Signals & System

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1. Introduction to Python
2. Basic Plotting of Signals
   a. Unit Step
   b. Unit Impulse
   c. Ramp
   d. Periodic Sinusoidal Sequences.
   e. Periodic Rectangular Pulse
   f. Asymmetric Sawtooth Waveform
   g. Periodic Gaussian Pulse
   Plot all the sequences.
3. Basic operation of signal
   a. Addition & Subtraction
   b. Multiplication & Division
   c. Time reversal, Scaling, and Shifting
4. Write a program to convolve two discrete-time sequences. Plot all the sequences. Verify the result by analytical calculation.
5. Write a program to find the Laplace Transform and inverse Laplace Transform of a signal and also verify that multiplication in s-domain is equivalent to convolution in t-domain.
6. Convolution of signals in transformed domain and verification of convolution property of Z-transform.
7. Convolution of signals in transformed domain and verification of convolution property of Fourier.
8. Study of LTI system and its stability

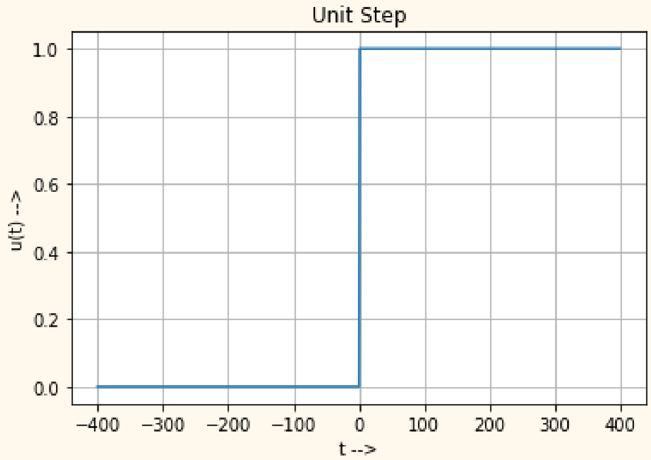
Lab 1. Introduction to Python

1. Basics: Input, Output
2. List: Slicing, Append, Length
3. Range
4. Loops
5. sum(), items(), enumerate(), reversed(), sorted()
6. Dictionary: Dictionaries are used to store data values in key:value pairs
7. Function: To declare a function : def <function name>(parameter list):
8. Numpy package:
   a. Import numpy as np
   b. np.array(), np.sin(), np.cos(), np.exp(), np.arange(), np.sort()
   c. Dimension of array : a.ndim
   d. Shape of array : a.shape -> (2,3)
   e. Reshape an array : a.reshape(4,3)
9. Matplotlib function:
   a. import matplotlib.pyplot as plt
   b. plt.plot(x, y)
   c. plt.xlabel(), ylabel()
   d. plt.title()
   e. plt.xlim(), ylim()
   f. plt.grid()
   g. plt.figure(figsize = (20,20))
   h. plt.subplot(total rows, total columns, plot no.)
   i. plt.show()
10. Codes of Unit Step and Unit impulse with different starting points.
11. Plot 2 graphs and then add them and show the graph.

Lab 2. Basic Plotting of Signals

1. Unit Step Function:

$$u(t) = \begin{cases} 1; t < 0 \\ 0; t \geq 0 \end{cases}$$

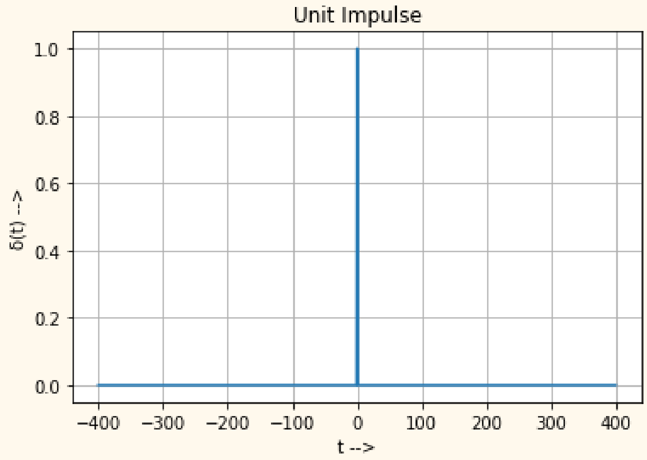


2. Unit Impulse Function:

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

or

$$\delta(t) = \frac{du(t)}{dt} = lim_{\Delta t \to 0} \frac{u(t + \Delta t) - u(t)}{\Delta t}$$

