- Digital Signal Processing
- Module 2_Part 1
- Processing of Discrete Time Signals

- Lecture Plan
-

* Topics to be Covered

1. Representation of Discrete Time Signal
2. LTI System
3. Convolution Sum (Numerical based) (2019)
4. Properties of Convolution Function
5. Causality & Stability (2019 Short Note)
6. Conditions of Time Invariance & Stability of Discrete Time System represented by Difference Equation (Numerical) (2019 marks

8. Applications of Correlation Process
9. Autocorrelation
10. Cross Correlation
11. Input-Output Correlation
12. Properties of Correlation Function

1. Representation of discrete time signals

There are three ways to represent discrete time signals.

1) Functional Representation

$$x(n) = \begin{cases} 4 & \text{for } n=1,3 \\ -2 & \text{for } n=2 \\ 0 & \text{elsewhere} \end{cases}$$

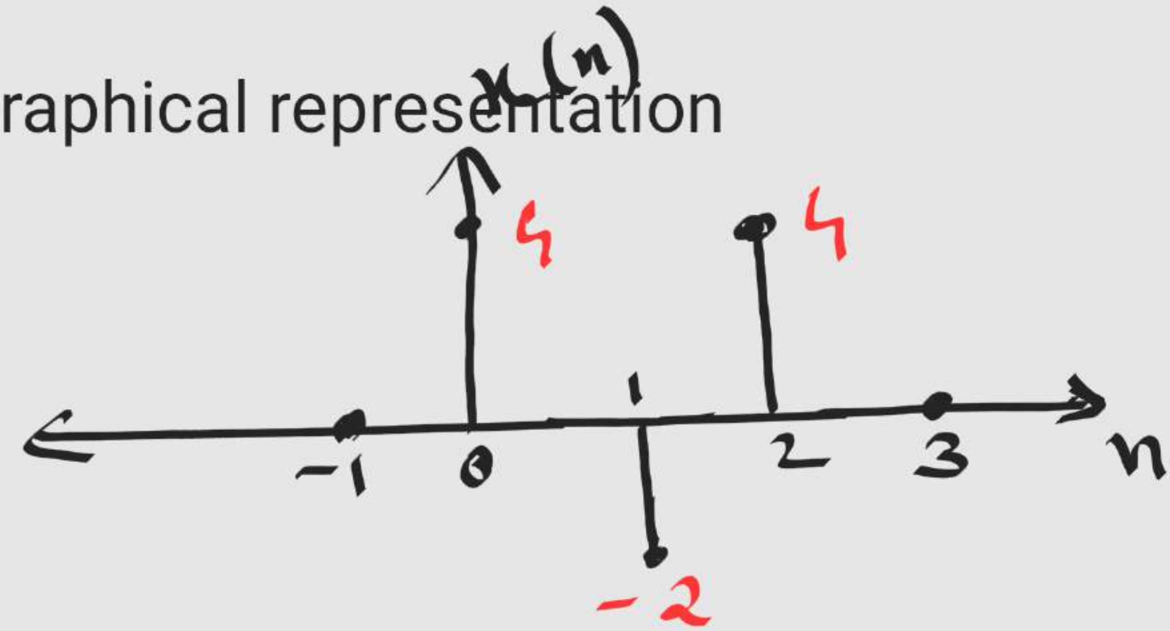
2) Tabular method of representation

n	-3	-2	-1	0	1	2	3	4	5
x(n)	0	0	0	0	4	-2	4	0	0

$$X(n) = \{ 0 , \underset{\substack{\uparrow \\ n=0}}{4} , -2 , 4 , 0 , \ldots\ldots \}$$

3) Sequence Representation

4) Graphical representation



2. LTI System

Linear Time Invariant System

* Basic Knowledge – about System

- [x] What is System?
- [x] Types of System
- [x] Classification of CTS & DTS
- [x] Causality & Stability
- [x] Linear & Time Invariant

1.) System – It may be defined as set of elements / functional blocks which are connected together & produces an o/p in response to an i/p signal.

$$x(t) \longrightarrow \boxed{\text{System}} \longrightarrow y(t)$$

→ The response of an system depends on T.F of a system

→ $x(t)$ is the i/p or excitation

→ $y(t)$ is the o/p or response

→ Means that i/p or excitation $x(t)$ produces an o/p or response $y(t)$

→ Examples of systems –

filters,
audio amplifiers,
Communication Channel

} Electrical System

T.V set → interconnection of small systems
(big system)

↓

(tuner, IF amplifier, Video amplifiers, Sound ")

2) Types of System →

- Continuous time System
- Discrete Time System

3) Classification of systems →
(Check previous notes)

Linear Time Invariant System

LTI → Linear (I)
→ Time Invariant (II)
} Properties

1. What is LTI system?

→ If a system has both the linearity & time-invariance properties, then this system is called Linear-Time Invariant System.

2. Charecterization of LTI system

(i) Linear System

(Superposition theorem)

System to be linear —

Q: Eqn between y & x,

Ex 1 $\longrightarrow$ $\boxed{y(t) = t\,x(t)}$

(1) For $x_1(t)$: $y(t) = t\,x_1(t)$
(i/p)

(2) For $x_2(t)$: $y(t) = t\,x_2(t)$

(3) $y'(t)$: $y'(t) = t[x_1(t)] + t[x_2(t)]$
(adding (1) & (2)) $= t[x_1(t) + x_2(t)]$

