

ECE 2025 Spring 2001
Lab #9: Two GUIs

Date: Week of 19-Mar-01

This is *the official* Lab #9 description.

This lab must be completed in Lab and the answer sheet at the end of this write-up must be completed and turned in to the Lab TA at the end of your lab time.

1 Introduction

This lab concentrates on the use of two MATLAB GUIs: one for continuous-time convolution and one for discrete-time frequency response.

1. **LTIdemo:** GUI for frequency response of discrete-time filter. An input sinusoid is transformed to an output sinusoid.
2. **cconvdemo:** GUI for continuous-time convolution.

Each one of these demos illustrates an important point about the behavior of a linear, time-invariant (LTI) system. They also provide a convenient way to visualize the sinusoidal response of LTI systems. For discrete-time systems, `LTIdemo` illustrates the use of the frequency response in the case of an infinitely long sinusoid that extends over the range $-\infty \leq n < \infty$. The `cconvdemo` GUI illustrates continuous-time convolution of finite-duration signals. By choosing input signals of very long duration, it is possible to illustrate what happens when a suddenly applied sinusoid is the input; i.e., an sinusoidal input that is zero for $t < 0$. We will see that in this case, the filters output will exhibit a start-up *transient* at the beginning of the output before settling into a *steady-state* behavior that is sinusoidal.

Both of these demos can be downloaded from WebCT: Look for “MATLAB GUIs” on the Course Menu.

All of the experiments in this lab are to be done in the laboratory period. Two question/answer pages are included with this assignment. You are to write your answers to the questions directly on these pages and hand them in at the end of the lab period. It would be a good idea to print the two answer sheets immediately and have them beside so that you can fill in the answers as you use the GUIs.

2 Lab Exercises

These GUIs have been introduced during lecture or recitation over the past few weeks. You must download the ZIP files for each and install them. Each one installs as a directory containing a number of files. It is best to run the GUIs from their home directories. When you start the GUI, it will set up the path automatically for you, but the path change will be temporary for that session of MATLAB.

2.1 Sinusoidal Response (LTIdemo)

In this demo, you can select an input signal that is a sinusoid, and see the change created by the frequency response. This demo reinforces the concept that “sinusoid in gives sinusoid out.” Figure 1 shows the interface for the LTI demo.

