# Experimental Report

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# 1 Experiment I: Voltage and Current Measurements, and Thevenin Equivalent Circuits

## 1.1 Task A: Measuring DC Voltage and Current

### 1.1.1 Introduction

When a DC current go through a resistor, it will result in a voltage decrease. The larger value of resistance the resistor is, the more voltage decrease it will cause which means the more difficult for a current to go through it. By applying this regular, a simple circuit shown in Figure 1 can be designed. In this circuit, a 10V voltage source generates a current, which go through three resistors which are 180 ohms, 100 ohms and 120 ohms accordingly.

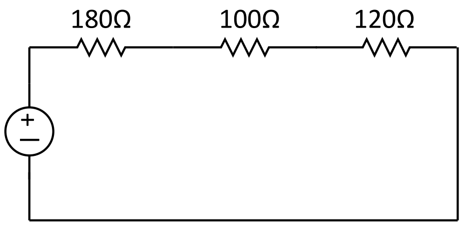



Figure 1

### 1.1.2 Methodology

To obtain an experimental result from measuring the circuit scientifically, five steps had been taken.

Firstly, a real circuit was set up according to Figure 1 on a breadboard. Choose these three resistors by the color loop on them and check each of the resistors' value utilizing a multimeter then record them. Finally, calculate the total value of these three resistors.

Secondly, set the DC power supply to output a 10V voltage. And then, verify the output voltage by multimeter as well.

Thirdly, connect the DC power supply to the breadboard and use the multimeter to measure the current and the voltage of the three resistors one by one and record them immediately. According to Ohm Law, the current in the circuit can be conducted by the following function [1].

$$R_T = \frac{V_T}{I} \tag{1}$$

Fourthly, since the value of each resistor had been measured and recorded before measuring their voltage in Step 1, it is possible to calculate a theoretical result of voltage beside each resistor by using Ohm Law in the situation that the total voltage $V_T$ was known.

$$V_1' = \frac{R_1}{R_1+R_2+R_3} V_T' \qquad [2]$$

By utilizing Function [2] conducted from Ohm Law, the voltage of R1 can be easily calculated. Similarly, the theoretical voltage value of R2 and R3 can be obtained.

$$\mathrm{I}' = \frac{V_T'}{R_T'} \qquad [3]$$

With the accordance of Function [3], the theoretical current going through the current can be solved.

### 1.1.3 Results and Discussions

By executing the steps in the last section, the experiment result was recorded shown as the following table.

| Resistor | $R_{180\Omega}$ | $R_{100\Omega}$ | $R_{120\Omega}$ | $R_{Tm}$ |
|---|---|---|---|---|
| Measured Resistance (Ω) | 181.1 | 98.3 | 115.4 | 394.8 |

Table 1

Table 1 shows the measured result of each resistor used. As you can see, the 180 ohms resistor is a little large than it should be while the other two resistors are somewhat smaller than their theoretical value, which result a practical smaller total value of resistor and a larger current. However, since all the deviation are less than 5%, these values are acceptable even if this may give rise to a somewhat different value with the expected theoretical value.

| $V_s$ (V) | $V_{180\Omega}$ (V) | $V_{100\Omega}$ (V) | $V_{120\Omega}$ (V) | $V_T$ (V) | $I$ (A) | $R_T = V_T/I$ (Ω) |
|---|---|---|---|---|---|---|
| 10 | 4.58 | 2.498 | 2.923 | 10 | 0.0252 | 396.8 |

Table 2

| $V_s$ (V) | $V'_{180\,\Omega}$ (V) | $V'_{100\ \Omega}$ (V) | $V'_{120\,\Omega}$ (V) | $V_T'$ (V) | $I'$ (A) | $R_T' = R_T^m$ (Ω) |
|---|---|---|---|---|---|---|
| 10 | 4.59 | 2.49 | 292 | 10 | 0.0253 | 394.8 |

Table 3

Table 2 and Table 3 show the measured values and the calculated result of the voltage around each resistor accordingly.

