# MECE-743 Digital Control Systems

## Computer Project #1: *System Identification*

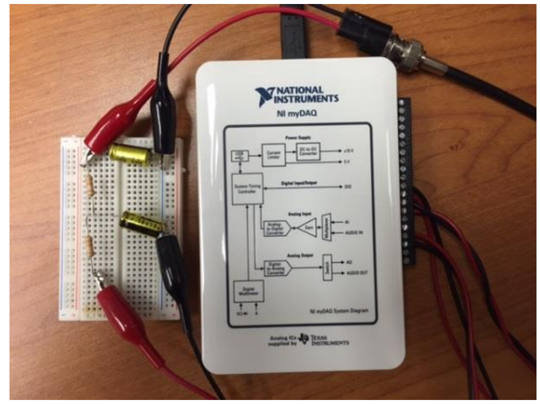

**Figure 1: National Instruments – *myDAQ* and a Driven & Measured RC-RC Circuit**

**Objective**: The goal of this lab is threefold:

1. The acquire input and output voltage data using a National Instruments myDAQ and Signal Express.
2. Identify a discrete time transfer function at several different sample rates.
3. Simulate the discrete-time transfer function versus the measured data.

**Experiment**:

First, construct a RC circuit where the time constant (τ=R*C) is about 1 second. (e.j. A 100kΩ resistor and a 10μF capacitor for a τ=1 second). Use a National Instruments myDAQ (**Figure 1**) to generate a square wave (0-4 volt) input to the circuit and measure the output voltage drop across the capacitor. (Use the Signal Express Tutorial (**Figure 2**) provided by Dr. Kolodziej if necessary.) Take a measurement set at three different sampling rates: 20Hz, 10Hz, and 5Hz. Rather than use the analog out on the myDAQ you can use an H/W function generator to create the input square wave. Use a frequency that captures <u>at least</u> a charging and discharging of the capacitor. In both cases make sure to record the actual circuit input on one of the analog input channels (AI0) and the voltage drop across the capacitor on the other channel (AI1). Save the data (txt, csv, xls) for post processing in Matlab. Collect two data sets for each sample time, one for <u>modeling</u> and one for <u>validation</u>.

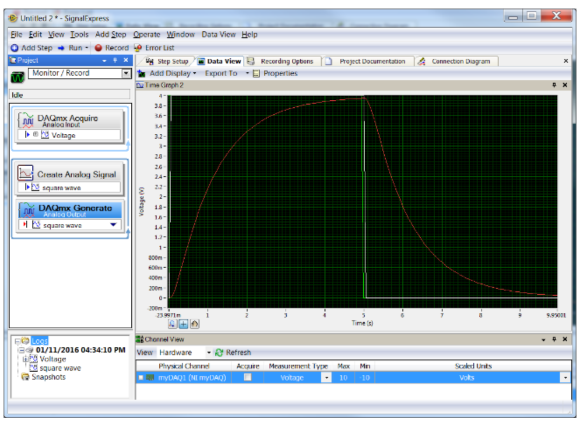

**Figure 2: National Instruments – *Signal Express***

Repeat the above experiment but for a 2nd order cascaded two RC circuit network (**Figure 3**). Select appropriate resistors and capacitors to obtain system time constants of about 0.2 seconds and 1.0 seconds. The following transfer function is the system model:

$$\frac{v_o}{v_s}(s) = \frac{1}{R_1 R_2 C_1 C_2 s^2 + (R_1 C_1 + R_2 C_2 + R_1 C_2) + 1}$$

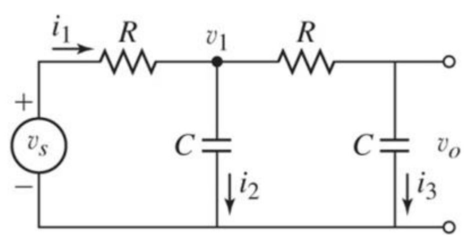


**Figure 3: 2nd Order - RC-RC Circuit**

Experiment with different sampling times to obtain two data sets: one that is suitable for a 1st order model and a second that captures the 2nd order behavior. (Hint: First try a very high sampling rate 1-kHz to see a near continuous time result.) Again, create an input square wave (0-4volts) frequency such that a full cycle or two are captured. Again, record a modeling data set <u>and</u> a validation data set for both sample rates.

