2.737 Lab 1

Assigned: Sept. 10, 2014
Due: In checkoffs Thurs. Sept. 18, 2014

This lab gives an introduction to using the myRIO with Labview to implement closed-loop control of an RC filter. We also ask you to experimentally investigate the effects of loading on some RC filters, in order to understand that the measurement system can affect the measurement. As well, the lab report must include answers to some circuit problems. These problems are taken from the file `archive.pdf` which is available on the course web page. Note that the archive also includes solutions to many of the problems.

The solutions to the assigned problems must be included with your lab report. The lab report should also clearly document your experimental work, predictions, results, and a comparison between these, with explanations of observed phenomena and discrepancies. Be sure to show us your *understanding* of the lab and design experiences. No formal lab report structure is required.

We will evaluate your work with a 30 minute checkoff on Thurs 9/18. Be sure to come to lab early enough that you have your experiments running and ready to show us. You will need to demonstrate the loading effects in the RC circuits as well as the closed-loop control implemented on the myRIO.

Lastly, be sure to start this work early, as there is a significant time commitment, and it is not likely to be well-solved at the last minute!

Readings: Please look online and get copies of: 1) the myDAQ users guide, 2) the myRIO users guide, and 3) the NI application note on analog signals, available by going to `ni.com/info` and entering the Info Code `analogwiring`. The myDAQ users guide has a useful section on how to work with the differential inputs. The myRIO user's guide has some details on the myRIO configuration, which includes the myDAQ input differential amplifiers on the myDAQ connectors. Note that the other analog inputs are *single-ended*, so these may require you to make your own differential amplifier for measuring any critical signals. The NI application note has much more information which is very useful for interfacing with sensors and other signal sources.

Specifically, we ask you to:

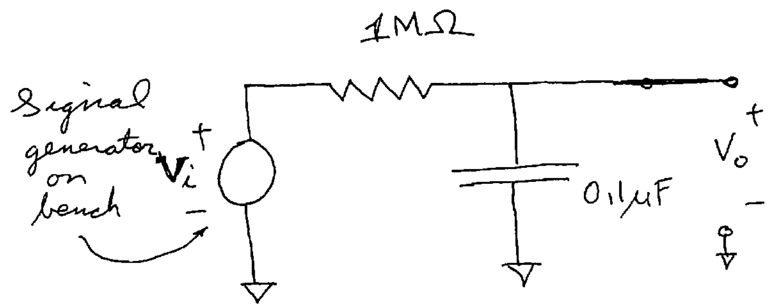
Archive Problem 8.3 Complete the solution of this problem and submit with your lab report.

Archive Problem 8.5 Complete the solution of this problem and submit with your lab report.

Archive Problem 9.2 Complete the solution of this problem and submit with your lab report.

Archive Problem 9.10 Complete the solution of this problem and submit with your lab report.

Lab exercise 1 Consider the circuit shown below:



For this circuit,

a) Sketch the response to a unit step input.

b) Construct the circuit on your protoboard, and drive it with the bench signal generator. We ask you to measure the response three ways:

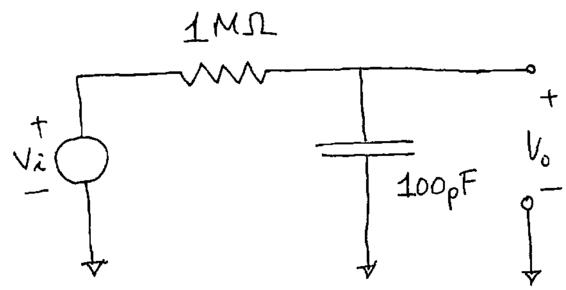
1) Connect the circuit output to the bench oscilloscope using a standard BNC cable, and display the response on the scope.

2) Connect the circuit output to the bench oscilloscope using the scope's 10x probe, and display the response on the scope.

3) Connect the circuit output directly to the differential amplifier input of the myRIO using wires on your protoboard. Display the response in Labview at a sufficiently high sample rate.

c) What do you observe with these three connection approaches? Include relevant waveforms/sketches and measurements to document your observations. Can you explain the observed behavior? What models might explain what you see? What have you learned about loading when connecting to circuit signals?