From the two tables, it can be indicated that I' is a little large than the measured current I. And also, the calculated R'T is somewhat smaller than the measured one. There are two possible explications for this fact. The first one is that when we connected the resistors to the breadboard, we directly insert their foot into holes, which may cause a large resistor at the connecting point. Secondly, we had verified the DC power supply at the beginning of the experiment, however, with the load changed from a multimeter to a circuit, the output voltage might have changed.

Basing on the data of Table 2, the sum of voltage of each resistor can be calculated and its value Vs is 10.001V. This is different from 10V less than 1%, so it can be regarded as 10V. However, the slight overload voltage can be explained by both the problem from DC power supply and the multimeter. When we measured the output voltage at the beginning of the experiment, we directly connected multimeter to it. There might exist an allocated voltage at the connecting point, thus the measured voltage was smaller than the real one.

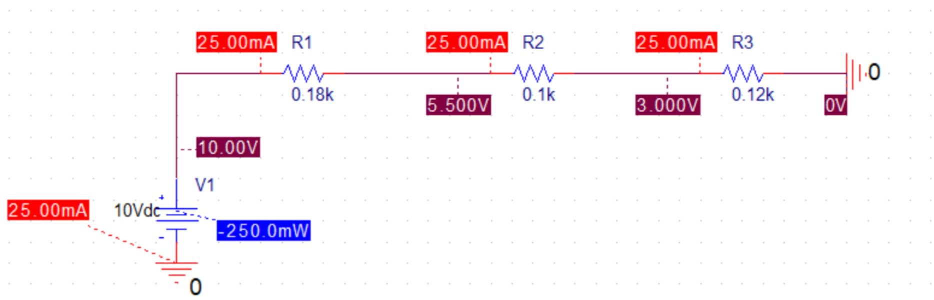



Figure 2

Figure 2 shows the simulation of the circuit we build. The voltage is different from what we measured and calculated mainly because of the practical resistor is not so accurate.

### 1.1.4 Conclusion

From this experiment, it can be proved that the current, voltage and resistor in a real current are acted just as the Ohm Law described. The practical result is always somewhat different from the theoretical one, however, this bias can be decreased by excellent experiment skills and accurate equipment.

## 1.2 Task B: Finding the Thevenin Equivalent Circuit

### 1.2.1 Introduction

Thevenin theorem is a convenient method on simplifying circuit for analysis. It can be described as that one voltage $V_{Th}$ and one resistor $R_{Th}$ can present all of the two-terminal circuit with resistors and voltage sources.

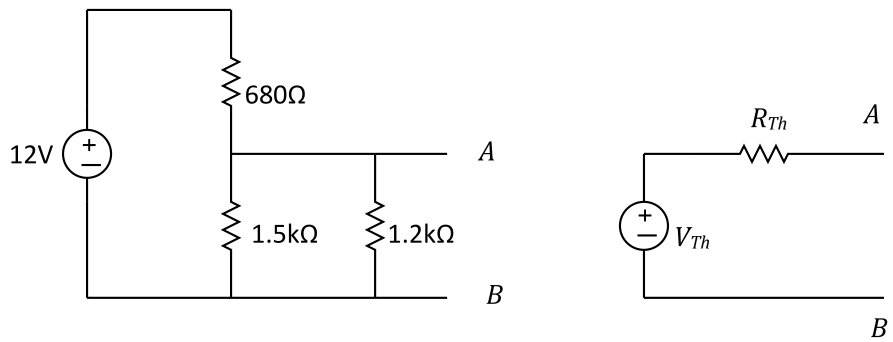



Figure 3

Figure 3 shows a circuit with one voltage source and three resistors and its Thevenin form. In the accordance with Thevenin theorem, these two circuits can have extremely same effect at the A and B terminals. This experiment aims to verify that the Thevenin circuit can substitute the original circuit in real world practice.

