GEORGIA INSTITUTE OF TECHNOLOGY
SCHOOL of ELECTRICAL and COMPUTER ENGINEERING

ECE 2025 Spring 2011
Lab #11: GUIs for Continuous-Time Signals & Systems

Date: 13–19 April 2011

This lab is in-Lab only. It will be graded out of 50 points.

You should read the Pre-Lab section of the lab and do all the exercises in the Pre-Lab section before your assigned lab time.

Verification: The Warm-up section of each lab must be completed **during your assigned Lab time** and the steps marked *Instructor Verification* must also be signed off **during the lab time**. When you have completed a step that requires verification, simply raise your hand and demonstrate the step to the TA or instructor. After completing the warm-up section, turn in the verification sheet to your TA *before leaving the lab*.

Forgeries and plagiarism are a violation of the honor code and will be referred to the Dean of Students for disciplinary action. You are allowed to discuss lab exercises with other students, but you cannot give or receive any written material or electronic files. In addition, you are not allowed to use or copy material from old lab reports from previous semesters. Your submitted work must be your own original work.

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1 Introduction

This lab concentrates on the use of one MATLAB GUI for continuous-time signals:

1. **`cconvdemo`:** GUI for continuous-time convolution.

$$y(t) = x(t) * h(t) = \int_{-\infty}^{\infty} x(\tau)h(t-\tau)d\tau = h(t) * x(t) = \int_{-\infty}^{\infty} h(\tau)x(t-\tau)d\tau \qquad (1)$$

2 Pre-Lab: Run the GUIs

Several GUIs have been developed to exhibit the interesting features continuous-time signals and systems. The first objective of this lab is to demonstrate usage of one of these GUIs.

2.1 Continuous-Time Convolution Demo

In this demo, you can select an input signal $x(t)$, as well as the impulse response of an **ANALOG** filter $h(t)$. Then the demo shows the "flipping and sliding" used when a convolution integral is performed. You can choose which signal will be flipped by selecting either $\boxed{\text{Flip } x(t)}$ or $\boxed{\text{Flip } h(t)}$. Figure 1 shows the interface for the `cconvdemo` GUI.
In the Pre-Lab, you should perform the following steps with the `cconvdemo` GUI.

(a) Set the input to a 4-second pulse $x(t) = u(t) - u(t-4)$. Check the $\boxed{\text{Flip } x(t)}$ option.

(b) Set the filter's impulse response to a shifted impulse, i.e., $h(t) = \delta(t-3)$.

(c) Use the GUI to produce the output signal. Use the *sliding hand tool* to grab the time marker and move it to produce the flip-and-slide effect of convolution.

(d) Set the input to a different shifted impulse, i.e., $x(t) = \delta(t-2)$. Use the GUI to produce the output signal. Notice that when flipping and sliding that there is only one time where the signals overlap.

