Experiment No 03

BECS 32461

Paper D

# VERIFICATION OF SAMPLING THEOREM IN TIME DOMAIN

Student Name: W. K. G. K. Jayawardana

Student No: EC/2021/006

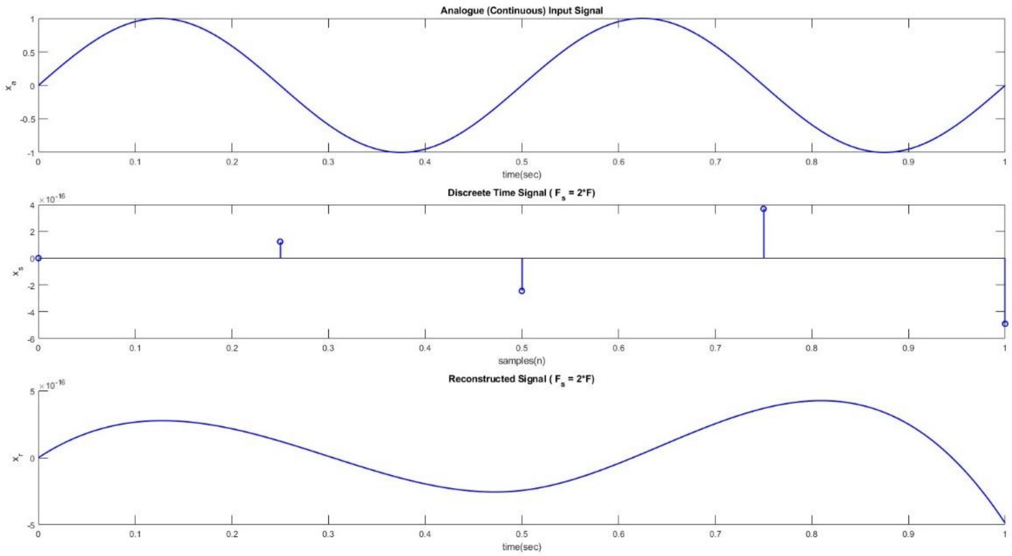
Date Performed: 2025/10/03

Date Submitted: 2025/10/03

**PROCEDURE**

F01.

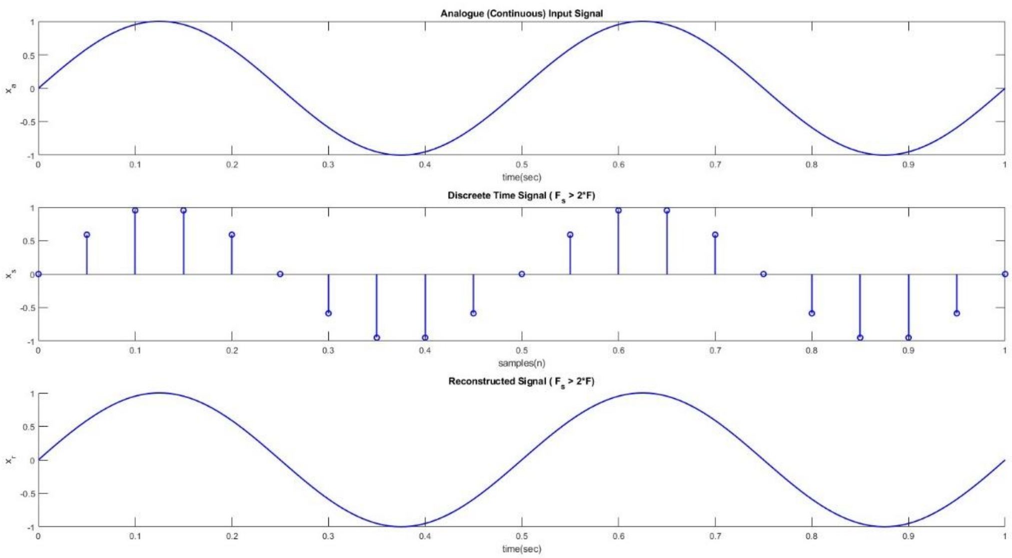
```
% Amplitude and Frequency
A = 1; F = 2;
%Time vector for continuous signal
t = 0:0.001:1;
% Continuous-time sine wave
x_a = A*sin(2*pi*F*t);

figure;
subplot(3,1,1)
plot(t,x_a,'-b')
title('Analogue (Continuous) Input Signal')
ylabel('x_a','Interpreter','tex')
xlabel('time(sec)')

% Sampling at Nyquist rate
F_s = 2*F;
% Sampling points
n = 0:1/F_s:1;
% Discrete-time signal
x_s = A*sin(2*pi*F*n);

subplot(3,1,2)
stem(n,x_s,'-b')
title('Discreete Time Signal ( F_s = 2*F)','Interpreter','tex')
xlabel('samples(n)')
ylabel('x_s','Interpreter','tex')


% Time vector for reconstruction
t_r = linspace(0, 1, 1000);
% Reconstruct signal using linear interpolation
x_linear = interp1(n, x_s, t_r, 'linear');
% Reconstruct signal using spline interpolation
x_spline = interp1(n, x_s, t_r, 'spline');

subplot(3,1,3)
hold on
plot(t_r,x_spline,'-b')
title('Reconstructed Signal ( F_s = 2*F)','Interpreter','tex')
xlabel('time(sec)')
ylabel('x_r','Interpreter','tex')
```