### 1.2.2 Methodology

There are seven steps needed to conduct this experiment.

Firstly, use multimeter to confirm that each resistor has the resistance value that it should be. If all the resistance values are acceptable, then build a circuit on breadboard like the first one in Figure 3.

Measure and record the value of $V_{Th}$ by measuring the open voltage between A and B terminal.

Calculate and record the value of theoretical $V_{Th}$ by applying the relation between current and voltage.

Measure and record the value of $R_{Th}$ by short-circuiting the voltage supply and using multimeter to measure the terminal resistance.

Calculate and record the value of $R_{Th}$ by theoretically computing the terminal resistance after open-circuiting the power source.

Measure and record the current going through a 1k ohms resistor between the A and B terminal in the original circuit.

Measure and record the current going through a 1K ohms resistor between the A and B terminal in the Thevenin circuit.

### 1.2.3 Results and Discussions

The result of the experiment was shown in the following tables.

| | Measured | Calculated |
|---|---|---|
| Thevenin voltage, $V_{Th}$ | 5.96V | 5.94V |
| Thevenin resistor, $R_{Th}$ | 331.0Ω | 336.6Ω |

Table 4

| | Original Circuit | Thevenin Equivalent Circuit |
|---|---|---|
| $I_{1k\Omega}$ | 4.44mA | 4.44mA |

Table 5

As shown in Table 4, the measured $V_{Th}$ was a little higher than the calculated one, and the $R_{Th}$ was a little smaller. However, they were approximately the same. And from Table 5, it can be pointed that the measured current of original circuit and the Thevenin circuit were astonishing similar, which indicated that for a two terminals network with pure voltage sources and resistors can be substituted to an equivalent circuit network with only one voltage source and one resistor which can perform an extremely similar function just as the original circuit dose.

Based on the result of this experiment, I think it is Ok to apply Thevenin theorem to many linear networks in future study because of the tiny distinction between the measured result between the original circuit and the substituted circuit. Besides the accurate reason, it is also the advantages of Thevenin theorem that it can greatly simplify the network analysis which could benefit our problem-solving process thus let us become more confident on handling more complex circuit analysis.

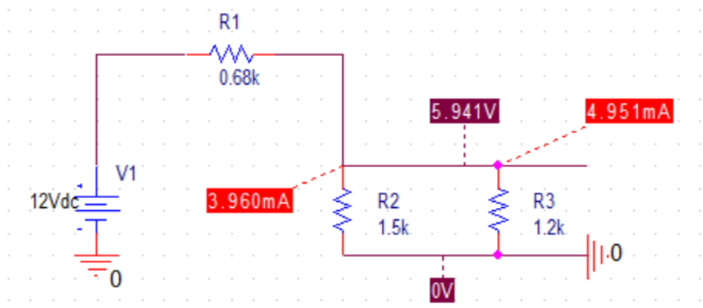



Figure 4

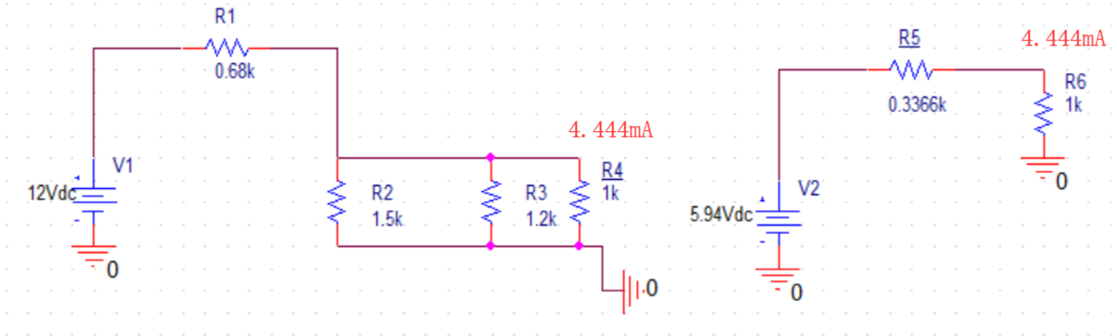



Figure 5

By utilizing PSpice, the solution (Figure 4 and Figure 5) can verify the experiment result. It can be seen that the 5.941V in Figure 4 is quite similar to the 5.96V measured. And the two 4.444mA current in Figure 5 is also approach our measured value which is 4.44mA. [Detailed output file please see attachment at the end of this report!]

