KATHMANDU UNIVERSITY

DHULIKHEL, KAVRE

Subject: COMP-407: Digital Signal Processing

Lab no: 3

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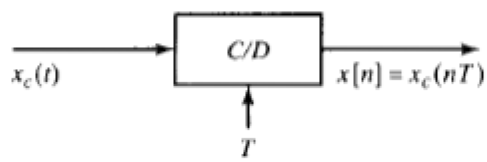
Sampling:

In signal processing, sampling is the reduction of a continuous-time signal to a discrete-time signal. A common example is the conversion of a sound wave (a continuous signal) to a sequence of samples (a discrete-time signal).

A sample is a value or set of values at a point in time and/or space.

The typical method of obtaining a discrete-time representation of a continuous-time signal is through periodic sampling, wherein a sequence of samples, x[n], is obtained from a continuous-time signal $x_c(t)$ according to the relation
$x[n] = x_c(nT)$ -oo < n < oo.

T is the sampling period, and its reciprocal, fs, = 1/ T. is the sampling frequency
The sampling frequency or sampling rate, fs, is the average number of samples obtained in one second (samples per second), thus fs = 1/T.



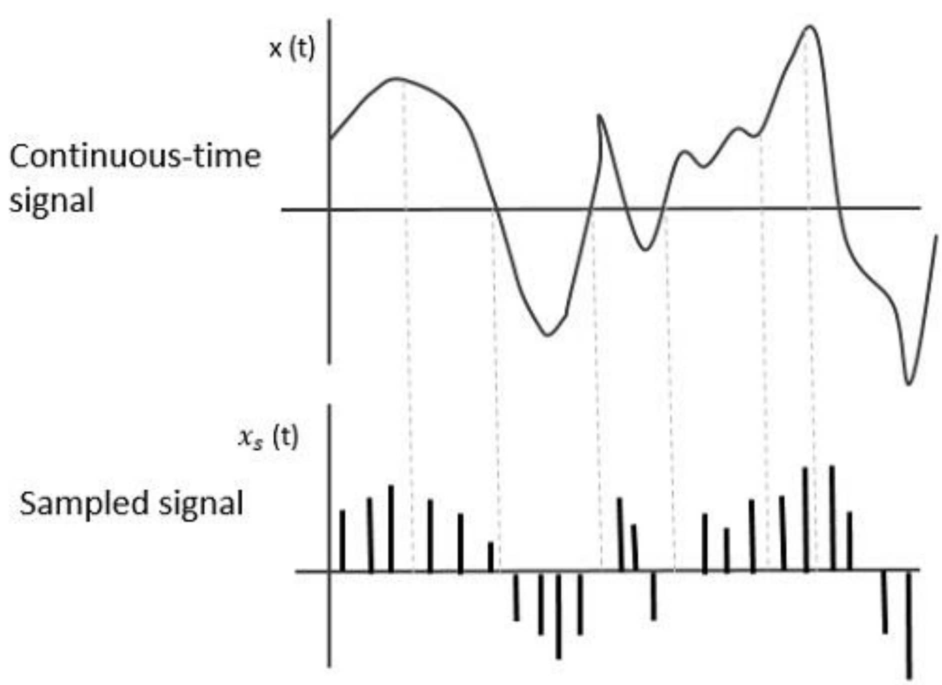


Fig: Sampling of continuous signal

Nyquist Sampling Theorem:
Let $x_c(t)$ be bandlimited signal with $X_c(J\Omega)=0$ for $|\Omega|\geq\Omega_N$, then $x_c(t)$ is uniquely determined by its samples $x[n] = x_c(nT)$ if $\Omega_s\geq2\Omega_N$;$n=0,\pm1,\pm2,\pm3,..$
Here, Ω_s is sampling frequency in radians per seconds
Ω_N is the maximum component frequency of the signal to be sampled
$X_c(J\Omega)$ is the Fourier transform of $x_c(t)$

Nyquist rate is twice the maximum component frequency of the function being sampled.

Aliasing
If the inequality $\Omega_s\geq2\Omega_N$ does not hold, the copies of $X_c(J\Omega)$ overlap, so that when they are added together, $X_c(J\Omega)$ is no longer recoverable by lowpass filtering. In this case, the reconstructed output $x_r(t)$ is related to the original continuous-time input through a distortion referred to as aliasing distortion, or simply, aliasing.