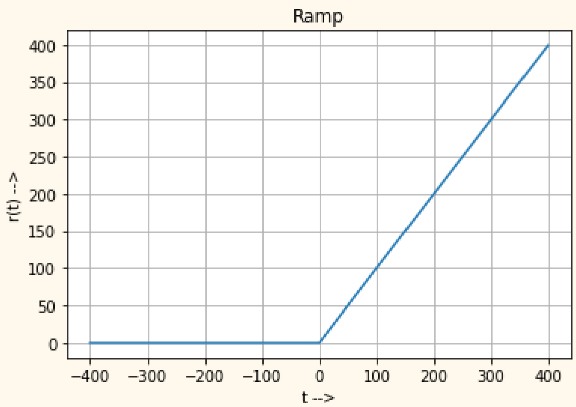


3. Ramp Function:

$$r(t) = \begin{cases} 1;\ t \geq 0 \\ 0;\ t < 0 \end{cases}$$

or

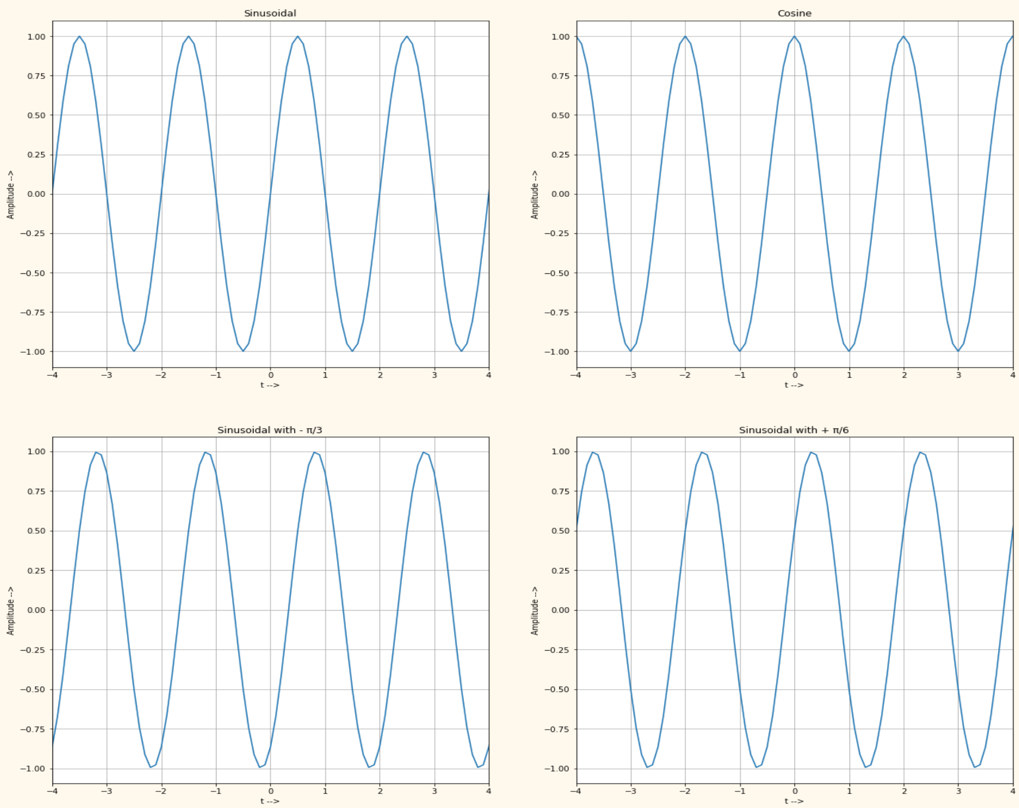
$$r(t) = \int_{-\infty}^{t} u(t)dt$$



4. Periodic Sinusoidal Sequences:

$y = sin(\omega t)\ or\ cos(\omega t)$

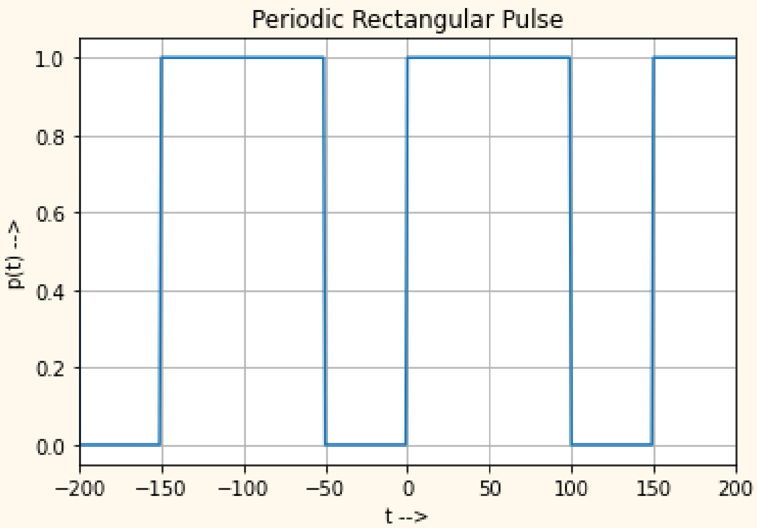