## 1.2.4 Conclusion

From this experiment, it had been verified that it is reliable to use Thevenin theorem for simplification when analyzing a two-terminal network current which only contain a series of liner components. This finding can greatly facilitate us when analyzing complex circuit in future study. And also, the Thevenin theorem provide the possibility for designing and utilizing a black-box circuit system without knowing what actually happens in it.

# 2 Experiment II: Using the Oscilloscope

## 2.1 Introduction

Oscilloscope is a classical experiment equipment which was designed for converting the measured voltage in circuit into digital format. It is very useful when analyzing a signal circuit or checking where the problem of a circuit is. This experiment will give us a brief introduction of oscilloscope about its calibration and its basic operating method when dealing with two sample RC circuit.

## 2.2 Methodology

For the purpose of getting familiar with Oscilloscope, experiment was conducted under Calibration Section (Task A) and Phase Shifted Signal Section (Task B).

The main aim of Calibration Section is to calibrate the Oscilloscope. To achieve, the first step was to connect a probe which under the state of x1 to CH1 input and connect it to the square-wave calibration point. Click the CH1 button to set the DC coupling mode to CH1. Then, change V/div to 0.5 and record the screen.

In the second step, the probe needed to be switch to x10 mode. Then adjusted the head of the probe until the square-ware was shown on screen and the upper line was stable by changing the screw near the switch. Record the screen again.

In the third step, open the AC signal generator to produce a 500Hz sine wave. Connect the signal to the Oscilloscope and increase the sine wave signal amplitude to 8 Vpp. Record the waveform on the screen with sec/div and V/div.

In the fourth step, utilize AC signal generator to generate a 100Hz 8Vpp signal. If the waveform was drifting then click the 50% button to reset the trigger level. Change the Oscilloscope CH1 mode to falling downward and rising upward flexibly. Finally adjust the trigger level until the moment that the signal became static and record the trigger voltage at this time.

Then in Task2, firstly build up two circuit shown as following figures.

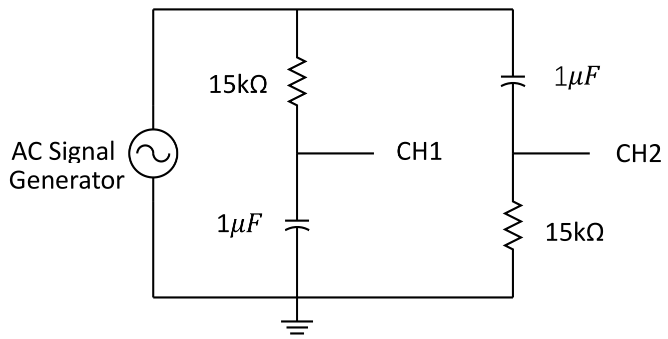



Figure 6

Figure 6 shows a RC circuit which contains two capacitors and two resistors. Then set up a real circuit on breadboard like Figure 6. Adjust the AC generator to output a 100Hz, 8Vpp ware and connect the circuit to the Oscilloscope as the figure shown. Click the auto button and record the two waveforms presented on the screen.