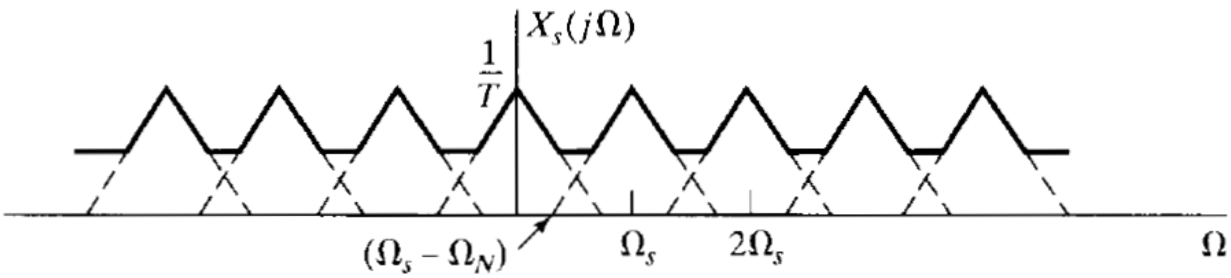


Fig: Aliasing

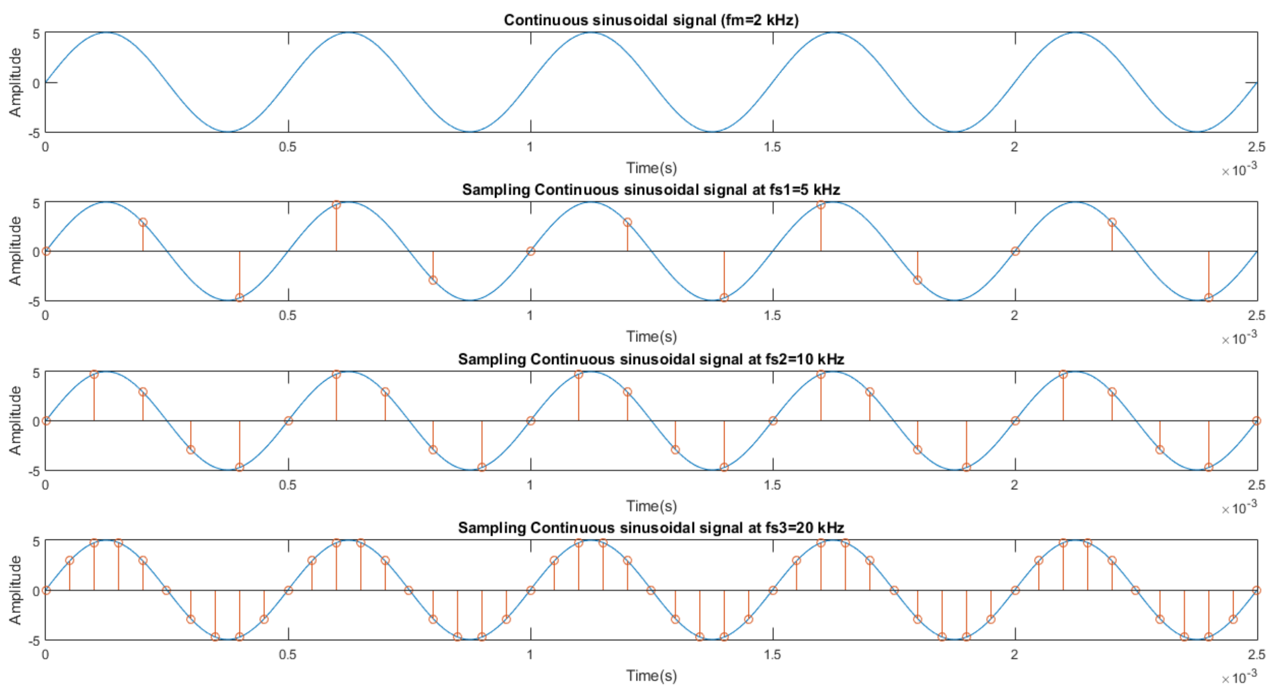
Question 1: Generate the signal x = 5sin(2 pi f t) with 5 cycles, where f = 2 kHz signal and sample the signal with frequency 5 KHz, 10 Khz, 20 KHz. (Title and label each figure)

Code:

```
f=2e3; %Frequency of sinusoid
cycles=5; %generate five cycles of sinusoid
t=0:1/500e3:cycles*1/f; %time index
x = 5*sin(2*pi*f*t);

subplot(4,1,1);
plot(t,x);
title('Continuous sinusoidal signal (fm=2 kHz)');
xlabel('Time(s)');
ylabel('Amplitude');

fs1=5e3; %5kHz sampling rate
t1=0:1/fs1:cycles*1/f; %time index
x1 = 5*sin(2*pi*f*t1);

fs2=10e3; %10kHz sampling rate
t2=0:1/fs2:cycles*1/f; %time index
x2=5*sin(2*pi*f*t2);
```

```
fs3=20e3; %20kHz sampling rate
t3=0:1/fs3:cycles*1/f; %time index
x3=5*sin(2*pi*f*t3);

subplot(4,1,2);
plot(t,x);
hold on;
stem(t1,x1);
title('Sampling Continuous sinusoidal signal at fs1=5 kHz');
xlabel('Time(s)');
ylabel('Amplitude');

subplot(4,1,3);
plot(t,x);
hold on;
stem(t2,x2);
title('Sampling Continuous sinusoidal signal at fs2=10 kHz');
xlabel('Time(s)');
ylabel('Amplitude');

subplot(4,1,4);
plot(t,x);
hold on;
stem(t3,x3);
title('Sampling Continuous sinusoidal signal at fs3=20 kHz');
xlabel('Time(s)');
ylabel('Amplitude');
```

