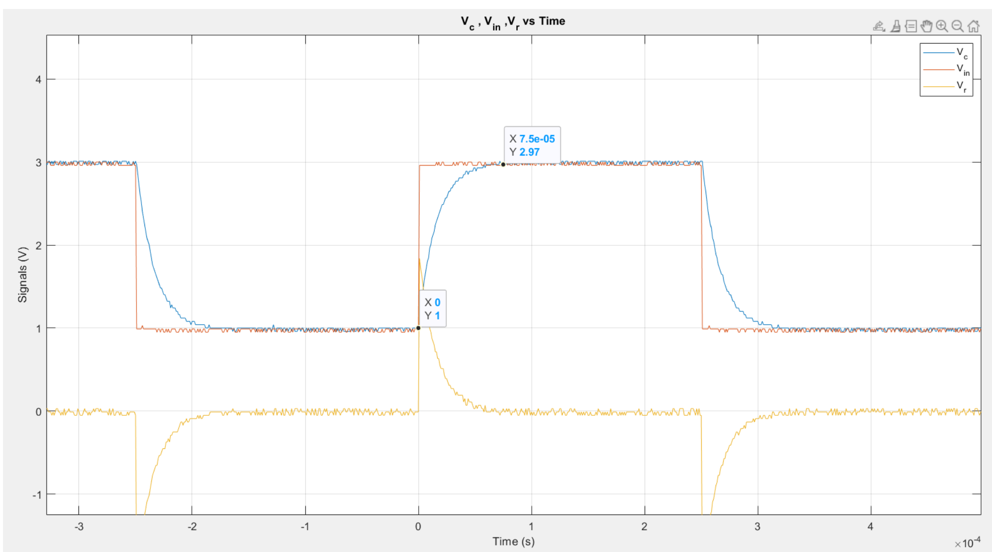

Figure 4: Data from plot

The result is obtained using 5 τ method. The time point where the charging of the capacitor completed is marked. Then it is divided into 5. The calculation result of τ is given in Table 2.

Table 2: RC circuit parameters

Experimental Calculation τ (μ sec	Theoretical Calculation τ (μ sec)
15	15.51

It can be stated that 5 Tau method is consistent with the theoretical calculations.

The result of the circuit with parameters of third row is given in Figure 5.

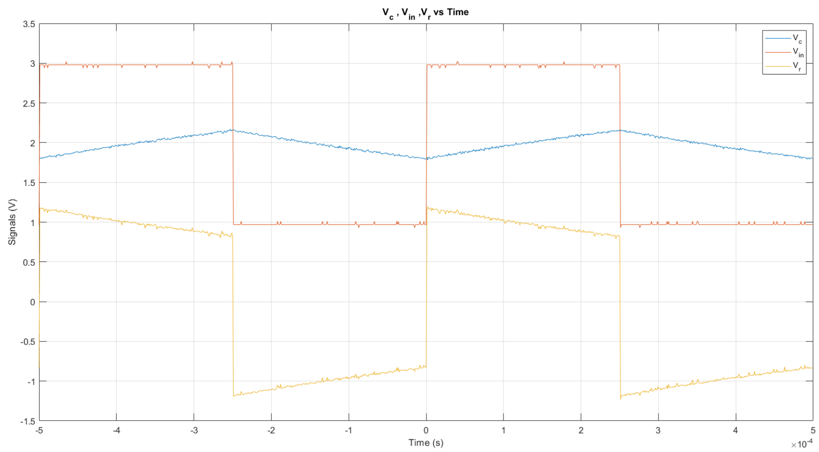

Figure 5: Second waveform for the step 1

To measure time constant experimentally following data is obtained from the plot.

