Experiment No. 5

Convolution of Continuous Time Signals

Objectives

This experiment is designed to familiarize the students with the basic concept of basic operations on systems with respect to continuous time signals. The main feature of the experiment includes:

1. Convolution of continuous time signals

Equipment

1. PC
2. Installed MATLAB

Introduction to Convolution

Convolution is a mathematical tool to combining two signals to form a third signal. Therefore, in signals and systems, the convolution is very important because it relates the input signal and the impulse response of the system to produce the output signal from the system. In other words, the convolution is used to express the input and output relationship of an LTI system.

Continuous-Time Convolution

The impulse response of a linear time-invariant system completely specifies the system. More specifically, if the impulse response of a system is known one can compute the system output for any input signal. We now present on of most important topics in signals and systems theory.

The response (or output) of a system to any input signal is computed by the convolution of the input signal with the impulse response of the system.

Suppose that $y(t)$ denotes the output of the system, $x(t)$ is the input signal, and $h(t)$ is the impulse response of the system. The mathematical expression of the convolution relationship is:

$$y(t) = x(t) * h(t)$$

Where, the symbol * denotes convolution, and it must not be confused with the multiplication symbol. The calculation of the convolution between two signals involves the computation of an integral. The complete form of is

$$y(t) = x(t) * h(t) = \int_{-\infty}^{\infty} x(\tau)h(t-\tau)d\tau$$

By alternation variables τ and t, becomes

$$y(t) = x(t) * h(t) = \int_{-\infty}^{\infty} x(t-\tau)h(\tau)d\tau$$

The Command *conv*

The computational process followed in the previous lab is the analytical way of deriving the convolution between two signals. In MATLAB, the command *conv* allows the direct computation of the convolution between two signals.

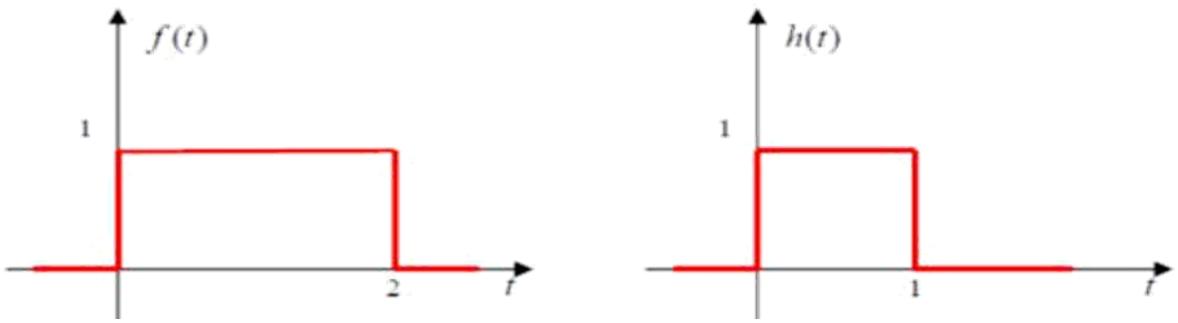
Activity-1: A system is described by the impulse response $h(t) = e^{-2t}u(t),\ -5 \le t \le 5$. Plot the response of the system to the input signal $x(t) = u(t)$.

```
t=-5:0.01:5;
x=heaviside(t);
h=exp(-2*t).*x;
y=conv(x,h);
subplot(311);plot(t,x);ylim([-0.1 1.1]);title('x(t) = u(t)');ylabel('Amplitude');
subplot(312);plot(t,h);ylim([-0.1 1.1]);title('h(t) = e^-^2^tu(t)');ylabel('Amplitude');
subplot(313);plot(y);title('y(t) = x(t) * h(t)');ylim([-10
60]);xlabel('time(s)');ylabel('Amplitude');
```

Activity-2: A system is described by the impulse response $h(t) = e^{-at}u(t),\ -5 \le t \le 5$. Plot the response of the system to the input signal $x(t) = e^{at}u(-t)$.

```
clear
close all
t=-5:0.01:5;
a=-5;
x=exp(a*t).*heaviside(-t);
h=exp(-a*t).*heaviside(t);
y=conv(x,h);
subplot(311);plot(t,x);title('x(t) = e^a^tu(-t)');ylabel('Amplitude');
subplot(312);plot(t,h);title('h(t) = e^-^a^tu(-t)');ylabel('Amplitude');
subplot(313);plot(y);title('y(t) = x(t) * h(t)');xlabel('time(s)');ylabel('Amplitude');
```

