Lab 3
Week of Nov. 7, 2010

This lab explores the parallels and differences between system design and “real world” implementation. Furthermore, the lab begins to build the foundation for basic system identification – the first step in understanding a system. We will accomplish this via three simple steps: a pre-lab, a quick measurement experiment, and a short essay, (which reflects on what was learned). Thus, the lab consists of three parts: the pre-lab: a Laplace first order circuit analysis; the experiment: the laboratory measurement and characterization of a 1\textsuperscript{st} order system; and the reflection: discussion and conclusions centered on what was learned while completing the lab. The process of system identification will be further expanded in the following lab when we study a 2\textsuperscript{nd} order system.

Useful Matlab commands: tf, step, figure, plot, title, xlabel, ylabel, grid

1. Pre-Lab: Laplace First Order Circuit Analysis:
   (a) Given the circuit below find the Laplace domain transfer function, i.e. \( \frac{V_o(s)}{V(s)} \), from \( v(t) \) to \( v_o(t) \), where \( v_o(t) \) is the measured voltage across the capacitor \( C \):

   \[
   \begin{array}{c}
   \text{R} \\
   \hline
   v(t) \\
   \downarrow \\
   \hline
   C \\
   \hline
   v_o(t)
   \end{array}
   \]

   (b) Given \( R = 10k\Omega \) and \( C = 0.1\mu F \), calculate the rise time, \( T_r \), for the system.

   (c) Recalculate the system’s transfer function and \( T_r \) for a change in the \( R \) and \( C \) values of \(+10\%\) and \(+15\%\) respectively.

   (d) Next, recalculate the system’s transfer function and \( T_r \) for the additional change of \( R \) and \( C \) of \(-10\%\) and \(-15\%\) respectively.

   (e) Using Matlab’s plotting functions, plot the step response for each of these systems on a single plot (plot the idealized system – the designed system – as a solid blue line, and the two extreme variational models as dashed red lines).

   (f) Write a paragraph on what you expect will occur when you attempt to discover/measure/model such a system in the lab.

2. Experiment: Laboratory Measurement & Characterization of a 1\textsuperscript{st} Order System
   (a) Choose a Box #1-15 and record it’s number (you will be using this box in later labs!). Using techniques from Circuits I, measure the input and output responses of the box to a unit step signal (i.e. a 0V - 1V signal change – one can generate such an input signal with a function generator and a low frequency square wave – remember to offset the square wave.) What type of system/order is your box? Explain the basis for your choice of system?

   (b) Using the system’s measured step response from part 2a, estimate the system’s \( T_r \).

   (c) With an ohmmeter, measure the system’s resistance. Based on your pre-lab analysis, calculate the systems capacitance.
(d) Based on your pre-lab analysis, what are the most likely design values for the system’s resistor and the capacitor, assuming standard component tolerances (10% resistors and 15% capacitors)? Furthermore, calculate the system’s $T_r$ based on the discovered parameters.

(e) Calculate the pole locations for both the measured and the designed systems.

(f) Using Matlab, plot the identified system’s response to a unit step (dotted green line) along with the system’s idealized response (solid blue line) and the tolerance bands (dashed red lines representing +tolerance and -tolerance bands, similarly found as in the pre-lab).

3. Laboratory Reflection

(a) Comment on the effects of variations within resistance and capacitance as they relate to system pole locations. How can these variations affect a system’s response? Furthermore, comment on the effects due to instrumentation and testing procedures. Consider and discuss what “real world” problems might arise when performing system identification. Further discuss what issues might arise surrounding performance due to circuit tolerances.