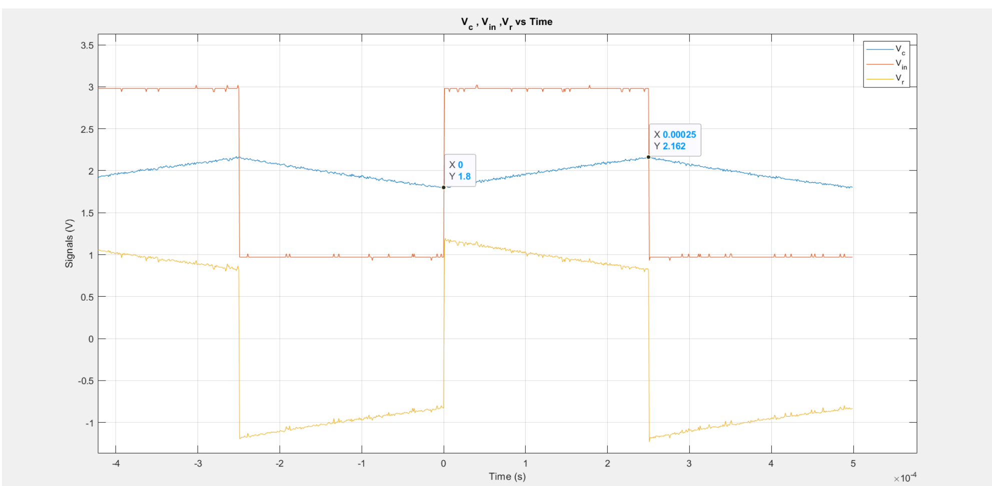

Figure 6: Data from plot

The calculation result of τ is given in Table 3. The τ can not be obtained using 5 τ method because of the fact that charging and discharging proccesses are not completed in a cycle. To obtain the τ value both graph data and the equation $V_c(t) = 3 - 2.2e^{-\frac{t}{\tau}}$ are used. The time points where the charging and the discharging of the capacitor are marked. When a half cycle is completed 0.25 millisecond passes, so when we set t to 0.25 millisecond we should get the $V_c = 2.162$ Volts. The calculation result of τ is given in Table 3.

Table 3: RC circuit parameters

Experimental Calculation τ (μ sec	Theoretical Calculation τ (μ sec)
969	680

It can be concluded that our theoretical calculations are quite consistent with the experimental results.

2.1.2 b)

For this part, the capacitor element in the previous part is replaced with an inductor. Apart from capacitor-inductor swap general outline of the setup is conserved. The set of data given in Table 4 is used for the measurements.

Table 4: RC circuit parameters

f (kHz)	R (kΩ)	L (H)	Theoretical Calculation τ μ sec)
2	3.3	0.1	0.3
10	3.3	0.1	0.3

The theoretical calculation of H are obtained from the general time constant equation of RL circuits;

$$\tau = \frac{L}{R}$$

The result of the circuit with parameters of first row is given in Figure 7.

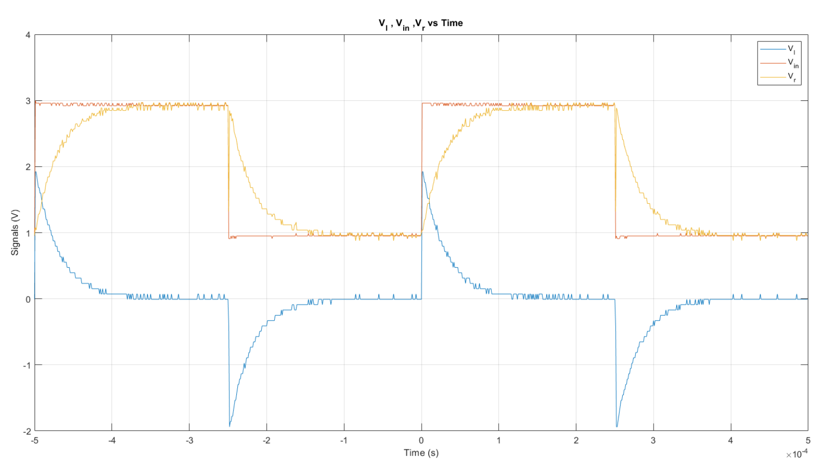

Figure 7: Waveform for the step 1 part 1 first row

To measure time constant experimentally following data is obtained from the plot.

