8. SS Lab 8

This Signals and Systems lab is about some very important topics causal and non-causal signals, as well as convolution of signals in the MATLAB environment.

Suggestions for improvement or correction of the manuscript would be appreciated.

8.1 Lab Objectives

In this lab, the following topics would be addressed:

- Converting signals from non-causal to causal
- Convolution of signals
- Properties of convolution

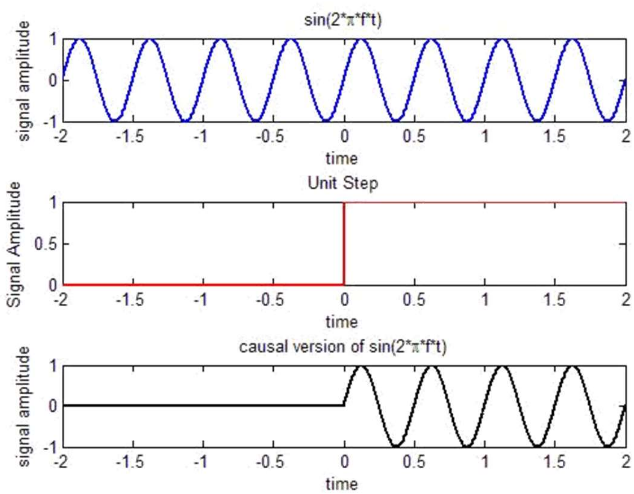
8.2 Coverting Signals from Non-Causal to Causal

A signal is said to be causal if it is zero valued for time $t < 0$. A signal can be converted into a causal by multiplying it with unit step.

Example:

```
clc
clear all
close all
t= -2:1/1000:2;
x1 = sin(2*pi*2*t);
subplot(3,1,1);
plot(t,x1,'LineWidth',2);
xlabel('time');
ylabel('signal amplitude');
title('sin(2*\pi*f*t)');
u = (t>=0);
x2 = x1.*u;
subplot(3,1,2);
plot(t,u, 'r','LineWidth',2);
xlabel('time');
ylabel('Signal Amplitude');
title('Unit Step');
subplot(3,1,3);
plot(t,x2, 'k','LineWidth',2);
xlabel('time');
```

```
ylabel('signal amplitude');
title('causal version of sin(2*\pi*f*t)');
figure;
plot(t,x1,t,u,'-.',t,x2,'LineWidth',2);
text(0,1.2,'u(t)','FontSize',16);
text(-1.2,-1.1,'x(t)','FontSize',16);
text(0.8,-1.1,'x(t)*u(t)','FontSize',16);
axis([-2 2 -1.5 1.5]);
```



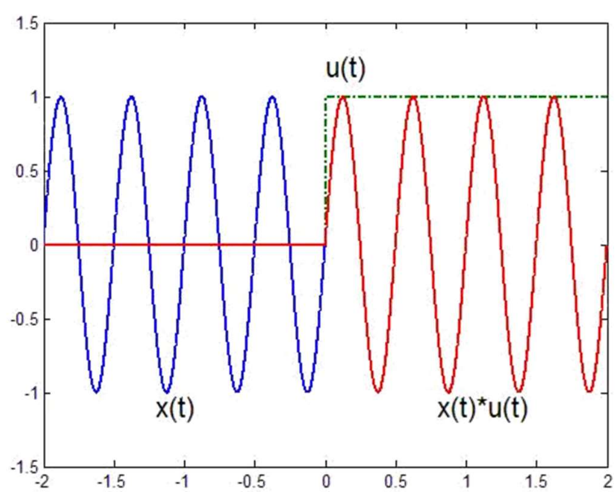


Figure 8.1: Converting signal into causal

8.3 Convolution

In MATLAB, convolution can be be performed by using the command `conv(h, x)` to find convolution result, where `h` is the impulse response and `x` is the input signal.

Example:

```
clc
clear all
close all
h = [1 2 3 4 5 4 3 2 1];
x = sin(0.2*pi*[0:20]);
y = conv(h, x);
figure(1);
stem(x);
title('Discrete Filter Input x[n]');
xlabel('index, n');
ylabel('Value, x[n]');
figure(2);
stem(y, 'r');
title('Discrete Filter Output y[n]');
xlabel('index, n');
ylabel('Value, y[n]');
```