Activity-3: Plot the result of continuous convolution of the two functions given below.



```
clear

close all

t=-5:0.0001:5;

f=heaviside(t)-heaviside(t-2);

h=heaviside(t)-heaviside(t-1);

y=conv(f,h);

subplot(311);plot(t,f);ylim([-0.1 1.1]);title('f(t)=u(t)-u(t-
2)');ylabel('Amplitude');

subplot(312);plot(t,h);ylim([-0.1 1.1]);title('h(t)=u(t)-u(t-
1)');ylabel('Amplitude');

subplot(313);plot(y);title('y(t) = f(t) *
h(t)');xlabel('time(s)');ylabel('Amplitude');
```

Lab Tasks (Psychomotor)

1. A system is described by the impulse response $\boldsymbol{h(t) = e^{-2t}u(t-1)}$. Plot the response of the system to the input signal $\boldsymbol{x(t) = u(t) - u(t-2)}$.

2. A linear time-invariant system is described by the impulse response,

$$\boldsymbol{h(t) = \begin{Bmatrix} 1-t & 0 \le t \le 1 \\ 0 & elswhere \end{Bmatrix}}$$

Plot the response of the system to the input signal,

$$\boldsymbol{x(t) = \begin{Bmatrix} 1, & 0 \le t \le 2 \\ 0 & elswhere \end{Bmatrix}}$$

3. A linear time-invariant system is described by the impulse response,

$$\boldsymbol{h(t) = e^{-t}u(t)}$$

Plot the response of the system to the input signal,

$$\boldsymbol{x(t) = \begin{Bmatrix} 0.6, & -1 \le t \le 0.5 \\ 0.3, & 0.5 < t \le 3 \\ 0, & t < -1 \; and \; t > 3 \end{Bmatrix}}$$

Lab Tasks (Cognitive)

Q. No.	Cognitive Assessment Question	Marks
1	For x(t)=u(t)−u(t−2) and h(t)=e^(−2t)u(t−1), determine the time interval over which the convolution integral can have a non-zero contribution.	2
2	For the same x(t) and h(t), identify the overlap condition between x(τ) and h(t−τ) that must be satisfied for y(t) to be non-zero.	2
3	For h(t)=1−t for $0 \leq t \leq 1$ and x(t)=1 for $0 \leq t \leq 2$, determine the possible time support of y(t)=x(t)*h(t).	2
4	For h(t)=e^(−t)u(t) and the piecewise x(t) specified in the manual, identify the earliest time at which the output can become non-zero.	2
5	Explain, using the convolution concept, why the output of an LTI system depends on both the input signal and impulse response.	2

Lab Exercise and Summary

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

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	MATLAB & CT Signal Setup (4)	Level 4	Correctly prepares MATLAB and defines the required continuous-time input x(t), impulse response h(t) and time vector.	4
		Level 3	Correctly prepares MATLAB 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 MATLAB and requires substantial assistance.	1
2	Convolution File Setup (4)	Level 4	Correctly organizes the script to generate x(t), h(t) and the continuous-time convolution response.	4
		Level 3	Organizes the script setup with minor errors or assistance.	3
		Level 2	Partially organizes the script setup with considerable assistance.	2
		Level 1	Organizes of the script setup is largely incomplete and requires substantial assistance.	1
3	Time & Signal Parameters (2)	Level 2	Correctly defines specified time intervals, signal expressions and sampling interval.	2
		Level 1	Defines specified time intervals, signal expressions and sampling interval with 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	CT Convolution Implementation & Safe Working Practice (4)	Level 4	Correctly implements the assigned continuous-time convolution procedure 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 & Verification (2)	Level 2	Correctly executes the convolution calculation and checks the generated response.	2
		Level 1	Executes the convolution calculation and checks the generated response with minor errors or assistance.	1
3	Convolution Results & Analysis (4)	Level 4	Produces correct input, impulse-response and output plots and verifies the system response.	4
		Level 3	Produces mostly correct input, impulse-response and output plots and verifies the system response with minor errors or omissions.	3
		Level 2	Produces partially correct input, impulse-response and output plots and verifies the system response with noticeable errors or omissions.	2
		Level 1	Produces largely incomplete correct input, impulse-response and output plots and verifies the system response with 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:** _____