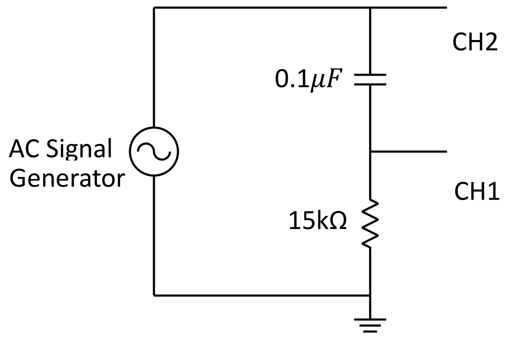



Figure 7

Then set up another circuit just as Figure 7. Record the output waveform from Oscilloscope after adjusting it properly.

## 2.3 Results and Discussions

The result of the experiment is presented in the following figures.

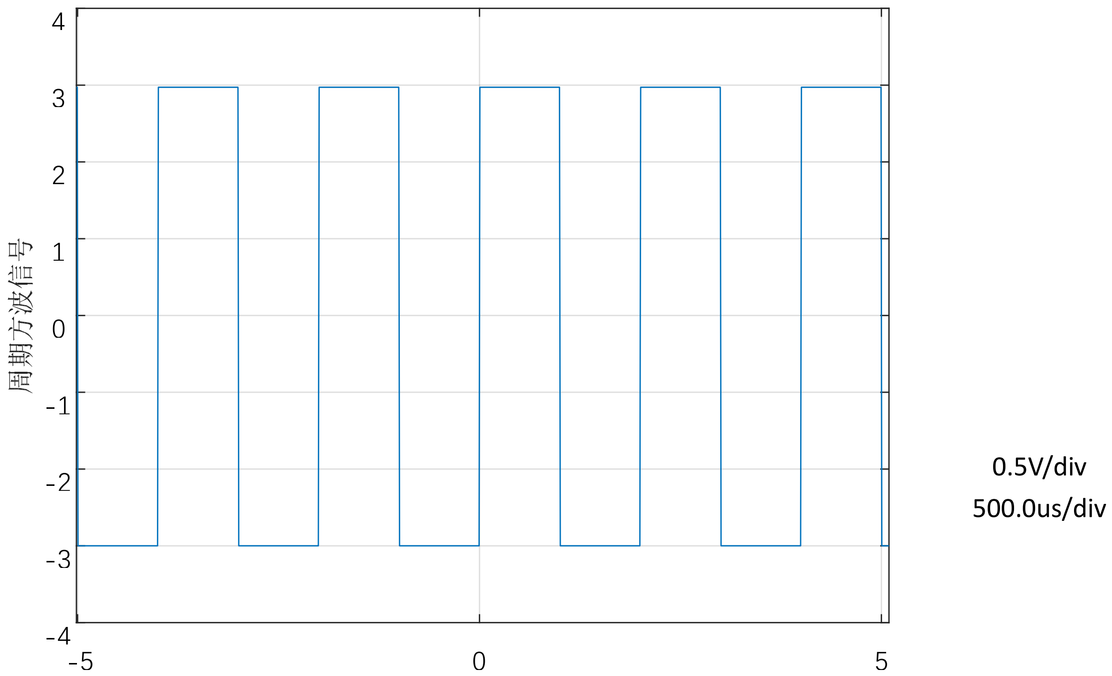
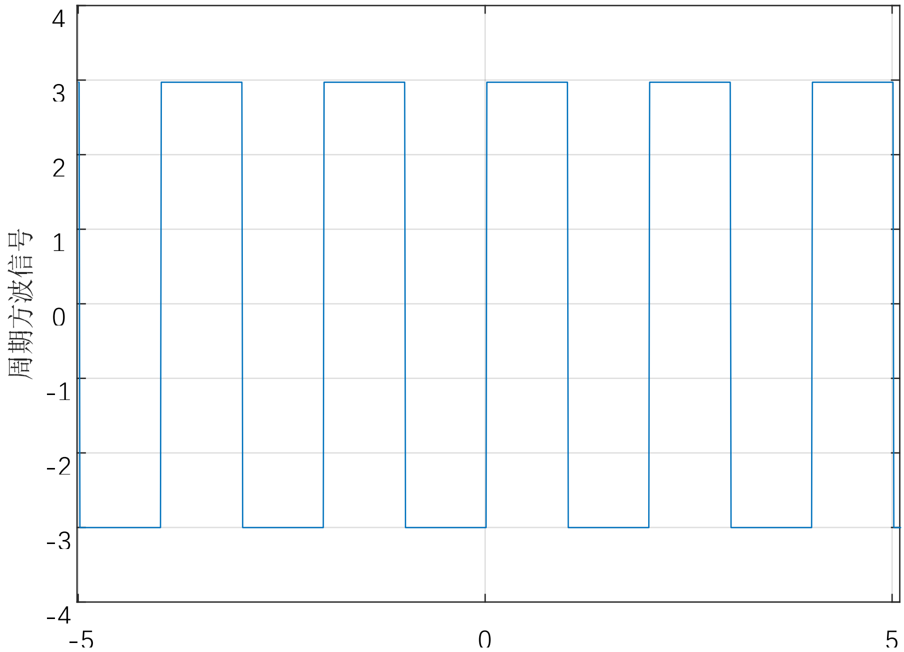



