

ECE 214 - Lab #2 — First Order RC Circuits

4 February 2019

Introduction In this lab you will investigate the magnitude and phase shift that occur in an RC circuit excited with a sinusoidal signal. You will also measure the circuit response to a square-wave input signal.

The circuit under test (CUT) is shown in Figure 1. Node voltages V_A and V_B will be measured using the two input channels on the oscilloscope. As in Lab #1, the input impedance of each channel will influence the circuit behavior. The 1X probe connecting the function generator to the circuit, and the scope probes connecting the CUT to the oscilloscope are not explicitly shown in Figure 1. However, the capacitance of these probes can influence the circuit behavior.

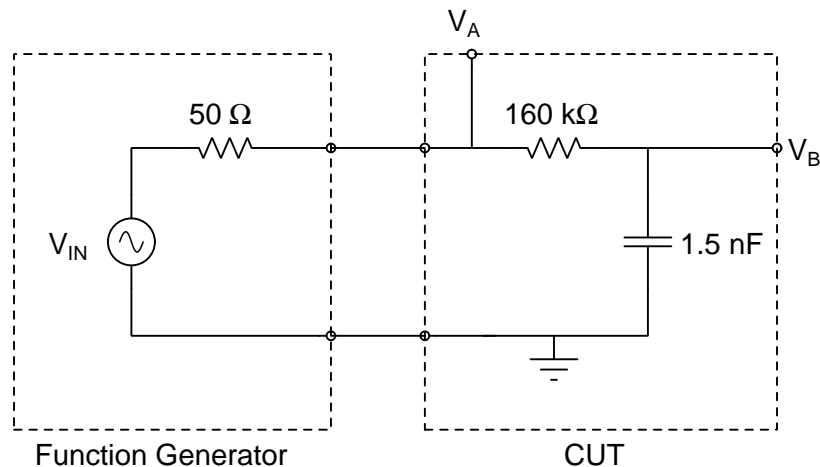


Figure 1: Circuit to be analyzed in Lab #2.

Pre-Lab

1. Based on your results from Lab #1, devise an experiment to measure the input resistance of your DVM when making a DC voltage measurement. Describe the experiment in your notebook.
2. For the RC circuit shown in Figure 1:
 - (a) What is the time constant of this RC circuit?
 - (b) Does this RC circuit behave as a low-pass filter or a high-pass filter?
 - (c) What is the cutoff frequency of this filter?
 - (d) Derive an expression that relates the rise-time of the signal at node V_B to the time constant of the signal at node V_B , when V_{IN} is a step function.

f (Hz)	Ideal Simulated Circuit			Complete Simulated Circuit		
	V_A	V_B	PS ($^{\circ}$)	V_A	V_B	PS ($^{\circ}$)
100						
200						
400						
600						
800						
1 k						
2 k						
4 k						
6 k						
8 k						
10 k						
20 k						
40 k						

Table 1: Simulated node voltages and phase shifts as a function of frequency for the “Ideal” and “Complete” circuit models.

3. Simulate the transient response of the circuit. A sample MATLAB[®] file and an hspc file are available on the course website.
 - (a) For the circuit in Figure 1, set the peak input voltage set to 1 V, and simulate the node voltages V_A and V_B and the phase shift (PS) in degrees between the two nodes. Record your results in the “Ideal Simulated Circuit” columns in Table 1.
 - (b) Modify the circuit schematic in Figure 1 to include the probe capacitances and the input impedances of the two oscilloscope channels at nodes V_A and V_B . With the peak input voltage set to 1 V, simulate the node voltages V_A and V_B and the phase shift (PS) in degrees between the two nodes. Record your results in the “Complete Simulated Circuit” columns in Table 1.
4. Does including the cable capacitance and input impedance of the oscilloscope scope channels make a difference when measuring this circuit?

Lab Procedure:

1. Determine the input resistance of your DVM when making a voltage measurement using the experiment you devised in step 1 of the Pre-Lab. Record in your notebook the manufacturer and model number of your DVM along with the measured input resistance. Put an entry for this data in the table of contents.
2. Measure the values for each component needed in the circuit shown in Figure 1 using the LCR meter and a DVM. When measuring the capacitance, measure both C and DF at frequencies of 1 kHz and 10 kHz. Calculate the ESR of the capacitor at these frequencies. Can the ESR be ignored? Explain your reasoning in your notebook.

f (Hz)	Measured Circuit		
	V_A	V_B	PS ($^\circ$)
100			
200			
400			
600			
800			
1 k			
2 k			
4 k			
6 k			
8 k			
10 k			
20 k			
40 k			
			45 $^\circ$

Table 2: Measured node voltages and phase shifts as a function of frequency.

3. Build the circuit shown in Figure 1:

- Set the FG to produce a 1 V peak sine wave at a frequency of 100 Hz. Make sure the peak voltage is really set to 1 V by measuring the signal on the scope.
- Measure the FG signal on your DVM using the AC voltage setting. Does the voltage measured on the DVM agree with that of the scope? If not, explain why.
- For each of the frequencies listed in Table 2, measure the peak voltages at V_A and V_B , and the phase shift between the two voltages. One probe should be connected to Channel #1 of the scope and the other to Channel #2. When making the measurements, use the averaging feature of the scope to improve the accuracy of the measurements. Record the results in Table 2.
- Does the voltage across the capacitor lead or lag the voltage across the resistor?
- Add one more frequency to your measurements: Determine the frequency needed to produce a 45 $^\circ$ phase shift between V_A and V_B . Use XY-mode and the Lissajous figures to help determine this frequency. Provide a sketch of the Lissajous figure in your notebook.

4. Change the FG to produce a square wave at a frequency of 100 Hz and a peak-to-peak voltage of 5 V. Verify the signal voltage on the scope.

- Measure the leading edge of the signal across the capacitor. Determine the time constant of this signal. Compare this time constant to the time constant predicted in part 2a of the Pre-Lab.
- Increase the FG frequency to 500 Hz. See <http://david.kotecki.com/ECE214/docs/FFT.pdf> for instructions on using the FFT feature of the scope.
 - Use the FFT function of the scope to display the voltage at Node V_A as a function of frequency and record the magnitude of the frequency components in your notebook.

- ii. Use the FFT function of the scope to display the voltage at Node V_B as a function of frequency and record the magnitude of the frequency components in your notebook.
- iii. Does the circuit act as a low pass or high pass filter?

Post-Lab

Use MATLAB® to generate graphs of the simulated and measured magnitudes and phase shifts as a function of frequency. Use a log scale when plotting the frequency. Generate two plots, each showing two sets of data, as described below. Make sure the axes of the graphs are properly labeled with the correct units.

Plot #1 Plot the peak voltage across the capacitor from the “simulated complete circuit” and the “measured circuit” as a function of frequency. These data should be plotted using a semi-log scale. The data from the “simulated complete circuit” should be plotted as a solid line, and the “measured” data should be represented as points (o) on the graph.

Plot #2 Plot the phase shift of the voltage across the capacitor with respect to V_A from the “simulated complete circuit” and the “measured circuit” as a function of frequency. These data should be plotted using a semi-log scale. The data from the “simulated complete circuit” should be plotted as a solid line, and the “measured” data should be represented as points (o) on the graph. The phase shift should be in degrees.