

## Prelab 1

## 2.737 Mechatronics

Assigned: 2/10/99

Due: in class on 2/17/99

Reading: Feedback system notes Ch. 3-6

**1: Calculations for Lab 1** Carry out all the requested paper calculations in support of the servo motor system modeling and controller designs for Lab 1. Simulate each of your controllers in Simulink driving a model of the motor. When studying the effect of anti-windup, you will need to introduce a saturation nonlinearity to model the voltage saturation of the power amplifier. The power amp will saturate at about  $\pm 13$  V when the supply rails are at  $\pm 17$  V. **Note: This is a significant amount of work, so start early!**

**2: Lab equipment** The purpose of this section is to familiarize you with the lab oscilloscope and function generator. Connect the function generator to one of the scope channels and observe the waveform output by the function generator. Play around with different waveforms - sinusoidal, triangular and square waves; frequencies; amplitudes and offsets. Familiarize yourself with the controls on both the function generator and the oscilloscope. You can refer to a copy of the scope manual left in the lab to help you use the various features of the scope. Please keep this manual in the lab so that others have access to it. No documentation is required for this section, but we will assume you are familiar with the scope in future labs; please ask any questions you may have about its operation.

**3: Analog filter simulation** A first-order analog filter with unity DC gain is given by

$$H(s) = \frac{1}{\tau s + 1}.$$

This has a unit step response of

$$y(t) = 1 - e^{-t/\tau}; \quad t \geq 0,$$

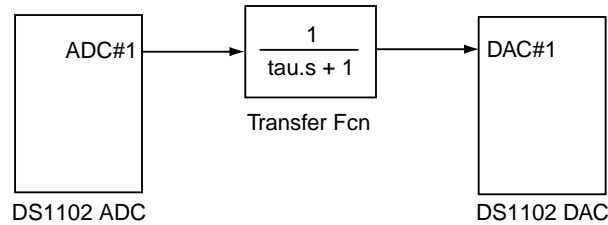
where  $y(t)$  is the filter output. In the next section we ask you to simulate such a filter as driven by a square wave in Simulink. We then ask you to go into the lab and implement this filter on the real-time DSP hardware.

**A: Simulink implementation** Note: This portion of the assignment can be done on any computer which has Simulink installed, such as an Athena machine, the lab computers, your home machine, etc. A student version of Matlab/Simulink is available for purchase at the Coop. Build a Simulink block diagram which implements the first-order analog filter given above, as driven by a signal generator, with the time constant  $\tau$  set to 1 msec. Your block diagram will look like

In order to make it easy to change the time constant, enter  $\tau$  as a variable name in the transfer function block. Then you can set  $\tau$  at the Matlab command line and this change will be reflected in a simulation, even when running. Look at the output on a Simulink scope window. With the signal generator set to produce a square wave at an appropriate frequency, you can generate the step response for this filter. Save step responses for several values of  $\tau$ , overlay these on one plot in the Matlab workspace and print this out on any convenient printer. Include a printout of your Simulink diagram and the resulting step responses in your lab report.

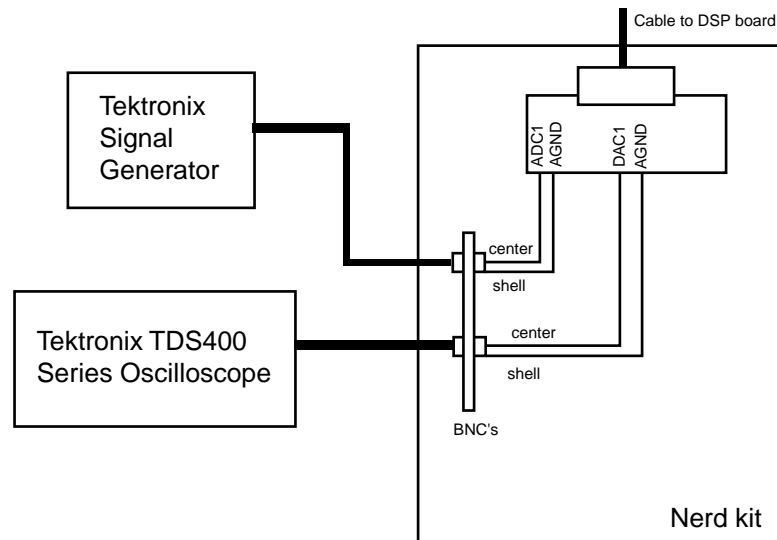
If you are unfamiliar with Simulink, take a look at the online manuals available on Athena or on the lab computers to see an example of building and simulating a block diagram in this environment. Alternately, you can look at the optional text on Simulink listed in the course information sheet (and our web page). It is important that you are comfortable in the Matlab/Simulink environment, since we will be using this to implement all the real-time algorithms on the course lab hardware.

**B: Filter implementation on dSPACE board** In this section, we ask you to implement the filter on the real-time DSP board. To do this, you will use the Tektronix signal generator for the source and the Tektronix oscilloscope as the display. The filter is implemented on the DSP through the Real Time Workshop (RTW) in Simulink. The connection is shown below:



The signal generator is read through A/D channel 1, the signal is filtered in digital form by the DSP and then output to analog form on D/A channel 1. The oscilloscope is used to display the analog output. You need to make the physical connections on the protoboard (as labeled on the green interface card), and the DSP processing connections in the block diagrams. The A/D and D/A icons in the diagram above provide the conceptual connection between these two systems.

The physical connections are shown below.



Note that since the BNC shell is tied to ground on the connected signal generator and scope, it is tied to the AGND pin on the DSP connector. *Be sure not to reverse the polarity of this connection, as you may damage the DSP card electronics. If you have any questions about this, ask one of the teaching staff before making the connections.*

Within the Simulation Parameters dialog in Simulink you will need to specify the integration routine and fixed-step sample time. Choose Euler (the simplest and fastest) and a sample time of 0.0001 sec. (**Note:** Be sure you understand the difference between simulating on the PC in non-real-time, and running on the DSP in real-time.)

The real-time constraint is why we adopt fixed-step algorithms on the DSP.) Set the signal generator to produce square waves, with a  $\pm 5$  volt peak amplitude.

Make a sketch of any interesting features of the waveforms that you observe on the scope. Is the filter accurately simulated? How does the output differ from an ideal analog filter? What does the waveform look like if the time base is expanded to 1 msec/div? 0.1 msec/div? Why? What evidence do you see for the discrete-time operation of the DSP? What happens if you increase the sample time?

**4:** Consider two systems with transfer functions

$$G_1(s) = \frac{(s + 0.2)^2 + 64}{s((s + 0.2)^2 + 100)}$$

and

$$G_2(s) = \frac{(s + 0.2)^2 + 100}{s((s + 0.2)^2 + 64)}$$

Each of these systems is imbedded in the forward path of the block diagram shown in Figure 3.4 in the notes. Assume that the feedback transfer function  $H(s) = 1$ , i.e., a unity-feedback system. Sketch a root locus for each of these two systems as the gain  $K$  is varied from 0 to infinity. In constructing your sketch, it will be very helpful to use the arrival and departure angle conditions. Which of these systems is stable for all positive values of  $K$ ? This problem has practical relevance for the situation where a notch filter is used to help stabilize a system with a lightly-damped pair of poles.

**Lab work:** Start the lab work portion early! The first step is to do the paper designs as requested in item 1 above. This assignment will require you to think carefully about your designs and will require significant effort in the lab. Start early! The payback is that you will quickly get comfortable with feedback as a design subject, which is far more exciting than working with it as an analysis subject.