EE 141: Digital Signal Processing

Lab 5: Discrete-time Processing of Continuous Signals

Lab Section: 022

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Objective:

The purpose of this lab is to process simple, artifically generated, continuous-time signals in discrete time. The generation of these continuous-time signals in dsicrete-time will include a differentiator and a delay element.

Question 1 (Differentiator):

Let

$$x_c(t) = \cos(10\pi t) + \frac{1}{2}\cos(5\pi t) - \frac{1}{4}\cos(20\pi t)$$

and create $x[n]$ for $0 \leq n \leq 300$ by sampling $x_c(t)$ with a period of $T = 0.01$ secs.

```
% Step 1: sample the continuous time signal x_c(t)
n = 0:300;
T = 0.01; % Sampling Period
t = n*T; % t is the point in s_c(t)

% Step 2: Get the discrete-time input, input
x_ct = cos((10*pi)*(t))+(0.5*cos((5*pi)*(t)))-(0.25*cos((20*pi)*(t)));

% Step 3: Truncate h[n] n ==> h_{hat}(n) filter
N = 1;
for n = 0:(2*N)
    if n==N
        truncated_H(n+1)=0;
    else
        truncated_H(n+1) = ((-1)^(n-N))/((n-N)*T);
    end
end

% Step 4: get the output y[n]
```

a) Let $N = 1$. Perform the convolution $y[n] = x[n] \star h[n]$ using the command conv.

```
y_n = conv(x_ct, truncated_H);
```

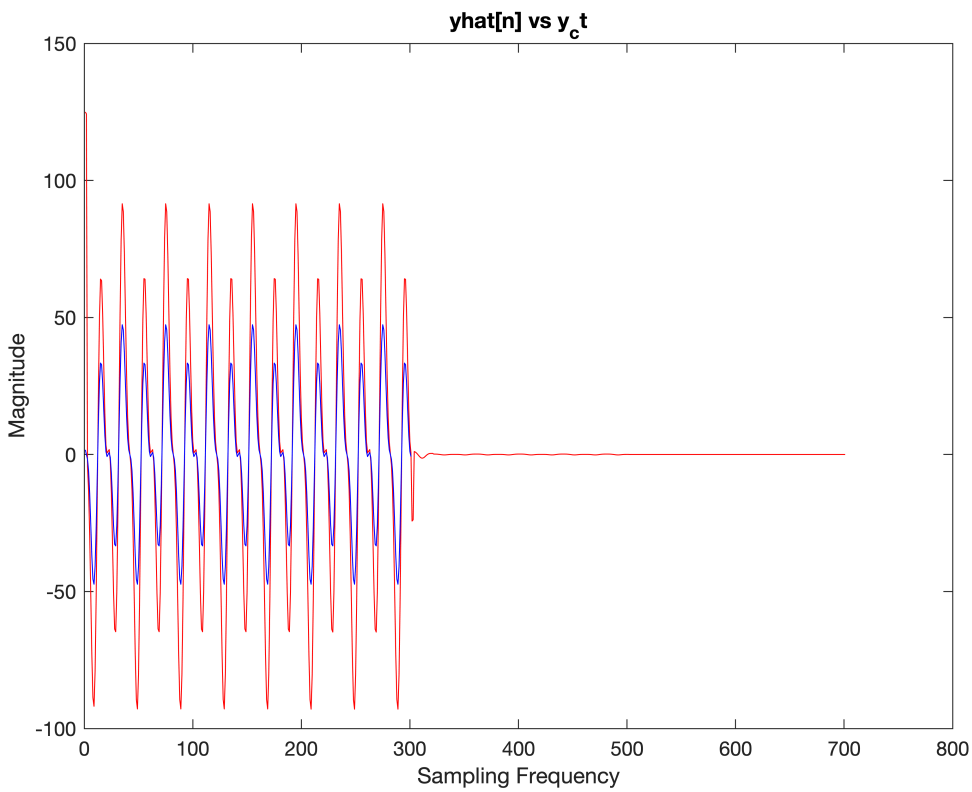
b) Analytically calculate $y_c(t)$ using (1) and (2)

```
diff = t -(N.*T);
% Differentiation of x_c(t)
y_ct = (-10*pi*sin((10*pi).*diff))+(.5*-5*pi*sin((5*pi).*diff))-(0.25*-20*pi*sin((20*pi
```

c) Compare $\widehat{y}[n]$ with $y[n] = y_c(\mathrm{nT})$ by plotting $y[n]$ and $\widehat{y}[n]$ on the same graph. Other than the "transient" effects yoou see on the plot of $\widehat{y}[n]$ around the borders, do $y[n]$ and $\widehat{y}[n]$ agree?

```
figure(1)

% Convolution
plot(y_n,'red')
hold on
% equation
plot(y_ct,'blue')
hold off
title('yhat[n] vs y_ct')
xlabel('Sampling Frequency')
ylabel('Magnitude')
```



