
UM-SJTU JOINT INSTITUTE
ELECTRONIC CIRCUITS
(VE311)

LABORATORY REPORT

LAB 1
LTI SYSTEMS

Name: Chao Junyu
Name: Liu Yihao

ID: 515370910206
ID: 515370910207

Date: 17 June 2017

1 Objectives

- To become familiar with the laboratory equipment: power supply, signal generator, digital oscilloscope, computer data acquisition system (Scope Connect).
- To review basic concepts of linear time-invariant systems.
- To illustrate several possible ways to determine the impulse response of a physical system from measured data.
- To use linearity, time-invariance and impulse response to compute the output of an LTI system when the input is a step, a pulse, or a more complicated signal. You will compare these calculations with actual measurements.
- To measure the frequency response of an LTI system and compare against theory.

2 Experiment procedures

2.1 Step Response

We are going to test the behavior that the resistance has to temperature, humidity, high current and voltage. By using a resistor of 220Ω , $10\text{ k}\Omega$ and the closest to 1Ω , perform the follow set of tests.

- Function generator:
Square wave V_{pp} : 1V frequency: 100Hz
- Oscillator:
CH1: 200mV/div CH2: 200mV/div Time: 2ms
- Bonus: Compare your results with the ideal case

2.2 Pulse Response

- Function generator: Pulse frequency: 100Hz
 1. Width: 1ms A: 100mV
 2. Width: 0.5ms A: 200mV

2.3 Ramp Response

- Function generator:
Ramp V_{pp} : 100mV frequency: 100Hz

2.4 Sine Response

- Function generator: 10 Vpp

Frequency (Hz)	Vout / Vin	Time Shift	Phase Shift
50			
500			
5k			

- Bonus: Compare your results with ideal case

3 Experimental results

3.1 Step Response

The figure was shown in Figure ??.

3.2 Pulse Response

The figure was shown in Figure ??.

3.3 Ramp Response

The data was shown in Table ??.

3.4 Sine Response

The data was shown in Table 1.

Frequency (Hz)	Vout / Vin	Time Shift (μs)	Phase Shift ($^\circ$)
50	$10.2 / 10.6 = 0.9623$	880	-15.84
500	$3.12 / 10.2 = 0.3059$	380	-68.40
5k	$0.385 / 10.1 = 0.0381$	46	-82.80

Table 1: Sine Response

In this table, phase shift is calculated according the equation

$$\angle = -2\pi f_c \Delta t RC \frac{180}{\pi} = -f_c \Delta t \cdot 3.6 \times 10^{-4}$$

4 Error analysis and discussion

4.1 Step Response

In ideal situation, we know

$$V_{in}(t) = u(t)$$

$$V_{out}(t) = y_{step}(t) = (1 - e^{-t/RC})u(t)$$

Then we can substitute $R = 1k\Omega$, $C = 1\mu F$ into $y_{step}(t)$ and plot the ideal graph when $t \in [0, 0.005)$ in MATLAB, as Figure ??.

We can find that in Figure ?? (experimental), $V_{in}(t)$ was not a straight line, it is probably because of the inner resistance of the experiment instruments. The shape of $V_{out}(t)$ in two figures are very similar.

4.2 Pulse Response

In the experiment, we can only simulate a δ function since instantaneous time period doesn't exist in real world. However, the smaller time period (width) we get, the more accurate the experiment is.

The ideal graphs of $h(t)$ with a width were shown in Figure ??. They are similar to those in the experiment.

We know the equation of the pulse response is

$$h(t) = \frac{dy_{step}(t)}{dt} = \frac{1}{RC}e^{-t/RC}u(t)$$

The ideal graph of $h(t)$ was shown in Figure ??. It is similar to the figure when width $\rightarrow 0$.

4.3 Ramp Response

A period of the ramp function in this experiment is

$$x(t) = \frac{0.1}{0.01}(t - 0.005) = 10(t - 0.005)$$

$$y(t) = x(t) * h(t)$$

The ideal graph of $y(t)$ was shown in Figure ?? . It fits the figure in the experiment well.

4.4 Sine Response

Theoretically, we have

$$\frac{V_{out}}{V_{in}} = \sqrt{1 + (2\pi f_c RC)^2}$$

$$\Delta t = \frac{\arctan(2\pi f_c RC)}{2\pi f_c RC}$$

$$\angle = -\arctan(2\pi f_c RC)$$

Then we can calculate the theoretic value in Table 2.

Frequency (Hz)	Vout / Vin	Time Shift (μs)	Phase Shift ($^\circ$)
50	0.9540	968.9	-17.4406
500	0.3033	401.9	-72.3432
5k	0.0318	49.0	-88.1768

Table 2: Ideal Sine Response

Comparing the results of Table 1 and Table 2, we can get a table of error in Table 3

Frequency (Hz)	Vout / Vin	Time Shift	Phase Shift
50	0.9%	9.2%	9.1%
500	0.9%	5.5%	5.4%
5k	19.8%	6.1%	6.1%

Table 3: Sine Response Error

There is a significant error in V_{out}/V_{in} when $f = 5000$, it is probably because the value of V_{out} is too small so that the system error of the experiment equipment is scaled.

5 Conclusion

In this experiment, we achieved a lot.

First, we became familiar with the laboratory equipment: power supply, signal generator, digital oscilloscope. We reviewed basic concepts of linear time-invariant systems. We illustrated several possible ways to determine the impulse response of a physical system from measured data. We recalled how to build a RC circuit as we did in VE215 course, and recorded our results into a usb disk. They are all basic skills in a Signals & Systems Lab.

Second, we used linearity, time-invariance and impulse response to compute the output of an LTI system when the input is a step, a pulse, or a more complicated signal. We measured the frequency response of an LTI system and compare against theory.

In the part of Step Response, we found that the measured $V_{in}(t)$ curve was not a straight line as the theory. It is probably because of the system error of the laboratory equipment which can't be cancelled.

In the part of Pulse Response, we compared the figures when we use different width for the pulse and realize the simulation of the pulse signal. We concluded the relationship between the figure we got and the width we set.

In the part of Ramp Response, we calculated the convolution of $x(t)$ and $h(t)$ and compared the result $y(t) = x(t) * h(t)$ with the experiment result.

In the part of Sine Response, we calculated the ratio of V_{out} and V_{in} , the time shift and the phase shift and compared them with the experimental ones. Some apparent errors occurred when the frequency becomes larger. It is probably because of the value of R and C is not accurate in the experiment.

6 Reference

6.1 MATLAB Code

6.2 References

1. PreLab1, Professor Kim Winick, Department of Electrical Engineering & Computer Science University of Michigan, 2008
2. Lab1 Manual