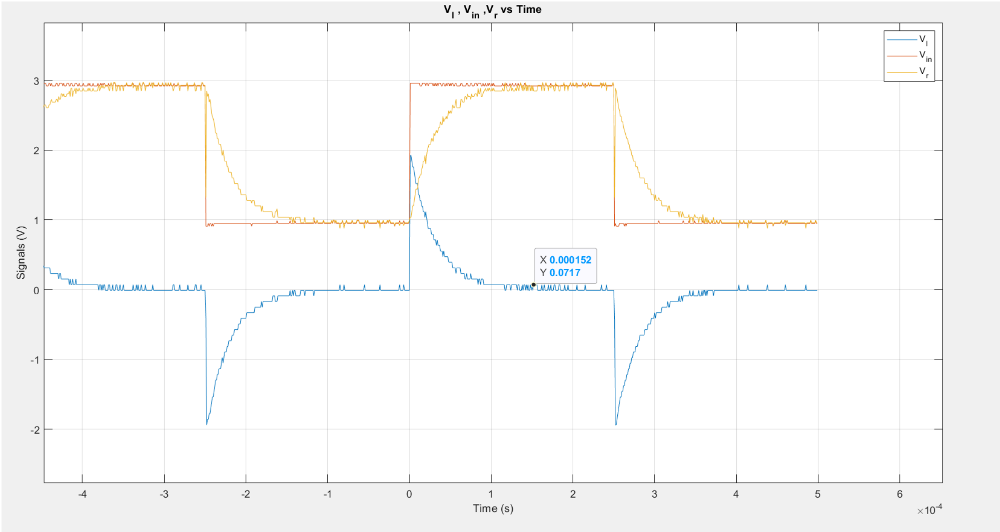

Figure 8: Data from plot

The result is obtained using 5 τ method. The time point where the charging of the capacitor completed is marked. Then it is divided into 5. The calculation result of τ is given in Table 5.

Table 5: RC circuit parameters

Experimental Calculation τ (μ sec	Theoretical Calculation τ (μ sec)
0.303	0.3

It can be said that 5 Tau method is consistent with the theoretical calculations. The result of the circuit with parameters of third row is given in Figure 5.

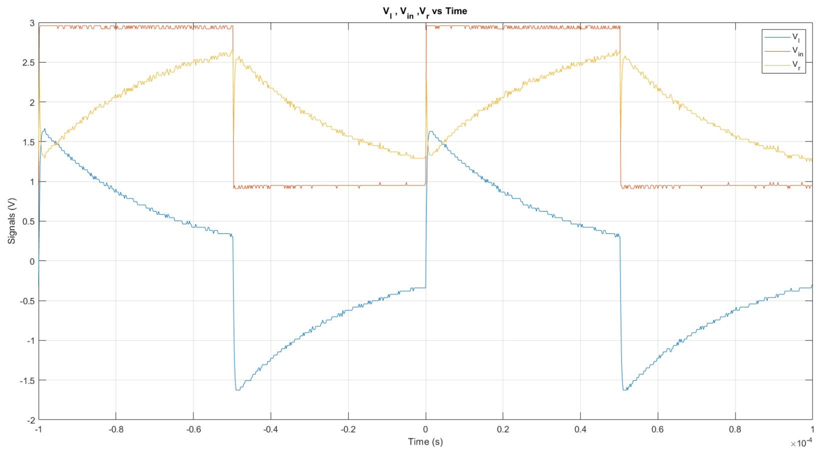

Figure 9: Second waveform for the step 1 part b

To measure time constant experimentally data in Figure 9 is obtained from the plot.

