

GEORGIA INSTITUTE OF TECHNOLOGY
School of Electrical and Computer Engineering
ECE 2040
Lab #2: First-Order Response: RC Circuits

GOAL

To gain experience with the first-order response of RC circuits.

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EQUIPMENT NEEDED

- 20k Ω resistor
- 2 x 10k Ω resistor
- 0.1 μ F capacitor
- Breadboard
- Jumper wires
- NI myDAQ

BACKGROUND

Resistors: The resistance of physical resistors is denoted by 4-5 color bands on the resistor. Generally speaking, 4 band resistors are light tan, whereas 5 band resistors are blue. Figure 1 below shows how to read the color code for a 4 band resistor (There is a more in depth color code diagram in Appendix A) as well as an example to get you started.

Color	Value
Black	0
Brown	1
Red	2
Orange	3
Yellow	4
Green	5
Blue	6
Purple	7
Grey	8
White	9

1st band and 2nd band give the first two significant numbers of the resistance
3rd band gives the base 10 multiplier, $\times 10^n$
4th band gives the tolerance (silver is $\pm 10\%$ and gold is $\pm 5\%$)



A resistor with bands (yellow, red, orange, silver) is a 42,000 Ω resistor with a tolerance of $\pm 10\%$.

Figure 1. 4 band resistor color code

Capacitors: Like resistors, capacitor values are also encoded on capacitors. Use the table in Appendix B to determine capacitor values from their codes or to determine the codes from their value. An example of what a standard capacitor looks like as well as what the code looks like is shown in Figure 2 below.



A capacitor labeled 154 has a value of 150 Nano Farads.

Figure 2. Capacitor example

Time Constants of RC Circuits: Given an RC circuit shown in Figure 3 below, the source voltage is v_s , and v_c represents the voltage across the capacitor.

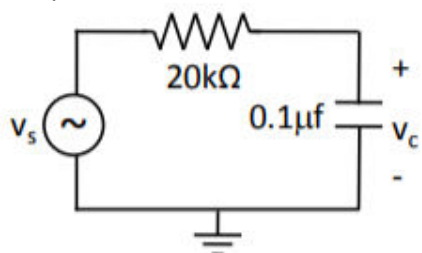


Figure 3. RC circuit example

When v_s is a step from 0V to V_f volts and the capacitor is initially uncharged, the voltage across the capacitor v_c varies with time as:

$$v_c(t) = V_f(1 - e^{-t/\tau})$$

Where τ is the circuit time constant given by:

$$\tau = RC$$

When $t = 0$ the capacitor voltage is the initial voltage of zero, and for large t , the capacitor voltage approaches V_f . At $t = \tau$ the following equation is true:

$$v_c(\tau) = V_f(1 - e^{-1}) = 0.64V_f$$

PRE-LAB ASSIGNMENT

1. Every Student needs to download the NI ELVISmx software, install it on your laptop, and bring your laptop to class. Make sure that the NI ELVIS Instrument Launcher software runs. *This process takes about an hour to do.* Failure to do this may result in not being able to perform the laboratory exercise. The software can be found on the National Instruments website at: <http://joule.ni.com/nidu/cds/view/p/id/2157/lang/en>.

For students using a MAC, you will need to install the software on a Windows partition and run it from there. The experiment will be done in pairs, so if you cannot get this software to run on your machine, then make sure that you arrange to have a partner who can run it.

2. Read the Background section of this laboratory exercise.

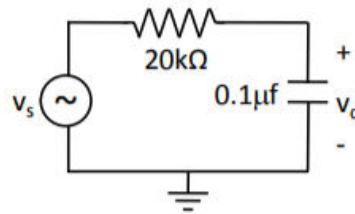
LAB PROCEDURES

At certain times during this lab you will be required to record data. Please use the answer sheet at the end of the lab to record your data and be sure to include units. There will be corresponding numbers listed in bold at the beginning of each question so that you may match them with your answer sheet. We will only be grading the answer sheet, so anything you write in the lab will not be counted. Please **PRINT** out your own answer sheet so that we are able to grade it. **Any answers listed on regular scratch paper will result in loss of a letter grade.**

1. Setting Up the Experiment

- On the protoboard, construct the RC circuit whose schematic is shown in Figure 4 below.