**Simulation**: The objective of this lab is to identify a discrete-time transfer function (*G(z)*) from each data set. System Identification is a discrete-time method with many varieties with the most common being Auto-Regressive with eXogeneous (ARX) input.

$$y(k) + a_1 y(k-1) + \cdots + a_{na} y(k-na) = b_1 u(k-nk) + \cdots + b_{nb} u(k-nk-nb+1)$$

Where $k$ is the sample, *na* is the system order (poles), *nb* is the input order (zeros), and *nk* is the pure time delay (assume *nk=0*). The coefficients (*a's* and *b's*) are determined by a least-squares method where *y* (capacitor voltage) is the output and *u* is the input (supply voltage). First simulate the continuous-time model versus the measurement data for both the 1st and 2nd order systems. Next, fit a 1st order ARX model to the RC circuit data for each sample rate. Verify your least-squares result with the Matlab System Identification Toolbox (*arx.m*). Notice how the coefficients determined are effected by the sample rate. Make a plot of data, continuous, and ARX models for each sample rate.

Redo this process for the 2nd order RCRC system. For this case each plot must have data, continuous model, a 1st order ARX model and a 2nd order ARX model. How does the model order effect the fit?

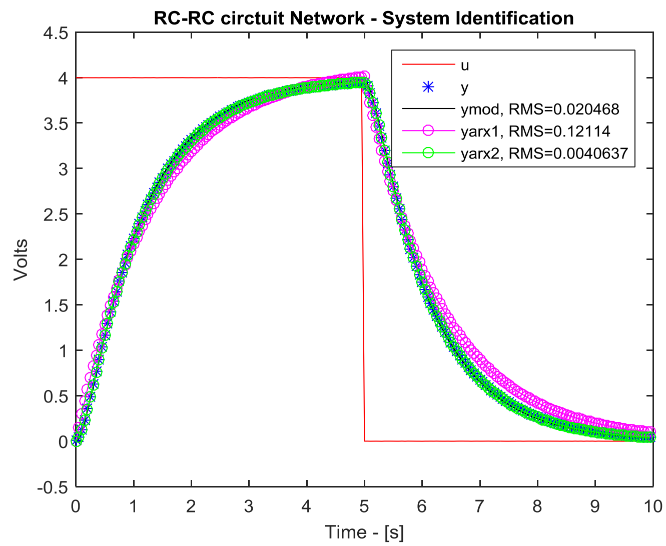


**Figure 4 - Capacitor Voltage vs. Time for Δt=0.05 seconds for the RCRC circuit network**

**Data Collection**: Collect two sets of data for each sample rate: (1) modeling set; (2) validation set. Obtain at least two step changes per file where each step achieves steady-state. Optional: take a set of data from each circuit with a different input stimulus.

**Considerations**: Using the modeling data set identify a first order discrete-domain transfer function (*G(z)*) that results from the ARX model form using the least-squares technique. Simulate in Matlab the identified transfer function with the same input data (*u(k)*) used to identify the model. How does the simulation compare to the data? Next simulate the identified transfer function versus the validation data set. How does this compare? Be sure to provide a quantitative measure (RMS, etc.) of the measurement minus model error. For every case plot the data and simulation on the same figure. Compare: Continuous vs. Discrete model? 1st order vs. 2nd order?

**Deliverable**: A concise <u>three</u> page (max.) report on the simulation approaches with a description of the results. The number of plots should be kept to a minimum but be of high quality and description (legends, captions). Always combine results when appropriate. A portion of the grade is reserved for the quality of the written report. **Style counts.** Please submit all of your Matlab/Simulink code <u>separately</u> as well and consolidate it to as few pages as possible.

**Due Date**: Two weeks after the assigned date.