

EE1002 Lab4: Study of RC Circuit with Oscilloscope

Safety Precautions

1. Always turn off the power when you reconnect the circuit.
2. Double check your circuit and the voltage source setting before reapplying power.

I. OBJECTIVES

1. To get familiar with the oscilloscope controls.
2. To study the phase angle measurements.
3. To find the reactance of a capacitor.
4. To study the effect of frequency on the impedance of a series RC circuit.

II. EQUIPMENT REQUIRED

1. Oscilloscope (60 MHz, dual beam)
2. Signal generator
3. Solderless breadboard
4. Components: 0.1 μF capacitor, 1 $\text{k}\Omega$ resistor

III. PROCEDURE

Part A. Get familiar with oscilloscope

In this part, you will learn how to locate the trace, vary the beam position on the screen, and use the oscilloscope to measure the amplitude and frequency of simple waveforms.

(i) Frequency Measurements

- (1) Turn on the oscilloscope and switch the VERT MODE to dual beam. Set the coupling source of the oscilloscope as Channel 1 (CH1) and choose Auto mode.
- (2) Set the vertical AC-GND-DC input coupling switches of both channel 1 (CH1) and channel 2 (CH2) to GND. Center the traces of both channels on the screen, and then switch both AC-GND-DC switches back to AC.
- (3) Set the signal generator to produce a sine wave at a frequency of 500 Hz, with an amplitude of 1 volt. Connect it to CH1 input of the oscilloscope
- (4) Use the oscilloscope to measure the period (see Figure 1). To obtain the best accuracy, ensure that the waveform is centered on the screen vertically to measure the correct zero crossing on the time axis.

- (5) Find the period T of the waveform. The frequency of the signal can be calculated using $f = 1/T$.
- (6) You can turn the TIME/DIV button to set the oscilloscope timebase (time/div). It will control the number of cycles on the screen.

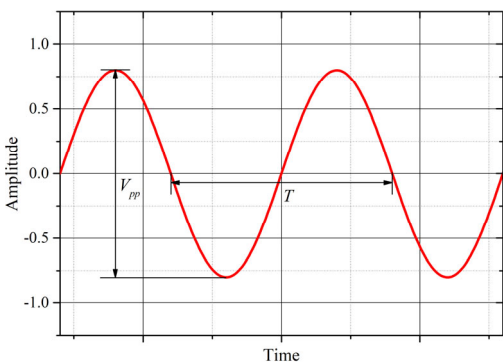


Figure 1. Signal period and peak-to-peak amplitude measurement.

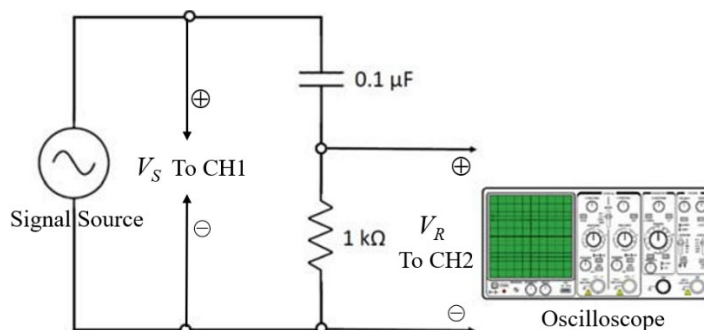


Figure 2. Measurement of voltage V_R across 1-k Ω resistor.

(ii) Amplitude Measurements

In this section, we use the oscilloscope to measure the amplitude of a simple waveform.

- (1) Keep the same setting of the signal generator in Part (i).
- (2) Set the CH1 sensitivity of the oscilloscope to 0.5 volt/div to display the signal properly. Connect the signal generator to CH1.
- (3) Set the TIME/DIV button to obtain several cycles on the display.
- (4) Measure the peak-to-peak value (see Figure 1) of the waveform.

Part B RC Circuit

When the dual-beam mode of an oscilloscope is used, it can display two electrical signals simultaneously. The phase shift of one signal relative to the other can be easily found from the time displacement between their waveforms. In this part, you will learn how to measure the phase shift between two signals.

- (1) Build the circuit shown in Figure 2.
 - (a) Connect the signal source to CH1 of the oscilloscope and keep the connection throughout the experiment.
 - (b) Measure the voltage V_R across the 1-k Ω resistor using CH2 of the oscilloscope.
- (2) Set the signal waveform in the signal generator as follows: 500-Hz sine wave with amplitude of 1 V and DC offset of 0V.

