Aim ↬ To study and generate various elementary continuous & discrete-time signals such as Unit Impulse, Unit Step, Ramp, Exponential, Sinusoidal, Sinc, Sampling, Rectangular, Triangular, etc., using MATLAB.

Software Required ↬ MATLAB

Theory ↬

A signal is a set of information or data that can be modeled as a function of one or more independent variables, such as speech, image, voltage, video, music, etc.

A signal represents information that can be classified based on how it is defined over time. **Continuous-time signals** are defined for all real values of time t and can take any value within a continuous range. These signals, often called analog signals, include phenomena like analog speech transmitted over a telephone line, where the signal varies smoothly over time.

Discrete-time signals are defined only at specific, discrete points in time, known as sample points. These signals, often called digital signals, result from sampling a continuous signal at regular intervals. For example, an audio recording on a digital device is a discrete-time signal, where the continuous sound wave has been converted into a sequence of discrete values.

Continuous Time Signals ↴

- **Unit Impulse (Dirac Delta) Signal ↪** A theoretical signal that is zero everywhere except at t=0, where it is infinitely high such that its integral over the entire time axis is one.

$$\delta(t) = \begin{cases} \infty, & \text{if } t = 0 \\ 0, & \text{if } t \neq 0 \end{cases}$$

- **Unit Step Signal ↪** A signal that is zero for all negative time and one for zero and positive time.

$$u(t) = \begin{cases} 0, & \text{if } t < 0 \\ 1, & \text{if } t \geq 0 \end{cases}$$

- **Ramp Signal ↪** A signal that increases linearly over time, starting from zero at t=0.

$$r(t) = \begin{cases} 0, & \text{if } t \geq 0 \\ t, & \text{if } t < 0 \end{cases}$$

- **Exponential Signal** ↪ A signal that grows exponentially over time.

$$e(t) = Ae^{\propto t}$$

- **Sinusoidal Signal** ↪ A smooth, periodic oscillation representing many natural phenomena such as sound waves and AC power.

$$x(t) = Asin(\omega t + \varphi)$$

- **Sinc Signal** ↪ A Signal commonly used in signal processing, particularly in interpolation and Fourier analysis.

$$sinc(t) = \frac{\sin(\pi t)}{\pi t}$$

- **Sampling Signal** ↪ This Signal is particularly important in the Nyquist-Shannon sampling theorem, where it is used to reconstruct a continuous signal from its samples.

$$sa(t) = \frac{\sin(t)}{t}$$

- **Rectangular Signal** ↪ A periodic waveform that alternates between a maximum and a minimum value at a fixed frequency.

$$\mathrm{sq(t)} = \mathrm{T} \qquad \text{for } -\frac{T}{2} \leq t \leq \frac{T}{2}$$

- **Triangular Signal** ↪ A periodic waveform that rises and falls linearly, forming a triangular shape.

$$\mathrm{tri(t)} = 1 - \frac{|t|}{T} \qquad \text{for } -T \leq t \leq T$$

Discrete-Time Signals ↴

- **Unit Impulse (Kronecker Delta) Signal** ↪ A theoretical signal that is zero everywhere except at n=0, where it is one.

$$\delta[\mathrm{n}] = \begin{cases} 1, & \text{if n} = 0 \\ 0, & \text{if n} \neq 0 \end{cases}$$

- **Unit Step Signal** ↪ A signal that is zero for all negative time and one for zero and positive time.

$$\mathrm{u}[n] = \begin{cases} 0, & \text{if n} < 0 \\ 1, & \text{if n} \geq 0 \end{cases}$$

- **Ramp Signal** ↪ A signal that increases linearly over time, starting from zero at n=0.

$$\mathrm{r}[n] = \begin{cases} 0, & \text{if n} < 0 \\ \text{n}, & \text{if n} \geq 0 \end{cases}$$

- **Exponential Signal** ↪ A signal that grows exponentially over time.

$$e[n] = Ae^{\propto n}$$

- **Sinusoidal Signal** ↪ A smooth, periodic oscillation representing many natural phenomena such as sound waves and digital modulation.

