# Experiment No. 2

## Understanding the Basic Signals using MATLAB

## Objectives

To familiarize the students with the basic continuous and discrete time signals using MATLAB. These signals include:

1. Unit Impulse
2. Unit Step
3. Sinusoidal
4. Exponential

## Equipment

1. PC
2. Installed MATLAB

## Introduction

### Characterization of Signal by Variable Type

### Continuous Time Signals

A signal is called continuous-time (or analog) signals if the independent variable (time) is defined in continuous interval. For $1-D$ signals, time domain of signal is continuous interval of the axis. In other words, for continuous-time signals the independent variable $t$ is continuous. Moreover, the dependent value that usually denotes the amplitude of the signal is also continuous variable. An example of such a signal is speech as a function of time. An analog signal is expressed by a function $x(t)$, where $t$ takes real values.

**Activity-1:** Plot the continuous time signal y($t$) = sin($t$) over -5 ≤ $t$ ≤ 5

```
clc        % Command to clear all the text from the Command Window
clear      % Command to clear all variables from the current workspace
close all % Command to clear open MATLAB figure windows
t=-5:0.001:5;
y=sin(t);
plot(t,y);
title('y(t)=Sin(t)')
xlabel('t')
ylabel('y(t)')
grid on
```

**Discrete Time Signals**

A signal is called a discrete-time signal if the independent variable (time) is defined in a discrete interval (e.g., the set of integer number), while the dependent variable is defined in a continuous set of values. In the following example, the discrete-time signal $y[n]$ = sin$[n]$ is plotted. Note that when referring to discrete time the variable n is typically used to represent the time.

**Activity-2:** Plot the discrete time signal y(n) = sin(n) over 0≤ n ≤ 5

```
clc        % Command to clear all the text from the Command Window
clear      % Command to clear all variables from the current workspace
close all% Command to clear open MATLAB figure windows
n=0:0.1:5;
y=sin(n);
stem(n,y);
title('y(n)=Sin(n)')
xlabel('n')
ylabel('y(n)')
grid on
```

A discrete time signal x[n] is usually obtained by sampling a continuous-time signal $x(t)$ at a constant rate. Suppose $T_s$is the sampling period, that is every $T_s$ we sample the value of $x(t)$. Suppose also that n∈$\mathbb{Z}$, i.e.

$n$ = 0, ±1, ± 2, ± 3,…...The sequence of the sample is derived from the continuous time signal $x(t)$.

**Digital Signals**

Digital signals are the signals that both independent and dependent variables take values from a discrete set. In the following example, the signal $y[n] = cos[n]$ is again plotted, but we use the command round to limit the set of values that $y[n]$ can take, that is, $y[n]$ can be $-1,0$ $or$ 1.

**Activity-3:** Plot the discrete time signal y(n) = sin(n) over 0≤ n ≤ 5

```
clc        % Command to clear all the text from the Command Window
clear      % Command to clear all variables from the current workspace
close all % Command to clear open MATLAB figure windows
n=0:0.1:5; y=sin(n); stem(n, round(y));
title('y(n)=Sin(n)'); xlabel('n'); ylabel('y(n)')
grid on
```

**Basic Continuous Time Signals**

We present the basic continuous time Signals along with the way they are implemented and plotted in MATLAB.

**Sinusoidal Signal**

The first basic category presented is that of sinusoidal signal. This type of signal is of the form:

$$x(t)=A\cos(\omega t+\theta)$$

Where

$\omega$ = angular frequency, given in radian/s

$A$ = amplitude of the signal

$\theta$ = the phase (in radians).

Sinusoidal signals are periodic signals with fundamental period $T$ given by:

$$T = 2\pi/\omega$$

Finally, a useful quantity is the frequency f given in Hertz. Frequency $f$ is defined by

$$f = \omega/2\pi$$

Another signal highly associated with sinusoidal signal is the complex exponential signal. $Ae^{j\Omega t+\theta}$ is also periodic with fundamental period given by $T=\frac{2\pi}{\omega}$.According to derived straightforward from Euler's Formula:

$$Ae^{j\Omega t+\theta}=A(\cos(\Omega t+\theta)+j\sin(\Omega t+\theta))$$

**Exponential Signal**

Exponential signals are signals of the form

$$x(t)=Ae^{bt}$$

If $b>0$, $x(t)$is an increasing function

If $b<0$, $x(t)$is a decreasing function.

At $t=0$ the signal takes the value:

$$x(0)=A\ as\ e^{bt}=1.$$

**Unit Step Function**

Another basic signal is unit step function u(t). The unit step function is given by:

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

The MATLAB command that generates the unit step function is the command **heaviside(t).**

According to MATLAB programmers, unit step function is given by

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

i.e. it is not defined at t=0.