The graphs $y[n]$ and $\hat{y}[n]$ agree in shape, but do not agree in amplitude. This is because my value for N is not large enough.

d) If they did not agree, your approximation $\hat{h}[n]$ must be too crude. Increase N and redo a through c until they $y[n]$ and $\hat{y}[n]$ more or less agree. (You should not have to increase N beyond 20)

```
% a
N = 20;
for n = 0:(2*N)
    if n==N
        truncated_H(n+1)=0;
    else
        truncated_H(n+1) = ((-1)^(n-N))/((n-N)*T);
    end
end

y_n = conv(x_ct, truncated_H);

diff = t -(N.*T);
% Differentiation of x_c(t)
y_ct = (-10*pi*sin((10*pi).*diff))+(.5*-5*pi*sin((5*pi).*diff))-(0.25*-20*pi*sin((20*p

% c
figure(1)
```

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% Convolution
plot(y_n, 'red')
hold on
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plot(y_ct, 'blue')
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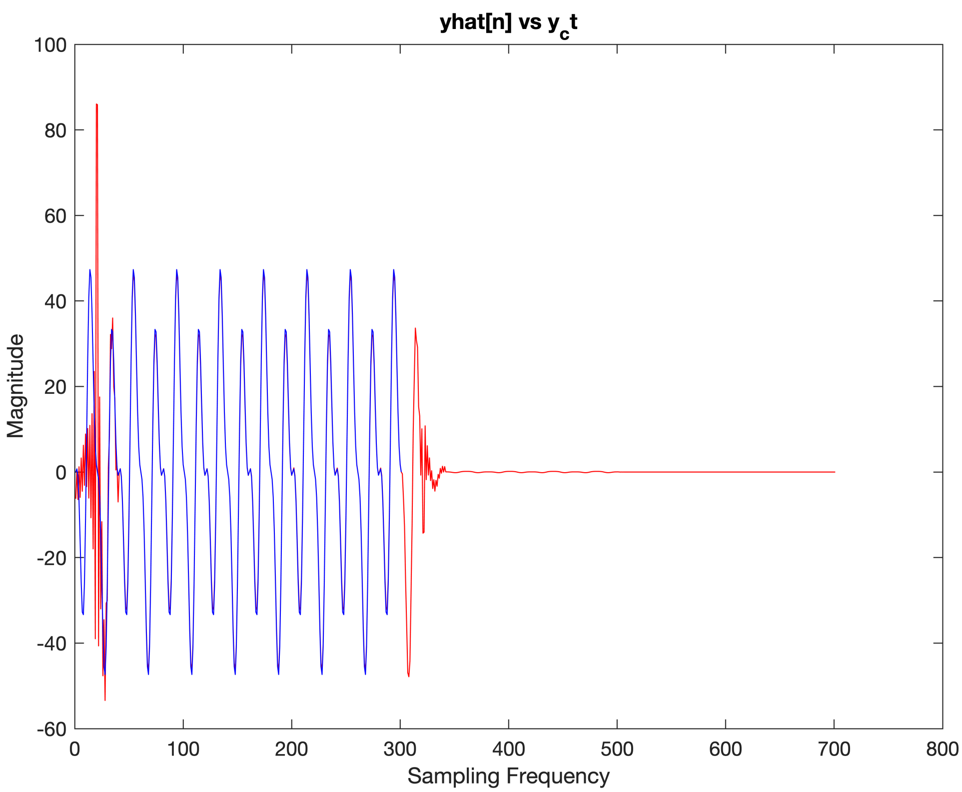

Question 2 (Fractional Sample Delay):