(4) $y''(t)$: $y''(t) = t[x_1(t) + x_2 t]$
(Replace 't' with $x_1(t) + x_2(t)$

$\because$ $y'(t) = y''(t) \Longrightarrow$

$\therefore \Rightarrow$ Linear system

If $y'(t) \neq y''(t) \Rightarrow$ Non-Linear

ii) Time Invariant System

① First Delay by k units

Delay $\Rightarrow x(t)$ by k

② Replace wherever you see 't'

with $(t-k)$

Replace $\Rightarrow t \rightarrow (t-k)$

③ If step ① = step ② (TIV

① $\neq$ ② (TV

TIV $\rightarrow$ Time invariant

TV $\rightarrow$ Time variant

Ex: $t\,x(t)$

① Delay : $y(t,k) = t\,x(t-k)$

② Replace : $y(t-k) = (t-k)\,x(t-k)$

③ $1 \neq 2 \Rightarrow$ Time variant //

Both CTS & DTS exhibit one property

→ Superposition theorem can be applied to find impulse response $y(t)$ to a given function

✓ To find response of LTI system to any given function, first we have to find response of LTI system

For CTS	For DTS
i/p → $x(t)$	i/p → $x(n)$
$\delta(t)$	$\delta(n)$
o/p → $y(t)$	o/p → $y(n)$
↓ $h(t)$	$h(n)$
(impulse response) for given $\delta(t)$	

LTI System (Diagram)

$$x(n) \longrightarrow \boxed{h(n)} \longrightarrow y(n)$$

$$\delta(n) \qquad\qquad\qquad\qquad h(n)$$

i/p

(1) Unit impulse response

o/p response

CTS

$$x(t) \longrightarrow \boxed{CTS} \longrightarrow y(t)$$

DTS

$$x(n) \longrightarrow \boxed{DTS} \longrightarrow y(n)$$

3) Convolution Sum

→ Properties of LTI system

(Output y(n) in discrete LTI system can be expressed as a convolution sum)

$$\boxed{\begin{aligned} y(n) &= \sum_{k=-\infty}^{\infty} x(k)\,h(n-k) \\ &\text{(or)} \\ y(n) &= x(n) * h(n) \end{aligned}}$$

Properties:

1. Commutative
2. Associative
3. Distributive
4. Static & Dynamic
5. Invertibility
6. Causality & Stability ✓ 2019

Convolution:

methods

Method 1 : Conventional method

Ex: Find the convolution of two signals shown in fig ①

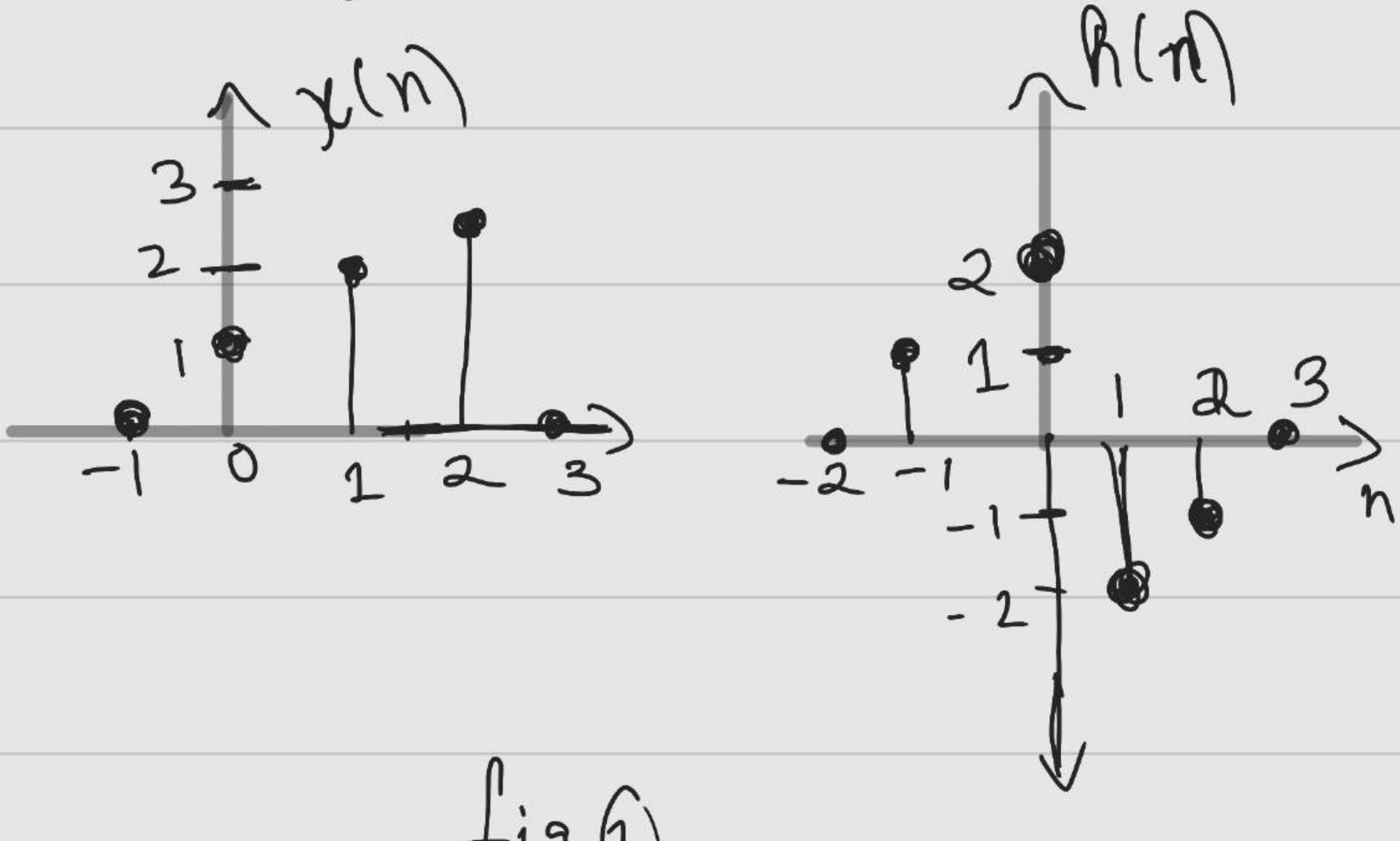


fig ①

Sol: Convoluted signal

$$y(n) = \sum_{k=-\infty}^{\infty} x(k)\, h(n-k)$$

From graph.

