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First-Order Response: RC Networks

Objective: To gain experience with

- first-order response of RC circuits

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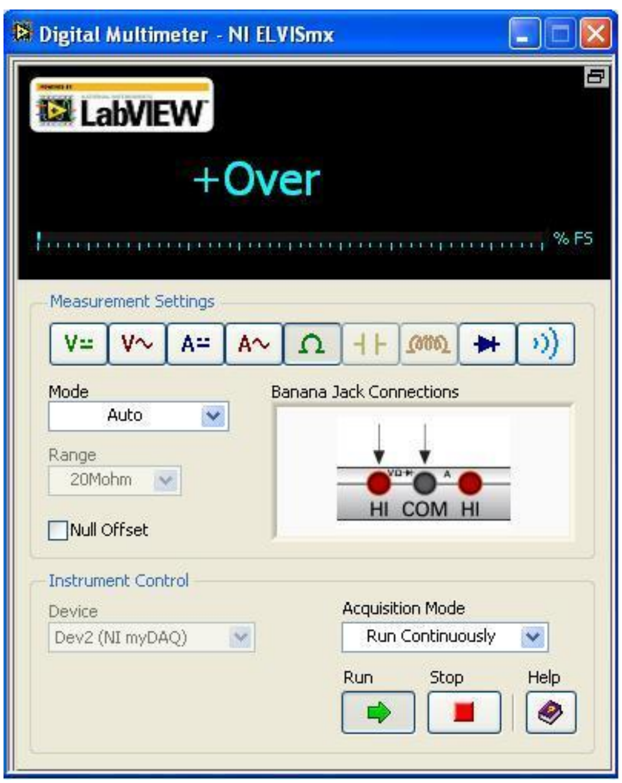
Pre-Lab Assignment

1) Every Student needs to download the NI ELVISmx software, install it on your laptop, and bring your laptop to class. 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
2) Read the Background section of this laboratory exercise.
3) Perform hand calculations on the circuits in part B1 to determine the expected values for the empirically determined unknowns.

Background

Learning how to use the DMM

1. To set up the DMM for measuring voltage:
   - Plug the myDAQ into a USB port on your computer
   - Start the NI ELVISmx Instrument Launcher software.
   - Click on the DMM icon to open the DMM screen shown below.
   - Match the settings in the screen below (Run Continuously, and Auto mode).
   - Click on the symbol V - - on the DMM screen.
   - Plug the black DMM lead into the COM plug on side of the myDAQ.
   - Plug the red DMM lead into the red terminal to the left of the COM terminal (marked with a VΩ label).
   - Click on "Run".



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Resistors

The resistance of physical resistors is denoted by four color bands on the resistor. The color code for bands 1-3 is

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

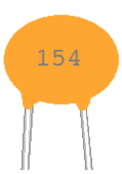
1st band and 2nd band give the first two significant numbers of the resistance
3rd band gives the base 10 multiplier, $x10^n$
4th band gives the tolerance (silver is ±10% and gold is ±5%)

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

Capacitors

Like resistors, capacitor values are also encoded on capacitors. Use the table below to determine capacitor values from their codes or to determine the codes from their value.

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



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

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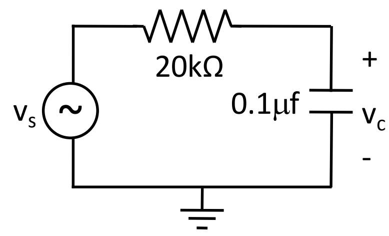
Time Constants of RC Circuits

Given an RC circuit shown below, the source voltage is v_s, and v_c represents the voltage across the capacitor.



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

$$\tau = RC$$

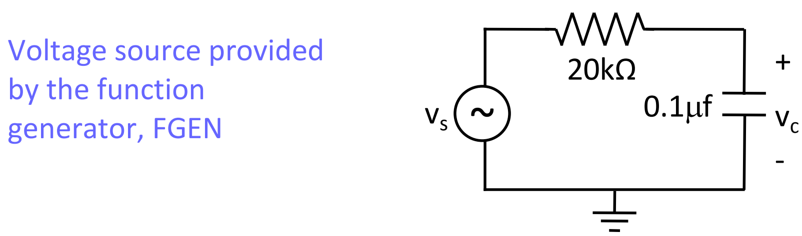
When t=0 the capacitor voltage is the initial voltage of zero, and for t large, the capacitor voltage approaches V_f. At $t = \tau$,

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

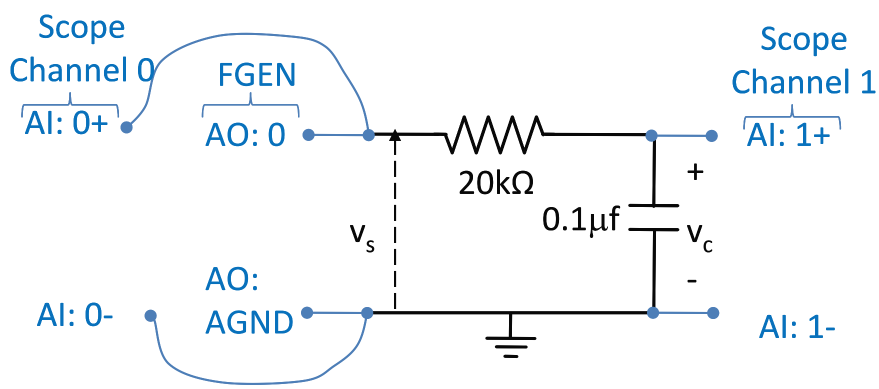
<u>**Lab Procedure**</u>

Part A) Experimental Set-up

1. On the protoboard, construct the RC circuit whose schematic is shown below.

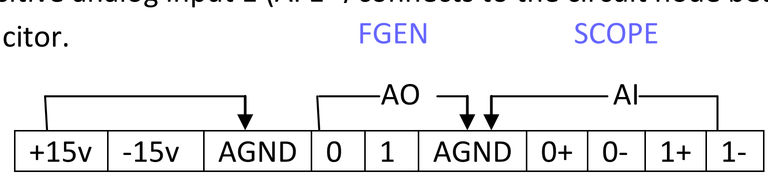


Circuit Schematic



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. 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 below.