Lab exercise 2 Consider the circuit shown below



For this circuit,

a) Sketch the response to a unit step input.

b) Construct the circuit on your protoboard, and drive it with the bench signal generator. We ask you to measure the response three ways:

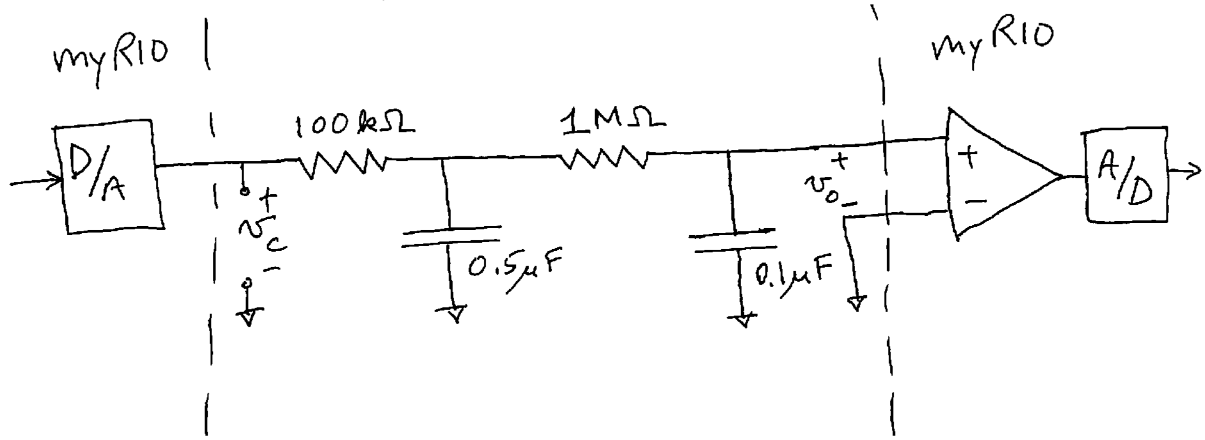
1) Connect the circuit output to the bench oscilloscope using a standard BNC cable, and display the response on the scope.

2) Connect the circuit output to the bench oscilloscope using the scope's 10x probe, and display the response on the scope.

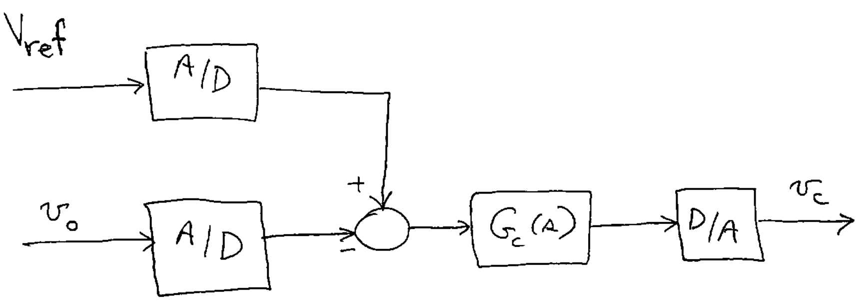
3) Connect the circuit output directly to the differential amplifier input of the myRIO using wires on your protoboard. Display the response in Labview at a sufficiently high sample rate.

c) What do you observe with these three connection approaches? Include relevant waveforms/sketches and measurements to document your observations. Can you explain the observed behavior? What models might explain what you see? What have you learned about loading when connecting to circuit signals?

Lab exercise 3 Consider the control system shown below



The second-order circuit shown is to be considered as the *plant* to be controlled by the myRIO. Specifically, the input to the plant is the D/A output voltage v_c, and the output of the plant is the voltage v_o. That is, the control loop configuration is:



We ask you to do the following:

a) Calculate the exact transfer function $V_o(s)/V_c(s)$. Use MATLAB® to compute the plant pole locations, step response, and Bode plot for this plant.

b) Assume that the second RC stage does not load the first. That is, since 1 MΩ >> 100 kΩ, we can assume that the two RC transfer functions may be computed independently. Under this assumption, calculate the approximate transfer function $V_o(s)/V_c(s)$. Use MATLAB to compute the plant pole locations, step response, and Bode plot for this plant. Compare these results with the exact results from a) above.

c) Design a continuous-time PID (lead/lag) controller of the form

$$G_c(s) = K_p \left(1 + \frac{1}{T_i(s)}\right) \frac{\alpha\tau s + 1}{\tau s + 1}.$$

Be sure to implement the integrator as a separate block with antiwindup included.

Design this controller to regulate the output voltage v_o to equal the reference signal V_{ref} measured on another A/D channel and supplied by the bench signal generator. Choose the controller parameters to give a crossover frequency $\omega_c = 1000$ rad/sec, with a phase margin $\phi_m = 45°$ using the exact plant transfer function.. Create an accurate hand-sketch of the loop return ratio showing the design and the crossover and phase margin. Also use MATLAB to confirm your design. What are the design values of T_i, α, and τ?

d) Implement this control loop inside the CD&Sim loop adapted from Lab 0. Record some interesting waveforms and compare with what would be predicted by theory. At a minimum, compare the step responses in v_c and v_o with the responses predicted using MATLAB.

Checkoff on Thursday 9/18: We will post a signup sheet for checkoffs. You will need to demonstrate your working circuits and associated signals on the oscilloscope for the lab exercises. Also plan to show us any interesting effects you have observed.