$x(n)$ starts from 0 to 2

$h(n)$ starts from -1 to 2

$y(n)$ starts from $\underbrace{0+(-1)}$ to $\underbrace{2+2}$

-1 to 4

$n = \uparrow \qquad n = \uparrow$

$k \longrightarrow 0$ to 2

When $n = -1$

$$y(-1) = \sum_{k=0}^{2} x(k)\,h(-1-k)$$

$$= x(0)\,h(-1) + x(1)\,h(-2)$$

$$x(2)\,h(-3)$$

$$= 1\times1 + 2\times0 + 2\times0$$

$$= 1$$

When $n = 0$

$$y(0) = \sum_{k=0}^{2} x(k)\,h(-k)$$

$$= x(0)\,h(0) + x(1)\,h(-1) +$$

$$x(2)\,h(-2)$$

$$= 1\times2 + 2\times1 + 2\times0 = 4$$

When $n = 1$

$$y(1) = \sum_{k=0}^{2} x(k)\,h(1-k)$$

$$= x(0)h(1) + x(1)\,h(0) + x(2)\,h(-1)$$

$$+ x(3)\,h(-2)$$

$$= 1 \times -2 + 2 \times 2 + 3 \times 1$$

$$= 5$$

When $n = 2$

$$y(2) = 1$$

When $n = 3$

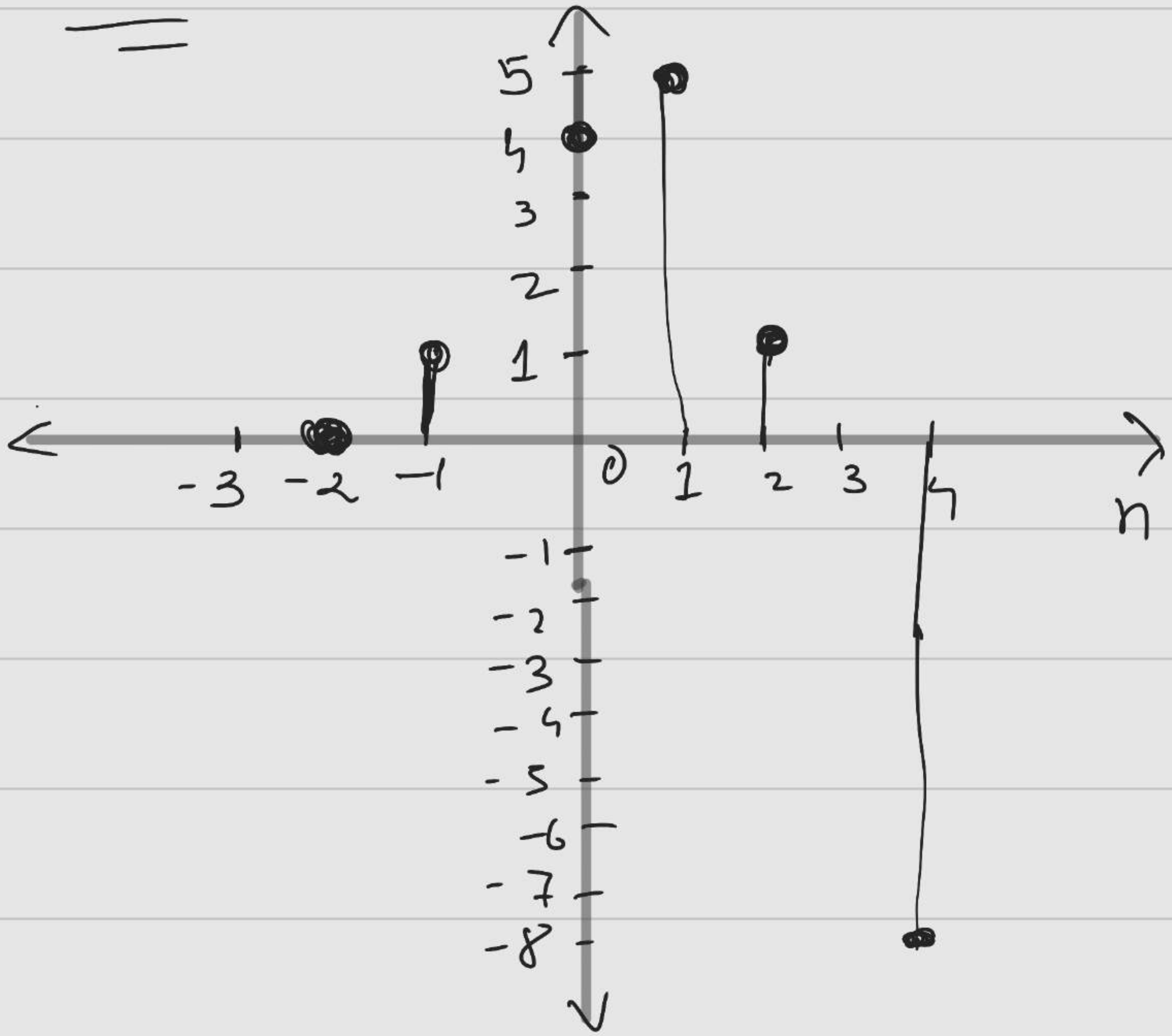
$$y(3) = -8$$

When $n = 4$

$$y(4) = -3$$

$$y[n] = [1, \underset{\uparrow}{4}, 5, 1, -8, -3]$$

Plot :



Example 5.22 *Find the convolution of two finite duration sequences*

Conventional

$$x(n)=\begin{cases}1, & -1\le n\le 1\\ 0, & \text{otherwise}\end{cases} \quad \text{and} \quad h(n)=\begin{cases}1, & -1\le n\le 1\\ 0, & \text{otherwise}\end{cases}$$

Solution The convolution of two finite duration sequences is given by

$$y(n)=\sum_{k=-\infty}^{\infty} x(k)\,h(n-k) \quad \text{or} \quad y(n)=\sum_{k=-\infty}^{\infty} x(n-k)\,h(k)$$

Step 1 Plot the given sequence, as shown in Fig. E5.22(a).