$y = sin(\omega t + \phi)\ or\ cos(\omega t + \phi)$



5. Periodic Rectangular Pulse:

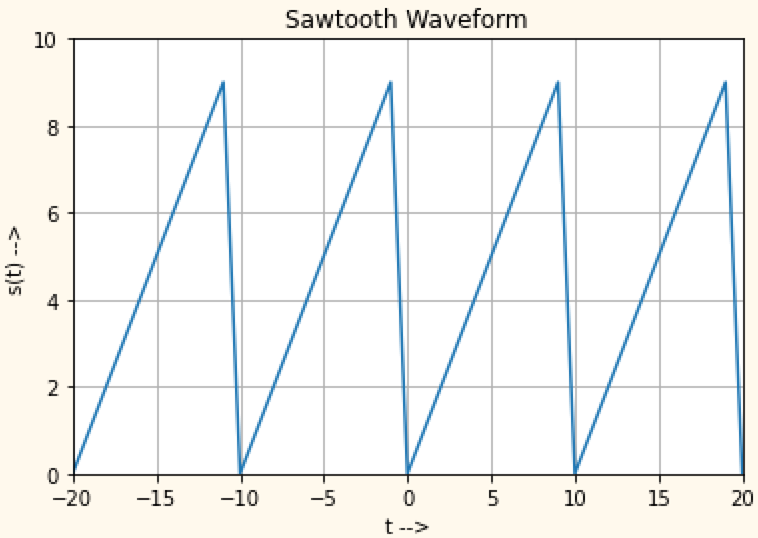
$$p(t) = \sum_{n=-\infty}^{\infty} A \cdot rect(\frac{t-nT}{Tp}) \text{ where}$$

$$rect(x) = \begin{cases} 1; \ |x| \le 0.5 \\ 0; \text{ otherwise} \end{cases}$$



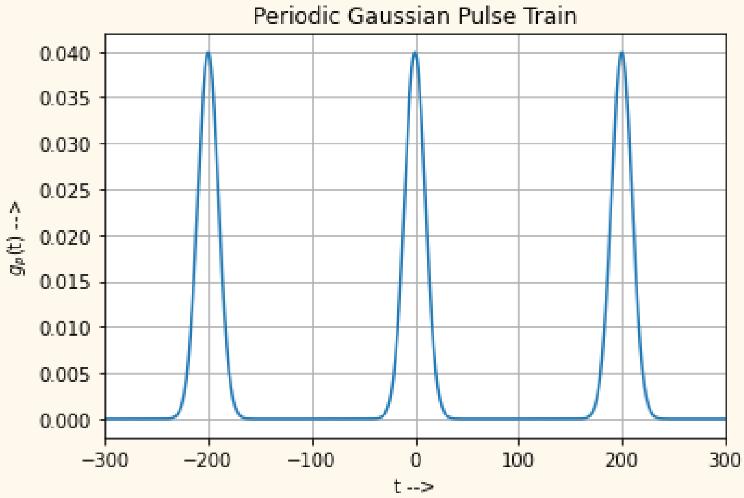
6. Asymmetric Sawtooth Waveform:

$s(t) = A(t - nT) \; for \; nT \le t < (n + 1)T$



7. Periodic Gaussian Pulse:

$$g_p(t) = \sum_{n=-\infty}^{\infty} A \cdot e\left(\frac{t-nT}{Tp}\right)^{-\frac{(t-nT)^2}{2\sigma^2}}$$

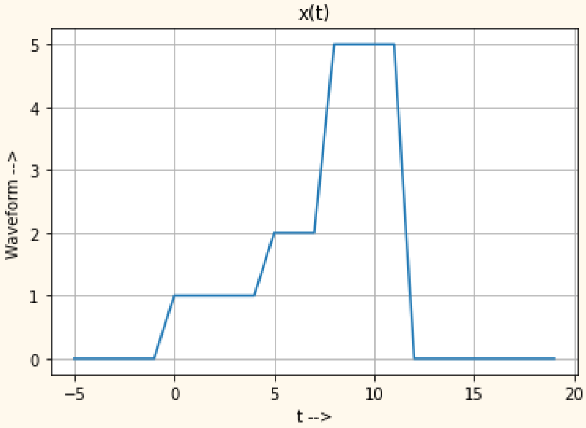


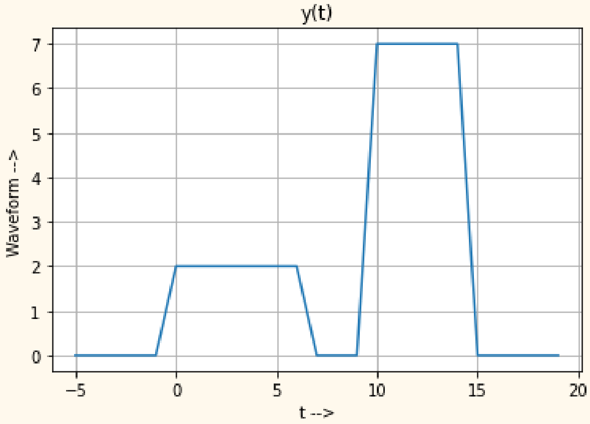
Lab 3. Basic Operation of Signal

$$x(t) = \begin{cases} 1, & 0 \leq t < 5 \\ 2, & 5 \leq t < 8 \\ 5, & 8 \leq t < 12 \\ 0, & t < 0 \text{ or } t \geq 12 \end{cases}$$

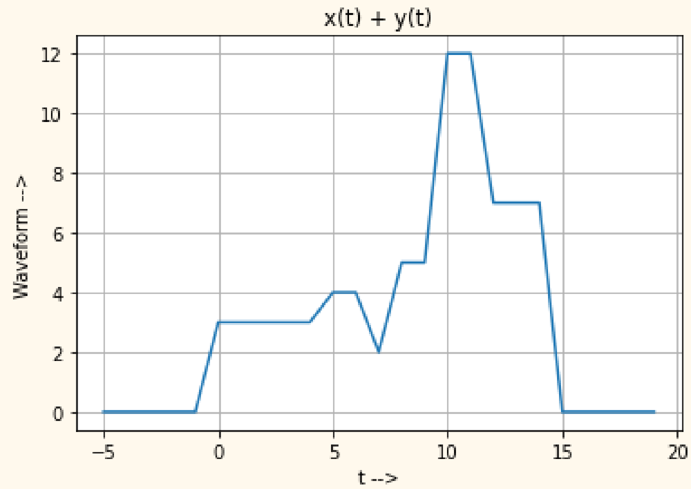
$$y(t) = \begin{cases} 2, & 0 \leq t < 7 \\ 0, & 7 \leq t < 10 \\ 7, & 10 \leq t < 15 \\ 0, & t < 0 \text{ or } t \geq 15 \end{cases}$$

1. **Generate x and y and perform**
   a. $x(t) + y(t)$,
   b. $x(t) - y(t)$,
   c. $x(t) * y(t)$,
   d. $\frac{x(t)}{2} + \frac{y(t)}{3}$,
   e. $x(-t)$,
   f. $y(-t)$,
   g. $x(2t)$,
   h. $x(-2t + 5)$,
   i. $x(0.5t - 5)$
   j. $x(-0.5t - 5)$