FO2.

```
% Amplitude and Frequency
A = 1; F = 2;
%Time vector for continuous signal
t = 0:0.001:1;
% Continuous-time sine wave
x_a = A*sin(2*pi*F*t);

figure;
subplot(3,1,1)
plot(t,x_a,'-b','LineWidth',1.5)
title('Analogue (Continuous) Input Signal')
ylabel('x_a','Interpreter','tex')
xlabel('time(sec)')

% Sampling at Nyquist rate
F_s = 10*F;
% Sampling points
n = 0:1/F_s:1;
% Discrete-time signal
x_s = A*sin(2*pi*F*n);

subplot(3,1,2)
stem(n,x_s,'-b','LineWidth',1.5)
title('Discreete Time Signal ( F_s > 2*F)','Interpreter','tex')
xlabel('samples(n)')
ylabel('x_s','Interpreter','tex')


% Time vector for reconstruction
t_r = linspace(0, 1, 1000);
```

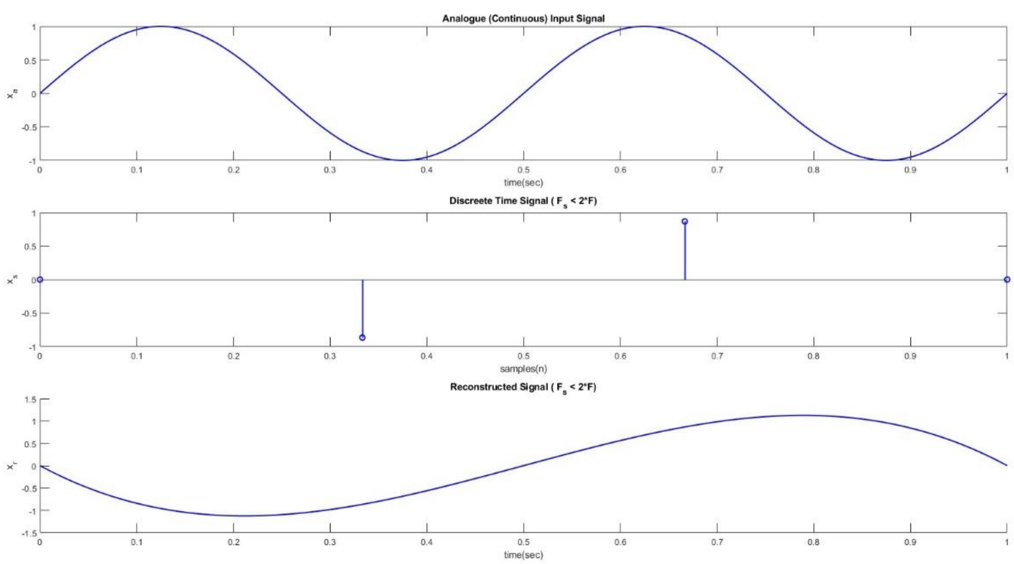
```
% Reconstruct signal using linear interpolation
x_linear = interp1(n, x_s, t_r, 'linear');
% Reconstruct signal using spline interpolation
x_spline = interp1(n, x_s, t_r, 'spline');

subplot(3,1,3)
hold on
plot(t_r,x_spline,'-b','LineWidth',1.5)
title('Reconstructed Signal ( F_s > 2*F)','Interpreter','tex')
xlabel('time(sec)')
ylabel('x_r','Interpreter','tex')
```




