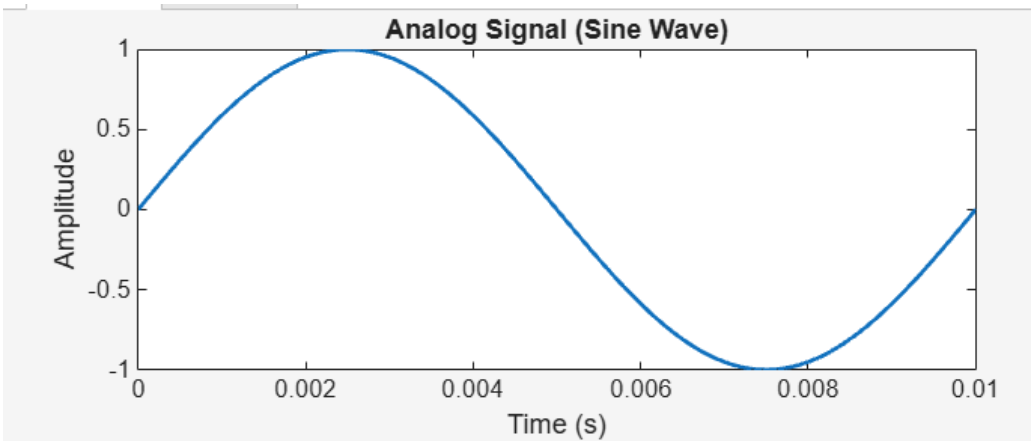
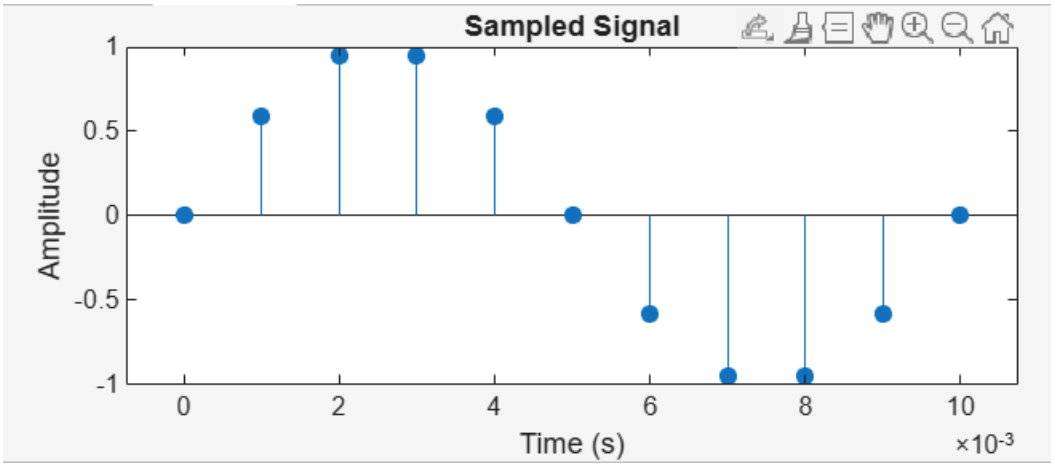
```
%% 1. Generate Analog Signal (conceptual)
t = 0:0.0001:0.01;        % very fine step (continuous-like time)
f = 100;                  % frequency = 100 Hz
x_analog = sin(2*pi*f*t);
figure;
plot(t, x_analog, 'LineWidth', 1.5);
title('Analog Signal (Sine Wave)');
xlabel('Time (s)'); ylabel('Amplitude');
```