Step 2 To find the convolution sum $y(n)$

When $n=0$

$$y(0)=\sum_{k=-\infty}^{\infty} x(k)\,h(-k)$$

$$=\ldots+x(-1)\,h(1)+x(0)\,h(0)+x(1)\,h(-1)+\cdots$$

$$=0+(1)\,(1)+(1)\,(1)+(1)\,(1)+0\,\ldots=3$$

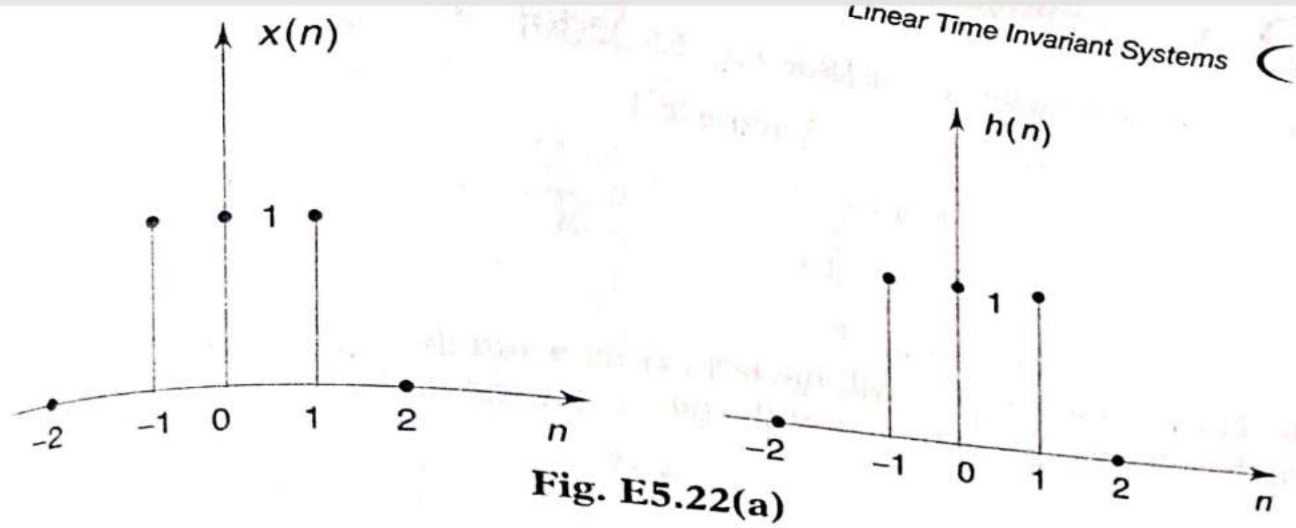


Fig. E5.22(a)

When $n = 1$

$$y(1) = \sum_{k=-\infty}^{\infty} x(k)\, h\,(1-k)$$

$$= \ldots + x(-1)\; h\;(2) + x(0)\; h\;(1) + x(1)\; h\;(0) + \ldots$$

$$= 0 + (1)\;(1) + (1)\;(1) + 0\ldots = 2$$

When $n = 2$

$$y(2) = \sum_{k=-\infty}^{\infty} x(k)\, h\,(2-k)$$

$$= \ldots + x(-1)\; h\;(3) + x(0)\; h\;(2) + x(1)\; h\;(1) + \ldots$$

$$= 0 + (1)\;(1) + 0\ldots = 1$$

When $n = 3$

$$y(3) = \sum_{k=-\infty}^{\infty} x(k)\, h\,(3-k) = 0$$

When $n = -1$

$$y(-1) = \sum_{k=-\infty}^{\infty} x(k)\, h\,(-1-k)$$

$$= \ldots + x(-1)\; h\;(1) + x(0)\; h\;(-1) + x(1)\; h\;(-2) + \ldots$$

$$= 0 + (1)\;(1) + (1)\;(1) + 0\;\ldots = 2$$

When $n = -2$

$$y(-2) = \sum_{k=-\infty}^{\infty} x(k)\, h\,(-2-k)$$

$$= \ldots + x(-1)\; h\;(-1) + x(0)\; h\;(-2) + x(1)\; h\;(-3) + \ldots$$

$$= 0 + (1)\;(1) + 0\;\ldots = 1$$

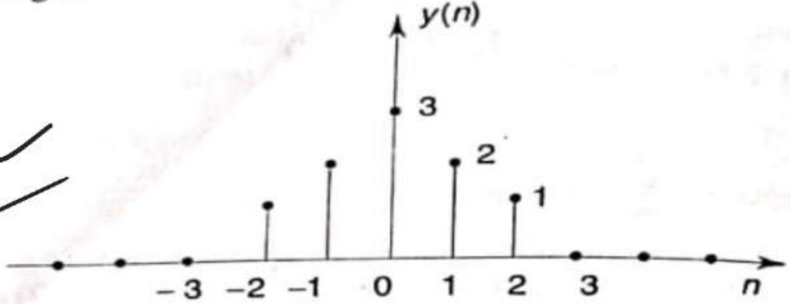
When $n = -3$

$$y(-3) = \sum_{k=-\infty}^{\infty} x(k)\, h\,(-3-k) = 0$$

The convolution signal $y(n)$ is [See Fig. E5.22(b)]

$$y(n) = 0,\ n \le -3 \text{ and } n \ge 3$$
$$y(n) = 1,\ n = \pm 2$$
$$y(n) = 2,\ n = \pm 1$$
$$y(n) = 3,\ n = 0$$

Note: For the convolved signal, the left extreme and the right extreme can be found using the left and right extremes of the two sequences to be convolved. That is,



Method 2
Graphical

Fig. E5.22(b)

$$y_l = x_l + h_l$$
$$y_r = x_r + h_r$$

where x_l, h_l and y_l are the left extremes of the signals x, h and y respectively. Similarly x_r, h_r and y_r are the right extremes of the signals x, h and y respectively.

