

7.5.1: Passive RC Circuit Step Response

Overview:

In this lab assignment, we will examine the step response of a simple RC circuit. We will use a square wave voltage source to emulate a step input to the system. An oscilloscope will be used to monitor both the applied input voltage and the response voltage from the circuit. Both the voltage across the capacitor and the voltage across the resistor will be measured and the waveforms across both inputs compared. We will also examine the effects of loading a passive RC circuit in this lab assignment.

Before beginning this lab, you should be able to:

- Determine the time constant of exponential functions
- State voltage-current relationships for inductors and capacitors
- Determine the natural response of passive first order (RL, RC) circuits
- Determine the step response of passive first order (RL, RC)

After completing this lab, you should be able to:

- Use a function generator to apply a square wave voltage input to an electrical circuit.
- Measure the time constant and steady-state response of first order passive electrical circuits
- State the potential effects of loading on a passive RC circuit

This lab exercise requires:

- Analog Discovery module
- Digilent Analog Parts Kit
- Digital multimeter (optional)

Symbol Key:

	Demonstrate circuit operation to teaching assistant; teaching assistant should initial lab notebook and grade sheet, indicating that circuit operation is acceptable.
	Analysis; include principle results of analysis in laboratory report.
	Numerical simulation (using PSPICE or MATLAB as indicated); include results of MATLAB numerical analysis and/or simulation in laboratory report.
	Record data in your lab notebook.

General Discussion:

This lab assignment will be concerned with the simple series RC circuit shown in Figure 1. We will be interested primarily in the measured vs. expected behavior of the capacitor voltage, but a secondary goal of this assignment is to compare the voltage differences across the capacitor and resistor. Thus, we will measure both the voltage differences $v_R(t)$ and $v_C(t)$ as shown in Figure 1¹.

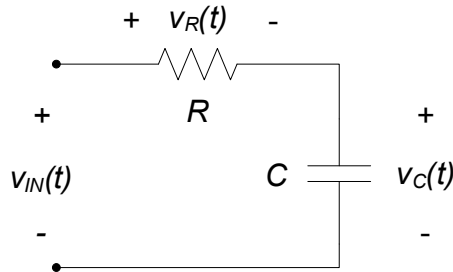


Figure 1. RC circuit being tested.

Pre-lab:

ANALYSIS

Estimate the time constant for the circuit shown in Figure 1 if $R=470\ \Omega$, and $C = 1\ \mu\text{F}$. Also determine the steady state response of $v_C(t)$ if v_{IN} is a step input with amplitude 5V. (e.g. $v_{IN} = 5u_0(t)$ V.) Note: you do not need to write or solve a differential equation for either of the circuits in order to do this.

Lab Procedures:

DATA

- Construct the circuit shown in Figure 1, using $R=470\ \Omega$ and $C = 1\ \mu\text{F}$. (As always, measure the actual resistance value; measure the capacitance value if you have the appropriated instrument – some DMMs have a capacitance meter – otherwise, assume that the nominal capacitance value is correct.)

DATA

- Apply a 4V peak-to-peak square wave input with period = 10 ms (frequency = 100Hz) as shown in Figure 2 to the circuit². Display both $v_{IN}(t)$ and $v_{OUT}(t)$ on your oscilloscope window. Record the image of the oscilloscope window, showing the waveforms and save the signals as a data file for later plotting³.

¹ The oscilloscope instrument on the Analog Discovery will allow you to take “double-sided” or “differential” voltage measurements – this allows you to directly measure the voltage difference across any component in the same way you measure a voltage difference using a DMM. Thus, we can measure the voltage differences in Figure 1 exactly as they are indicated on that figure. Many oscilloscopes, however, make single-sided measurements, in which voltage differences are all measured with respect to a “common” or ground node. In order to measure the voltage across the resistor in Figure 1 using a single-sided oscilloscope, we would typically measure $v_{in}(t)$ and $v_C(t)$ and then using a math channel on the oscilloscope to take the difference between the two to get the voltage across the resistor

² In the terminology used in the Analog Discovery waveform generators, we would say that the waveform of Figure 1 has an amplitude (zero-to-peak) of 2V and an average value (or offset) 1V.

³ The “Export” button on the oscilloscope toolbar allows you to save measured data as a .csv file.

ANALYSIS

- ii. Calculate the time constant and steady state response of the output voltage. Compare your results with your expectations based on the pre-lab analysis and comment on any differences.

DEMO

- iii. Demonstrate operation of your circuit to a teaching assistant and have them initial your lab notebook and the lab checklist.

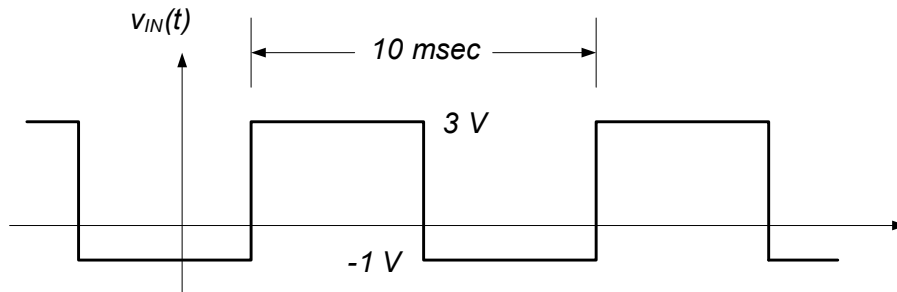


Figure 2. Input voltage signal.

- b. RC circuits are often used for signal conditioning. The conditioned signal will, in general, be applied to a load in order to be useful.
 - i. Apply a load to the RC circuit of Figure 1 by constructing the circuit shown in Figure 3. Use $R = R_L = 470\ \Omega$, and $C = 1\ \mu\text{F}$. Measure the output voltage across the load resistor, for the input voltage shown in Figure 2. Record the image of the oscilloscope window, showing the waveforms and their measured amplitudes, and save the signals as a data file for later plotting.

DATA

ANALYSIS

- ii. Determine a time constant and steady state response from your measured data. How do these parameters compare with those of the unloaded circuit of part (a)? Do the loaded circuit parameters agree with your expectations? (Hint: calculate an equivalent resistance seen by the capacitor.)

DEMO

- iii. Demonstrate operation of your circuit to a teaching assistant and have them initial your lab notebook and the lab checklist.

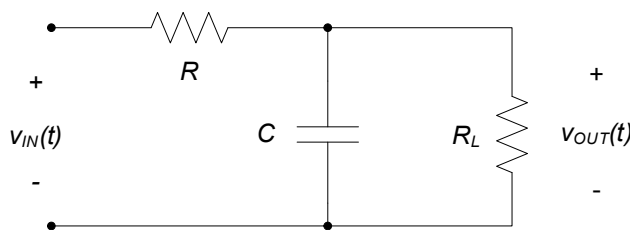


Figure 3. Loaded passive RC circuit.

Post-lab Exercises:

ANALYSIS

- a. Import the oscilloscope data you acquired in part (a) of the lab procedures into Excel, Matlab, or any similar software package which provides basic mathematics and plotting capabilities. Plot the resistor and capacitor voltages. Use your software to sum the capacitor and resistor voltages. Plot the result and compare it to the input waveform you applied to the circuit. Comment on differences or similarities.

ANALYSIS

- b. Import the voltage $v_{OUT}(t)$ you acquired in part (b) of the lab procedures. Create a plot displaying this data overlayed with the capacitor voltage of the unloaded circuit acquired in part(a) of the lab procedures. Comment on the differences between the two, including qualitative comparisons of the time constants and steady-state responses.