Aim ↬ **Overview**

- **Verify sampling theorem in MATLAB**
- **Plot signals and determine Nyquist Rate & Nyquist Interval**
  - a) $\boldsymbol{sinc(4000t)}$
  - b) $\boldsymbol{sinc(2000t) + sinc(6000t)}$
  - c) $\boldsymbol{sin(100t) + sin(100\pi t)}$

Software Required ↬ MATLAB

Theory ↬

Digital communication refers to the process of transmitting information in digital form over a communication channel from a source to a destination. It involves encoding data into digital signals, transmitting these signals, and decoding them back into their original form. This process is essential in modern telecommunications, computing, and media technologies.

In digital communication, information is represented as discrete values or symbols rather than continuous signals. This is achieved through a series of encoding, modulation, transmission, and decoding processes. Digital communication systems are preferred over analog systems due to their robustness against noise and interference, ease of data compression, and efficient error detection and correction mechanisms. The digital nature of the signals allows for precise data handling and facilitates sophisticated techniques for error control, security, and data integrity.

The core of digital communication involves several key processes. Sampling converts continuous-time signals into discrete-time signals, ensuring that the original information can be accurately represented if sampled at or above the Nyquist rate. Quantization follows sampling, where continuous amplitude values are approximated to a finite set of levels, which introduces quantization error. Modulation techniques, such as amplitude, frequency, and phase modulation, are then employed to encode the digital information onto carrier signals for transmission. The received signals undergo demodulation and decoding to retrieve the original information. This structured approach enhances the reliability and efficiency of data transmission over various communication channels, including wired, wireless, and optical systems.

Digital communication has revolutionized how information is transmitted and processed, enabling the development of advanced technologies like the Internet, mobile communications, and digital broadcasting. Its ability to handle large amounts of data with high fidelity and security makes it a cornerstone of modern information and communication systems.

