دانشگاه صنعتی امیرکبیر
(پلی تکنیک تهران)

Signals and Systems

Assignment 2

Fall 2020

MohammadKhalaji76@gmail.com - JaliliA370@gmail.com
Telegram Channel: @signals_systems_99

Question1

Convolve the following pairs of signals.

(a) $\begin{cases} x_1[n] = (\frac{1}{2})^n u[n] \\ x_2[n] = u[n+3] - u[n-3] \end{cases}$

(b) $\begin{cases} x_1[n] = (\frac{1}{3})^n (u[n] - u[n-7]) \\ x_2[n] = u[n] - u[n-10] \end{cases}$

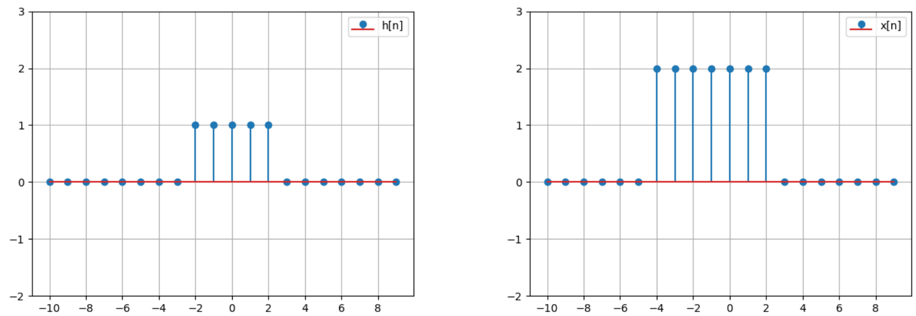
(c) $\begin{cases} x_1(t) = e^{2t} u(t-2) \\ x_2(t) = u(t) - u(t-3) \end{cases}$

(d) $\begin{cases} x_1(t) = e^{2t} u(2-t) \\ x_2(t) = u(t) + u(t-2) \end{cases}$

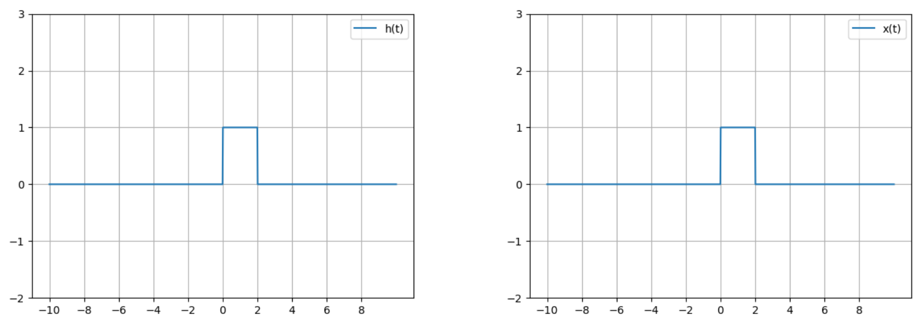
Question2

For each pair of impulse response and input, determine LTI system's output. Sketch the results.

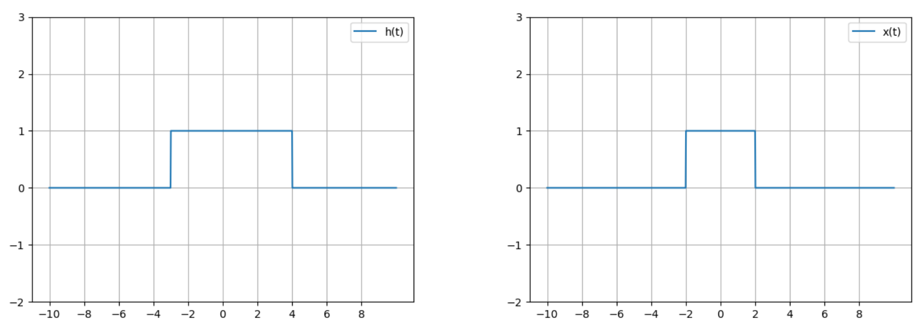
(a)



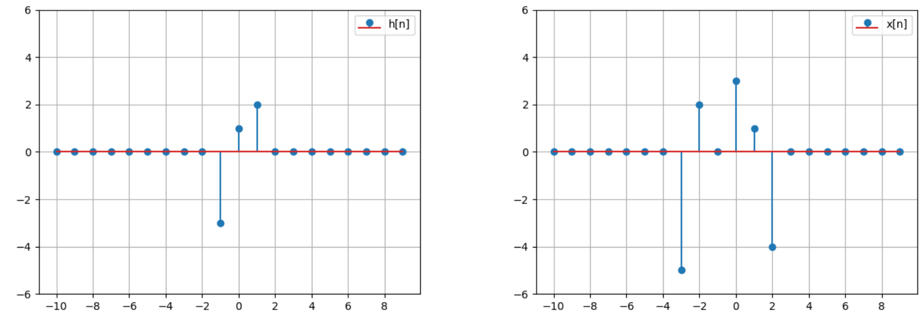
(b)