F03.

```
% Amplitude and Frequency
A = 1; F = 2;
%Time vector for continuous signal
t = 0:0.001:1;
% Continuous-time sine wave
x_a = A*sin(2*pi*F*t);

figure;
subplot(3,1,1)
plot(t,x_a,'-b','LineWidth',1.5)
title('Analogue (Continuous) Input Signal')
ylabel('x_a','Interpreter','tex')
xlabel('time(sec)')

% Sampling at Nyquist rate
F_s = 1.5*F;
% Sampling points
n = 0:1/F_s:1;
% Discrete-time signal
```

```
x_s = A*sin(2*pi*F*n);

subplot(3,1,2)
stem(n,x_s,'-b','LineWidth',1.5)
title('Discreete Time Signal ( F_s < 2*F)','Interpreter','tex')
xlabel('samples(n)')
ylabel('x_s','Interpreter','tex')


% Time vector for reconstruction
t_r = linspace(0, 1, 1000);
% Reconstruct signal using linear interpolation
x_linear = interp1(n, x_s, t_r, 'linear');
% Reconstruct signal using spline interpolation
x_spline = interp1(n, x_s, t_r, 'spline');

subplot(3,1,3)
hold on
plot(t_r,x_spline,'-b','LineWidth',1.5)
title('Reconstructed Signal ( F_s < 2*F)','Interpreter','tex')
xlabel('time(sec)')
ylabel('x_r','Interpreter','tex')
```