- (3) Find the period T of the signal source (input signal). Also, find the magnitude and the phase angle of V_R from t in Figure 3. The phase shift can be calculated with $|\Delta\phi| = 360^\circ \times t/T$. ($\Delta\phi$ will be positive (negative) if the output signal leads (lags) the input signal)
- (4) Compute the current I_R of the resistor ($I_R = V_R/R$). Fill in the columns (both magnitude and phase angle) of V_R and I_R in Table I.

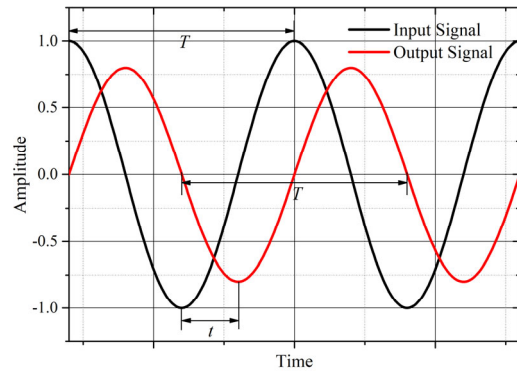


Figure 3. The input (signal source) and output (V_R) signals of the circuit in Fig. 2 with a period of T and time shift of t .

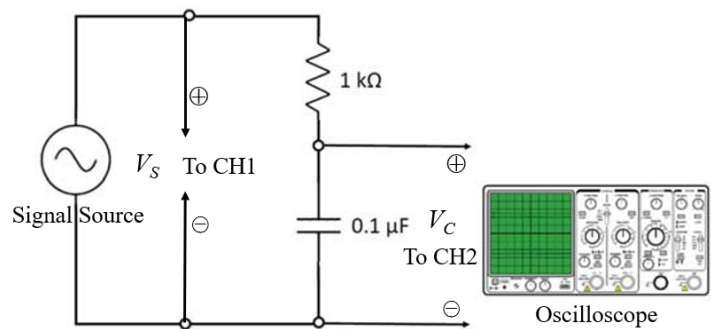


Figure 4. Measurement of voltage V_C across the 0.1- μ F capacitor.

- (5) Now measure V_C across the 0.1- μ F capacitor with CH2 of the oscilloscope, as shown in Figure 4. Fill in the columns (both magnitude and phase angle) of V_C in Table I.
- (6) Let $Z_{\text{Total}} = R + jX_C$, where $R = 1 \text{ k}\Omega$ and jX_C is the reactance of the capacitor given by $X_C = V_C/I_R$. Fill in the columns of “Measurement ($Z_{\text{Total}} = R + jX_C$)” and “Theoretical Reactance (jX_C)” in Table I.
- (7) Repeat steps 1 to 6 and fill in the table for the following frequencies: 1 kHz, 2 kHz, and 5 kHz.

Table I. Measured/calculated values of RC Circuit given in Figures 2 and 4.

Freq. (kHz)	Period (ms)	V_R (peak-to-peak)		I_R (peak-to-peak)		V_C (peak-to-peak)		Measurement $Z_{\text{Total}} = R + jX_C$		Theoretical Reactance (jX_C)
		mag(V)	angle	mag(mA)	angle	mag(V)	angle	$R \text{ (k}\Omega\text{)}$	$jX_C \text{ (}\Omega\text{)}$ $= V_C/I_R$	$jX_C \text{ (}\Omega\text{)}$ $= 1/(j\omega C)$
0.5*	2	0.54	72°	0.54	72°	1.82	-18°	1	$3.37 \times 10^3 \angle -90^\circ$	$3.18 \times 10^3 \angle -90^\circ$
1										
2										
5										

* The measured and calculated results at Frequency = 500 Hz are provided as a reference.

IV. Discussion

1. Explain the discrepancy between the measured and theoretical X_C values in Table I.

2. Discuss the dependency between the frequency and phase shift based on the results in Table I.
3. What will happen if we change the resistance of R ? Explain your answer.

V. REFERENCES

1. Helfrick, A.D. and Cooper, W.D. "Modern Instrumentation and Measurement Techniques": Chapter 7, Sections 1, 2, 4, and 10.1.
2. Bell, D.A. "Electronic Instrumentation and Measurements": Chapter 11, Sections 1-4 and 6.