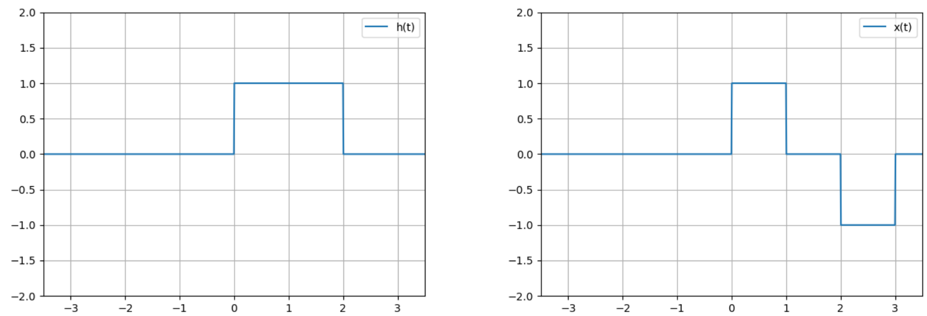
(c)



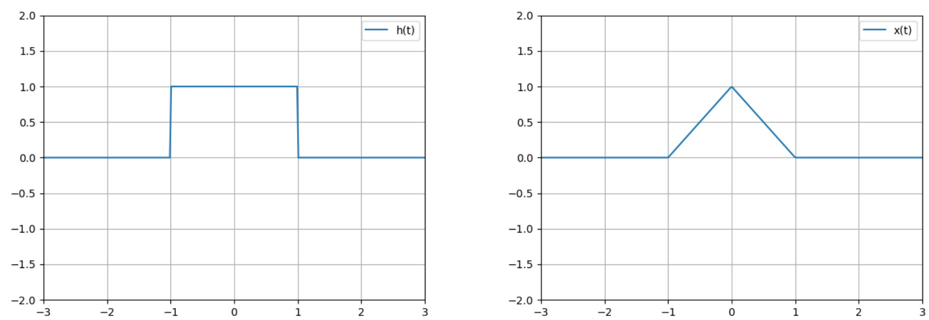
(d)



(e)



(f)



Question3

For each of the following impulse responses, determine whether the corresponding LTI system is memoryless, casual and stable. Justify your answers.

(a) $h(t) = e^{-2|t|}$

(b) $h(t) = sin(t)u(1 - t)$

(c) $h(t) = (t^2 + 1)\delta(t)$

(d) $h[n] = (\frac{1}{2})^n u[n + 1]$

(e) $h[n] = e^n u[-n]$

(f) $h[n] = cos(\frac{\pi}{2} n)u[n + 2] + \delta[n + 2]$

Question4

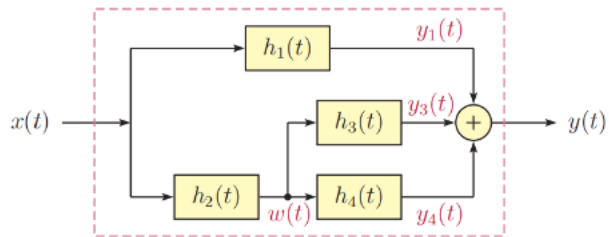
Consider the cascaded interconnection of LTI systems shown below where:

$$h_1(t) = sin(\frac{\pi}{3}t)$$

$$h_2(t) = e^{2t}u(1-t)$$

$$h_3(t) = u(t)$$

$$h_4(t) = \delta(t+1)$$



(a) Determine the impulse response h_{eq} of the equivalent system.

(b) Let the input signal be $x(t) = u(t+1) - u(t-1)$. Determine the signals $w(t)$, $y_1(t)$, $y_3(t)$ and $y_4(t)$.

Question5

For each pair of impulse responses below, determine whether the corresponding systems are inverses of each other.

(a) $h_1[n] = (\frac{1}{5})^n u[n] \quad , \quad h_2[n] = \delta[n] - \frac{1}{5}\delta[n]$

(b) $h_1(t) = e^{-t}u(t) \quad , \quad h_2(t) = \delta(t) + \delta'(t)$

(c) $h_1[n] = u[n] \quad , \quad h_2[n] = \delta[n] - \delta[n-1]$

(d) $h_1(t) = u(t-1) \quad , \quad h_2(t) = e^t$

Question6

Find the step response for systems with the following impulse responses.

(a) $h(t) = \delta(t+1) - \delta(t-1)$

(b) $h[n] = e^n(\frac{1}{4})^n u[n+1]$

(c) $h(t) = 2\delta^2(t)$

(d) $h(t) = te^{-|t|}$

Note: *Step Response* of a system is the system's output given unit step as input.

Programming Assignment 1

Convolve the following pairs of signals and plot the results.