Alternate (Graphical) Method

The given problem can be solved by using the graphical method as shown in Fig. E5.22(c). We know that $y(n) = \sum_{k=-\infty}^{\infty} x(k)\,h(n-k)$

When $n = 0, y(0) = \sum_{k=-\infty}^{\infty} y_0(k) = \sum_{k=-\infty}^{\infty} x(k)\,h(-k) = 3$

When $n = 1, y(1) = \sum_{k=-\infty}^{\infty} y_1(k) = \sum_{k=-\infty}^{\infty} x(k)\,h(1-k) = 2$

When $n = 2, y(2) = \sum_{k=-\infty}^{\infty} y_2(k) = \sum_{k=-\infty}^{\infty} x(k)\,h(2-k) = 1$

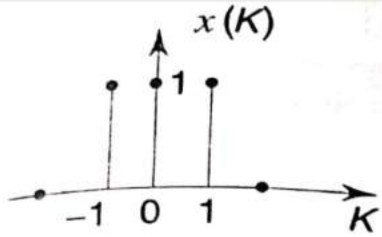
When $n = 3, y(3) = \sum_{k=-\infty}^{\infty} y_3(k) = \sum_{k=-\infty}^{\infty} x(k)\,h(3-k) = 0$

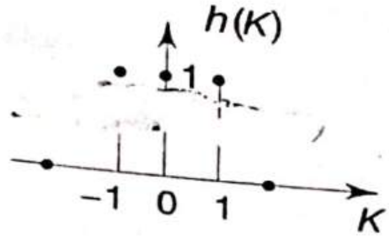
When $n = -1, y(-1) = \sum_{k=-\infty}^{\infty} y_{-1}(k) = \sum_{k=-\infty}^{\infty} x(k)\,h(-1-k) = 2$

When $n = -2, y(-2) = \sum_{k=-\infty}^{\infty} y_{-2}(k) = \sum_{k=-\infty}^{\infty} x(k)\,h(-2-k) = 1$

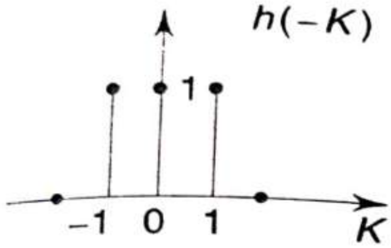
When $n = -3, y(-3) = \sum_{k=-\infty}^{\infty} y_{-3}(k) = \sum_{k=-\infty}^{\infty} x(k)\,h(-3-k) = 0$

When these sequence values are plotted in Fig. E5.22(c), we find that the result is identical to the result shown in Fig. E5.22(b).

