LAB 1: Time-Domain Analysis of Discrete-Time Systems -Part 1

Objective

In lab 1, you will learn about the concepts of discrete-time signals. You will apply a different transformation to discrete signals, plot the signals and learn how to find the energy and power of a signal. Also, you will find the equation of a discrete system and recursively compute zero-input, zero-state and total system responses.

Preparation

- Read chapter 3 of the textbook (*Linear Signals and Systems) by B.P. Lathi*.
- For this lab, you may use *anonymous* functions in Matlab to write simple functions. For example, the function *Cube* returns the cube of the input x.

  $Cube\ =\ @(x)(x\verb|^|3);$

  $x\ = 0{:}\,0.05{:}\,10;$

  $Plot(x, Cube(x))$

- To plot discrete signals, use *stem* command from MATLAB.

Lab Assignment

A. Signal transformation

1) In this assignment, you will perform shifting and time reversal transformations on a discrete time signal. Use MATLAB to plot the following discrete time signals.

   I. $\delta[n-3]$

   II. $u[n+1]$

   III. $x[n] = \cos\left(\frac{\pi n}{5}\right) u[n]$

   IV. $x_1[n] = x[n-3]$

V. $x_2[n] = x[-n]$

Explain what transformations are performed in $x_1[n], x_2[n]$.

2) In this part, you will study the effects of scaling on a discrete time signal. Plot the signals in the interval $[-10,70]$ and explain the effect of transformation on $y_1[n]$ and $y_2[n]$ given below.

   I. $y[n] = 5e^{-\frac{n}{8}}(u[n] - u[n-10])$
   II. $y_1[n] = y[3n]$
   III. $y_2[n] = y[\frac{n}{3}]$

3) In this assignment, you will investigate that sampling of a continuous signal and applying a linear transformation after will not always generate the same result as if first applying the transformation and then executing sampling. For this purpose, consider the continuous signal $z(t)$

$$z(t) = 5e^{-\frac{t}{8}}\big(u(t) - u(t-10)\big),\ \ t = -10{:}\,0.1{:}\,70\,.$$

   I. First, find $y_3(t) = z(\frac{t}{3})$ and then plot the discrete signal $y_3[n]$.
   II. Explain why $y_2[n]$ obtained in part 2(III) above and $y_3[n]$ obtained in here are not the same.

Note: When defining signal $z(t)$ make sure to use continuous $u(t)$.

B. Recursive Solution of difference equation

In this assignment, you will write a system equation for a real-world problem and understand the meanings of zero-input, zero-state, and total system responses.

1) A person makes a deposit (the input) in a bank regularly every month from January. The bank pays 2% interest on the account balance. Find the equation relating the output $y[n]$ (the balance) to the input $x[n]$ (the deposit). Consider the account balance at the beginning of the year is \$2000. (Use example 3.6 from the text book for help.)

2) If no deposit is made in the new year, what will be the output $y[n]$. Use MATLAB to recursively compute the zero input response $y[n]$ and plot it.
3) If the person deposits $x[n] = 100n$ dollars each month, and n is the month number (for example, for February n=2), what will be the total response $y[n]$. Use MATLAB to recursively compute and plot $y[n]$.

C. Design a filter: N-point maximum filter

In this assignment, you will design a causal N-point maximum filter. This filter finds the maximum of the signal among N points $\{x[n], x[n-1], \ldots, x[n-(N-1)]\}$ and assigns it to the output $y[n]$.

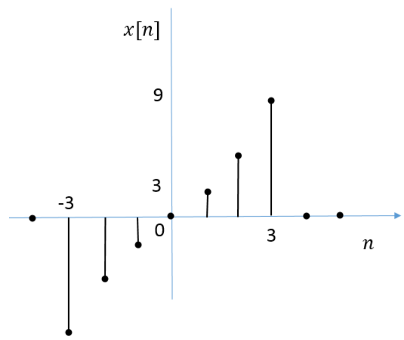
1) Write a MATLAB function that performs maximum filtering on an input vector x with length M. The inputs of the maximum function are vector x and scalar N. To create a length-M output vector y, initially pad the input vector with $N-1$ zeros. i.e. the output $y[n]$ would have the same length as input $x[n]$. You can use MATLAB command *MAX* for this assignment.
2) Apply maximum filter on the input $x[n]$ defined as below, where the length of the input is 45. Separately plot the results for $N = 4, N = 8$ and $N = 12$.

$$x[n] = \cos\left(\frac{\pi n}{5}\right) + \delta[n-20] - \delta[n-35]$$

3) Explain how the response changes for different values of N.

D. Energy and power of a discrete signal

1) Write a MATLAB function that receives a finite length vector $x[n]$ and returns the energy and power of the vector.
2) Calculate the energy and power of the signal $x[n]$ illustrated below (Fig.P3.1-1 (c) of the text book).


$x[n]$
9
3
-3
0
3
n