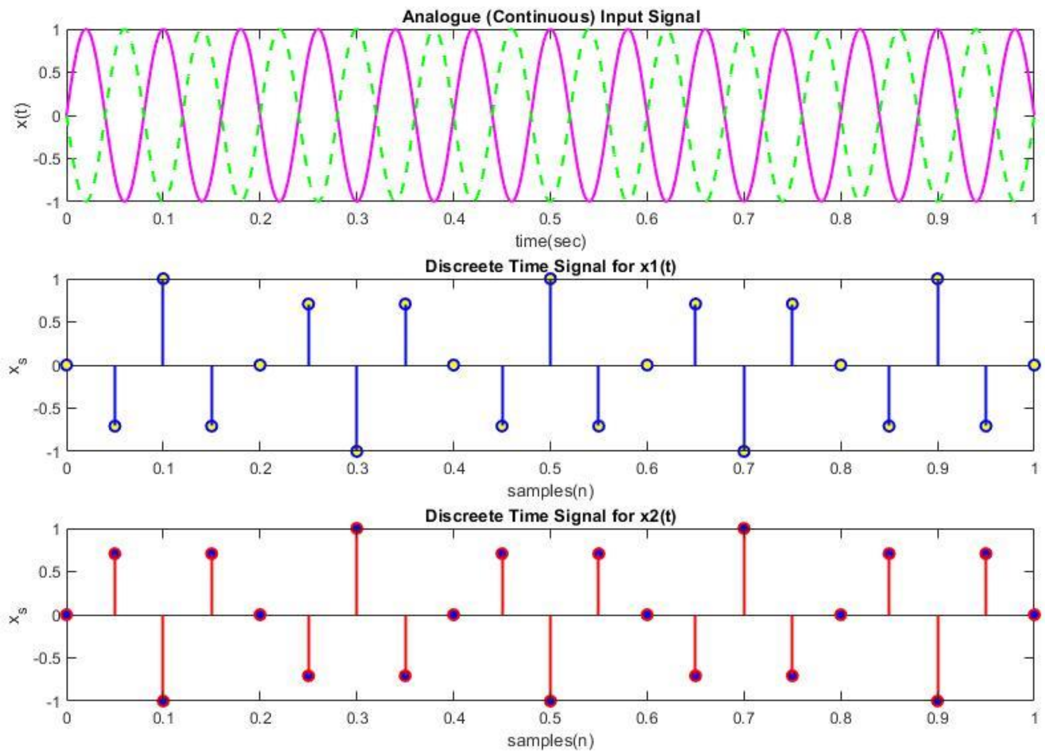


## EXERCISE

E01.

```
%Time vector for continuous signal
t = 0:0.001:1;
% Continuous-time sine waves
x1 =sin(25*pi*t);
x2 =sin(25*pi*(t-0.2));

figure;
subplot(3,1,1)
plot(t,x1,'-m','LineWidth',1.5)
hold on
plot(t,x2,'--g','LineWidth',1.5)
hold off
title('Analogue (Continuous) Input Signal')
ylabel('x(t)','Interpreter','tex')
xlabel('time(sec)')

% Sampling at Nyquist rate
F_s = 20;
% Sampling points
n = 0:1/F_s:1;
% Discrete-time signals
x1_s =sin(25*pi*n);
x2_s =sin(25*pi*(n-0.2));

subplot(3,1,2)
stem(n,x1_s,'b','filled','MarkerFaceColor','yellow','LineWidth',1.5)
title('Discreete Time Signal for x1(t)','Interpreter','tex')
xlabel('samples(n)')
ylabel('x_s','Interpreter','tex')

subplot(3,1,3)
stem(n,x2_s,'r','filled','MarkerFaceColor','blue','LineWidth',1.5)
title('Discreete Time Signal for x2(t)','Interpreter','tex')
xlabel('samples(n)')
ylabel('x_s','Interpreter','tex')
```

- x1(t) and x2(t) time shifting is clearly visible but it is obscured by aliasing.
- To avoid aliasing Fs should be increase to at least $2\times12.5=25$ Hz or higher, as per the Nyquist criterion.