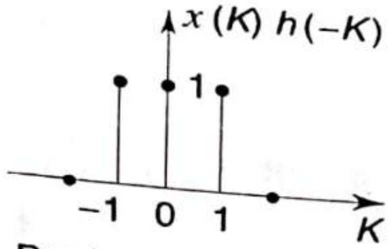




When $n = 0$

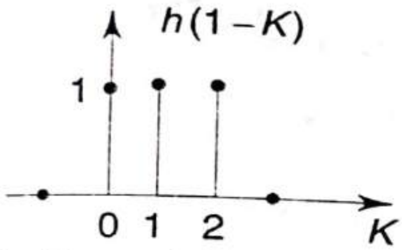


$h(-K) \Leftrightarrow$ fold $h(K)$

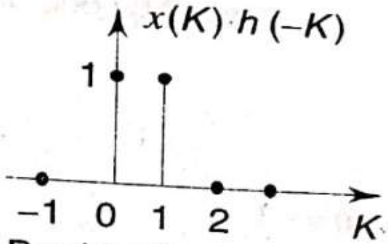


Product Sequence,
$y_0(K) = x(K)\, h(-K)$

When $n = 1$

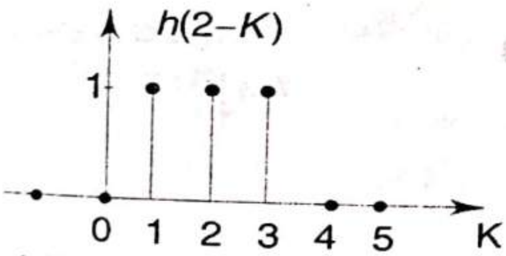


$h(1-K) \Leftrightarrow$ shift $h(-K)$
to right by one unit

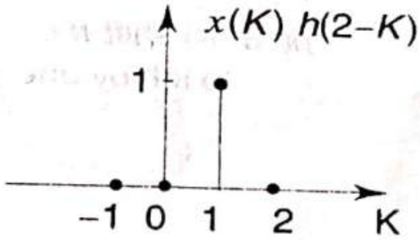


Product Sequence,
$y_1(K) = x(K)h(1-K)$

When $n = 2$

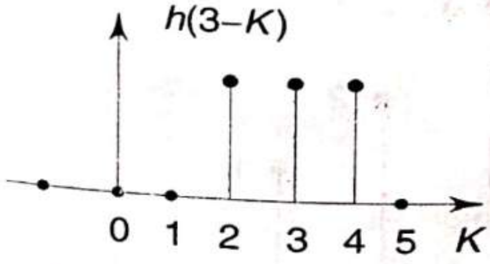


$h(2-K) \Leftrightarrow$ shift $h(1-K)$
to right by one unit

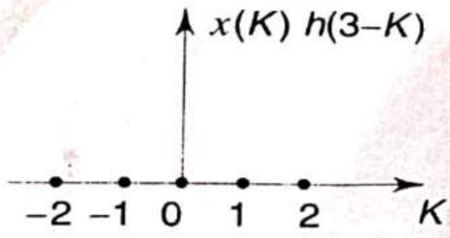


Product Sequence,
$y_2(K) = x(K)h(2-K)$

When $n = 3$

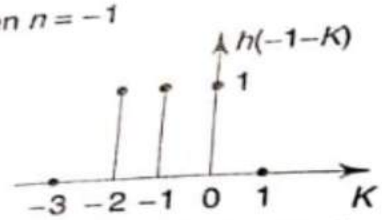


$h(3-K) \Leftrightarrow$ shift $h(2-K)$
to right by one unit

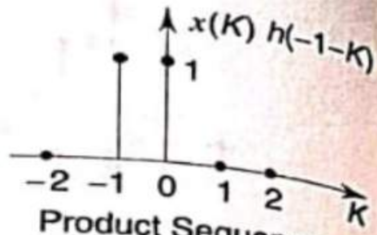


Product Sequence,
$y_3(K) = x(K)h(3-K)$

When $n = -1$

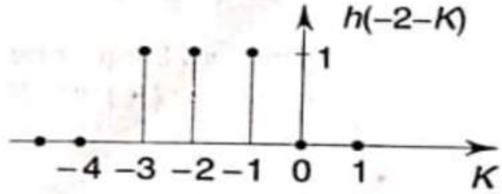


$h(-1-K)$ shift $h \Longleftrightarrow (-K)$
to left by one unit

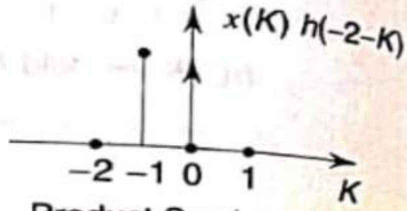


Product Sequence,
$y_{-1}(K) = x(K)\, h(-1-K)$

When $n = -2$

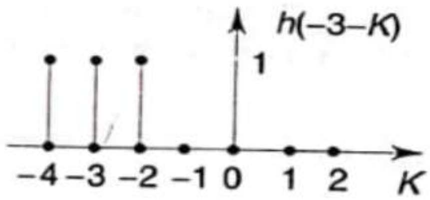


$h(-2-K)$ shift $h \Longleftrightarrow (-1-K)$
to left by one unit

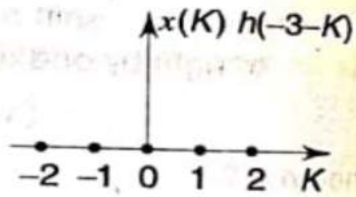


Product Sequence,
$y_{-2}(K) = x(K)\, h(-2-K)$

When $n = -3$



$h(-3-K)$ shift $h \Longleftrightarrow (-2-K)$
to left by one unit



Product Sequence,
$y_{-3}(K) = x(K)\, h(-3-K)$

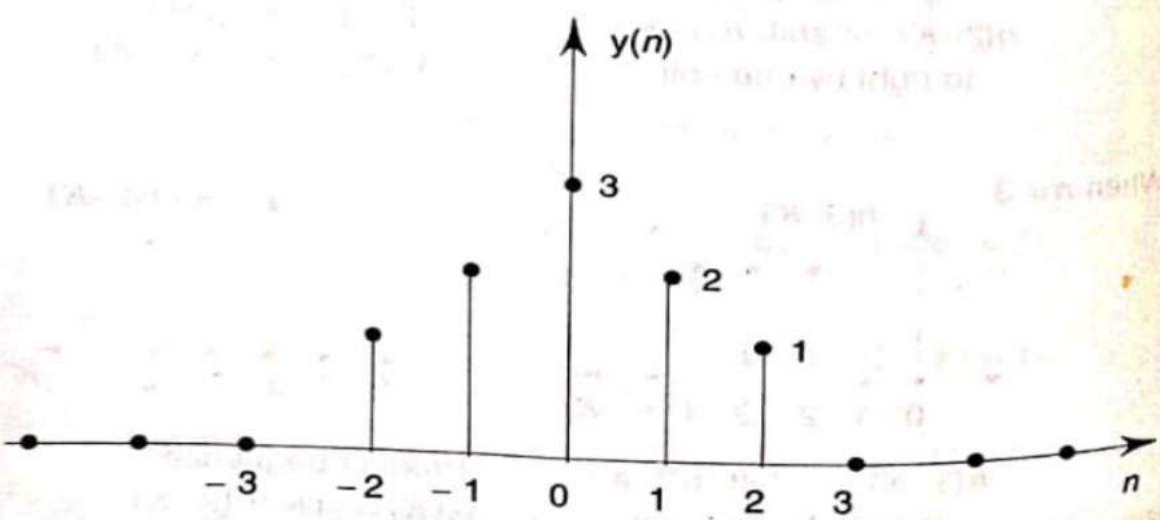


Fig. E6.3(c) *Graphical Method*

These

Example 5.25 *Compute the convolution $y(n) = x(n) * h(n)$ of the signals*

$$x(n) = \left\{\begin{matrix}1, 1, 0, 1, 1, \\ \uparrow\end{matrix}\right\} \text{ and } h(n) = \left\{\begin{matrix}1, -2, -3, 4 \\ \qquad\qquad \uparrow\end{matrix}\right\}$$

Solution The sequences of the given two signals are plotted in Fig. E 5.25(a).