Figure 8

Figure 8 shows the waveform which was detected in the first step of calibration. As it shows, the Oscilloscope had been reset to adjust and output the most suitable waveform screen.

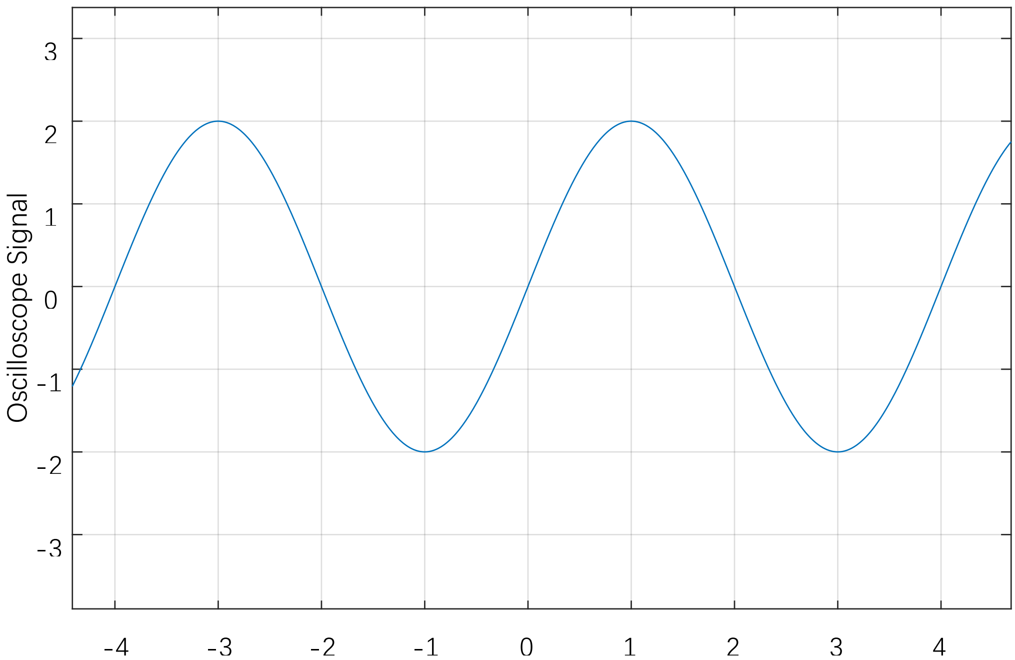



500mV/div

500.0us/div

Figure 9

Figure 9 shows the output result of the second step in the Calibration Section. As you can see, after switching the probe to x10 mode and change the Oscilloscope to x10 mode, the waveform output was quite similar with the result in step 1 which shown in Figure 8.