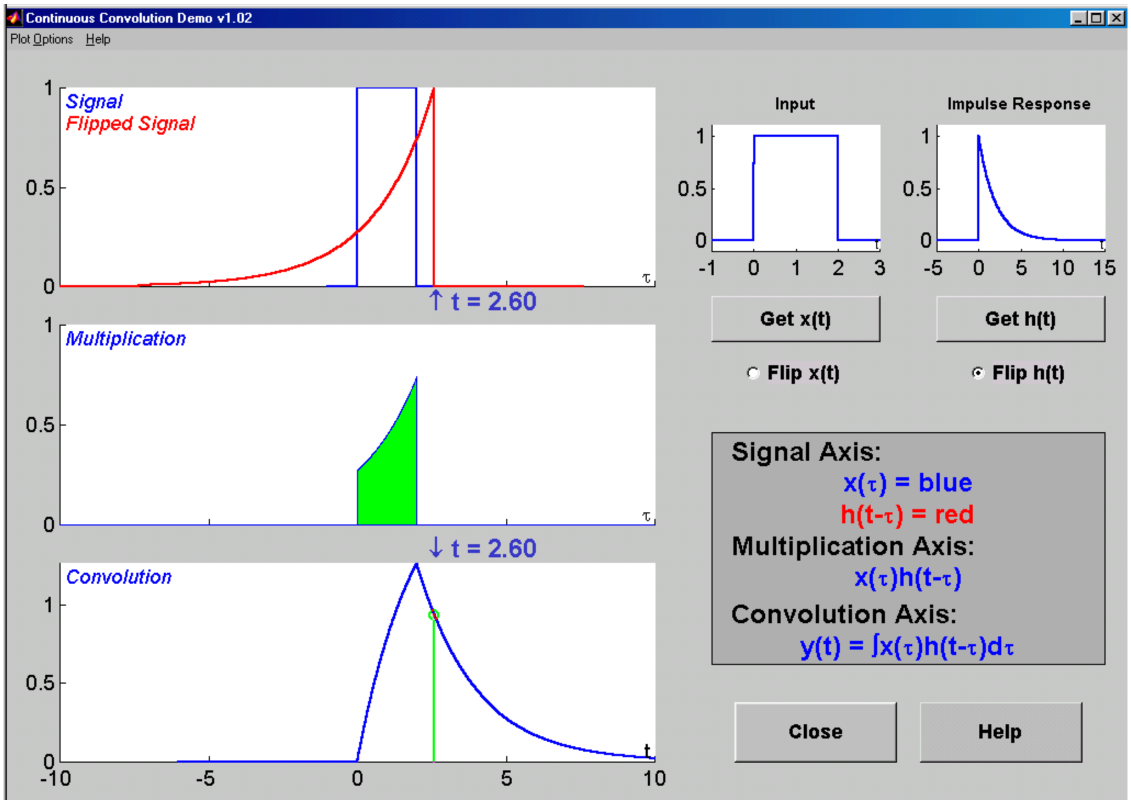

Figure 1: Interface for the continuous-time convolution GUI **cconvdemo**.

(e) Compare the outputs from parts (c) and (d). Use properties of the impulse signal to explain the different outputs.

2.1.1 Convolving Rectangles

Two more simple cases to do with the `cconvdemo` GUI.

(a) Set the input to a 4-second pulse $x(t) = u(t) - u(t-4)$.

(b) Set the filter's impulse response to a 2-second pulse with amplitude $\frac{1}{2}$, i.e., $h(t) = \frac{1}{2}\{u(t) - u(t-2)\}$.

(c) Use the GUI to produce the output signal. Use the *sliding hand tool* to grab the time marker and move it to produce the flip-and-slide effect of convolution.

(d) Set the filter's impulse response to a 4-second pulse with amplitude $\frac{1}{4}$, i.e., $h(t) = \frac{1}{4}\{u(t) - u(t-4)\}$. Use the GUI to produce the output signal; then describe its shape.

(e) Compare the outputs from parts (c) and (d). Notice the different shapes (triangle or trapezoid), the different maximum values, and the different durations of the output signals.
If the duration of $x(t)$ is T_x and the duration of $h(t)$ is T_h, what will the duration of $y(t)$ be?

3 Warm-up: Analyze LTI Systems with the GUIs

The objective of the warm-up in this lab is to use the GUIs to study how systems process different kinds of signals. Write down your observations on the *Verification Sheet.*

3.1 Convolving Continuous-Time Signals

In the `cconvdemo` GUI, you can select an input signal $x(t)$, as well as the impulse response of an ***analog*** filter $h(t)$. Then the demo shows the "flipping and sliding" used when a convolution integral is performed. Figure 1 shows the interface for the `cconvdemo` GUI.

3.1.1 Convolving Rectangles

In the Warm-up, you should perform the following steps with the `cconvdemo` GUI.

(a) Set the input to a 4-second pulse with amplitude 2: $x(t) = 2u(t-1) - 2u(t-5)$.

(b) Set the filter's impulse response to a 2-second pulse with amplitude $\frac{1}{2}$, i.e., $h(t) = \frac{1}{2}\{u(t) - u(t-2)\}$.

(c) Use the GUI to produce the output signal. Flip the impulse response signal $h(t)$. Use the *sliding hand tool* to grab the time marker and move it to produce the flip-and-slide animation of convolution.

(d) The top panel is a plot of $x(\tau)$, overlayed with the "flipped" impulse response $h(t-\tau)$ used to produce the "flip and slide" effect of convolution. The middle panel shows the integrand which is the product of $x(\tau)$ and $h(t-\tau)$. The green-shaded area is where the integral calculates area. As you slide the flipped signal in the top panel, the horizontal length of the green region changes which indicates that the limits of integration are changing. The top two plots are functions of τ, while the bottom plot of $y(t)$ is a function of t. Observe that the output $y(t)$ is composed of **five distinct regions:** no overlap (on the left side), partial overlap (on the left), complete overlap, partial overlap (on the right), and no overlap (on the right). If you substitute $x(t)$ and $h(t)$ from from parts (a) and (b) into Eq. (1), you can show that the output is given by the piecewise equation

$$y(t) = \begin{cases} 0 & t < T_1 & \text{Region 1} \\ \displaystyle\int_{L_1}^{L_2} K_1 \, d\tau & T_1 \le t < T_2 & \text{Region 2} \\ \displaystyle\int_{L_3}^{L_4} K_1 \, d\tau & T_2 \le t < T_3 & \text{Region 3} \\ \displaystyle\int_{L_5}^{L_6} K_1 \, d\tau & T_3 \le t < T_4 & \text{Region 4} \\ 0 & T_4 \le t < \infty & \text{Region 5} \end{cases} \tag{2}$$

Use the GUI to observe that $y(t)$ does indeed have five distinct regions, and use it to determine the values for T_1, T_2, T_3, and T_4. Then determine the limits of integration for each integral above (from the green region in the middle panel). Make sure that you are flipping and sliding $h(t)$.
Note: the limits of integration might depend on the variable t.

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(e) Set the filter's impulse response to a 4-second pulse with amplitude $\frac{1}{4}$, i.e., $h(t) = \frac{1}{4}\{u(t) - u(t-4)\}$. Use the GUI to produce the output signal; then describe its shape.