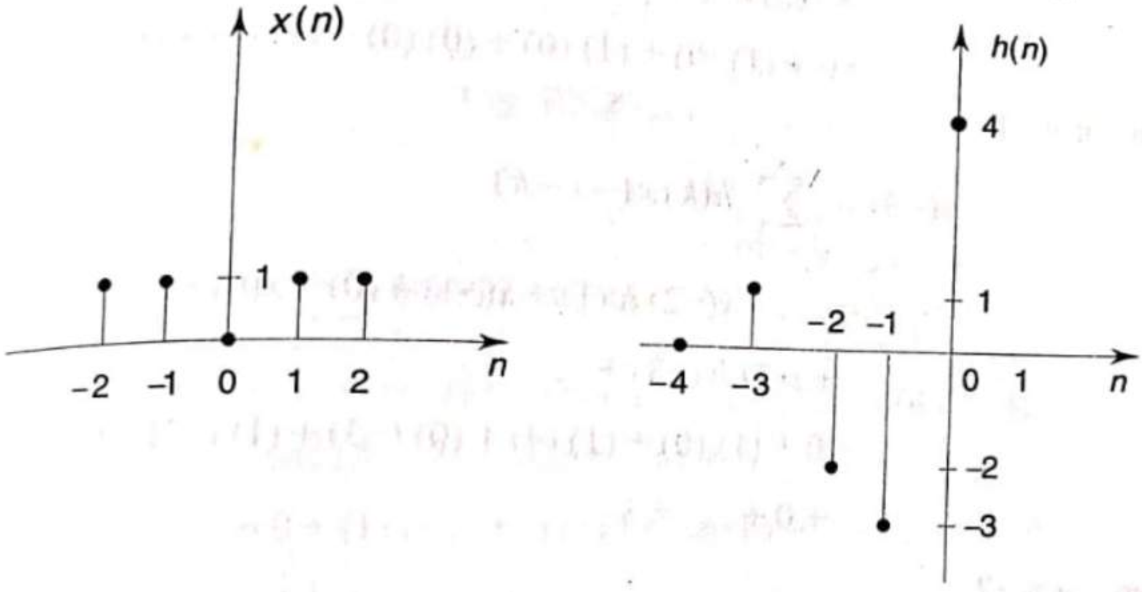


Fig. E5.25(a)

From the graph,

$$x_l = -2, x_r = 2, h_l = -3, h_r = 0$$

Hence the left and right extremes of the convoluted signal $y(n)$ are calculated as

$$y_l = x_l + h_l = -2 + (-3) = -5$$

$$y_r = x_r + h_r = 2 + 0 = 2$$

The convolution signal $y(n)$ is given as

$$y(n) = \sum_{k=-\infty}^{\infty} h(k)\, x(n-k)$$

When $n = 0$

$$y(0) = \sum_{k=-\infty}^{\infty} h(k)\, x(-k)$$

$$= \ldots + 0 + x(-2)\, h(2) + x(-1)\, h(1) + x(0)\, h(0) + x(1)$$

$$h(-1) + x(2)\, h(-2) + 0 + \ldots$$

$$= 0 + (1)(0) + (1)(0) + (0)(4) + (1)(-3) + (1)(-2) + 0 + \ldots = -5$$

When $n = 1$

$$y(1) = \sum_{k=-\infty}^{\infty} h(k)\,x(1-k)$$

$$= \ldots + x(-2)\,h(3) + x(-1)\,h(2) + x(0)\,h(1) + x(1)\,h(0) + x(2)\,h(-1) + \ldots$$

$$= 0 + (1)(0) + (1)(0) + (0)(0) + (1)(4) + (1)(-3) + 0 + \ldots = 1$$

When $n = 2$

$$y(2) = \sum_{k=-\infty}^{\infty} h(k)\,x(2-k)$$

$$= \ldots + x(-2)\,h(4) + x(-1)\,h(3) + x(0)\,h(2) + x(1)\,h(1) + x(2)\,h(0) + \ldots$$

$$= 0 + (1)(0) + (1)(0) + (0)(0) + (1)(4) + (1)(0) + \ldots = 4$$

When $n = -1$

$$y(-1) = \sum_{k=-\infty}^{\infty} h(k)\,x(-1-k)$$

$$= \ldots + x(-2)\,h(1) + x(-1)\,h(0) + x(0)\,h(-1) + x(1)\,h(-2) + x(2)\,h(-3) + \ldots$$

$$= 0 + (1)(0) + (1)(4) + (0)(-3) + (1)(-2) + (1)(1) + 0 + \ldots = 3$$

When $n = -2$

$$y(-2) = \sum_{k=-\infty}^{\infty} h(k)\,x(-2-k)$$

$$= \ldots + x(-2)\,h(0) + x(-1)\,h(-1) + x(0)\,h(-2) + x(1)\,h(-3) + x(2)\,h(-4) + \ldots$$

$$= 0 + (1)(4) + (1)(-3) + (0)(-2) + (1)(1) + (1)(0) + 0 \ldots = 2$$

When $n = -3$

$$y(-3) = \sum_{k=-\infty}^{\infty} h(k)\,x(-3-k)$$

$$= \ldots + x(-2)\,h(-1) + x(-1)\,h(-2) + x(0)\,h(-3) + x(1)\,h(-4) + x(2)\,h(-5) + \ldots$$