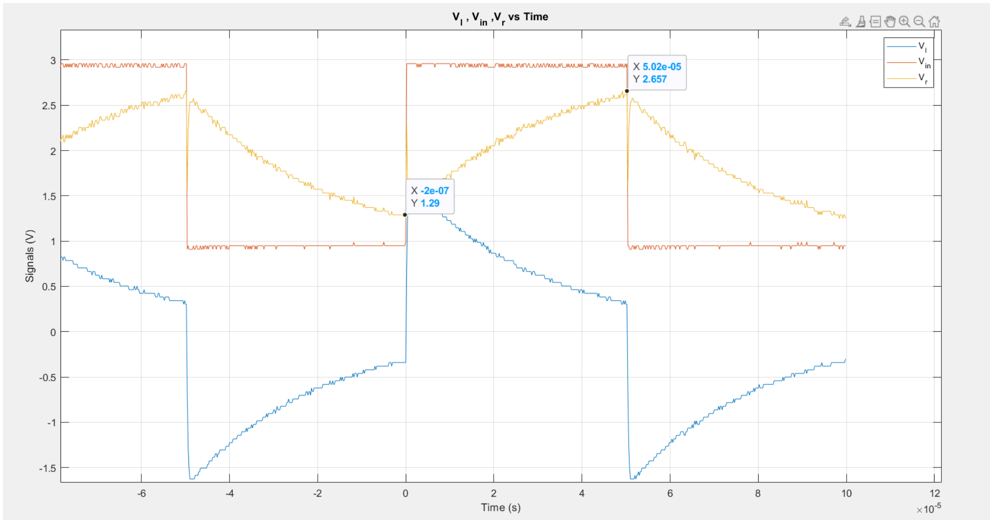

Figure 10: Data from plot

The calculation result of τ is given in Table 6. The τ can not be obtained using 5 τ method because of the fact that charging and discharging proccesses are not completed in a cycle. To obtain the τ value both graph data and the equation $i_c(t) = 10^{-3} * (1 - 0.609e^{-\frac{t}{\tau}})$ are used. The time point where the charging and the discharging of the inductor is marked. When a half cycle is completed 0.05 millisecond passes, so when we set t to 0.05 millisecond we should get the $i_c = 0.8052 * 10^-3$ Amps. The calculation result of τ is given in Table 6 .

Table 6: RC circuit parameters

Experimental Calculation τ (μ sec)	Theoretical Calculation τ (μ sec)
0.437	0.303

It can be concluded that our theoretical calculations are quite consistent with the experimental results regarding the error is approximately a tenths of a millisecond.

2.2 2

The circuit given in Figure 11 is constructed. Function generator is adjusted so that it supplies square waves with frequency of 100Hz and $V_{pp} = 6$Volts.

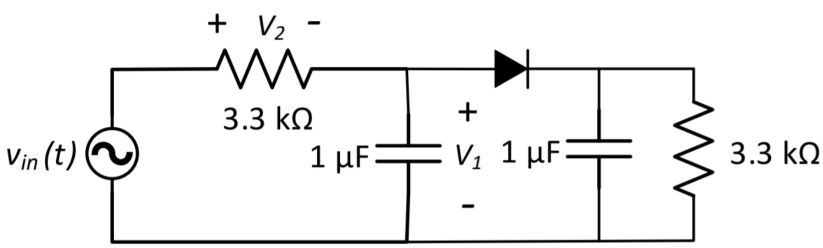

Figure 11: Circuit schematic for step 2

Then the plot shown in Figure 12 is obtained.

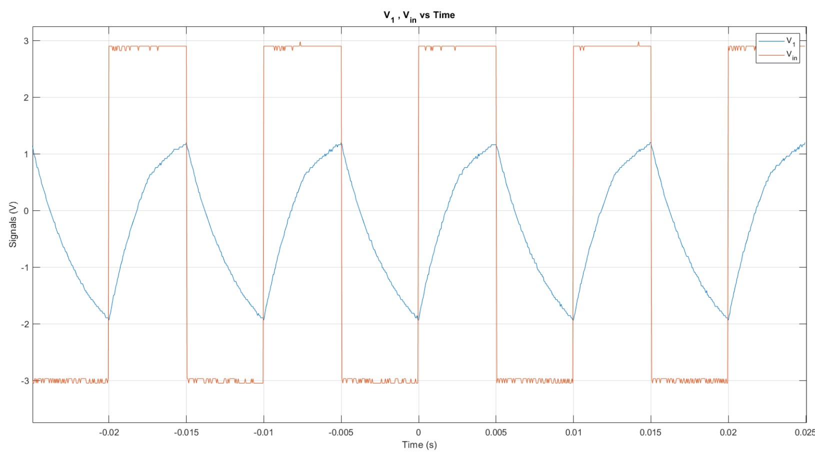

Figure 12: V_1 and V_{in} vs Time

Now, the time constant τ can be obtained for two states of which signal is positive and negative. For negative region it can be calculated theoretically easily by multiplying R and C. On the other hand for positive region it can be obtained after finding thevenin equivalent of the circuit. But, those values also can be obtained from the plot given in Figure 12. To do this the measurements on the plot is made and given in Figure 13.