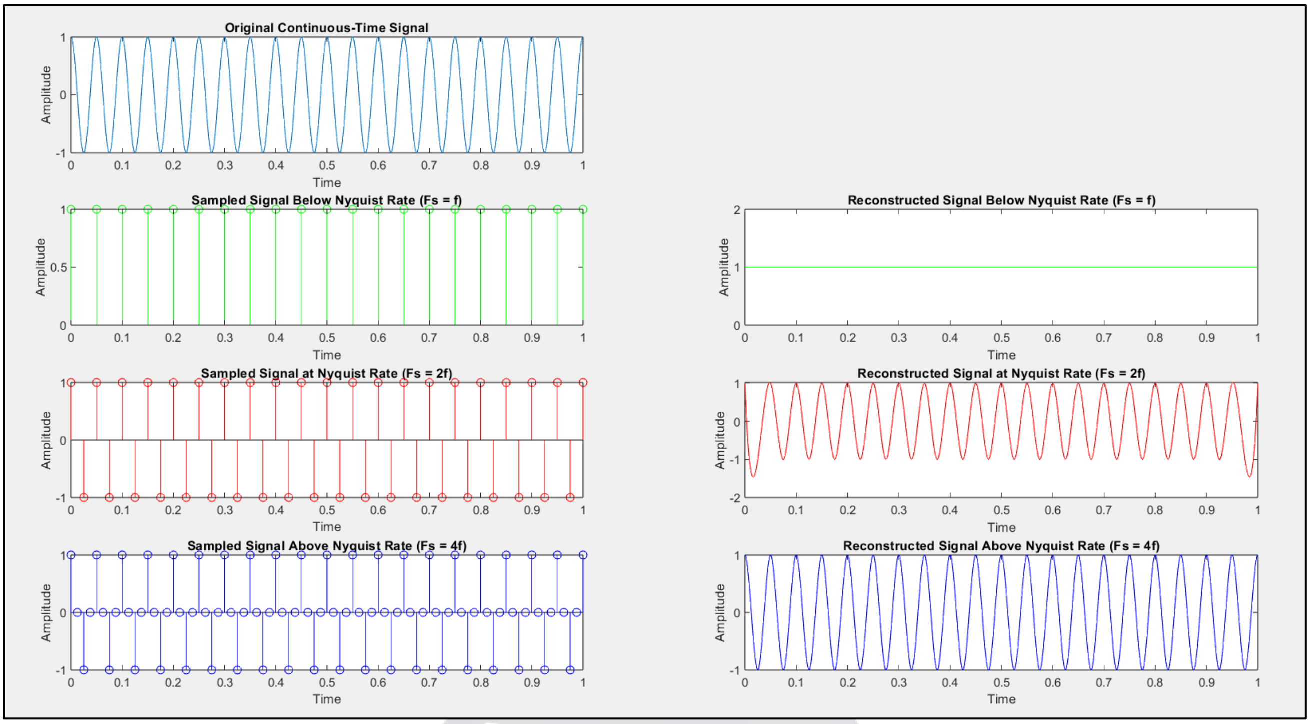
Code ↬

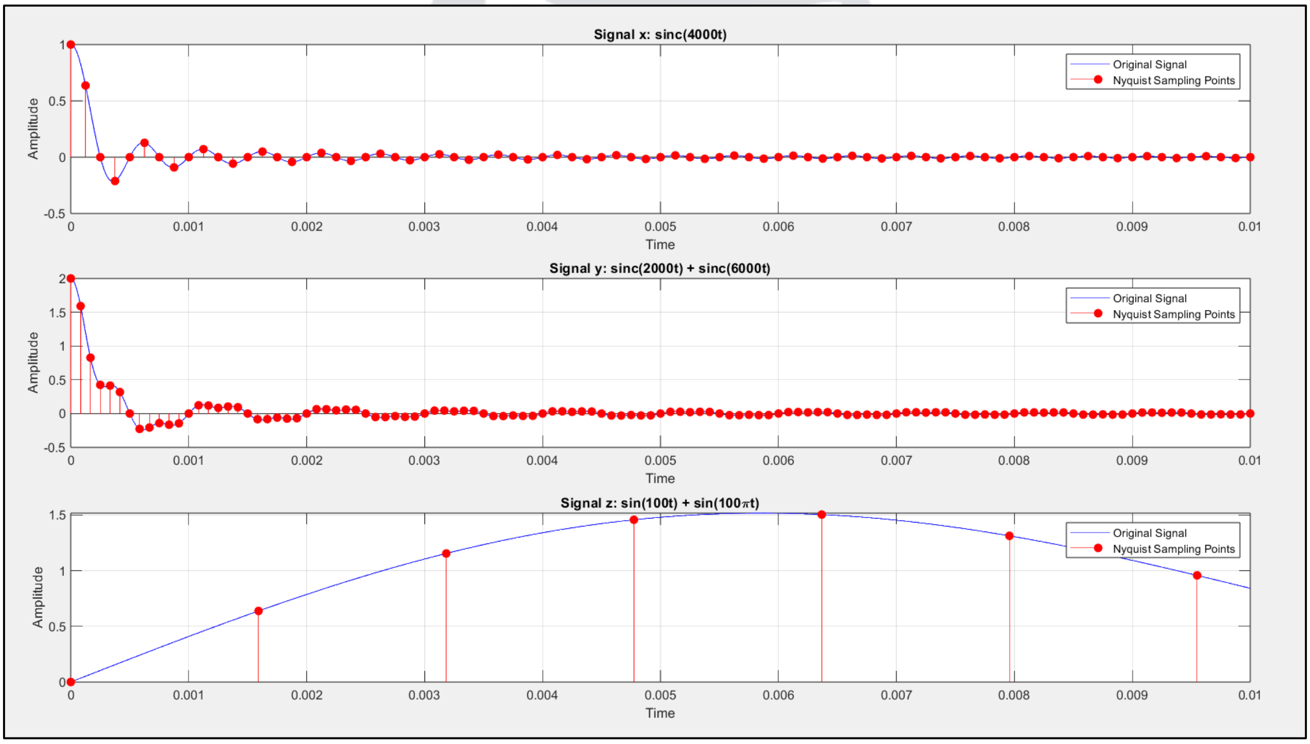
```
%Sampling Theorem
Fs = 1000;
t = 0:1/Fs:1;
f = 20;

x = cos(2*pi*f*t);

subplot(4,2,1);
plot(t, x);
title('Original Continuous-Time Signal');
xlabel('Time');
ylabel('Amplitude');

Fs1 = 2*f;
Fs2 = f;
Fs3 = 4*f;

t1 = 0:1/Fs1:1;
t2 = 0:1/Fs2:1;
t3 = 0:1/Fs3:1;

x1 = cos(2*pi*f*t1);
x2 = cos(2*pi*f*t2);
x3 = cos(2*pi*f*t3);

subplot(4,2,2);
stem(t1, x1, 'r');
title('Sampled Signal at Nyquist Rate (Fs = 2f)');
xlabel('Time');
ylabel('Amplitude');

subplot(4,2,3);
stem(t2, x2, 'g');
title('Sampled Signal Below Nyquist Rate (Fs = f)');
xlabel('Time');
ylabel('Amplitude');

subplot(4,2,4);
stem(t3, x3, 'b');
title('Sampled Signal Above Nyquist Rate (Fs = 4f)');
xlabel('Time');
ylabel('Amplitude');

t_interp = 0:1/Fs:1;
```

```
x1_interp = interp1(t1, x1, t_interp, 'spline');
x2_interp = interp1(t2, x2, t_interp, 'spline');
x3_interp = interp1(t3, x3, t_interp, 'spline');

subplot(4,2,5);
plot(t_interp, x1_interp, 'r');
title('Reconstructed Signal at Nyquist Rate (Fs = 2f)');
xlabel('Time');
ylabel('Amplitude');

subplot(4,2,6);
plot(t_interp, x2_interp, 'g');
title('Reconstructed Signal Below Nyquist Rate (Fs = f)');
xlabel('Time');
ylabel('Amplitude');

subplot(4,2,7);
plot(t_interp, x3_interp, 'b');
title('Reconstructed Signal Above Nyquist Rate (Fs = 4f)');
xlabel('Time');
ylabel('Amplitude');


%Nyquist Rate
Fs = 100000;
t = 0:1/Fs:0.01;

x = sinc(4000*t);
y = sinc(2000*t) + sinc(6000*t);
z = sin(100*t) + sin(100*pi*t);

NR_x = 2 * 4000;
NI_x = 1 / NR_x;

NR_y = 2 * max(2000, 6000);
NI_y = 1 / NR_y;

NR_z = 2 * max(100, 100*pi);
NI_z = 1 / NR_z;

fprintf('Signal x:\nNyquist Rate: %.2f Hz\nNyquist Interval: %.4f
seconds\n', NR_x, NI_x);
fprintf('Signal y:\nNyquist Rate: %.2f Hz\nNyquist Interval: %.4f
seconds\n', NR_y, NI_y);
fprintf('Signal z:\nNyquist Rate: %.2f Hz\nNyquist Interval: %.4f
seconds\n', NR_z, NI_z);
```

```
figure;