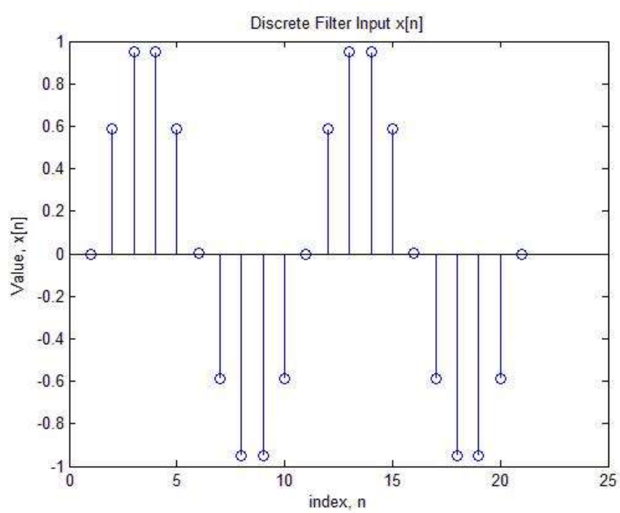


Figure 8.2: Discrete filter input

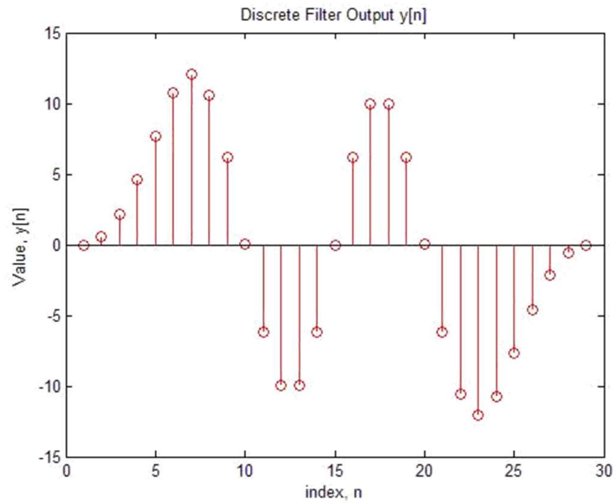


Figure 8.3: Discrete filter output

Even though there are only 21 points in the `x` array, the `conv` function produces 8 more points because it uses the convolution summation and assumes that $x[n] = 0$ when $n > 20$.

8.4 Tasks

Perform the following tasks:

8.4.1 Task 01

Sample the signal given in example in section 8.4.1 to get its discrete-time counterpart (take 10 samples/sec as sampling rate). Make the resultant signal causal. Display the lollipop plot of each signal.

8.4.2 Task 02

A signal is said to be anti-causal if it exists for values of n<0. Make the signal given in example in section 8.4.1 anti-causal.

8.4.3 Task 03

Create a function by name of `sig_causal` in MATLAB that has two input arguments: (i) a discrete-time signal, and (ii) a position vector. The function should make the given signal causal and return the resultant signal to the calling program.

A non-causal signal is shown in the Figure 8.4. Write MATLAB code to make the signal causal by calling the above-mentioned function. Plot the original non-causal signal and the resultant causal signal.

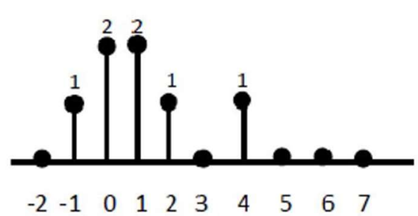


Figure 8.4: Converting signal into causal

8.4.4 Task 04

Convolve the following signals:

```
x =[2 4 6 4 2];
```

```
h =[3 -1 2 1];
```

Plot the input signal as well as the output signal.

8.4.5 Task 05

Convolve the signal `x[n]=[1 2 3 4 5 6]` with an impulse delayed by two samples. Plot the original signal and the result of convolution.

8.4.6 Task 06

Convolution is associative. Given the three signal `x1[n]`, `x2[n]`, and `x3[n]` as: \

```
x1[n]= [3 1 1]
```

```
x2[n]= [4 2 1]
```

```
x3[n]=[3 2 1 2 3]
```

Show that `(x1[n] * x2[n]) * x3[n] = x1[n] * (x2[n] * x3[n])`.

8.4.7 Task 07

Convolution is commutative. Given `x[n]` and `h[n]` as:

```
x[n]=[1 3 2 1]
```

```
h[n]=[1 1 2]
```

Show that `x[n] * h[n] = h[n] * x[n]`.

8.4.8 Task 08

Given the impulse response of the systems as:

```
h[n]= 2δ[n] + δ[n-1]+ 2δ[n-2]+ 4δ[n-3]+ 3δ[n-4]
```

If the input `x[n] = δ[n]+ 4δ[n-1] +3δ[n-2] + 2δ[n-3]` is applied to the system, determine the output of the system.

8.4.9 Task 09

Two systems are connected in cascade:

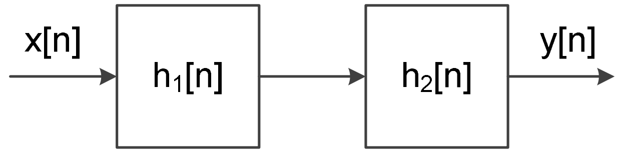


Figure 8.5: Cascaded systems

```
h1[n]=[1 3 2 1]
```

```
h2[n]=[1 1 2]
```

If the input `x[n] = δ[n]+ 4δ[n-1] +3δ[n-2] +2δ[n-3]` is applied, determine the output.

8.4.10 Task 10

Given the signals:

```
x1[n]= 2δ[n] -3δ[n-1]+ 3δ[n-2] +4δ[n-3] -2δ[n-4]
x2[n]= 4δ[n]+ 2δ[n-1]+ 3δ[n-2] - δ[n-3] -2δ[n-4]
x3[n]= 3δ[n]+ 5δ[n-1]-3δ[n-2] +4 δ[n-3]
```

Verify that

```
x1[n] * (x2[n] * x3[n])
= (x1[n] * x2[n]) * x3[n] x1[n] * x2[n]
= x2[n] * x1[n]
```