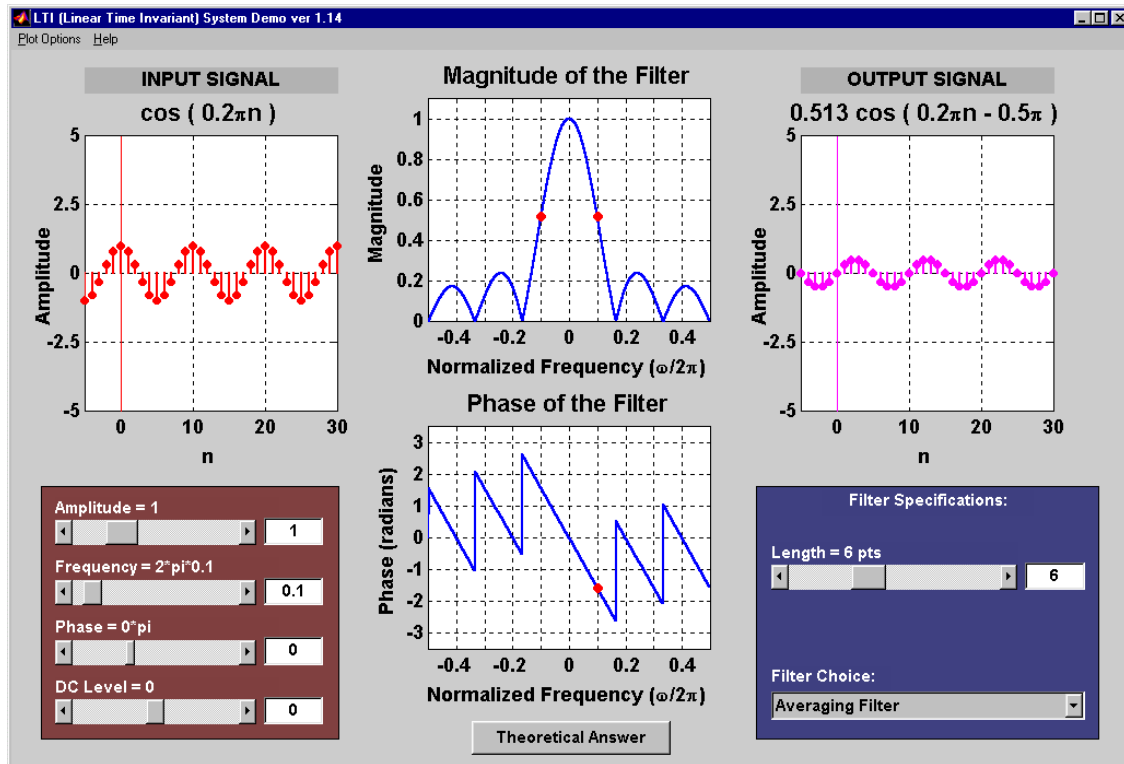


Figure 1: LTI demo interface.

We know that if the input to an FIR LTI discrete-time system is a sinusoid of the form

$$x[n] = A + B \cos(\hat{\omega}_0 n + \phi) \quad -\infty < n < \infty \quad (1)$$

then the corresponding output is

$$y[n] = A\mathcal{H}(0) + B|\mathcal{H}(\hat{\omega}_0)| \cos[\hat{\omega}_0 n + \phi + \mathcal{L}\mathcal{H}(\hat{\omega}_0)] \quad -\infty < n < \infty, \quad (2)$$

where

$$\mathcal{H}(\hat{\omega}) = \sum_{k=0}^M h[k] e^{-j\hat{\omega}k} \quad (3)$$

is the *frequency response* of the FIR LTI system. The LTIdemo GUI illustrates this for a variety of FIR filters.

- (a) Use the LTIDemo GUI to find the output of a five-point moving average filter (select “Averaging Filter” from the menu and set the length to 5). We have shown that the frequency response of this filter is

$$\mathcal{H}(\hat{\omega}) = \frac{\sin(\hat{\omega}5/2)}{5 \sin(\hat{\omega}/2)} e^{-j\hat{\omega}2}. \quad (4)$$

- (i) Set the input to

$$x[n] = 1.0 + \cos(0.1\pi n).$$

(Note that the GUI inputs frequencies as normalized cyclic frequency $\hat{f} = \hat{\omega}/(2\pi)$.) Look at the output and compare its amplitude and phase to the input amplitude and phase. Click the box labeled “Theoretical Answer” and record the result. **Answer Questions**

- (ii) Keeping the DC level and the amplitude of the cosine the same, use the slider to increase the frequency and observe the change in the output. Keep increasing the slider until the frequency is $\hat{\omega} = 1.9\pi$ (or $\hat{f} = .95$). Compare the output in this case to the output at the original frequency of $\hat{\omega} = 0.1\pi$. **Answer Questions**

- (iii) Set the frequency of the sinusoid so that the output consists *only* of the DC component. (There may be more than one answer.) **Answer Questions**

- (b) Set the frequency of the input to $\hat{\omega} = 0.1\pi$ and change the filter to “First Difference”. Observe the output as the frequency is increased. Record your observations. **Answer Questions**

- (c) **Optional:** There are several other filters. Take a look if you have time.

2.2 Continuous-Time Convolution (cconvdemo)

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 shifting” used when a convolution integral is performed. Figure 2 shows the interface for the `cconvdemo` GUI.

Continuous-time convolution is defined by the integral

$$y(t) = \int_{-\infty}^{\infty} x(\tau)h(t - \tau)d\tau = \int_{-\infty}^{\infty} x(\tau)h(t - \tau)d\tau \quad (5)$$

As we have seen, if $x(t)$ is the input to an LTI system with impulse response $h(t)$, then the output of the system is given by the convolution integral in Eq. (5). In this section, we will use the continuous-time convolution GUI, `cconvdemo`, to solve two problems.

