EENG/INFE 226 SIGNALS AND SYSTEMS

LAB EXPERIMENT 3

SOME FUNDAMENTAL PROPERTIES OF SIGNALS

Objective

This experiment aims to introduce using MATLAB to define an LTI system and determine its main features, such as; linearity, causality stability invertibility and time variance. This is achieved by examining the performance of the system for particular inputs that will show those characteristics.

Preliminary Work:

Signals and Systems, 2nd edition, John Wiley & sons

1. Linearity:

A system is linear if superposition holds. Specifically, a linear system must satisfy the two properties:

- **1 Additive**: the response to $x_1(t)+x_2(t)$ is $y_1(t) + y_2(t)$
- **2 Scaling**: the response to $ax_1(t)$ is $ay_1(t)$ where $a \in C$
- **Combined**: $ax_1(t)+bx_2(t) \rightarrow ay_1(t) + by_2(t)$

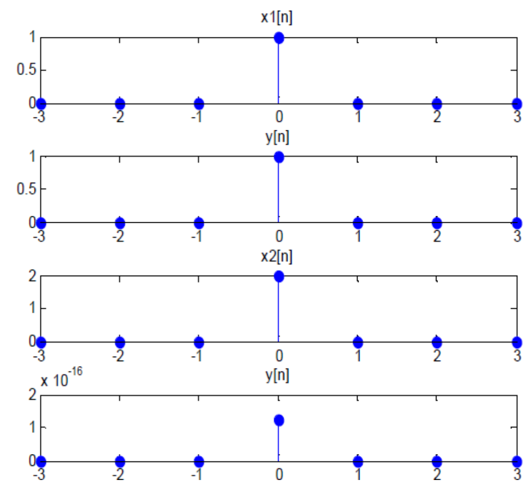

Figure 1 Exercise 1 Result

Example 1

The system is $y[n] = \sin\left(\frac{\pi}{2} x[n]\right)$ is not linear. Show that it violates linearity by giving a counter-example. A good example is the set of signals

$$x_1[n] = \delta[n]$$

$$x_2[n] = 2\delta[n]$$

Write a MATLAB code to demonstrate this example. This can be done as follows:

- Define the domain of the two signals to be from -3 to 3 and save it as a vector n
- Define the signal x_1 as a vector of the values [0 0 0 1 0 0 0]
- Define the signal $x_2 = 2x_1$
- Evaluate the output corresponding to the x_1 input, and label it as y_1
- Evaluate the output corresponding to the x_2 input, and label it as y_2

Plot the signals x_1, x_2, y_1 and y_2 using the commands (subplot) and (stem) on the same graph window. Your results should be as depicted in Figure 1.

2. Causality

A causal system is a system where the current output depends on past/current inputs but not future inputs.

Example 2

The system $y[n] = x[n] + x[n+1]$ is not causal. Use the input signal $x[n] = U[n]$ to show this, as follows:

- Define the time (sample) interval to be between -6 and 9, and label it as n.
- Define the signal *x[n]=U[n]* as an array with the values 0 for n<0 and 1 for n>=0 and label it as *x*.

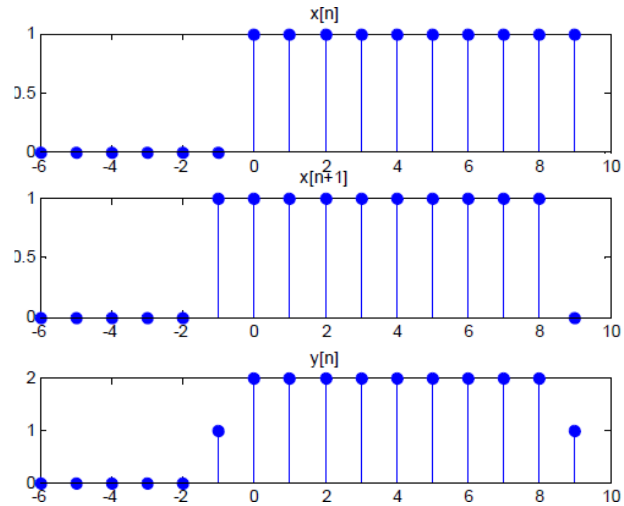

Figure 2 Exercise 2 Result

- Define the signal *x[n+1] =U[n+1]* as an array of zeros for *n*<-1 and 1 for *n*>=-1 and labelit as x_shift.
- Define the output signal *y[n]* as *x[n]+x[n+1]* .
- On the same window, plot the signals *x[n]*, *x[n+1]* and *y[n]* using the commands (subplot) and (stem).You should have a plot identical to the one shown in Figure 2.