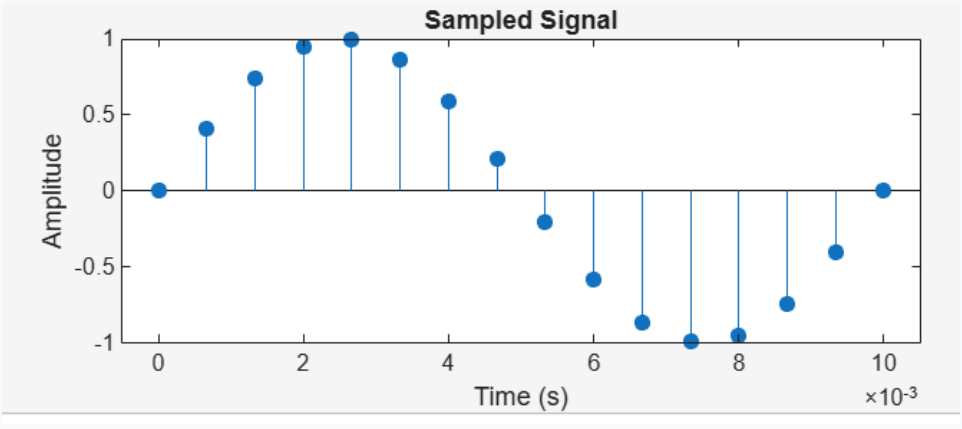

```
%% 2. Sampling
Fs = 1000;                % Sampling frequency = 1 kHz
Ts = 1/Fs;                % Sampling period
n = 0:Ts:0.01;            % Discrete sample points
x_sampled = sin(2*pi*f*n);
figure;
stem(n, x_sampled, 'filled');
title('Sampled Signal');
xlabel('Time (s)'); ylabel('Amplitude');
```



- below Nyquist

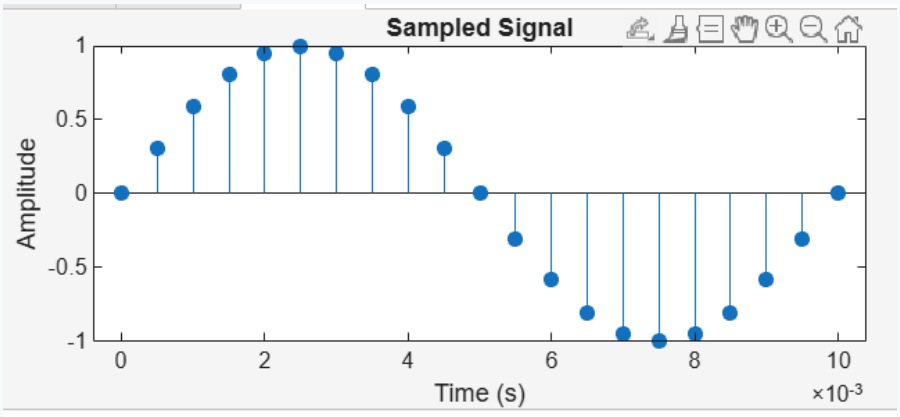
```
%% 2. Sampling
Fs = 1500;                % Sampling frequency = 1.5 kHz
```

```
Ts = 1/Fs;                  % Sampling period
n = 0:Ts:0.01;              % Discrete sample points
x_sampled = sin(2*pi*f*n);
```



- at Nyquist

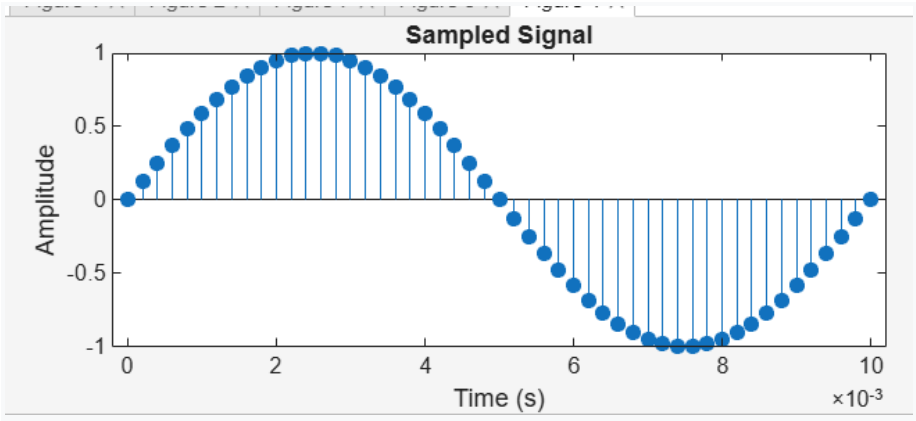
```
Fs = 2000;                  % Sampling frequency = 2 kHz
Ts = 1/Fs;                  % Sampling period
n = 0:Ts:0.01;              % Discrete sample points
x_sampled = sin(2*pi*f*n);
figure;
stem(n, x_sampled, 'filled');
title('Sampled Signal');
xlabel('Time (s)'); ylabel('Amplitude');
```