(f) Set the filter's impulse response to a shifted impulse, i.e., $h(t) = \delta(t-2)$. Use the GUI to produce the output signal; then describe its shape.

(g) Compare the outputs from parts (c), (e) and (f). Notice the different shapes (triangle, rectangle or trapezoid), the different maximum values, and the different durations of the output signals. Be prepared to explain these differences.
In general, if the duration of $x(t)$ is T_x and the duration of $h(t)$ is T_h, what is the formula for the duration of $y(t)$?

Instructor Verification (separate page)

3.1.2 Convolving an Exponential with a Pulse

In the warm-up, you should perform the following steps with the `cconvdemo` GUI.

(a) Set the filter's impulse response to a rectangular pulse: $h(t) = \frac{1}{2}\{u(t) - u(t-2)\}$.

(b) Set the input to a one-sided exponential: $x(t) = e^{-0.3t}u(t)$. Strictly speaking you cannot make an infinitely long signal in `cconvdemo`, but if you make the length greater than 29, you will have a very long finite-duration signal which is long enough that you will not see the end within the GUI display.

(c) Use the GUI to produce a plot of the output signal. Use the *sliding hand tool* to grab the time marker and move it to produce the flip-and-slide effect of convolution.
Note: if you move the hand tool past the end of the plot, the plot will automatically scroll in that direction.

(d) The top panel is a plot of $x(\tau)$, overlayed with the "flipped" impulse response $h(t-\tau)$ used to produce the "flip and slide" effect of convolution. The middle panel shows the integrand which is the product of $x(\tau)$ and $h(t-\tau)$. The green-shaded area is where the integral calculates area. As you slide the flipped signal in the top panel, the horizontal length of the green region changes which indicates that the limits of integration are changing. The top two plots are functions of τ, while the bottom plot of $y(t)$ is a function of t. Observe that the output $y(t)$ is composed of 3 distinct regions: no overlap (on the left side), partial overlap (on the left), and complete overlap. If you substitute $x(t)$ and $h(t)$ from from parts (a) and (b) into Eq. (1), you can show that the output is given by the piecewise equation

$$y(t) = \begin{cases} 0 & t < T_1 & \text{Region 1} \\ \displaystyle\int_{L_1}^{L_2} \tfrac{1}{2}e^{-0.3\tau}d\tau & T_1 \le t < T_2 & \text{Region 2} \\ \displaystyle\int_{L_3}^{L_4} \tfrac{1}{2}e^{-0.3\tau}d\tau & T_2 \le t < \infty & \text{Region 3} \end{cases} \tag{3}$$

Use the GUI to observe that $y(t)$ does indeed have three distinct regions, and use it to find T_1 and T_2. Then determine the limits of integration for each integral above. Make sure that you are flipping and sliding $h(t)$.
Also, notice that the limits of integration might depend on the variable t.

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(e) Usually the convolution integral must be evaluated in 5 different regions: no overlap (on the left side), partial overlap (on the left side), complete overlap, partial overlap (on the right side), and no overlap (on the right side). In this case, there are only 3 regions. Why?

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INSTRUCTOR VERIFICATION PAGE

For each verification, be prepared to explain your answer and respond to other related questions that the lab TA's or professors might ask. Turn this page in at the end of your lab period.

Name: ______________________________ Date of Lab: __________

⟹ Completed Peer Evaluation?
Uploaded ZIP file with .m and .doc files?

Lab #10: Demonstrate the Cochlear Implant Filter Bank system.

Verified:____________________ Date/Time:__________

Part 3.1.1: Demonstrate that you can run the continuous-time convolution demo. Explain how to find the separate regions for this convolution integral. Use the plots of $x(\tau)$ and $h(t-\tau)$ together with the corresponding plot of $y(t)$ to complete the following table with the correct values for the integral limits in Eq. (2).

$T_0 = -\infty$	$T_1 =$			Region 1
$T_1 =$	$T_2 =$	$L_1 =$	$L_2 =$	Region 2
$T_2 =$	$T_3 =$	$L_3 =$	$L_4 =$	Region 3
$T_3 =$	$T_4 =$	$L_5 =$	$L_6 =$	Region 4
$T_4 =$	$T_5 = \infty$			Region 5

Explain the above answers to your TA.

Verified:____________________ Date/Time:__________

Part 3.1.1(e,f,g): Explain the different convolution output shapes to your TA.

Verified:____________________ Date/Time:__________

Part 3.1.2: Explain how to find the separate regions for this convolution integral with an exponential. Use the plots of $x(\tau)$ and $h(t-\tau)$ together with the corresponding plot of $y(t)$ to complete the following table with the correct values for the integral limits in Eq. (3).

	$T_0 = 0$			Region 1
$T_1 = 0$	$T_2 =$	$L_1 =$	$L_2 =$	Region 2
$T_2 =$	$T_3 = \infty$	$L_3 =$	$L_4 =$	Region 3

Note that the area under the curve in the middle plot is shaded green. When you set the time indicator to $t = 5$, how is the shaded area related to $y(5)$? How does the shaded area tell you the limits of integration? Explain the above answers to your TA.

Verified:____________________ Date/Time:__________