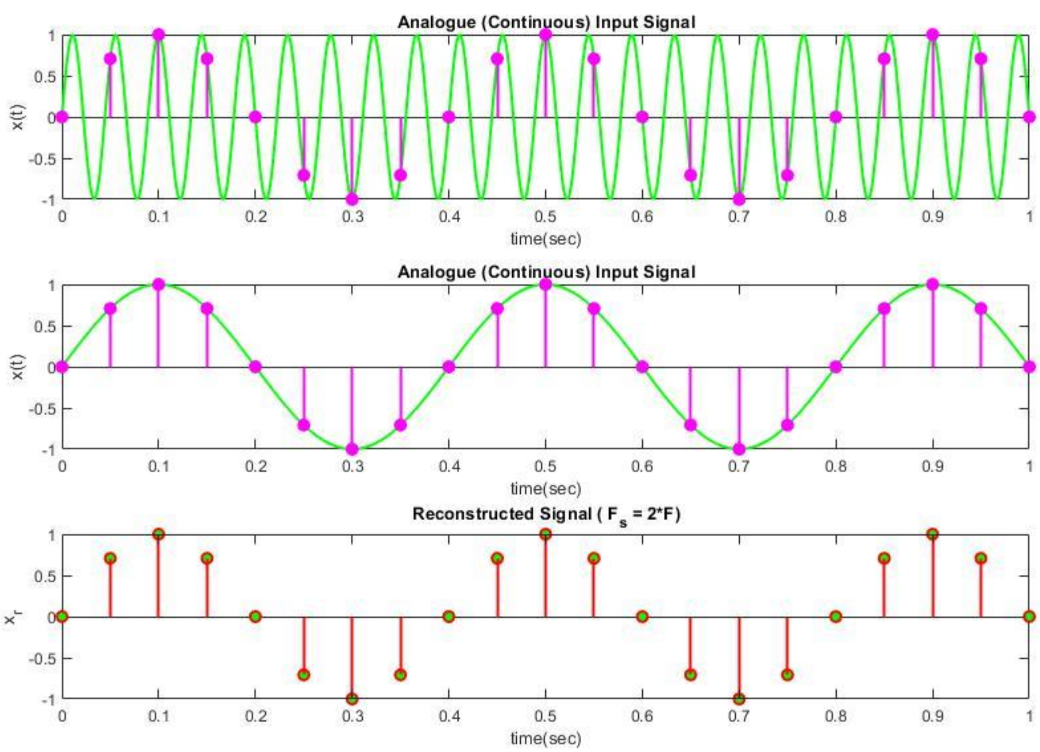



E02.

```
%Time vector for continuous signal
t = 0:0.001:1;
% Continuous-time sine waves
x1 =sin(45*pi*t);
x2 =sin(5*pi*(t));

% Sampling at Nyquist rate
F_s = 20;
% Sampling points
n = 0:1/F_s:1;
% Discrete-time signals
x1_s =sin(45*pi*n);
x2_s =sin(5*pi*n);

figure;
subplot(3,1,1)
plot(t,x1,'-g','LineWidth',1.5)
hold on
stem(n,x1_s,'m','filled','LineWidth',1.5)
hold off
title('Analogue (Continuous) Input Signal')
ylabel('x(t)','Interpreter','tex')
xlabel('time(sec)')
```

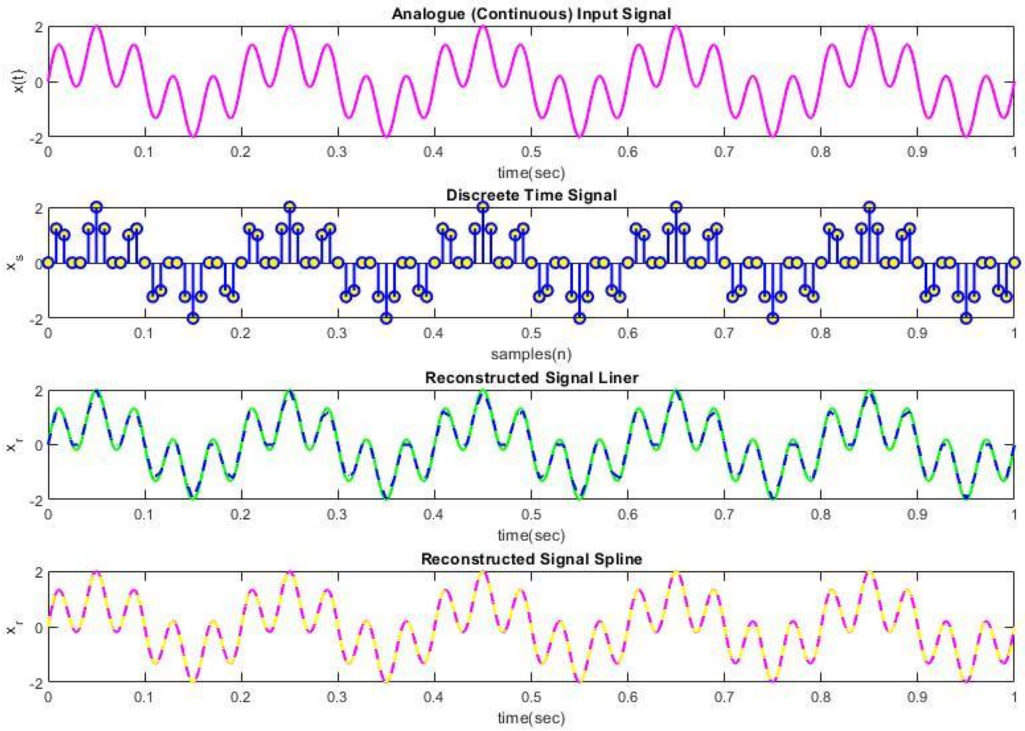
```
subplot(3,1,2)
plot(t,x2,'-g','LineWidth',1.5)
hold on
stem(n,x2_s,'m','filled','LineWidth',1.5)
title('Analogue (Continuous) Input Signal')
ylabel('x(t)','Interpreter','tex')
xlabel('time(sec)')

subplot(3,1,3)
stem(n,x1_s,'g','filled','LineWidth',1.5)
hold on
stem(n,x2_s,'r','LineWidth',1.5)
hold off
title('Reconstructed Signal ( F_s = 2*F)','Interpreter','tex')
xlabel('time(sec)')
ylabel('x_r','Interpreter','tex')
```