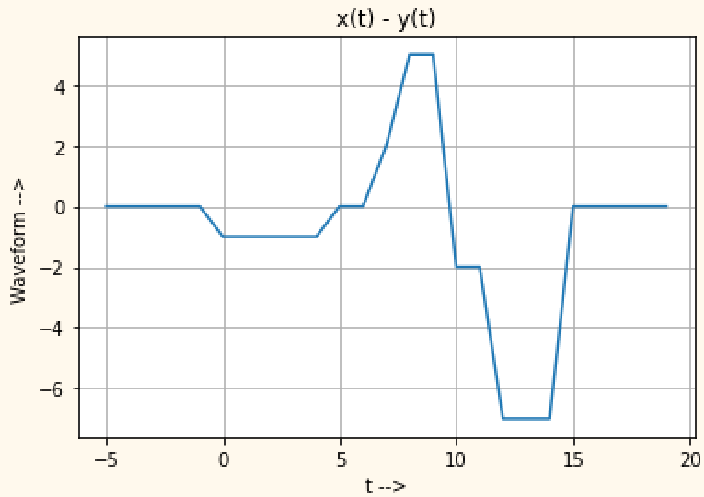




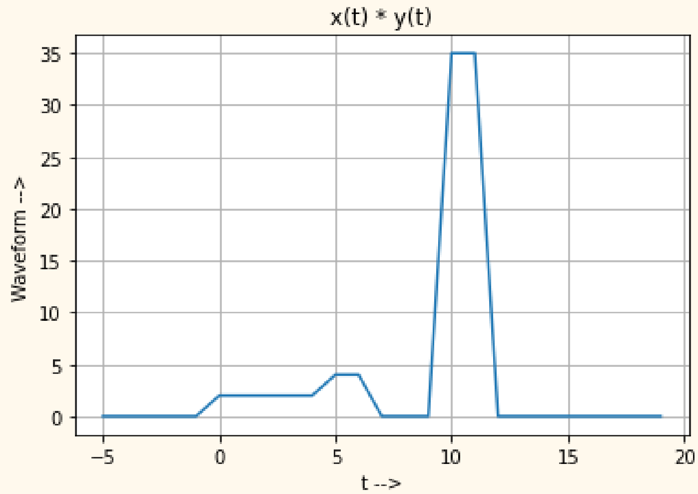
a.


x(t) + y(t)
Waveform -->
t -->
0
2
4
6
8
10
12
−5
0
5
10
15
20

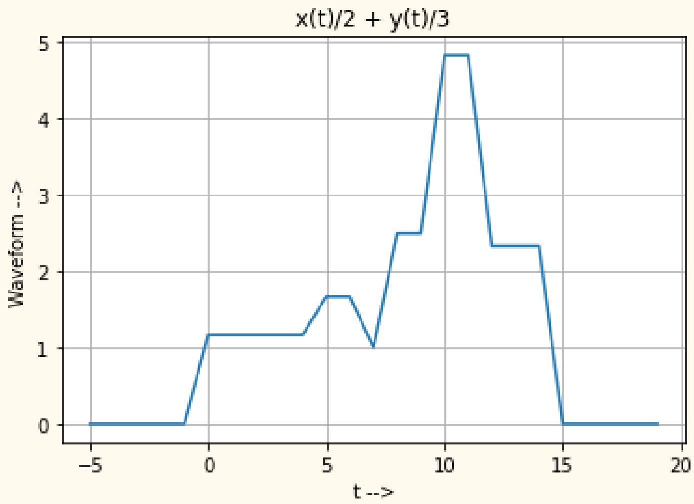
b.


x(t) - y(t)
Waveform -->
t -->
4
2
0
−2
−4
−6
−5
0
5
10
15
20

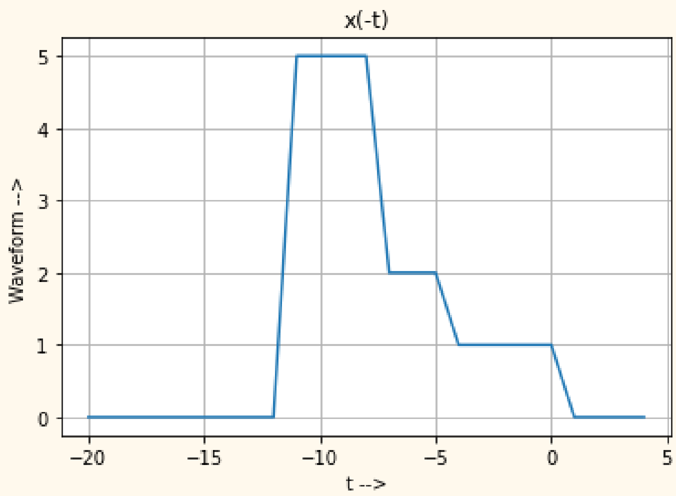
c.