- (a) Use the GUI `cconvdemo` to find the output of an analog filter whose impulse response is

$$h(t) = e^{-0.1(t-2)}[u(t-2) - u(t-12)] = \begin{cases} e^{-0.1(t-2)} & 2 < t < 12 \\ 0 & \text{otherwise,} \end{cases} \quad (6)$$

when the input is

$$x(t) = e^{-0.25t}[u(t) - u(t-6)] = \begin{cases} e^{-0.25t} & 0 < t < 6 \\ 0 & \text{otherwise.} \end{cases} \quad (7)$$

- (i) Select the appropriate input signal and impulse response from the menus. Experiment with the “sliding hand tool” to grab the time marker and move the “flipped” impulse response $h(t - \tau)$ around to produce the “flip and slide” effect of convolution. Note that the top two plots are

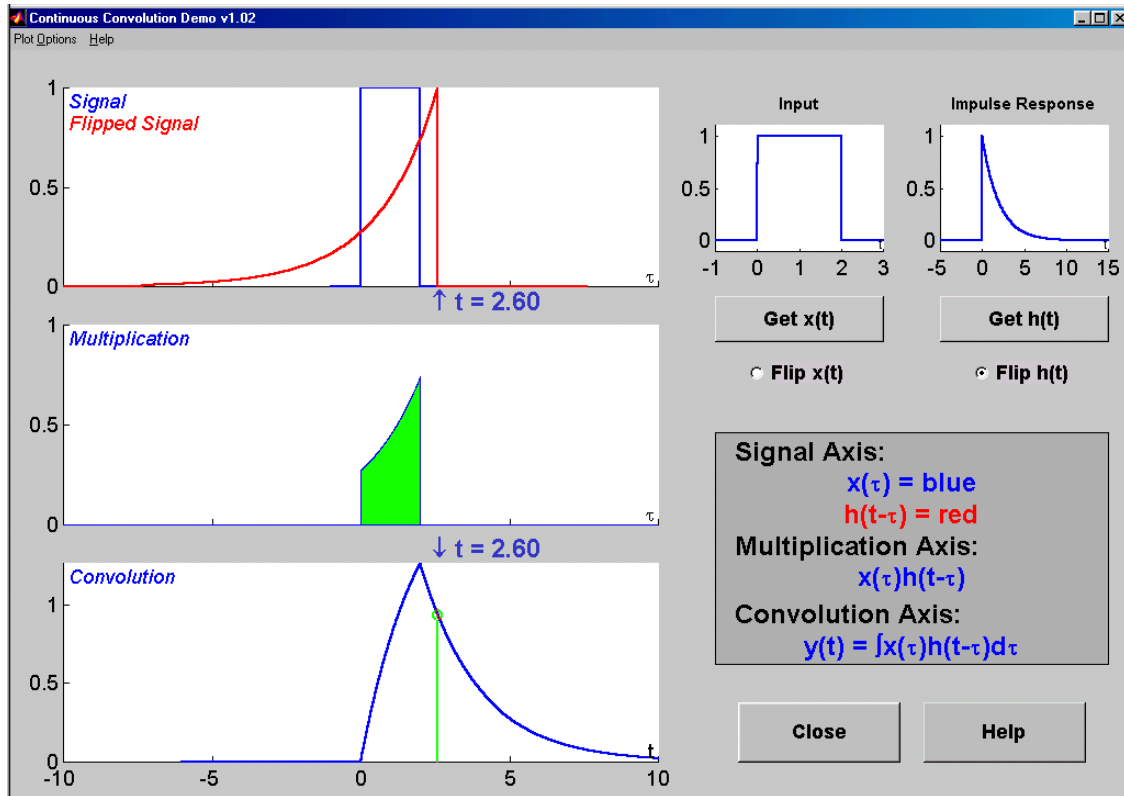


Figure 2: Interface for continuous-time convolution GUI.

functions of τ and the bottom plot of $y(t)$ is a function of t . Observe that the output $y(t)$ is composed of five distinct regions. If you substitute $x(t)$ and $h(t)$ from Eqs. (6) and (7) into Eq. (5), you can show that the output is given by the piecewise equation

$$y(t) = \begin{cases} 0 & t < T_0 \\ \int_{L_1}^{L_2} e^{-0.25\tau} e^{-0.1(t-\tau-2)} d\tau & T_1 \leq t < T_2 \\ \int_{L_3}^{L_4} e^{-0.25\tau} e^{-0.1(t-\tau-2)} d\tau & T_3 \leq t < T_4 \\ \int_{L_5}^{L_6} e^{-0.25\tau} e^{-0.1(t-\tau-2)} d\tau & T_5 \leq t < T_6 \\ 0 & T_7 \leq t \end{cases} \quad (8)$$