**Unit Impulse or Dirac Delta Function**

The Dirac delta$\delta(t)$, strictly speaking, is not a function but is defined through its properties. The main property is

$$\int_{-\infty}^{\infty} f(t)\delta(t) = f(0),$$

Where $f(t)$ is an arbitrary function. Suppose that $f(t)$ = 1, t∈ (−∞, ∞). Then

$$\int_{-\infty}^{\infty} \delta(t) = 1$$

For special reasons, $\delta(t)$can be defined as a function that is infinite at t=0 and zero elsewhere. This is the way that $\delta(t)$is implemented from the MATLAB programmers. The mathematical expression is:

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

An alternative definition for the Dirac function that is usually applicable when dealing with discrete-time signal is given now. In this case, we refer to $\delta(t)$ as the $Delta$ or the Kronecker function. The mathematical definition of delta function is

$$\delta(t) = \begin{cases} 1, & t = 0 \\ 0, & t \neq 0 \end{cases}$$

**Basic Discrete Time Signals**

Now we will discuss the discrete time signals. Discrete time signals are the sequences. A sequence

$x[n]$. $n$∈ (−∞ ∞) consists of infinite (real or complex) elements or samples. DT signals are treated in the same way as the continuous time signals. However, there are two main differences.

1. The definition of the time. For the discrete time signals, time is defined by the step1.
2. The graph of the discrete time signals is obtained by the “stem” command.
   Stem is similar to plot but is suitable for discrete time signals.

**Unit Impulse Sequence**

The unit impulse sequence is the counter part of the dirac delta function when dealing with discrete time signals. It is also known as Kronecker delta. The mathematical expression of the $\delta[n]$ is:

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

In general, the unit impulse sequence is given by:

$$\delta[n - n_o] = \begin{cases} 1, & n = n_o \\ 0, & n \neq n_o \end{cases}$$

**Unit Step Sequence**

The unit step sequence is the counter part of the unit step function when dealing with discrete time signals. The mathematical expression is

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

In general case, the unit step sequence is given by

$$u[n - n_o] = \begin{cases} 1, & n \geq n_o \\ 0, & n < n_o \end{cases}$$

The command of the Heaviside is not applicable to the unit step sequence.

**Real Exponential Sequence**

The mathematical expression of a real valued exponential sequence is $x[n] = a^n$, $a \in R$, the sequence $x[n]$ is ascending if |a|>1 and descending if $|a| < 1$.

**Sinusoidal Sequence**

The sinusoidal sequence is defined by the expression of the form;

$$x[n]=A\cos(\omega n+\phi) \qquad or \qquad x[n]=A\sin(\omega n+ \phi)$$

Where

$A = Apmlitude$

$\omega = angular\ frequency$

$\phi = phase$

## Lab Tasks (Psychomotor)

1. Plot unit step function u(t) using “ones” and “zeros” commands. Use the time interval $-10 \leq t \leq 10$.
2. Plot unit step function u(t) using ”heaviside” command. Use time interval $-5 \leq t \leq 5$.
3. Plot unit impulse function δ(t) using “ones” and “zeros” commands. Use time interval $-10 \leq t \leq 10$
4. Plot unit impulse function $\delta(t)$ using ”dirac” command. Use time interval $-1 \leq t \leq 1$.
5. Plot the following signals in the time interval $-5 \leq t \leq 5$.
    1. $\delta(t) + 2\,\delta(t)$
    2. $u(t) + 2u(t)$
    3. $\delta(t + 1) + 2\,\delta(t - 1)$

4. $u(t + 1) + u(t - 1)+1$
5. $u[n] + 1$
6. $u[n-1]+ 1$

6. Plot the continuous time signal $x(t) = \cos(\pi t)$ and discrete time signal $x[n] = \cos(\pi n)$ in same figure using time interval
   **– (Last 2 digits of Reg. #) ≤ t ≤ (Last 2 digits of Reg. #).**
7. Plot the digital signal $x[n] = \cos(\pi n)$ for
   **–(Last 2 digits of Reg. #) ≤ n≤ (Last 2 digits of Reg. #).**

## Lab Tasks (Cognitive)

| Q. No. | Cognitive Assessment Question | Marks |
|---|---|---|
| **1** | For x(t)=u(t), determine x(−1), x(0), and x(2) using the definition of the unit-step signal. | 2 |
| **2** | For x(t)=r(t)=tu(t), determine x(−2), x(0), and x(3). | 2 |
| **3** | A sinusoidal signal is x(t)=3sin(4πt). Determine its amplitude, frequency, and fundamental period. | 2 |
| **4** | An exponential signal is x(t)=e^(−2t)u(t). Determine whether its magnitude increases or decreases as t increases for t≥0, and justify from the expression. | 2 |
| **5** | An impulse signal δ(t) is shifted by 3 units. State the location of the impulse in δ(t−3) and explain the effect of the shift. | 2 |

# Lab Exercise and Summary

**Summary should cover Introduction, Procedure, Data Analysis and Evaluation.**

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**Student's Signature: _____ Date: _____**