Let

$$x_c(t) = \cos(2\pi t)$$

and create $x[n]$ for $0 \leq n \leq 300$ by sampling $x_c(t)$ with a period of $T = 0.1$ secs.

```
% Step 1: sample the continuous time signal x_c(t)
n = 0:300;
T = 0.1; % Sampling Period
t = n*T; % t is the point in s_c(t)

% Step 2: Get the discrete-time input, input
x_ct = cos((2*pi)*(t));
```

```
% Step 3: Truncate h[n] n ==> h_{hat}(n) filter
N = 15;
for n = 0:(2*N)
    if(n<0 || n>2*N)
        truncated_H(n+1)=0;
    else
        truncated_H(n+1) = sinc(pi*(n-N-0.03));
    end
end

% Step 4: get the output y[n]
```

a) Let $N = 1$. Perform the convolution $y[n] = x[n] \star h[n]$ using the command conv.

```
y_n = conv(x_ct, truncated_H);
```

b) Analytically calculate $y_c(t)$ using (1) and (2)

```
delta = 0.03;
% Differentiation of x_c(t)
y_ct = cos((2*pi)*(t-(N*T)-delta));
```

c) Compare $\widehat{y}[n]$ with $y[n] = y_c(\mathrm{nT})$ by plotting $y[n]$ and $\widehat{y}[n]$ on the same graph. Other than the "transient" effects yoou see on the plot of $\widehat{y}[n]$ around the borders, do $y[n]$ and $\widehat{y}[n]$ agree?

```
figure(1)

% Convolution
plot(y_n,'red')
hold on
% equation
plot(y_ct,'blue')
hold off
title('yhat[n] vs y_ct')
xlabel('Sampling Frequency')
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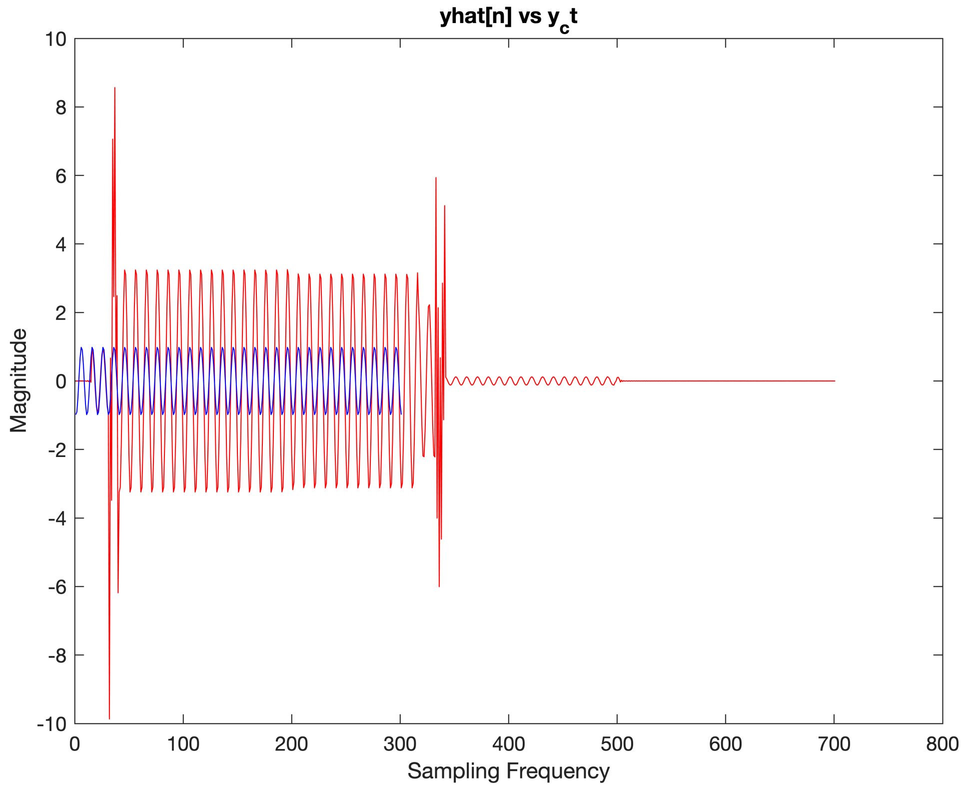

The graphs $y[n]$ and $\hat{y}[n]$ agree in shape, but do not agree in amplitude. This is because my value for N is not large enough.

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```
N = 20;
for n = 0:(2*N)
    if((n < 0) || (n>(2*N)))
        truncated_H(n+1)=0;
    else
        truncated_H(n+1) = sinc(pi*(n-N-0.03));
    end
end

y_n = conv(x_ct, truncated_H);

delta = 0.03;
% Differentiation of x_c(t)
y_ct = cos((2*pi)*(t-(N.*T)-delta));

figure(1)

% Convolution
```

```
plot(y_n,'red')
hold on
% equation
plot(y_ct,'blue')
hold off
title('yhat[n] vs y_ct')
xlabel('Sampling Frequency')
ylabel('Magnitude')
```