subplot(3,1,1);
plot(t, x, 'b');
title('Signal x: sinc(4000t)');
xlabel('Time');
ylabel('Amplitude');
grid on;
hold on;
stem(0:NI_x:max(t), sinc(4000*(0:NI_x:max(t))), 'r', 'filled');
legend('Original Signal', 'Nyquist Sampling Points');
hold off;

subplot(3,1,2);
plot(t, y, 'b');
title('Signal y: sinc(2000t) + sinc(6000t)');
xlabel('Time');
ylabel('Amplitude');
grid on;
hold on;
stem(0:NI_y:max(t), sinc(2000*(0:NI_y:max(t))) +
sinc(6000*(0:NI_y:max(t))), 'r', 'filled');
legend('Original Signal', 'Nyquist Sampling Points');
hold off;

subplot(3,1,3);
plot(t, z, 'b');
title('Signal z: sin(100t) + sin(100\pit)');
xlabel('Time');
ylabel('Amplitude');
grid on;
hold on;
stem(0:NI_z:max(t), sin(100*(0:NI_z:max(t))) +
sin(100*pi*(0:NI_z:max(t))), 'r', 'filled');
legend('Original Signal', 'Nyquist Sampling Points');
hold off;
```

Output ↬






```
>> Nyquist_Rate
Signal x:
Nyquist Rate: 8000.00 Hz
Nyquist Interval: 0.0001 seconds
Signal y:
Nyquist Rate: 12000.00 Hz
Nyquist Interval: 0.0001 seconds
Signal z:
Nyquist Rate: 628.32 Hz
Nyquist Interval: 0.0016 seconds
>>
```

Result ↬

Various continuous-time signals, including cosines and sinc functions, were generated and sampled in MATLAB. The signals were plotted to observe their characteristics at different sampling rates.

Conclusion ↬

The experiment demonstrated the Sampling Theorem and the impact of sampling rates on signal reconstruction, emphasizing the importance of the Nyquist rate to prevent aliasing. MATLAB simulations provided valuable insights into signal processing and digital communication.

Precautions ↬

- Ensure the correct sampling rate is chosen to avoid aliasing, adhering to the Nyquist criterion.
- Verify the mathematical expressions for signal generation to avoid errors.
- Use appropriate labels and titles for plots to clearly identify each signal and sampling rate.
- Handle potential issues like division by zero, especially in functions like sinc, carefully.