Voltage source provided
by the function
generator, FGEN



Circuit Schematic

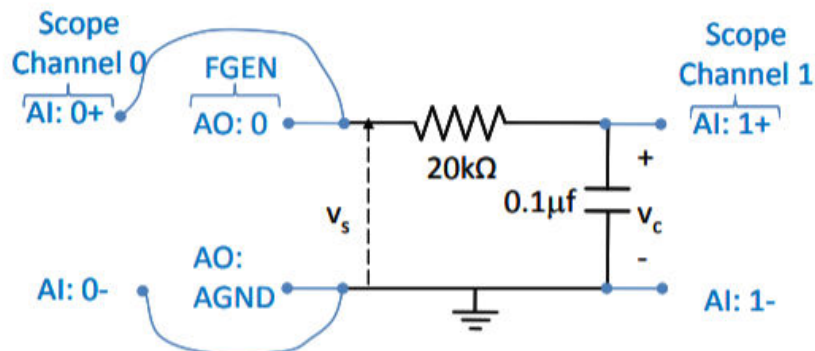


Figure 4. Circuit Schematic with myDAQ connections

- Connect the myDAQ function generator and oscilloscope to the circuit as shown in the schematic. The function generator supplies the source voltage, v_s . The scope measures v_s on Channel 0 and v_c on Channel 1. The myDAQ inputs and outputs are connected to the nodes of the circuit. For example, AI: 0-, AI: 1-, and AO: AGND are all connected together while the positive analog input 1 (AI: 1+) connects to the circuit node between the resistor and the capacitor.

2. Launching the Function Generator and Oscilloscope

- Double click on FGEN to launch the function generator. Double click on Scope to launch the oscilloscope. A sample screen shot of the myDAQ instruments and the launcher is shown in Figure 5 below.

