ECE 220 SIGNALS & SYSTEMS I

Laboratory Project 2

Spring 2007

Time allotted: 1 week **Report Due:** 1 week after lab session completed

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The purpose of this project is twofold. First, it will help you to review two basic properties of continuous-time systems: linearity and time invariance. Second, it will give you the opportunity to analyze a Matlab function to determine how it works.

Your report for this project will consist of all the analytical (*i.e,* pencil/paper) work, Matlab plots and code, and relevant explanations. A list of guidelines for preparing the lab report is posted on the ECE 220 website. Each student must do his or her own work on this project, however you may ask other students or any of the teaching staff for advice. As stated in the guidelines given in the ECE 220 course information packet, you should identify any students you talk to about the project.

1 Prelab Reading Assignment

Before going to lab, please reread sections 1.7-1 and 1.7-2 in the textbook (*Linear Systems and Signals* by B. P. Lathi). (These sections were assigned in the second week of class.)

2 Linearity and Time Invariance

Download the Matlab function called `lab2systems` from the course website. This function implements 4 different systems. Type `help lab2systems` at the command line prompt to see instructions for how to use it. This function takes a signal vector `x` and its associated time vector `t` as inputs and produces an output vector `y`. Your task is to analyze `lab2systems` to determine whether each of the 4 systems it implements are linear and/or time invariant.

(a) Read the Matlab code for the function. Based on it, write a mathematical definition for each system. For example, here is a mathematical description of a system that adds 72 to the input signal $x(t)$: $y(t) = x(t)+72$.

(b) Define a set of test signals to use as inputs to determine whether these systems are linear and/or time invariant. A convenient test signal might be the square pulse $x(t) = u(t)-u(t-1)$. You can define this signal in Matlab as follows:

```
t=-2:.005:10;
x1=(t>=0 & t<1);
```

Use the command `plot(t,x1)` to verify that this produces the desired signal. Recall that test for time invariance, we have to examine the output for an input that is a shifted version of the original input. For example, we could define a shifted version of `x1` as follows:

```
t=-2:.005:10;
x1=(t>=-1.5 & t<-.5);
```

Recall that to test for linearity, we need to examine the system's behavior for two test signals, $x_1(t)$ and $x_2(t)$. You can easily define other square pulse test signals as necessary. If you would like to use a test signal other than a square pulse, feel free to do so. Your report should indicate what types of signals you use and why.

(c) Using the test signals you defined, determine whether each of the 4 systems is linear and/or time invariant. Make a set of plots that indicate whether each of these systems is time invariant or time-varying and linear or nonlinear.

(d) To prove that a system is time invariant, we must demonstrate that a shift in the input results in a shift in the output for *every possible input/output pair*. Note that it is not enough to demonstrate that this property holds true for one input; we must demonstrate that the property holds true for all possible inputs. This requires an analystical proof. On the other hand, to prove that a system is not time invariant, we only need to give one example where the property does not hold. The same holds true for linearity. We need an analytical proof to show that a system behaves linearly for all inputs. To show that a system is nonlinear, we only need one set of signals for which the input/output behavior is not linear. For this part, you should provide analytical proofs that support your conclusions from part c.

Your report should describe your analysis of the linearity and time invariance of each system. Describe the test signals you used, and the results of the tests. Include analytical proofs that support the conclusions you make about the linearity and time invariance of each system. Note: please define a Matlab script file (or M-file) that generates all the plots for this section. Include a copy of this script file as an appendix to your lab report.