UM–SJTU JOINT INSTITUTE

ELECTRONIC CIRCUITS
(VE311)

LABORATORY REPORT

LAB 1

Name: Chao Junyu ID: 515370910206
Name: Liu Yihao ID: 515370910207

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1 Objectives

- Test the behavior that the resistance has to temperature, humidity, high current and voltage.
- Understand what happened when a series of capacitors behave at different conditions.
- Analyze the behavior of a simple array of resistors.

2 Experiment procedures

2.1 Resistor behavior

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

- By using a wave generator and an oscilloscope, measure the resistor response for a voltage of 1, 5, 10 and 15 V by sweeping the frequency from 10 Hz up to 50 MHz in each case.
- In each case heat or warm the resistance and see if there is any change in the oscilloscope signal.
- "Carefully" reduce the temperature of the resistance and see what happen to the signal.

2.2 Capacitors

The second part considers the use of capacitors. In here, we are going to use a series of capacitors and to understand what happened when they behave at different conditions.

- Use the capacitors: 0.1 μF, 4.7 pF and 3.3 μF. Each one of the capacitors is to be in series with a 10 kΩ resistor. By applying 1 V_{pp} you're going to sweep the frequency ranging from 50 MHz or the highest to 60 Hz.
- Invert the order of the devices and perform the same test.

2.3 Array of resistors

Finally, with an inductor, we are going to perform a set of experiments. By using a simple array of a 10 kΩ resistor in series with an inductor, we're going to analyze the behavior of the array. By using the wave generator, we are sweeping a range of frequencies from 50 MHz up to 1 Hz with a 1 V_{pp} .

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 (°)
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

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

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 $\to 0$.

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

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

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

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

Then we can calculate the theoretic value in Table 2.

Frequency (Hz)	Vout / Vin	Time Shift (μs)	Phase Shift (°)
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 out 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