2.00V/div

500.0us/div

Figure 10

Figure 10 presented the result of the third step of Task A. As it illustrated, the output waveform is a sine waveform with a max/min 4V and a 2ms period which is corresponded with the AC signal generator which provided a 500Hz, 8Vpp sine signal in this experiment.

Then the experimental result of the fourth step of the Calibration Section was that the Trigger voltage=4.00V/-4.12V. This result was obtained by adjusting the trigger level knob to record both the upper voltage and lowest voltage where the signal begins to drift. There exist two value because that the upper largest voltage and the lowest negative largest voltage was different and in different direction. This result remained us to think a little bit more when conducting an experiment because there may be other possible result unexpected.

In Task B, the observation had been recorded and the result was shown in the following figures.

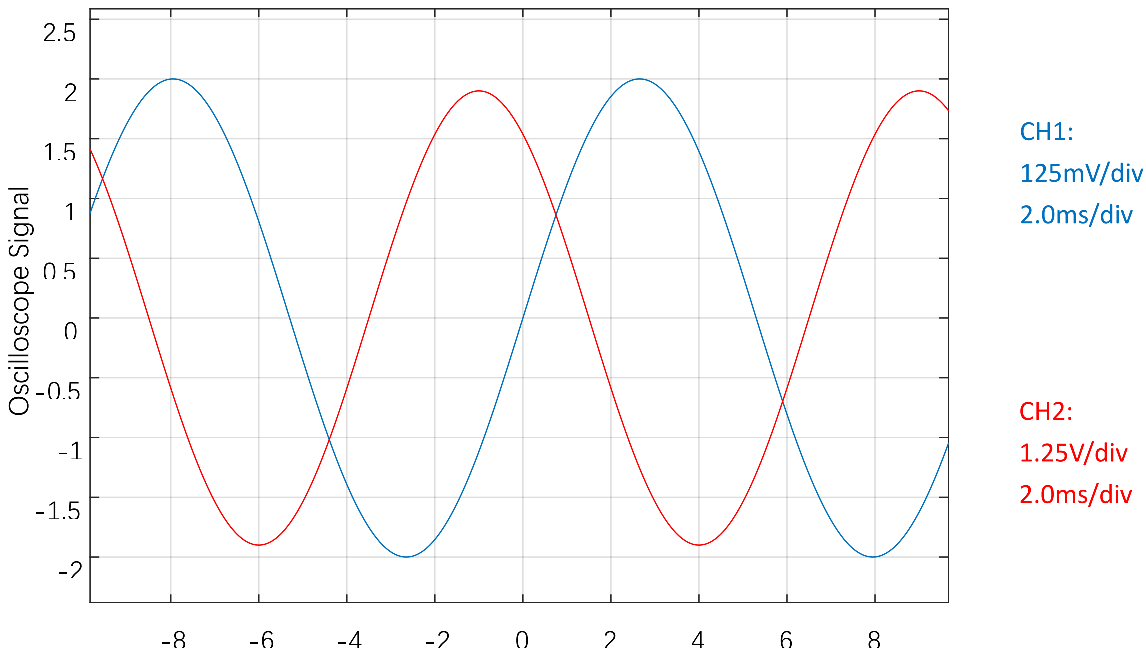



Figure 11

As it shown in Figure 11, there were two output waveforms accordingly with CH1 and CH2. Inevitably, it can be figured that the two waves were sine wave and the CH1 signal was nearly ten times smaller than the CH2 signal. And also, we noticed that the red waveform was a little early than the blue one. This may indicate that the waveform character in an AC circuit can be different even if the circuit was astonishing symmetry. One possible reason for this is that in AC circuit, a capacitor tends to have a resistant effect on an AC current. Because of this, if we define the bottom of the circuit in Figure 6 as the ground, it makes sense that the voltage of CH1 and CH2 were different.

On the other hand, from the perspective of the charge and discharge process of the two capacitors, it is likely that one of the waves is a little later than the other one since the charging and discharging speed of the passive capacitor piece might be a little later than the driving piece. As the CH1 detected the driving piece of the capacitor and the CH2 is connected to the passive capacitor piece, then CH2 is a little later with CH1 can be explained.