(a) $\begin{cases} x_1(t) = sin(t/2) \\ x_2(t) = cos(t/2) \end{cases}$ x_1 and x_2 within interval $-10 \leq t \leq 10$

(b) $\begin{cases} x_1[n] = (0.73)^n u[n] \\ x_2[n] = u[n] - u[n-3] \end{cases}$ x_1 and x_2 within interval $-5 \leq n \leq 15$

Note: You can set the size of the output of the convolution function by doing the following:

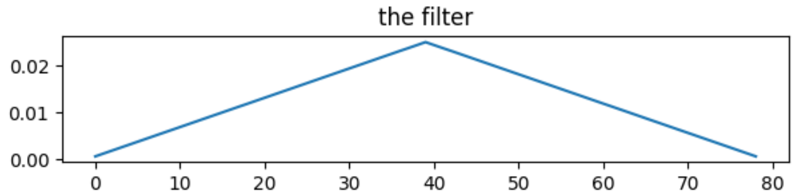
- If you are using *python*, use the *mode* argument of *convolve()*.
- If you are using *Matlab*, use the *shape* argument of *conv()*.

Programming Assignment 2

One of the applications of convolution in signal processing is applying filters. In this assignment we are going to convolve the data of an audio file with a triangular signal, and see how it affects its sound.

(a) Open and read the data of *giggle_mono.wav* audio file provided with this assignment. You can use the *wave* module which is a standard python module. Use *open()* and *readframes()* functions in order to open and read the data of the audio file respectively. Here is the link to *wave*'s documentation.

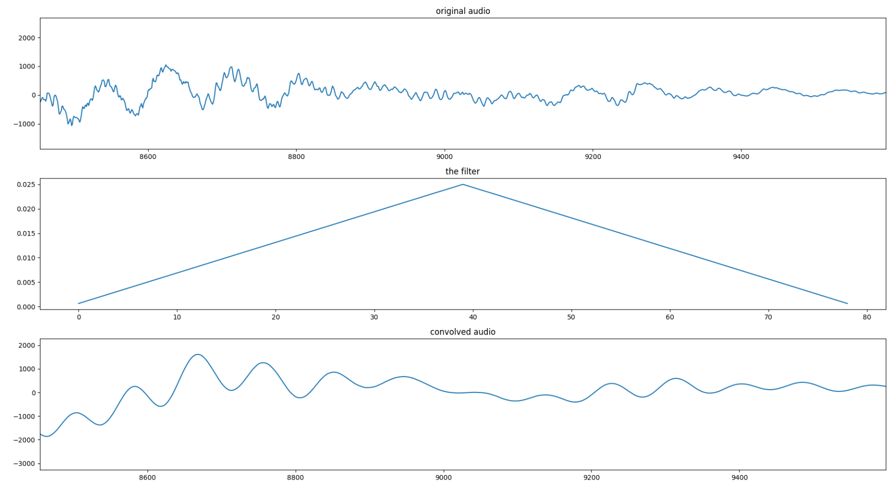
(b) Create and plot a triangular signal similar to the one depicted below:



(c) Convolve the audio data with the filter signal. Note that you might have to scale the result so it has the same loudness as the original signal.

(d) Using the *wave* module again, write the result of the convolution to a new audio file named *result_giggle_mono.wav*. Don't forget to set the parameters of the *Wave_Write* object using *setparams()* function before writing it into the new audio file.

(e) Using your knowledge about convolution and its mathematical definition, explain how convolving the triangular signal with the original audio signal has this *smoothing effect* on it. Plotting the original and the convolved signals might give you some intuition:



Note: Please put the results from parts (b), (d) and (e) as well as your final code together in a separate folder so I can easily find them.
Note: You will have a deeper understanding of how filters, including the triangular filter, work when you learn the Fourier Transform.

Programming Assignment 3 (Bonus)

An important concept in many communications applications is the *correlation* between two signals. Let x(t) and y(t) be two signals; then the *correlation function* is defined as:

$$\phi_{xy}(t) = \int_{-\infty}^{+\infty} x(t+\tau)y(\tau)d\tau$$

As we can see, its definition is quite similar to *convolution*. However, there are some important differences. For example:

- Unlike convolution, correlation does not reverse one of the signals.
- Unlike convolution, correlation is not commutative. Meaning:

$$\phi_{xy}(t) \neq \phi_{yx}(t)$$

In this assignment, we are going to get familiar with correlation through experimentation. You can use any of the following to correlate two signals:

- *numpy*'s *correlate()* function.
- *scipy*'s *correlate()* function.
- *Matlab*'s *corr()* function.

(a) Correlate sin(t) with sin(t) within interval $-100 \leq t \leq 100$ and plot the result. You should see many peaks in the result. In which t values are the positive and negative peaks located? Is there any relationship between the location of peaks and the period of the input signal?

(b) Create and plot signal $f(t) = sinc(t) + sinc(t-2)$ within interval $-10 \leq t \leq 10$. Correlate f(t) and f(t-2); then plot the result. Locate the peak in the correlation result. Does the peak location have any relationship with the time shift between the two input signals?

(c) Create two uniform random signals within interval $-10 \leq t \leq 10$. Correlate these two signals and plot the result. Can you locate any sharp peaks similar to the ones in parts (a) and (b)?

(d) Explain what a peak in correlation of two signals indicates. Can you think of some applications for the correlation operation?

Note: Please put the results from all sections (codes, plots, etc) in a separate folder so I can easily find them.