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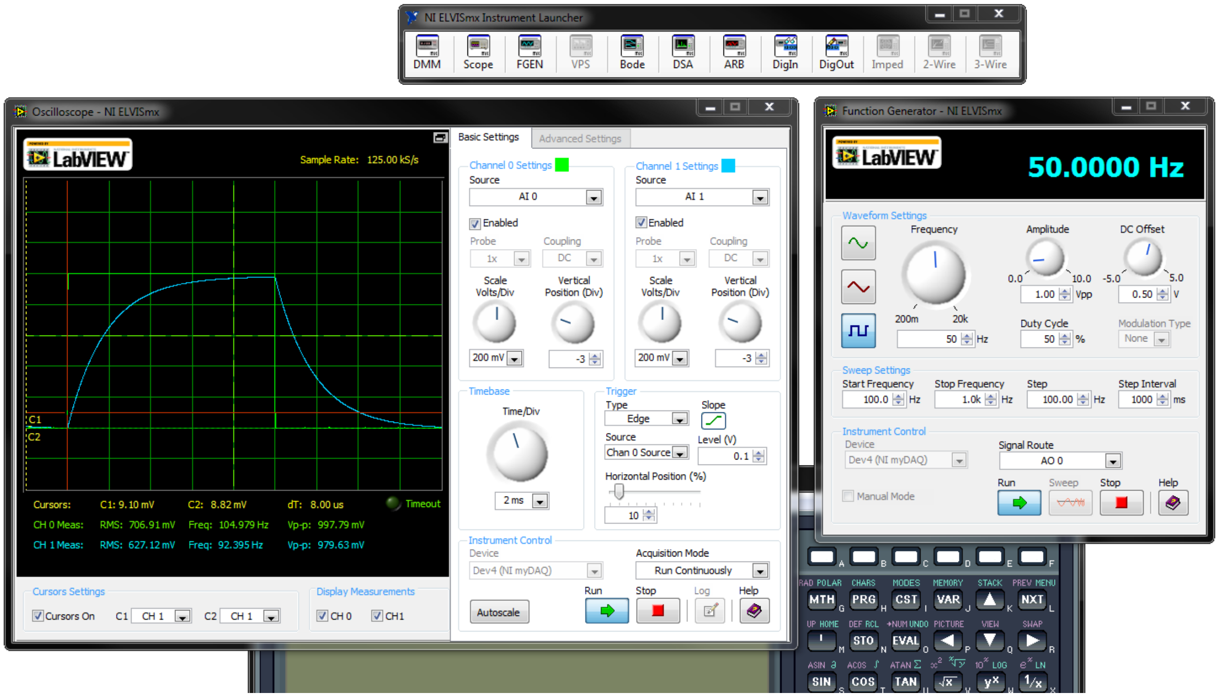

3. Set up the instruments:
    a. Function Generator
        - Match the settings in the screen shot to produce a 50 Hz 1 V peak-to-peak square wave with a dc offset of 0.5 V.
    b. Oscilloscope, enable Channel 1 then set:
        - the trigger type to edge
        - the trigger level to 0.1 V
        - 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

4. Click Run on both the function generator and the oscilloscope.
5. Verify that both the circuit input voltage, v_s, and the voltage across the capacitor, v_c, are displayed properly:
    - v_s shown on scope channel 0 is a square wave that varies from zero to 1 V
    - v_c displayed on channel 1 does not respond instantly to the input voltage. Instead, it slowly approaches the applied input voltage.
6. 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.

Not Working:

- Make sure that the interface is pushed into to the myDAQ unit all the way. If it comes loose, good electrical connections may not be present.
- Make sure that only the FGEN and SCOPE are connected to the circuit. **The 15V power supply should not be connected to this circuit.** The circuit is being powered by the function generator. (FGEN)
- Make sure that the rest of the circuit is connected correctly (according to the schematic). It is generally good practice to use short wires and as few wires as possible.Make sure the 

button is pressed on both the function generator and the oscilloscope.

Part B) First-Order Response of RC Circuits

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.

1. Calculate the time constant of the circuit by using the equation in the theory section assuming the nominal circuit component values:

   τ = _________ sec

2. 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)
   - Record the difference in time between these two values, designated as dT (also below the display). This is the time constant.

   τ = _________ sec

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3. Calculate the percent error in the experimentally determined value:

4. What are possible causes of any error?

5. Determine what resistor value should be placed in parallel with the 20k resistor in the circuit to reduce the time constant in half:

6. Insert this resistor into the circuit. 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:

7. Leave the additional resistor in the circuit. What would happen if a second 0.1 uF capacitor were placed in parallel with the first? Predict the behavior, explain your reasoning below, then try it. What happens?

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?

9. Change the input voltage waveform to a sinusoid and increase and decrease the frequency. 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).