- above Nyquist

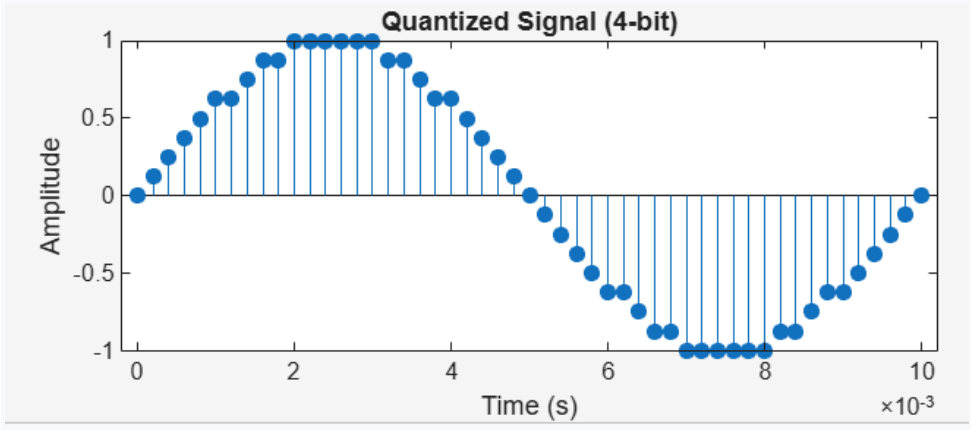
```
Fs = 5000;                  % Sampling frequency = 5 kHz
Ts = 1/Fs;                  % Sampling period
n = 0:Ts:0.01;              % Discrete sample points
x_sampled = sin(2*pi*f*n);
figure;
stem(n, x_sampled, 'filled');
```

```
title('Sampled Signal');
xlabel('Time (s)'); ylabel('Amplitude');
```



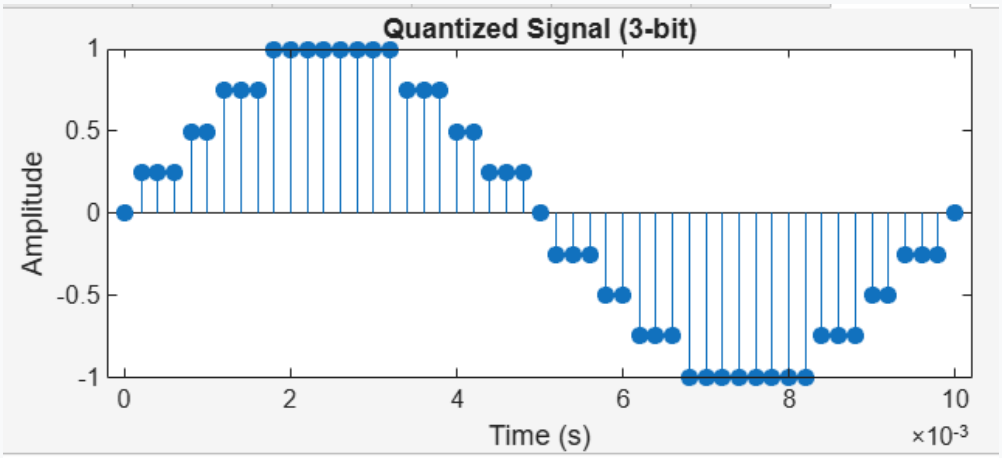
Below Nyquist → severe aliasing
At Nyquist → ambiguous waveform
Above Nyquist → clear sine wave

```
%% 3. Quantization
bits = 4;                   % Number of bits
levels = 2^bits;            % Quantization levels
x_min = min(x_sampled);
x_max = max(x_sampled);
q_step = (x_max - x_min)/levels;    % Step size

x_index = round((x_sampled - x_min)/q_step); % Map samples to indices
x_quantized = x_index*q_step + x_min;       % Map back to amplitude

figure;
stem(n, x_quantized, 'filled');
title(['Quantized Signal (' num2str(bits) '-bit)']);
xlabel('Time (s)'); ylabel('Amplitude');
```