- The sampled version of x1(t) x1(t) appears identical to x2(t) x2(t) due to aliasing. This happens because the sampling frequency Fs=20 Hz is insufficient to distinguish between the two signals.
- The aliasing phenomenon occurs because the frequency of x1(t) x1(t) exceeds the Nyquist frequency (Fs/2=10 Hz).



E03.

```
%Time vector for continuous signal
t = 0:0.001:1;
% Continuous-time sine waves
x =sin(10*pi*t) + sin(50*pi*t);

figure;
subplot(4,1,1)
plot(t,x,'-m','LineWidth',1.5)
title('Analogue (Continuous) Input Signal')
ylabel('x(t)','Interpreter','tex')
xlabel('time(sec)')

% Sampling at Nyquist rate
F_s = 120;
% Sampling points
n = 0:1/F_s:1;
% Discrete-time signals
x_s =sin(10*pi*n) + sin(50*pi*n);

subplot(4,1,2)
stem(n,x_s,'-b','MarkerFaceColor','yellow','LineWidth',1.5)
title('Discreete Time Signal','Interpreter','tex')
xlabel('samples(n)')
ylabel('x_s','Interpreter','tex')

% Time vector for reconstruction
t_r = linspace(0, 1, 1000);
% Reconstruct signal using linear interpolation
x_linear = interp1(n, x_s, t_r, 'linear');
% Reconstruct signal using spline interpolation
x_spline = interp1(n, x_s, t_r, 'spline');

subplot(4,1,3)
plot(t,x,'-g','LineWidth',1.5)
hold on
plot(t_r,x_linear,'--b','LineWidth',1.5)
title('Reconstructed Signal Liner','Interpreter','tex')
xlabel('time(sec)')
ylabel('x_r','Interpreter','tex')

subplot(4,1,4)
plot(t,x,'-m','LineWidth',1.5)
hold on
plot(t_r,x_spline,'--y','LineWidth',1.5)
title('Reconstructed Signal Spline','Interpreter','tex')
xlabel('time(sec)')
ylabel('x_r','Interpreter','tex')
```




E04.

```
%Time vector for continuous signal
t = 0:0.001:1;
% Continuous-time sine waves
x =sin(50*pi*t) + sin(90*pi*t);

figure;
subplot(3,1,1)
plot(t,x,'-g','LineWidth',1.5)
title('Analogue (Continuous) Input Signal')
ylabel('x(t)','Interpreter','tex')
xlabel('time(sec)')

% Sampling at Nyquist rate
F_s = 190;
% Sampling points
n = 0:1/F_s:1;
% Discrete-time signals
x_s =sin(50*pi*n) + sin(90*pi*n);

subplot(3,1,2)
plot(t,x,'-g','LineWidth',1.5)
hold on
stem(n,x_s,'-b','MarkerFaceColor','yellow','LineWidth',1.5)
```

```
hold off
title('Discreete Time Signal','Interpreter','tex')
xlabel('samples(n)')
ylabel('x_s','Interpreter','tex')

% Time vector for reconstruction
t_r = linspace(0, 1, 1000);
% Reconstruct signal using spline interpolation
x_spline = interp1(n, x_s, t_r, 'spline');

subplot(3,1,3)
plot(t,x,'-g','LineWidth',1.5)
hold on
plot(t_r,x_spline,'--m','LineWidth',1.5)
title('Reconstructed Signal Spline','Interpreter','tex')
xlabel('time(sec)')
ylabel('x_r','Interpreter','tex')
```