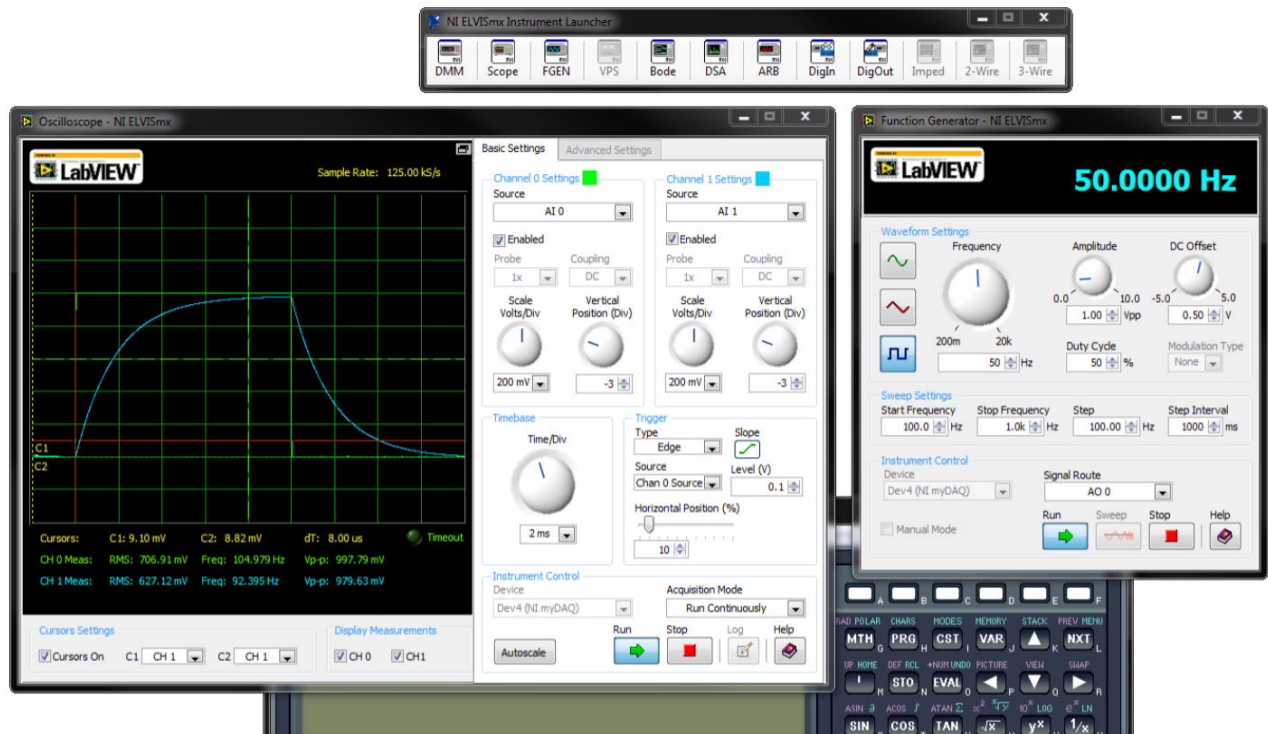


Figure 5. Oscilloscope Interface (left) and Function Generator (right)

3. Setting Up the Instruments

a. Function Generator

- Match the settings in the screen shot to produce a 50 Hz 1 V peak-to-peak square wave with a dc offset of 0.5 V.

b. Oscilloscope, enable Channel 1 then set:

- The trigger type to edge
- The trigger level to 0.1V
- The horizontal position to 10%
- The Volts/Div on both channels to 200 mV
- The vertical position of both channels to -3 divisions
- The Time/Div setting to 5ms (this is different from the setting in the figure) the source for channel 1 to AI1

c. Click run on both the function generator and the oscilloscope

d. Verify that both the circuit input voltage, v_s , and the voltage across the capacitor, v_c , are both displayed properly.

- v_s shown on scope channel 0 is a square wave that varies from zero to 1V
- v_c displayed on channel 1 does not respond instantly to the input voltage. Instead, it slowly approaches the applied input voltage.

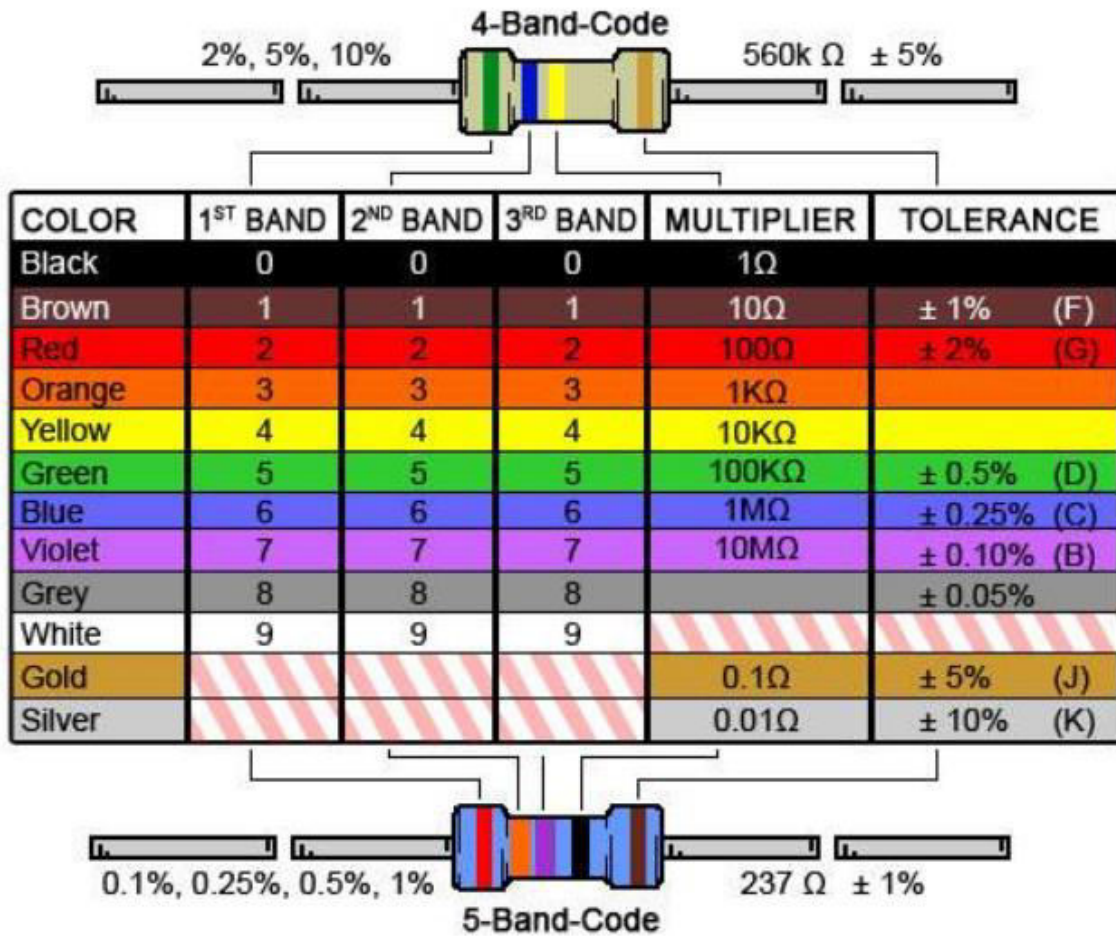
e. Zoom in on the measured voltages by changing the timebase to 2ms per division. The scope should now display the input voltage and the capacitor voltage for approximately one period of the input. The voltages displayed should be similar to those shown in the scope display figure above.