$$x[n] = Asin(\omega n + \varphi)$$

- **Rectangular Signal** ↪ A periodic waveform that alternates between a maximum and a minimum value at a fixed frequency.

$$\mathrm{sq}[n] = \mathrm{N} \qquad\qquad \text{for } -\frac{N}{2} \leq n \leq \frac{N}{2}$$

- **Triangular Signal** ↪ A periodic waveform that rises and falls linearly, forming a triangular shape.

$$\mathrm{tri}[n] = 1 - \frac{|n|}{N} \qquad\qquad \text{for } -N \leq n \leq N$$

Code ↬

```
% Continuous Time Signals
clc;
clear;

t = -20:0.01:20;
k = 0:0.01:40;

figure;
% Impulse Function
d = (t==0);
subplot(3,3,1);
plot(t,d);
xlabel("Time");
ylabel("Amplitude");
title("Impulse Function");

% Unit Step Function
u = (t>=0);
subplot(3,3,2);
plot(t,u);
xlabel("Time");
ylabel("Amplitude");
title("Unit Step Function");

% Ramp Function
r = t.*(t>=0);
subplot(3,3,3);
plot(t,r);
xlabel("Time");
ylabel("Amplitude");
title("Ramp Function");
```

```
% Exponential Function
e = exp(t);
subplot(3,3,4);
plot(t,e);
xlabel("Time");
ylabel("Amplitude");
title("Exponential Function");

% Sinusoidal Function
s = sin(t);
subplot(3,3,5);
plot(t,s);
xlabel("Time");
ylabel("Amplitude");
title("Sinusoidal Function");

% Sinc Function
si = sinc(t);
subplot(3,3,6);
plot(t,si);
xlabel("Time");
ylabel("Amplitude");
title("Sinc Function");

% Sampling Function
sa = sin(t)./t;
subplot(3,3,7);
plot(t,sa);
xlabel("Time");
ylabel("Amplitude");
title("Sampling Function");

% Rectangular Function
rec = (-10<t&t<10);
subplot(3,3,8);
plot(t,rec);
xlabel("Time");
ylabel("Amplitude");
title("Rectangular Function");

% Triangular Function
tri = (1-(abs(t)./10)).*(t>=-10 & t<=10);
subplot(3,3,9);
plot(t,tri);
xlabel("Time");
ylabel("Amplitude");
title("Triangular Function");

% Trapezium Function
T = 10;
figure;
u = (t>=-T) & (t<=T);
tri = (1-(abs(t)./T)).*(t>=-T & t<=T);
func = u + tri;
plot(t,func);
ylabel("Amplitude");
xlabel("Time");
title("Trapezium Function");


% Discrete Time Signals
clc;
clear;

n = -20:1:20;

figure;
% Impulse Function
d = (n==0);
subplot(3,3,1);
stem(n,d);
xlabel("Time");
ylabel("Amplitude");
title("Impulse Function");

% Unit Step Function
u = (n>=0);
subplot(3,3,2);
stem(n,u);
xlabel("Time");
ylabel("Amplitude");
```

```
title("Unit Step Function");

% Ramp Function
r = n.*(n>=0);
subplot(3,3,3);
stem(n,r);
xlabel("Time");
ylabel("Amplitude");
title("Ramp Function");

% Exponential Function
e = exp(n);
subplot(3,3,4);
stem(n,e);
xlabel("Time");
ylabel("Amplitude");
title("Exponential Function");

% Sinusoidal Function
s = sin(n);
subplot(3,3,5);
stem(n,s);
xlabel("Time");
ylabel("Amplitude");
title("Sinusoidal Function");

% Sinc Function
si = sinc(n);
subplot(3,3,6);
stem(n,si);
xlabel("Time");
ylabel("Amplitude");
title("Sinc Function");

% Sampling Function
sa = sin(n)./n;
subplot(3,3,7);
stem(n,sa);
xlabel("Time");
ylabel("Amplitude");
title("Sampling Function");

% Rectangular Function
rec = (-10<n&n<10);
subplot(3,3,8);
stem(n,rec);
xlabel("Time");
ylabel("Amplitude");
title("Rectangular Function");

% Triangular Function
tri = (1-(abs(n)./10)).*(n>=-10 & n<=10);
subplot(3,3,9);
stem(n,tri);
xlabel("Time");
ylabel("Amplitude");
title("Triangular Function");
```