## LABORATORY SKILLS ASSESSMENT (Cognitive)

| | |
|---|---|
| **Obtained Marks** | /10 |

**Instructor's Signature: _____ Date: _____**

## LABORATORY SKILLS ASSESSMENT (Psychomotor)

### Psychomotor Activity 1 — Experimental Setup

| S. No | Criteria | Performance | Description | Marks |
|---|---|---|---|---|
| **1** | **Basic Signal Environment Setup (4)** | Level 4 | Prepares MATLAB and the required continuous/discrete signal plotting environment correctly and independently. | 4 |
| | | Level 3 | Correctly prepares required environment with minor errors or assistance. | 3 |
| | | Level 2 | Partially prepares the required environment and requires considerable assistance. | 2 |
| | | Level 1 | Shows limited ability to prepare required environment and requires substantial assistance. | 1 |
| **2** | **Signal Definition Setup (4)** | Level 4 | Creates the script and correctly defines the required unit-step, ramp, impulse, exponential and/or sinusoidal signals | 4 |
| | | Level 3 | Completes the signal definition setup with minor errors or assistance. | 3 |
| | | Level 2 | Partially completes the signal definition setup and requires considerable assistance. | 2 |
| | | Level 1 | signal definition setup is largely incomplete and requires substantial assistance. | 1 |
| **3** | **Time & Signal Parameters (2)** | Level 2 | Correctly defines time/sample indices, amplitude, frequency and other specified parameters. | 2 |
| | | Level 1 | Defines time and signal parameters with minor errors or assistance. | 1 |
| **Total Obtained** | | | | /10 |

## If a student is absent:

| Criteria | Description | Marks |
|---|---|---|
| **Absent** | Student is absent from the laboratory activity. | **0** |

## Psychomotor Activity 2 — Implementation + Results

| S. No | Criteria | Performance | Description | Marks |
|---|---|---|---|---|
| 1 | **Basic Signal Implementation & Safe Working Practice (4)** | Level 4 | Correctly implements the assigned basic signal expressions in MATLAB independently and follows proper laboratory practices. | **4** |
| | | Level 3 | Implements the assigned work with minor errors or assistance and generally follows proper laboratory practices. | **3** |
| | | Level 2 | Partially implements the assigned work and requires considerable assistance or repeated guidance. | **2** |
| | | Level 1 | Implementation is largely incomplete, requires substantial assistance, or shows poor adherence to proper laboratory practices. | **1** |
| 2 | **Execution & Plotting (2)** | Level 2 | Correctly executes the script and generates the required plots using suitable plotting commands. | **2** |
| | | Level 1 | Performs basic execution and plotting with minor errors or assistance. | **1** |
| 3 | **Signal Plots & Verification (4)** | Level 4 | Produces correct waveforms/plots and verifies the expected behavior of each assigned signal appropriately. | **4** |
| | | Level 3 | Produces correct waveforms and verifies the expected behavior of each assigned signal with minor errors/ assistance. | **3** |
| | | Level 2 | Produces partially correct results/plots with noticeable errors or omissions and verifies the expected behavior of each assigned signal with considerable assistance. | **2** |
| | | Level 1 | Results/plots are largely incorrect or incomplete and verification requires substantial assistance. | **1** |
| | **Total Obtained** | | | /10 |

## If a student is absent:

| Criteria | Description | Marks |
|---|---|---|
| **Absent** | Student is absent from the laboratory activity. | **0** |

**Instructor's Signature:** _____ **Date:** _____

## LABORATORY SKILLS ASSESSMENT (Affective)

### Affective Activity — Lab Report + Viva Voce

| S. No | Criteria | Performance | Description | Marks |
|---|---|---|---|---|
| 1 | **Lab Report Completeness & Organization (4)** | Level 4 | Report is complete, well-organized, properly presented, and demonstrates responsible completion of the assigned Signals and Systems laboratory work. | **4** |
| | | Level 3 | Report is complete with minor omissions or organizational issues and demonstrates satisfactory responsibility for the assigned work. | **3** |
| | | Level 2 | Report is partially complete with several omissions and demonstrates limited responsibility for the assigned work. | **2** |
| | | Level 1 | Report has major omissions or poor organization and demonstrates minimal responsibility for the assigned work. | **1** |
| 2 | **Code, Results & Conclusion (2)** | Level 2 | MATLAB code, results/plots, and conclusion are correctly presented and discussed, demonstrating ownership of the assigned work. | **2** |
| | | Level 1 | MATLAB code, results/plots, or conclusion are presented with minor errors or omissions. | **1** |
| 3 | **Viva Voce (4)** | Level 4 | Clearly explains the assigned MATLAB code, signal/system concepts, analysis, results, and plots, demonstrating individual responsibility, participation, and effective communication. | **4** |
| | | Level 3 | Explains most of the assigned work and results correctly, with minor difficulty, and demonstrates good individual participation. | **3** |
| | | Level 2 | Explains basic aspects of the assigned work with some prompting and demonstrates basic participation. | **2** |
| | | Level 1 | Demonstrates limited understanding or involvement and requires substantial prompting to explain the assigned work. | **1** |
| | **Total Obtained** | | | /10 |

**The student has not submitted the report and has not appeared in the Viva Voce.**

| Criteria | Description | Marks |
|---|---|---|
| **Lab Report and Results Not Submitted** | Student has not submitted the report and results file. | **0** |
| **Absent in Viva Voce** | Student is absent from the viva voce. | **0** |

**Instructor's Signature:** _____ **Date:** _____