4. Time Constant Measurements

The transition of the square wave from 0 V to 1 V approximates a step input to the circuit. The response of the circuit to this step input can be used to calculate the circuit time constant as discussed in the background section. The scope has cursors that allow you to precisely measure the voltage at a specific point in the waveform.

- a. **[1]** Calculate the time constant of the circuit by using the equation in the background section assuming the nominal circuit component values.
- b. Use the scope cursors to measure two points on the capacitor voltage waveform shown on Channel 1.
 - Click the Cursors On box located below the scope display
 - Change the cursors to measure the voltage across the capacitor by changing both drop down options under the scope display to CH 1
 - Drag the cursors from the left side of the screen. (Vertical dashed lines labeled C1, C2)
 - Position the first cursor to the point where the capacitor voltage just starts to rise
 - Position the second cursor to the point where the capacitor voltage is 0.64 of its final value (the voltage at the cursor value is shown below the display)
 - **[2]** Record the difference in time between these two values, designated as Δt (also below the display). This is the time constant.
- c. **[3]** Calculate the percent error in the experimentally determined value.
- d. **[4]** List any possible causes of error.
- e. **[5]** Determine what resistor value should be placed in parallel with the 20k resistor in the circuit to reduce the time constant in half (show your work).
- f. **[6]** Insert this resistor into the circuit (you may need to use a combination of resistors to get this value). Watch the oscilloscope display as one end of this second resistor is inserted and removed from the protoboard. Does the capacitor voltage behave as expected? Explain
- g. **[7]** What would happen if a second 0.1 μF capacitor were placed in parallel with the first? Predict the behavior, explain your reasoning.
- h. **[8]** Place the mouse over the FGEN frequency dial and move it around to increase and to decrease the input frequency. Sketch the input and output voltage waveforms for a high frequency signal and sketch the input and output voltage waveforms for a low frequency signal. What are the significant differences between the responses of a low frequency and a high frequency voltage signal?
- i. **[9]** Change the input voltage waveform to a sinusoid and increase and decrease the frequency. Draw and explain what happens to the output voltage waveform compared to the input voltage waveform as the frequency is increased (pay attention to the relative amplitudes and time lags).

APPENDIX A: Resistor Color Codes



APPENDIX B: Capacitor Codes

Code	Value (nF)	Code	Value (nF)	Code	Value (nF)	Code	Value (nF)
100	0.01	331	0.33	472	4.7	154	150
150	0.015	471	0.47	502	5	254	200
220	0.022	561	0.56	562	5.6	224	220
330	0.033	681	0.68	682	6.8	334	330
470	0.047	751	0.75	103	10	474	470
101	0.1	821	0.82	153	15	684	680
121	0.12	102	1	223	22	105	1000
131	0.13	152	1.5	333	33	155	1500
151	0.15	202	2	473	47	205	2000
181	0.18	222	2.2	683	68	225	2200
221	0.22	332	3.3	104	100	335	3300

APPENDIX C: Answer Sheet**1:****2:****3:****4:****5:****6:****7:****8:****9:**