EX 753 Digital Signal Processing

Lab 1 : Familiarization with basic CT/DT functions

Functions Used:

Understand the following functions using Matlab online-help feature.
who, whos, input(), disp(), subplot(), figure(), clear all, close all, home, hold on, grid on, grid off, grid, demo, ver, lookfor, length(), pause, plot(), stem(), real(), imag(), *zeros(), ones(), exp()* functions, *for* statement, *if-else* statement ...

Background:

Being the very first lab, the main objective is to familiarize you with the various Matlab functions and use the same to plot the basic signals and display the results.

Problems:

1. Plot the following basic signals using Matlab

   (a) Impulse response.

   (b) Unit step.

   (c) Ramp.

   (d) Rectangular.

2. Plot the following Continuous Time (CT) signals.

   (a) $x(t) = Ce^{at}$, where C and a are real numbers and choose C and a both positive and negative.

   (b) Plot the same signal taking a as pure imaginary number.

   (c) Consider complex exponential signal as specified in (a), where **C** is expressed in polar form i.e., ($C = |C|e^{j\theta}$) and a in rectangular form i.e., ($a = r + j\omega_o$). Then your function $x(t)$, on simplification, becomes

   $$x(t) = |C|e^{rt}[\cos(\omega_o t + \theta) + j\sin(\omega_o t + \theta)].$$

   Now, plot the signal for different values of **r** and comment on the results.

      i. $r = 0$.

      ii. $r < 0$.

      iii. $r > 0$.

3. Plot the Discrete Time (DT) exponential function : $x[n] = a^n$, $a = |a|e^{j\theta}$.
   Choose the suitable value of $|a|$ and θ, then plot the function **x[n]**.

4. Synthesize the signal from the Fourier Series Coefficients : $C_0 = 1$, $C_1 = C_{-1} = \frac{1}{4}$, $C_2 = C_{-2} = \frac{1}{2}$, $C_3 = C_{-3} = \frac{1}{3}$.

5. Plot fundamental sinusoidal signal, its higher harmonics up to 5^{th} harmonics and add all of them to see the result. Comment on the result.

EX 753 Digital Signal Processing

Lab 2 : Convolution

Objective:

- To be able to perform convolution of two given signal using basic formula.
- To be able to perform convolution of two given signals using Matlab function.

Functions Used

conv(), sinc() ...

Background:

Convolution Sum:

The output of any Linear Time Invariant (LTI) system is some sort of operation between input and system response; the operation is nothing but convolution, denoted by symbol '$*$', and defined as

$$y(t) = x(t)*h(t) = \int_{-\infty}^{\infty} x(\tau)h(t-\tau)d\tau \text{ —— For continuous time.}$$

$$y[n] = x[n]*h[n] = \sum_{k=-\infty}^{\infty} x[k]h[n-k] \text{ —— For discrete time.}$$

For a causal LTI system, convolution sum is given by

$$y[n] = \sum_{k=0}^{n} x[k]h[n-k]$$

The process of computing the convolution between $x[k]$ and $h[k]$ involves the following four steps:

1. Folding : Fold h[k] about $k = 0$ to obtain $h[-k]$.
2. Shifting: Shift $h[-k]$ by n_0 to the right (left if n_0 is positive (negative), to obtain $h[n_0 - k]$.
3. Multiplication: Multiply $x[k]$ by $h[n_0 - k]$ to obtain the product sequence $V_{n_0}[k] = x[k]h[n_0 - k]$.
4. Summation: Sum all the values of the product sequence $V_{n_0}[k]$ to obtain the value of the output at times $n = n_0$.

Don't worry! You can use Matlab's built in function to calculate those.

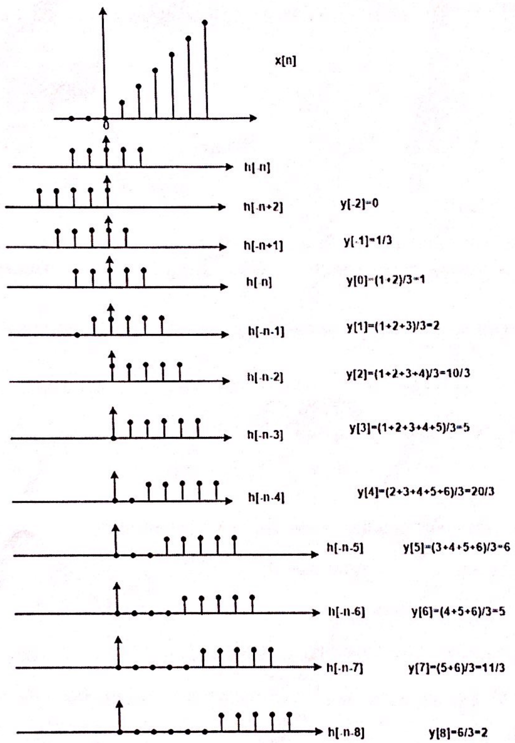
Illustration of convolution:

$$x[n] = \begin{cases} \frac{1}{3}n & \text{for } 0 \le n \le 6 \\ 0 & \text{elsewhere} \end{cases} \quad \text{and} \quad h[n] = \begin{cases} 1 & \text{for } -2 \le n \le 2 \\ 0 & \text{elsewhere} \end{cases}.$$

Convolution of signals x[n] and h[n] can be obtained by two methods:

EX 753 Digital Signal Processing

Graphical Method:



Tabular Method:

	1	1	1	1	1
→ 0	0	0	$\boxed{0}$	0	0
1	1	1	1	1	1
2	2	2	2	2	2
3	3	3	3	3	3
4	4	4	4	4	4
5	5	5	5	5	5
6	6	6	6	6	6

y[n]={0,1,3,6,10,15,20,18,15,11,6}/3={0,1/3,1,2,10/3,5,20/3,6,5,11/3,2}

EX 753 Digital Signal Processing

References:

a) For the folding operation:
```
function [y,n]=sigfold(x,n)
y=fliplr(x);
n=-fliplr(n);
```

b) For the shifting operation:
```
function [y,n]=sigshift(x,m,n0)
n=m+n0;
y=x;
```

c) For the multiplication:
```
function [y,n]=sigmulti(x1,n1,x2,n2)
nl=min(min(n1),min(n2));
nu=max(max(n1),max(n2));
n=nl:nu
y1=zeros(1,length(n));
y2=y1;
y1(find((n>=min(n1))&(n<=max(n1))==1))=x1;
y2(find((n>=min(n2))&(n<=max(n2))==1))=x2;
y=y1.*y2;
```

d) Using *conv()* function
```
x=[1,0,-1,1,2,1];
n1=[-2,-1,0,1,2,3];
nx=length(x);
h=[1,1,1,1,1];
n2=[0,1,2,3,4];
nh=length(h);
y=conv(x,h)
nmin = min(min(n1),min(n2));
n= nmin:1:nx+nh-2+ nmin;
stem(n,y);
```

Problems:

1. Find the convolution result of the following signal using basic convolution formula :
   $X_1(n_1) = [1, 1, 1, 1, 1]$ $\quad n_1 = [-2, -1, 0, 1, 2]$
   $X_2(n_2) = [1, 0, 0, 0, 0, 0, 0, 0, 0, 0]$ $\quad n_2 = [-4, -3, -2, -1, 0, 1, 2, 3, 4, 5]$
   X_2 is a periodic signal. $\quad Y2 = X1 * X2.$

2. Find the convolution of following using *conv()* function.

   (a) $x[n] = \begin{cases} \frac{1}{3}n & \text{for } 0 \le n \le 6 \\ 0 & \text{elsewhere} \end{cases}$ and $h[n] = \begin{cases} 1 & \text{for } -2 \le n \le 2 \\ 0 & \text{elsewhere} \end{cases}$.

   (b) $x(t) = u(t)$ *and* $h(t) = e^{-at}u(t)$, where $a > 0$.

3. Consider two discrete time sequences $x[n]$ and $h[n]$ given by
   $x[n] = \begin{cases} 1 & \text{for } 0 \le n \le 4 \\ 0 & \text{elsewhere} \end{cases}$ and $h[n] = \begin{cases} 2^n & \text{for } 0 \le n \le 6 \\ 0 & \text{elsewhere} \end{cases}$.

   (a) Find the response of the LTI system with impulse response $h[n]$ to input $x[n]$.

   (b) Plot the signals and comment on the result.

4. If the impulse response of a LTI system is given by **sinc** function as
   $h[n] = \frac{2\tau}{T_p}\text{sinc}(n\frac{2\tau}{T_p})$
   and input signal is a rectangular wave given by
   $x[n] = \begin{cases} 1 & \text{for } 1 \le n \le 100 \\ 0 & \text{elsewhere} \end{cases}$.
   Find output of the system for different values of τ. Comment on the result.