x(t) * y(t)
Waveform -->
t -->
35
30
25
20
15
10
5
0
−5
0
5
10
15
20

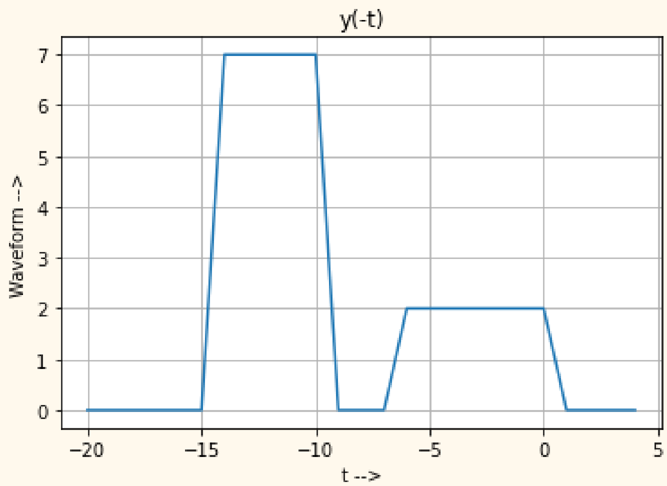
d.


x(t)/2 + y(t)/3
Waveform -->
t -->
5
4
3
2
1
0
−5
0
5
10
15
20

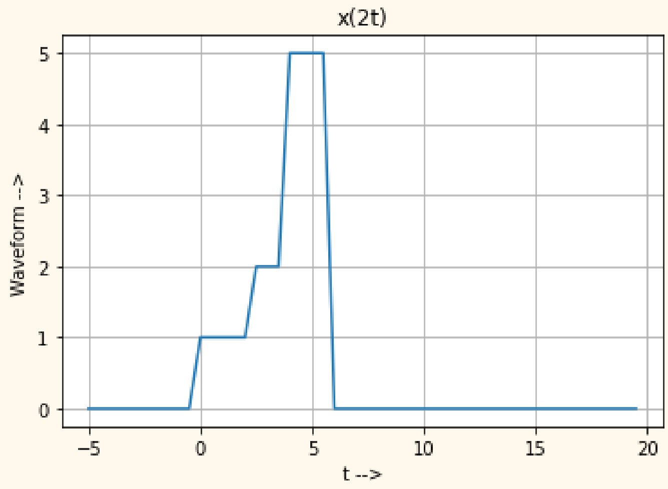
e.


x(-t)
Waveform -->
t -->
5
4
3
2
1
0
−20
−15
−10
−5
0
5

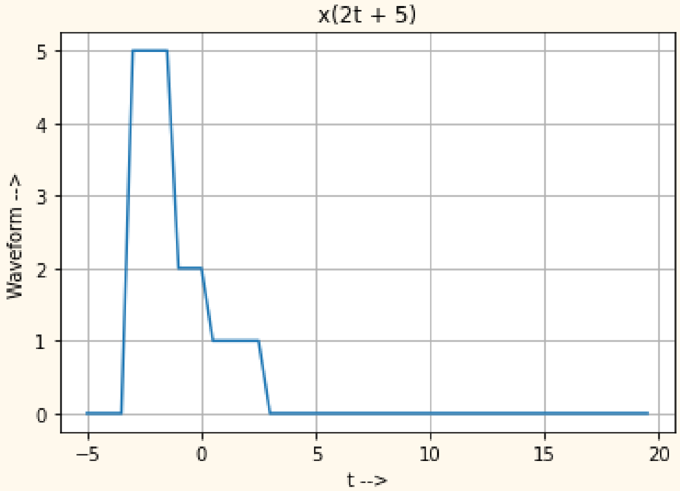
f.


