UM-SJTU Joint Institute

Intro to Signals and Systems

(VE216)

Laboratory Report

Lab 1

LTI System

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Contents

1 Objectives

In lab 1, our objectives are:

1. Getting familiar with lab equipment, including power supply, signal generator, digital oscilloscope, computer data acquisition system (Scope Connect).
2. Measuring the output response of the series RC circuit for a variety of inputs, including a step, a combination of a step and a ramp, and a sinusoid.
3. Comparing results to those computed as part of pre-lab assignment.

2 Experiment Procedures

First, we connected the series RC circuit according to the lab manual. In this lab, R has the value of 1KΩ, and C has the value of 1μF.

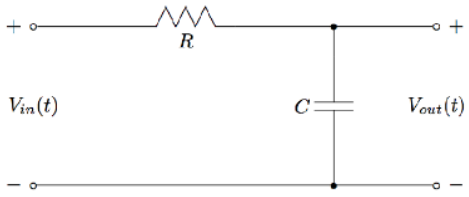

Figure 1: RC series circuit

Then, we setup the function generator(High Z mode) and the oscillator(Basic Trigger Mode, Rising Edge, DC Coupling). Next, we set the function generator to generate square wave, pulse wave, ramp wave and sine wave respectively for part1-4, and take record of the results on the oscillator.

3 Experimental Results

3.1 Step Response

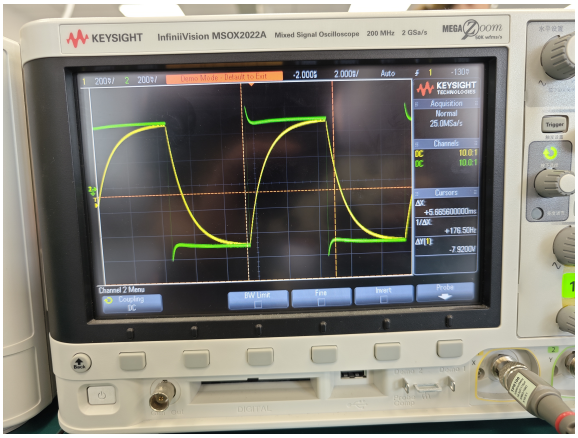

Figure 2: Experimental Step Response

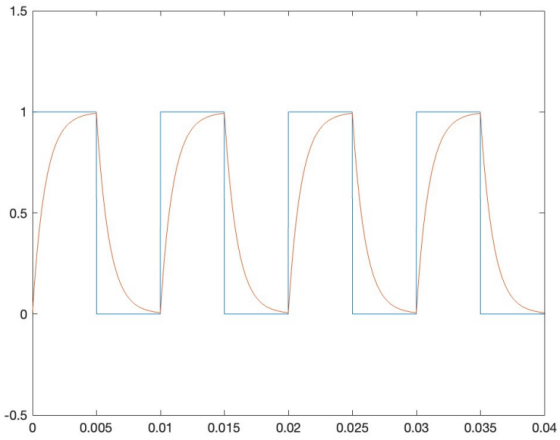

Figure 3: Theoretical Step Response

The step response in this lab is shown in Figure 2. The theoretical plot we get is shown in Figure 3. Comparing these two figures, we can observe that the results are

similar.

3.2 Pulse Response

The experimental pulse response we got in lab 1 whose pulse function has a width of $1ms$ and amplitude of $100mV$ is shown in Figure 4.

Figure 4: Pulse Response(Width = $1ms$, Amplitude = $100mV$)

Then, we switch the function generator, making the width to be $0.5ms$ and amplitude to be $200mV$. The experimental pulse response is shown in Figure 5. Comparing the results, we can find that the responses have different amplitude and period.

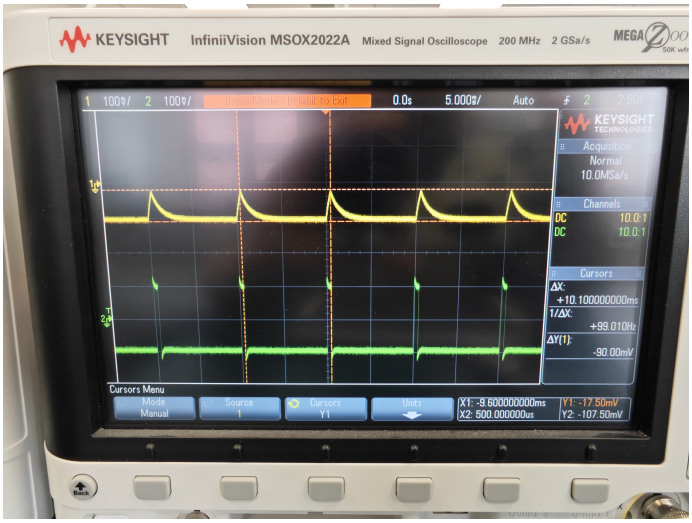

Figure 5: Pulse Response(Width = $0.5ms$, Amplitude = $200mV$)

3.3 Ramp Response

The experimental ramp response is shown in Figure 6.