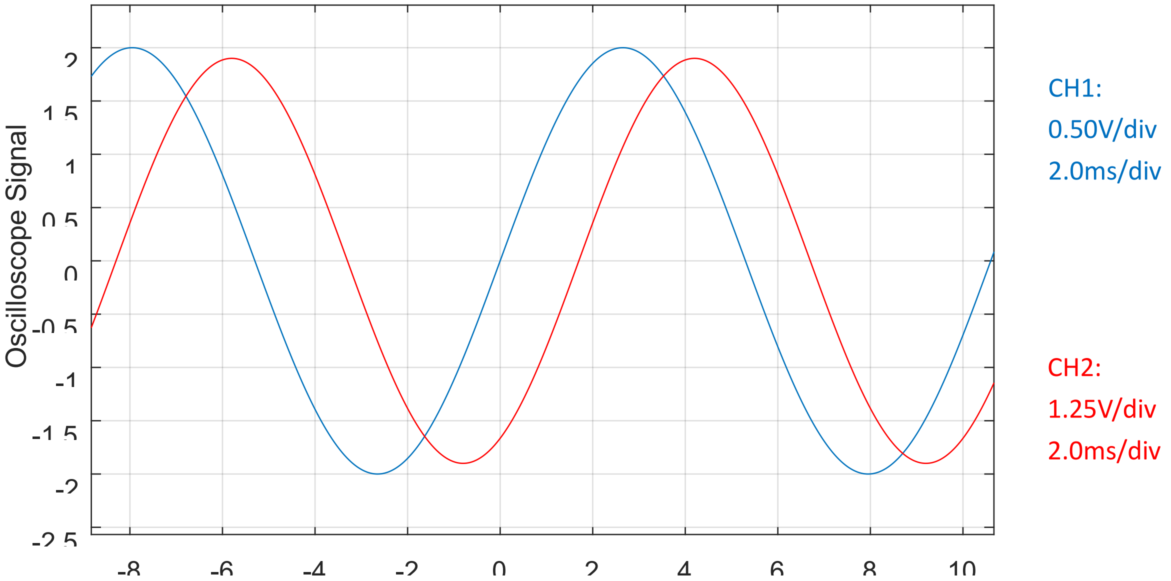



Figure 12

By conducting the experiment like Figure 7, we got the screen of Figure 12. In Figure 12, it shows two sine waveforms. After observation, it can be noticed that the max voltage of CH2 is approximately 4V, which is corresponded with the AC signal generator's output which was 8 Vpp. Besides, it can be found that the output voltage of CH1 was nearly two over five smaller than the CH2 in Figure 11, where the capacitor is 10 times large than the one in Figure 12.

Comparing with the waveforms of Figure 11 and Figure 12, it can be pointed that these two figures can both put up a phase shift. There are different phase shifts in these two circuits because firstly the capacitor is ten times different. Then, the detected points are also different. Its these reasons that result in two totally different wave phase shift in Figure 11 and Figure 12.

## 2.4 Conclusion

Overall, Oscilloscope is a very useful tool not only in signal observation but also in analyzing an AC circuit. With an Oscilloscope, we can easily find what the voltage waveform is at nearly any point of a circuit. Besides, by utilizing an Oscilloscope, it is more possible to vividly learn the difference among many points in a circuit and obtain a deep impression about each electronic component. Additionally, this experiment provides us a view that what exactly the voltage and current is in an AC circuit, where both capacitors and resistors can result in a signal phase shift.

## 3 PSpice Attachment

Task A: Measuring DC Voltage and Current
https://yimian.xyz/file/ee103/ex1.out.txt

Task B: Finding the Thevenin Equivalent Circuit
https://yimian.xyz/file/ee103/ex2_1.out.txt
https://yimian.xyz/file/ee103/ex2_2.out.txt