y(-t)
Waveform -->
t -->
7
6
5
4
3
2
1
0
−20
−15
−10
−5
0
5

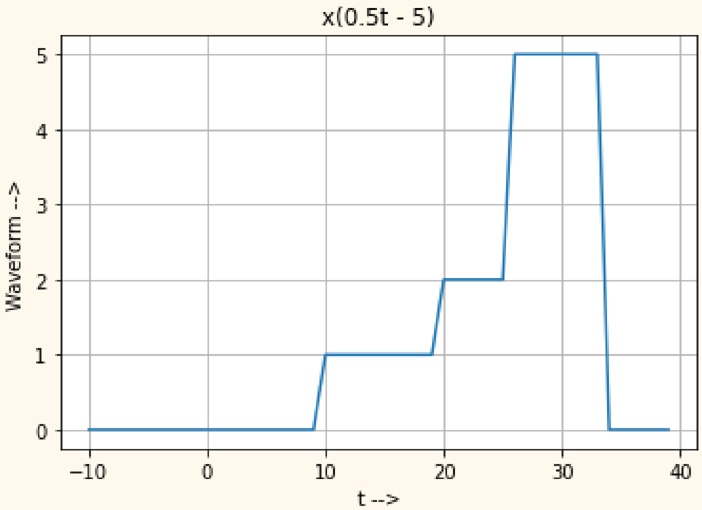
g.


x(2t)
Waveform -->
t -->
5
4
3
2
1
0
−5
0
5
10
15
20

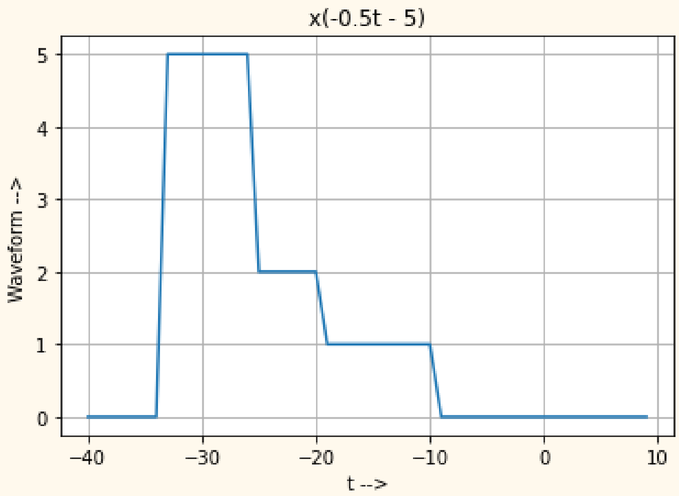
h.


x(2t + 5)
Waveform -->
t -->
5
4
3
2
1
0
−5
0
5
10
15
20

i.


x(0.5t - 5)
Waveform -->
t -->
5
4
3
2
1
0
−10
0
10
20
30
40

j.



Lab 4. Convolution in Time Domain

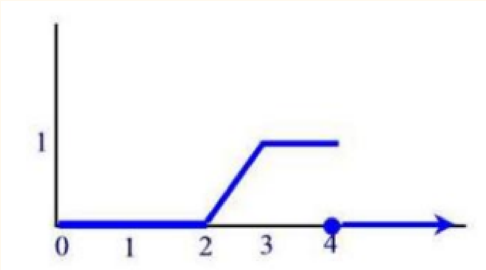
1. Write a program to convolve two discrete-time sequences. Plot all the sequences. Verify the result by analytical calculation.
2. Verify that $x(t) * h(t) = h(t) * x(t)$
3. Find the convolution of two Non Causal Signal $x(n) = 3\delta(n + 2) - \delta(n - 1) + 2\delta(n - 3)$ and $h(n) = u(n + 4) - u(n - 3)$. Plot all the sequences. The value of n should be 50.
4. Generate a one-dimensional signal x, which may be a sinusoidal signal or any random signal with $-2 < x < 2$. Add an additive random noise and find the response of an LTI system on x whose impulse response $h1 = \frac{ones(1,3)}{3}$, $h2 = \frac{ones(1,3)}{7}$, $h3 = \frac{ones(1,11)}{11}$ and also analyze:
    a. What is the effect of the convolution in this example?
    b. How is the length of y related to the length of x and h?
    c. Plot x(n) and y(n) on the same graph. What problem do you see for different impulse responses?