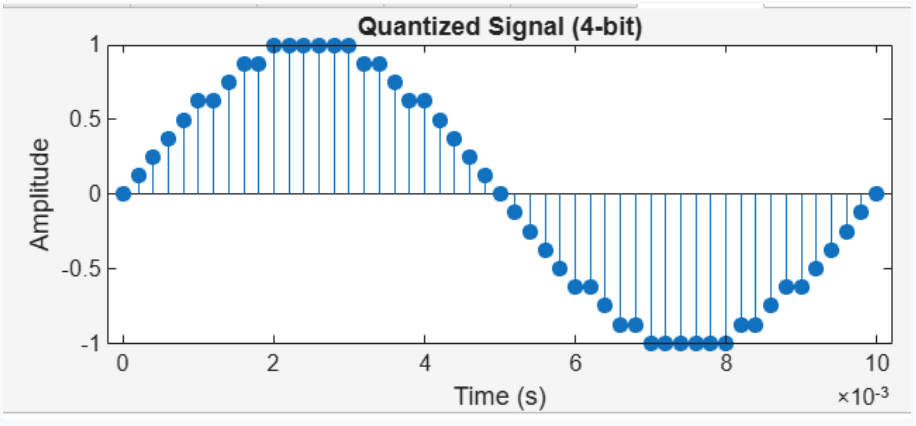
- 8 levels:

```
bits = 3;                               % Number of bits
levels = 2^bits;                        % Quantization levels
x_min = min(x_sampled);
x_max = max(x_sampled);
q_step = (x_max - x_min)/levels;        % Step size
x_index = round((x_sampled - x_min)/q_step); % Map samples to
indices
x_quantized = x_index*q_step + x_min;         % Map back to
amplitude
figure;
stem(n, x_quantized, 'filled');
title(['Quantized Signal (' num2str(bits) '-bit)']);
xlabel('Time (s)'); ylabel('Amplitude');
```