Output:

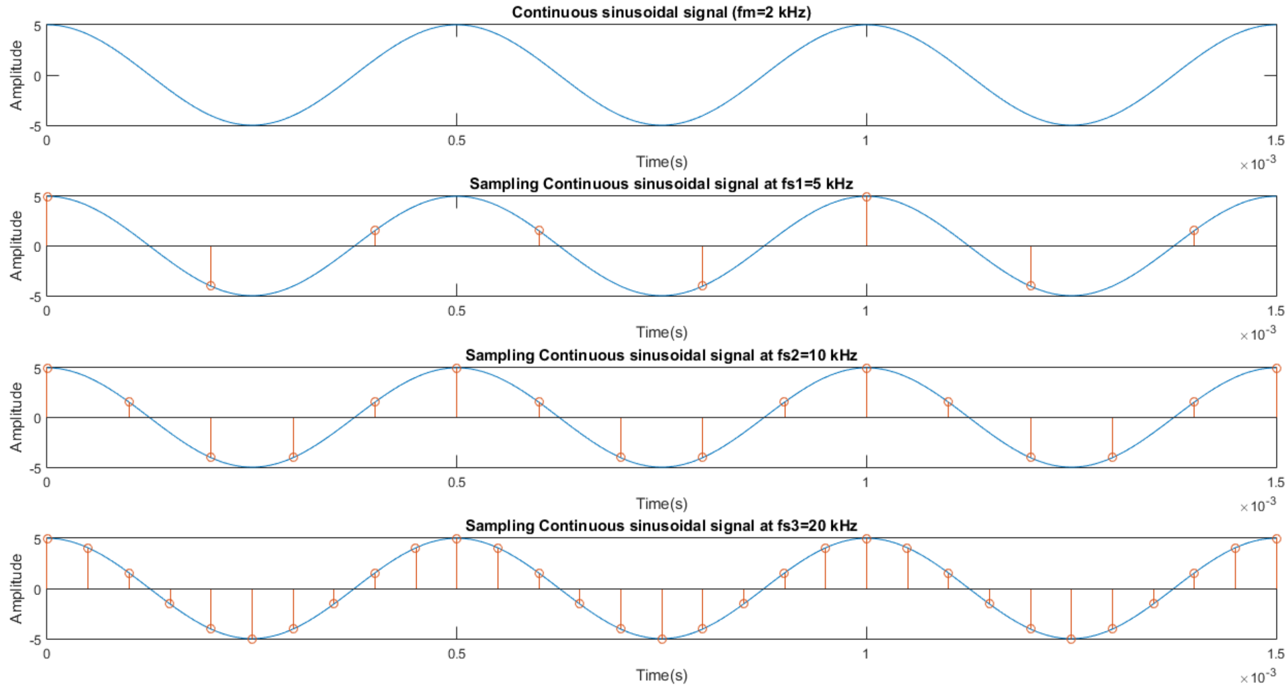


Question 2: Generate the signal x = 5cos(2 pi f t) with 3 cycles, where f = 2 kHz signal and sample the signal with frequency 5 KHz, 10 Khz, 20 KHz. (Title and label each figure)

Code:

```
%ques 2
f=2e3; %Frequency of sinusoid
cycles=3; %generate five cycles of sinusoid
t=0:1/500e3:cycles*1/f; %time index
x = 5*cos(2*pi*f*t);

figure;
subplot(4,1,1);
plot(t,x);
title('Continuous sinusoidal signal (fm=2 kHz)');
xlabel('Time(s)');
ylabel('Amplitude');

fs1=5e3; %5kHz sampling rate
t1=0:1/fs1:cycles*1/f; %time index
x1 = 5*cos(2*pi*f*t1);

fs2=10e3; %10kHz sampling rate
t2=0:1/fs2:cycles*1/f; %time index
x2=5*cos(2*pi*f*t2);

fs3=20e3; %20kHz sampling rate
t3=0:1/fs3:cycles*1/f; %time index
x3=5*cos(2*pi*f*t3);

subplot(4,1,2);
plot(t,x);
hold on;
stem(t1,x1);
title('Sampling Continuous sinusoidal signal at fs1=5 kHz');
xlabel('Time(s)');
ylabel('Amplitude');

subplot(4,1,3);
plot(t,x);
hold on;
stem(t2,x2);
title('Sampling Continuous sinusoidal signal at fs2=10 kHz');
xlabel('Time(s)');
ylabel('Amplitude');

subplot(4,1,4);
plot(t,x);
hold on;
stem(t3,x3);
title('Sampling Continuous sinusoidal signal at fs3=20 kHz');
xlabel('Time(s)');
ylabel('Amplitude');
```

Output:



Conclusion:

Thus, we performed sampling on continuous sinusoidal waves at different sampling frequencies and viewed the results in MATLAB