Use the GUI to observe that $y(t)$ does indeed have five distinct regions. **Answer Questions**

(ii) The duration of a finite-duration signal is simply the amount of time that the signal is non-zero. What are the durations of $x(t)$ and $h(t)$? Observe that the convolution $y(t)$ of two finite-duration signals also has finite duration. **Answer Questions**

(iii) Observe what happens in the middle plot, which shows $x(\tau)h(t-\tau)$ as a function of τ for the value of t selected. Note in which of the five regions $t = 5$ falls. **Answer Questions**

(iv) Click the button to flip $x(t)$ instead of $h(t)$. Observe what happens to $y(t)$. Answer Questions

(b) Now let the input signal be

$$x(t) = \cos(0.2\pi t)u(t), \quad (9)$$

Note: the GUI requires that $x(t)$ have finite length, but the definition above is infinite (and one-sided). To fake out the GUI, make the length of $x(t)$ equal to 100. Then IGNORE the ending part of the signal, i.e., ignore all output points for $t \geq 50$. The plot of the GUI will only show a small region of about 20 seconds, so it will be easy to ignore the ending part of the signal.

(i) First let the impulse response be

$$h(t) = u(t) - u(t - 5), \quad (10)$$

a square pulse of duration 5. The output will have two regions, which are called the transient region and the steady-state region. The transient part is the time interval just after $t = 0$. The steady-state part is where the output becomes a perfect sinusoid. Determine the beginning and end of the transient region. Answer Questions

(ii) Now let the impulse response be

$$h(t) = u(t) - u(t - 10), \quad (11)$$

a square pulse of duration 10. Observe the transient and steady state portions of the output waveform in this case. Answer Questions

(c) **Optional:** There are lots of other inputs and impulse responses. Check them out if you have time.

Lab #9
ECE-2025 – Spring 2001
ANSWER SHEET

Turn in this sheet at the end of your lab period.

Name: _____ Date of Lab: _____

Sinusoidal Response LTIdemo

(a) Five-point Averager

(i) Write the equation for the output $y[n]$ that was provided by the GUI.

Why is the DC component the same size as the DC component of the input?

Use MATLAB to evaluate the frequency response (magnitude and phase) in Eq. (4) at the frequency $\hat{\omega} = 0.1\pi$ and verify that the answer given above is correct.

(ii) What happens to the amplitude of the cosine component of the output when the frequency increases?

Why do $\hat{\omega} = 0.1\pi$ and $\hat{\omega} = 1.9\pi$ give the same result?

(iii) For what frequency (or frequencies) of the cosine component of the input does the output contain only the DC component?

(b) When you changed to “First Difference”, what happened to the DC component? Why?

Continuous-Time Convolution (cconvdemo)

(a) Convolution of two exponential signals:

- (i) Use the GUI to solve the problem posed. Use the plots of $x(\tau)$ and $h(t - \tau)$ together with the corresponding plot of $y(t)$ to fill in the following table with the correct values for the time region boundaries and integral limits in Eq. (8):

$T_0 =$	
$T_1 =$	$L_1 =$
$T_2 =$	$L_2 =$
$T_3 =$	$L_3 =$
$T_4 =$	$L_4 =$
$T_5 =$	$L_5 =$
$T_6 =$	$L_6 =$
$T_7 =$	

- (ii) Observe that $y(t)$ is zero for $t < T_0$ and for $t \geq T_7$. If T_a and T_b are the starting and ending times of $x(t)$ and T_c and T_d are the starting and ending times of $h(t)$, How are T_0 and T_7 related to the starting and ending times of $x(t)$ and $h(t)$?

- (iii) 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 $y(5)$?

- (iv) What did you observe when you flipped $x(t)$ instead of $h(t)$? What property of convolution does this illustrate?

linearity time-invariance causality associativity commutativity stability

(b) Sinusoidal Input:

- (i) Where does the transient region end and the steady-state region begin?

How is this duration related to the duration of the impulse response?

Describe the steady-state part of the output waveform. What does it resemble?

- (ii) Why is the steady-state part of the output zero in this case? You should be able to see the answer by looking at the upper plot that shows both $x(\tau)$ and $h(t - \tau)$.