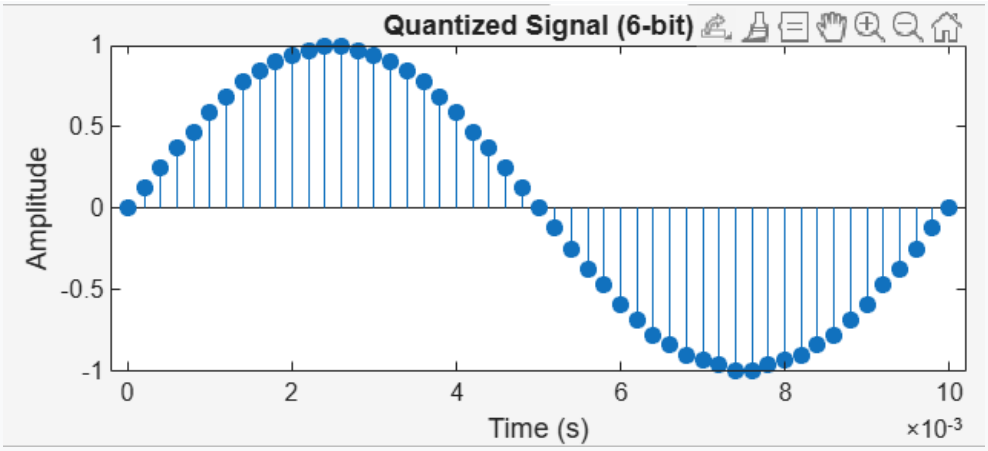
- 16 levels:

```
bits = 4;                               % Number of bits
levels = 2^bits;                        % Quantization levels
x_min = min(x_sampled);
x_max = max(x_sampled);
q_step = (x_max - x_min)/levels;        % Step size
x_index = round((x_sampled - x_min)/q_step); % Map samples to
indices
x_quantized = x_index*q_step + x_min;         % Map back to
amplitude
figure;
stem(n, x_quantized, 'filled');
title(['Quantized Signal (' num2str(bits) '-bit)']);
xlabel('Time (s)'); ylabel('Amplitude');
```



- 64 levels:

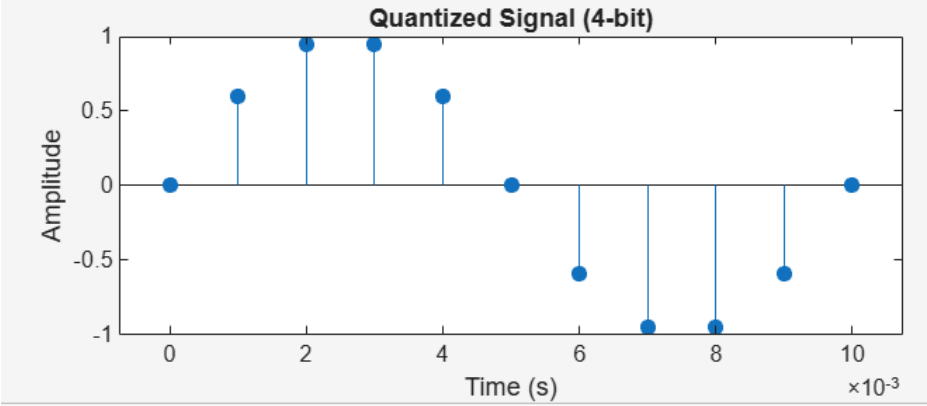
```
bits = 6;                                % Number of bits
levels = 2^bits;                         % Quantization levels
x_min = min(x_sampled);
x_max = max(x_sampled);
q_step = (x_max - x_min)/levels;     % Step size
x_index = round((x_sampled - x_min)/q_step); % Map samples to
indices
x_quantized = x_index*q_step + x_min;        % Map back to
amplitude
figure;
stem(n, x_quantized, 'filled');
title(['Quantized Signal (' num2str(bits) '-bit)']);
xlabel('Time (s)'); ylabel('Amplitude');
```



8 levels → coarse steps
16 levels → better resolution
64 levels → looks very close to the original

```
%% 4. Encoding (Binary Representation)
binary_codes = dec2bin(x_index, bits); % Convert indices to binary
words
disp('--- First 10 encoded samples ---');
```

```
disp(binary_codes(1:10));
```




```
%% 5. Digital Bitstream
bitstream = reshape(binary_codes.',1,[]); % Concatenate into one string
disp('--- First 40 bits of the stream ---');
disp(bitstream(1:40));


%% Summary
fprintf('\nSimulation complete!\n');
fprintf('Analog -> Sampling -> Quantization -> Binary Encoding -> Digital Stream\n');
fprintf('Bits per sample: %d\n', bits);
fprintf('Total samples: %d\n', length(x_sampled));
fprintf('Total bits: %d\n', length(bitstream));
```