Output ↬

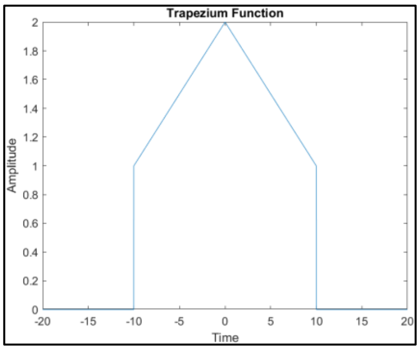

Fig. i] Trapezium Signal

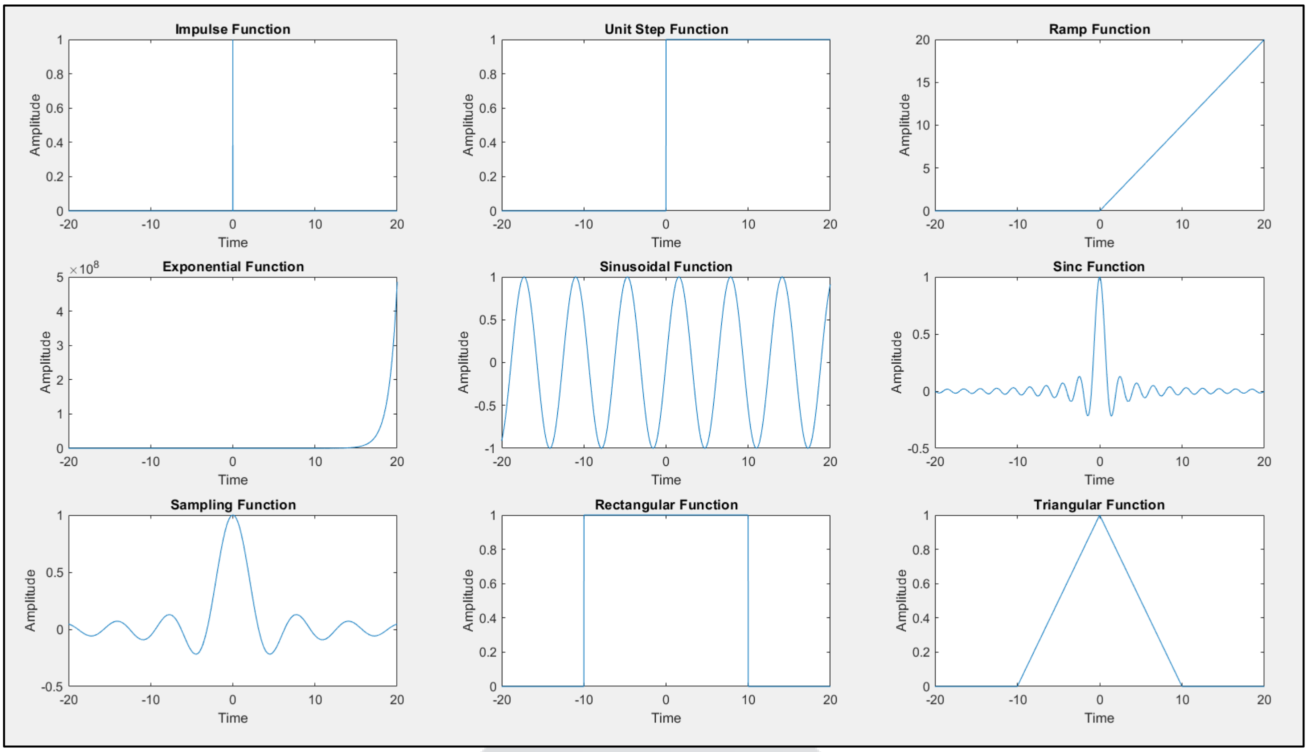

Fig. ii] MATLAB plots of various Elementary Continuous Time Signals

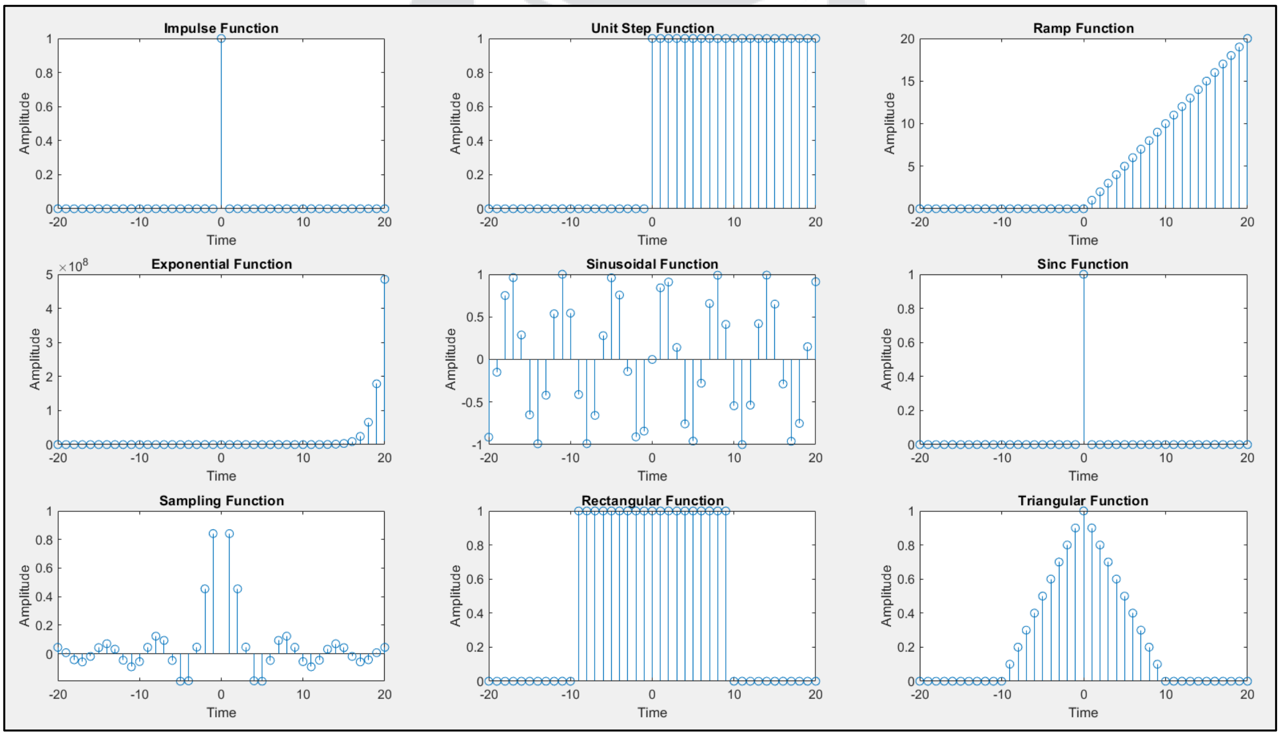

Fig. iii] MATLAB plots of various Elementary Discrete Time Signals

Result ↬

The experiment successfully demonstrated the generation of various elementary continuous and discrete-time signals. These signals were visualized using MATLAB, providing insight into their mathematical representations and practical applications.

Conclusion ↬

The experiment successfully demonstrated the ability to generate and visualize different elementary signals using MATLAB. Understanding these signals' properties is crucial in signal processing and related fields.

Precautions ↬

- Ensure the time variable's correct range and step size to visualize the signals accurately.
- Verify the mathematical expressions used for each signal to avoid errors in signal generation.
- Handle division by zero carefully, especially for the sinc function.