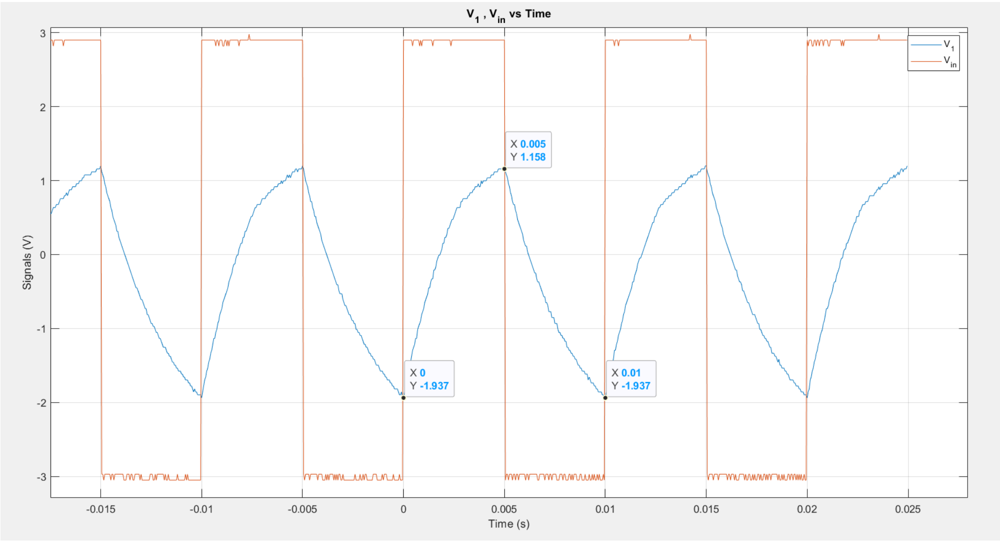

Figure 13: Data marks for the step 2

Again, for this step 5 τ method can not be used since the period of charge and discarge is not complete. For positive region the equation is;

$$V_c = 3 - 4.937e^{-\dfrac{t}{\tau_+}}$$

$$1.158 = 3 - 4.937e^{-\frac{0.005}{\tau_+}}$$

For negative region the equation is,

$$V_c = -3 + 4.158e^{-\dfrac{t}{\tau_-}}$$

$$-1.937 = -3 + 4.158e^{-\frac{0.005}{\tau_-}}$$

So the results of experimental calculations are given in Table 7.

Table 7: RC circuit parameters

	Experimental Calculation τ (sec)	Theoretical Calculation
τ_+	$5.07 * 10^{-3}$	$3.3 * 10^{-3}$
τ_-	$3.666 * 10^{-3}$	$3.3 * 10^{-3}$

As mentioned, the theoretical results are obtained using several calculations ,but it can be convinient to use experimental approach because of its simplicity. To sum up, the circuit operates in positive and negative regions. In positive region, both of the capacitors are charging. In negative region both of the capacitors are discharging but while left capacitor charges from opposite direction, right capacitor discharge its energy to rightmost resistor. Also the even though τ values of positive region and negetive region are same in theoretical manner, the since the internal resistances and initial conditions of capacitors neglected, there are deviation on the results.

2.3 3

The circuit given in Figure 14 is taken as the reference for the differentiator setup.

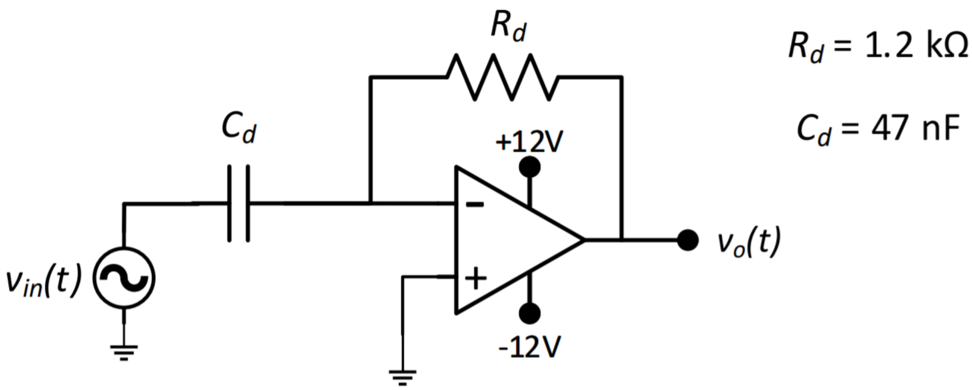

Figure 14: Differentiator circuit schematic

Then the circuit is constructed in LTSpice environment which is shown in Figure 15.