Lab 5. Laplace Transform

1. Find the Laplace transform of the following and verify the results by applying the inverse Laplace transform to them:
   a. $y = t^2$
   b. $y = e^{-at} + e^{-3at}$
   c. $y = e^{2t} sin(2t)$
   d. $y = e^{3t} + cos(6t) - e^{-3t} cos(6t)$
   e. $y = u(t - 2) + 2u(t - 3) - 2r(t - 2)$
2. Consider the two functions $f(t) = u(t)u(3 - t)$ and $g(t) = u(t) - u(t - 3)$.
   a. Are the two functions identical?
   b. Show that $L[f(t)] = L[g(t)]$
3. Using the definition, find $L[f(t)]$, if it exists. If the Laplace transform exists, then find the domain of $F(s)$.

$$f(t) = \begin{cases} 0, & 0 \le t < 1 \\ t - 1, & 1 \le t < 2 \\ 0, & 2 \le t \end{cases}$$

4. Find the inverse Laplace transform of the following and verify the results by applying the Laplace transform to them:
   a. $F(s) = \frac{1}{s}$
   b. $F(s) = \frac{10}{s^2+25} - \frac{4}{s - 3}$
   c. $F(s) = \frac{e^{-3s}(2s+7)}{s^2+16}$
   d. $F(s) = \frac{s^2 + 5s - 3}{(s^2+16)(s-2)}$
5. The graph of $f(t)$ is given below. Represent $f(t)$ as a combination of Heaviside step functions calculate the Laplace transform of $f(t)$.



6. Solve the initial value problem using Laplace transform:
   a. $y' + 2y = 4t,\ y(0) = 3$
   b. $y'' + 3y' + 2y = 6e - t,\ y(0) = 1,\ y'(0) = 2$
   c. $y' + 4y = g(t),\ y(0) = 2,\ where\ g(t) = 12\ if\ (1 < t < 3)\ else\ 0$
7. Verify that multiplication in s domain is equivalent to Convolution in time domain.

Lab 6. Z-transform

1. Find the Z- transform of the following in symbolic form
   a. $f(k) = sin(k)$
   b. $f(n) = a^{n}$
   c. $f(n) = u(n - 3)$
   d. $f[n] = (\frac{1}{4})^{n} u[n]$
   e. $f(n) = 2^{n+1} + 4\left(\frac{1}{2}\right)^{n}$
2. Find the inverse Z-transform of the following in symbolic form
   a. $x(z) = \frac{2z}{(2z-1)}$
   b. $x(z) = \frac{6 - 9z^{-1}}{(1-2.5z^{-1}+z^{-2})}$
   c. $x(z) = (\frac{1}{6-5z^{-1}+z^{-2}})(\frac{4z}{4z-1} - z^{-1} + 5z^{-1})$

Lab 7. Fourier transform

1. Find the Fourier transform of the following in symbolic form
    a. $f = a|t|$
    b. $f = acos\omega t$
    c. $f = e^{-t|a|}u(t)$
    d. $f = e^{-t^2 - x^2}$
2. Find the Inverse Fourier transform of the following in symbolic form
    a. $F = e^{\frac{-\omega^2}{4}}$
    b. $F = e^{-\omega^2 - a^2}$
3. Solve the differential Equation and analyze the response of the system for given input
   $6y(n) - 5y(n - 1) + y(n - 2) = \frac{1}{4^n}, n \geq 0 \; and \; y(n - 1) = 1, \; y(n - 2) = 0$
4. Verification of convolution property of Fourier and Z-transform
    a. $F[x1(t) * x2(t)] = X1(f)X2(f)$
    b. $Z[x1(n) * x2(n)] = X1(z)X2(z)$

Lab 8. LTI System

1. For each of the following system. Determine whether or not the system is time-invariant
    a. $y(t) = tx(t)$
    b. $y(t) = e^{x(t)}$
    c. $y(t) = x(t + 10) + x^2(t)$
    d. $y(n) = sin(x(n))$
    e. $y(n) = x(n + 1) + x(n) + x(n - 1)$
2. Differential Equation of a system is given by: $y''(t) - y'(t) - 2y(t) = x(t)$
    a. Determine system is LTI or not?
    b. Find the impulse response of the system
    c. Find the stability of system
3. The output response $y(t)$ of a continuous time LTI system is $2e^{-3t}u(t)$, when the input $x(t)$ is $u(t)$. Find the system function
4. Find the output response of an LTI system with impulse response $h(t) = \delta(t - 3)$ for input $x(t) = cos4t + cos7t$