3. Stability

For a stable system, if an input signal is bounded, then the output signal must also be bounded.

Exercise 3

The system *y[n]=log(x[n])* is not stable because the (log) function goes to minus infinity at the 0input. Write a MATLAB code to illustrate this. Proceed as follows:

- Define the domain vector as n ranging between -2 and 3.
- Define the input signal x as a vector of the values: 1, 2, 0, 3, 4 and 5.

- Declare the output vector as *y= log(x)*. using the(log) function.
- Using stem and subplot commands, plot the input signal *x[n]* and the correspondingoutput signal *y[n]*. The result should appear as shown in Figure 3.

4. Invertible and Inverse Systems

Invertible System A system is invertible if the input signal can be uniquely determined from knowledge of the output signal. Therefore, invertibility requires the system to be one-to-one and generate a distinct output for each input.

Example 4

The system $y[n] = \sin(2\pi x[n])$ where $x[n]=[0\ 1\ 2\ 3\ 4\ 0]$ is not invertible. Illustrate this by showing that the system is not one-to-one. As follows:

- Define a vector of n values of 0,1,2,3,4 and 5 and label it as n.
- Define *x[n]* as a vector of the values 0,1,2,3,4 and 5.
- Define the output as $y[n] = \sin(2\pi x[n])$.
- Plot *x[n]* and *y[n]* using the commands (stem) and (subplot). Your result should be asshown in Figure4.

***Q**: Comment on the result justifying the claim that the system in not invertible*

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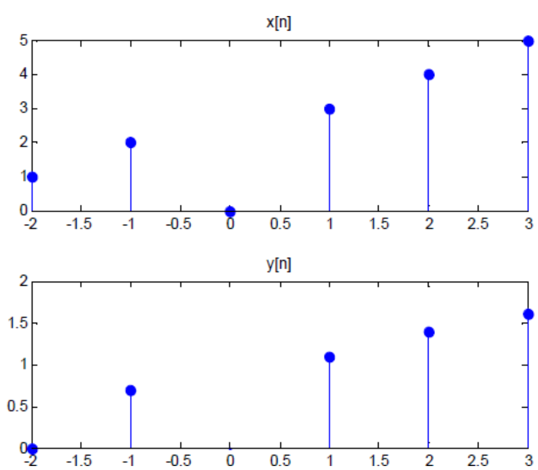

Figure 3 Exercise 3 Result

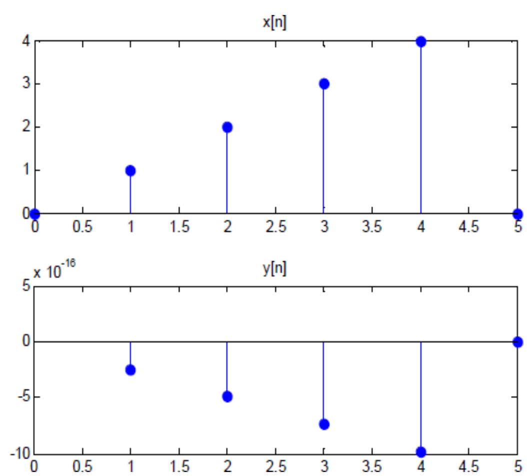

Figure 4 Exercise 4 Result

Assignment:

For each of the following systems, state whether or not the system is linear, time-invariant, causal, stable, and invertible. For each property, you claim the system does not possess, construct a counter-argument using MATLAB to demonstrate how the system violates the property in question.

a) $y[n] = x^3[n]$

b) $y[n] = nx[n]$