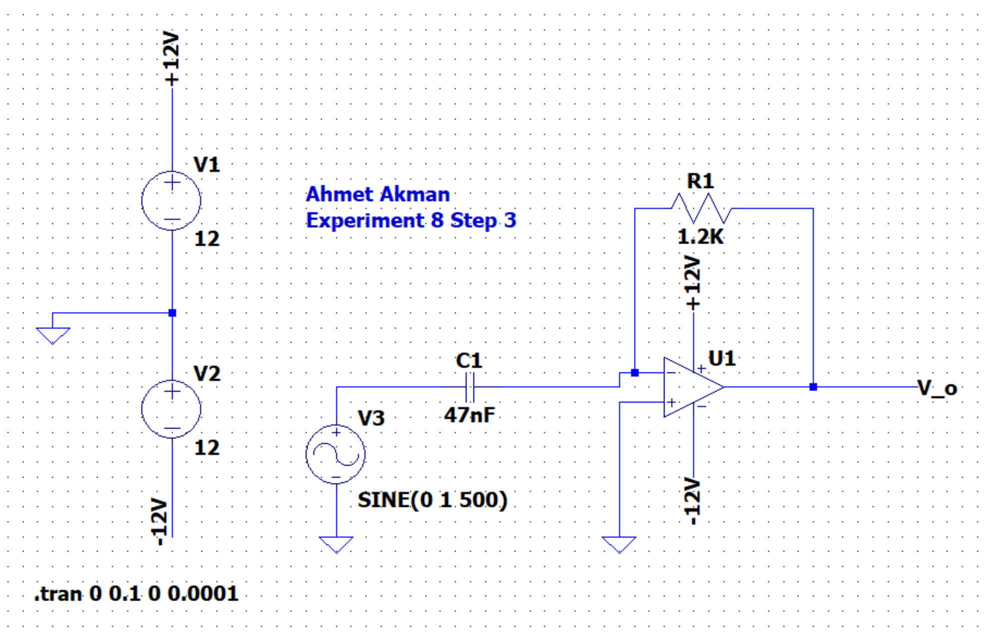

Figure 15: Differentiator circuit in LTSpice

Then the input versus output characteristics are obtained as given in Figure 16.

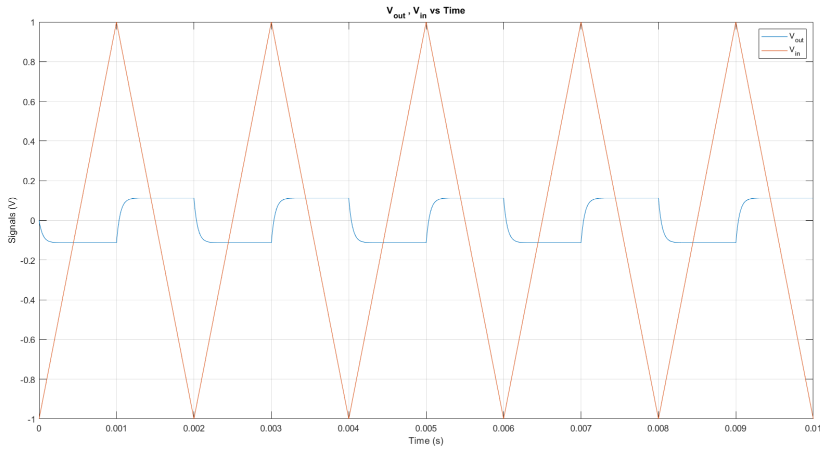

Figure 16: Differentiator circuit output

As a result, it can be said that this circuit configuration is able to differentiate the given signal.

3 Conclusion

In conclusion, in experiment 7, "Rectifiers, Capacitors and Inductors," as students, we have learned how various functional circuit setups rectifiers constructed. Preliminary laboratory work is done via simulations of the rectifier, capacitor, and inductor circuits in an LTSpice environment and by mathematical relations. As students, we have seen how half-wave and full wave rectifiers behave. We have inferred the capacitance and inductance values indirectly and compared them with the direct ones. The characteristics of the q-v and ϕ-i are observed with the help of their calculations. Lastly, different inductors and their behaviors are observed, and the mathematical expressions are verified via measurements. To sum up, in this experiment, as students, we have experimented with how different rectifier circuits operate, how we can measure or calculate the inductance and capacitance values.

Appendix I

Total time spent on/during:

- Pre-lab preparation: 5 hours (including the preliminary work and simulations)
- Experimental work: 2 hours (hours spent in lab)
- Report writing: 5 hours

Appendix II

The outputs of the simulations are fetched from LTSpice and plotted in MATLAB.