Figure 6: Experimental Ramp Response

The ideal ramp response is shown in Figure 7. Compare these two figures, we can find that our experimental result in lab 1 is similar to the ideal result.

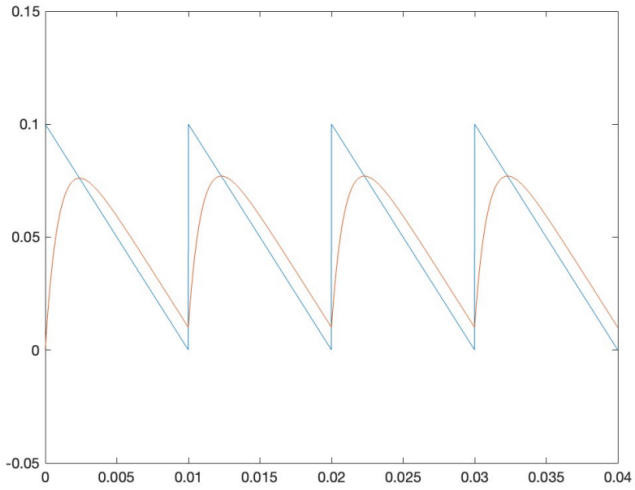

Figure 7: Ideal Ramp Response

3.4 Sine Response

We set the function generator to generate sine waves with frequency of $50Hz$, $500Hz$ and $5kHz$ respectively in this part. Then, we record the V_{out} / V_{in}, Time Shift and Phase Shift shown on the oscillator in Table 1.

Frequency (Hz)	V_{out} / V_{in}	Time Shift	Phase Shift
50	0.980	$1.20ms$	$-15.0°$
500	0.312	$0.420ms$	$-70.0°$
5000	0.0320	$0.0450ms$	$-82.0°$

Table 1: Experimental Sine Response Results

The theoretical value which we obtained in the pre-lab is listed in the Table 2.

Frequency (Hz)	V_{out} / V_{in}	Time Shift	Phase Shift
50	0.954	$0.969ms$	$-17.44°$
500	0.303	$0.402ms$	$-72.34°$
5000	0.0318	$0.0490ms$	$-88.18°$

Table 2: Sine Response Theoretical Results

Compare the experimental and theoretical results, we can find that there exists some difference. The detailed error analysis is shown in the following section.

4 Error Analysis

For f=50Hz, the experimental value of $|H|$ is higher than theoretical one, and the experimental value of $\angle H$ is higher than theoretical one. The relative error are calculated as below:

$$e_{|H|,50Hz} = \frac{|0.980 - 0.954|}{|0.954|} = 2.73\% \tag{1}$$

$$e_{\angle H,50Hz} = \frac{|-15.0° + 17.44°|}{|-17.44°|} = 14.0\% \tag{2}$$

For f=500Hz, the experimental value of $|H|$ is higher than theoretical one, and the experimental value of $\angle H$ is higher than theoretical one. The relative error are calculated as below:

$$e_{|H|,500Hz} = \frac{|0.312 - 0.303|}{|0.303|} = 2.97\% \tag{3}$$

$$e_{\angle H,500Hz} = \frac{|-70.0° + 72.34°|}{|-72.34°|} = 3.23\% \tag{4}$$

For f=5KHz, the experimental value of $|H|$ is higher than theoretical one, and the experimental value of $\angle H$ is higher than theoretical one. The relative error are calculated as below:

$$e_{|H|,5KHz} = \frac{|0.0320 - 0.0318|}{|0.0318|} = 0.63\% \tag{5}$$

$$e_{\angle H,5KHz} = \frac{|-82.0° + 88.18°|}{|-88.18°|} = 7.00\% \tag{6}$$

5 Discussion

In the above section, we can find that most of the errors are acceptable, while some of them are relatively large. The errors may be caused by the following reasons:

1. The accuracy of lab equipment is limited, then the values we read from the oscillator may generate some error.

2. The wire and the bread board may have some resistance, which increases the whole resistance, causing some error.

3. The function generator may not generate exactly the same function as we set, so the wave will be different from the theoretical wave, which leads to some error.

6 Conclusion

In this lab, we study the property of RC circuit, as a simple LTI system. We also take some common signals as examples to verify the theory about LTI system that we have learnt in lectures.

1. In the first part, we find that the experimental step response is close to the theoretical one. Thus, we can verify that the pulse response is $y(t) = (1 - e^{-\frac{t}{RC}})u(t)$

2. In the second part, we find that the experimental pulse response also has the same shape as the theoretical one. Thus, we can verify that the step response is $y(t) = \frac{1}{RC} e^{-\frac{t}{RC}}$

3. In the third part, the experimental ramp response also coincide with the theoretical result.

4. In the fourth part, we compare the experimental and theoretical value of the V_{out} / V_{in}, Time Shift and Phase Shift under different sine frequency. The errors are acceptable, which indicates that our experiment is successful.

Overall, we have achieved our objectives for this lab.