$$= 0 + (1)(-3) + (1)(-2) + (0)(1) + (1)(0) + (1)(0) + 0 \ldots = -5$$

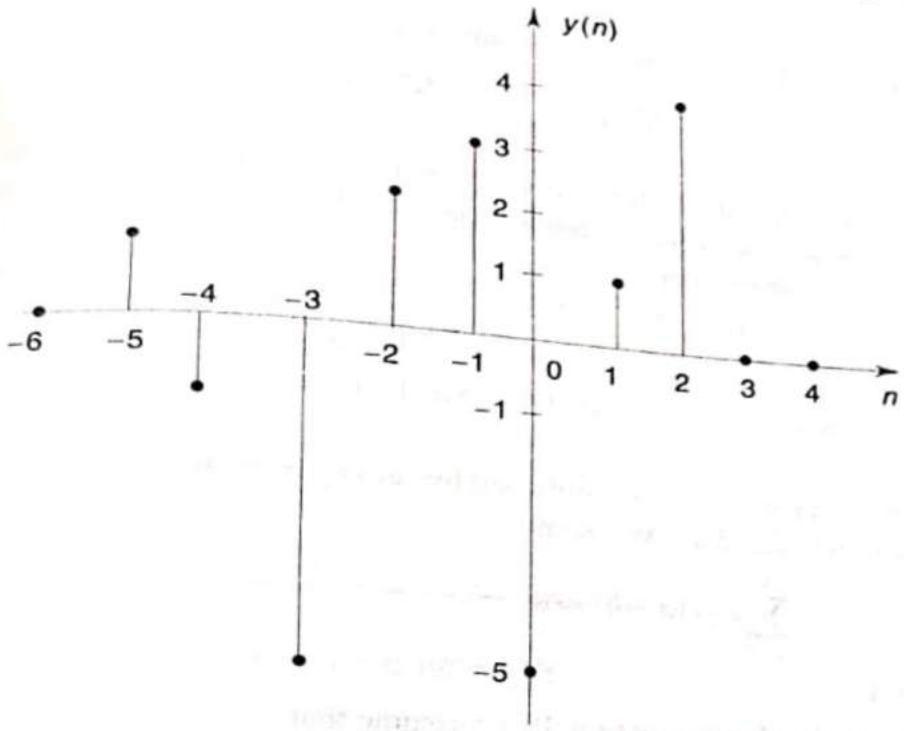


Fig. E5.25(b)

When $n=-4$

$$y(-4)=\sum_{k=-\infty}^{\infty} h(k)\,x(-4-k)$$

$$=\ldots+x(-2)\,h(-2)+x(-1)\,h(-3)+x(0)\,h(-4)+x(1)\,h(-5)+x(2)\,h(-6)+\ldots$$

$$=0+(1)(-2)+(1)(1)+(0)(0)+(1)(0)+(1)(0)+0+\ldots=-1$$

When $n=-5$

$$y(-5)=\sum_{k=-\infty}^{\infty} h(k)\,x(-5-k)$$

$$=\ldots+x(-2)\,h(-3)+x(-1)\,h(-4)+x(0)\,h(-5)+x(1)\,h(-6)+x(2)\,h(-7)+\ldots$$

$$=0+(1)(1)+0+\ldots=1$$

These sequence values are plotted in Fig. E5.25(b).

LINEAR CONSTANT

Convolution using

(3) Tabular Method

Ex:

$$x(n) = \{-\underset{\uparrow}{2}, -1, 0, 1, 2\}$$

$$h(n) = \{-\underset{\uparrow}{3}, -2, -1, 0\}$$

Sol:

$x(n)$ \ $h(n)$	-3	-2	-1	0
-2	$+6$	4	2	0
-1	3	2	1	0
0	0	0	0	0
1	-3	-2	-1	0
2	-6	-4	-2	0

$n=0$

origin

diagonal sum

① Multiply

$x(n)$ $h(n)$

sequence

② Add the sequence

$y(n) = \{ 4+6,\ 3+4,\ 0+2+2,\ -3+0,\ 1+0,\ -6-2+0+0,\ -4-1+0,\ -2+0,\ 0 \}$

$$\boxed{y(n) = \{ \underset{\uparrow\ n=0}{4+6},\ 7,\ 4,\ -2,\ -8,\ -2,\ 0 \}}$$

Ans

⟹ array method

7.7.5 Cross Correlation of Discrete-time Signals (GTU, Gujrat, Sem. Exam., 2009-10)

The cross correlation of two discrete-time signals is a measure of similarity between them. We will define the cross correlation for energy and power discrete-time signals.

7.7.6 Cross Correlation of Discrete-time Energy Signals

Definition

Let x_1 and x_2 (n) denote a pair of real valued discrete-time energy signals. Then the cross correlation function of such a pair is defined as under:

$$R_{12}(k) = \sum_{n=-\infty}^{N} x_1(n) . x_2(n-k) \quad ...(7.70)$$

The second cross correlation function of x_1 (n) and x_2 (n) is defined as under:

$$R_{21}(k) = \sum_{n=-\infty}^{\infty} x_1(n-k)\, x_2(n) \quad ...(7.71)$$

sequence ... have a finite value.

EXAMPLE 7.25. Obtain the cross correlation of the following sequences.

$$x_1(n) = [\underset{\uparrow}{2}, 3, 4] \text{ and } x_2(n) = [\underset{\uparrow}{1}, 2, 3]$$

Solution: There are two methods of solving this example. There are

1. Direct computation method
2. Graphical method

Method I: Direct computation method

The cross correlation is defined as under:

$$\boxed{R_{12}(k) = \sum_{n=-\infty}^{\infty} x_1(n)\, x_2(n-k)}$$

Now, let us obtain the values of R_{12} (k) for different values of k. Since, x_1 (n) exists from n = 0 to n = 2, the product term x_1 (n) x_2 (n – k) will be non-zero only for these values of n.

$$\text{Therefore, } R_{12}(k) = \sum_{n=0}^{2} x_1(n)\, x_2(n-k)$$

1. R_{12} (k) for k = – 3.

Let us arbitrarily start at k = – 3. → k ⇒ -3 to 3

$$\text{Therefore, } R_{12}(-3) = \sum_{n=0}^{2} x_1(n)\, x_2(n+3)$$

$$= x_1(0)\, x_2(3) + x_1(1)\, x_2(4) + x_1(2)\, x_2(5)$$

$$= (2 \times 0) + (3 \times 0) + (4 \times 0) = 0$$

This shows that for $k \le -3$, $R_{12}(k) = 0$

2. $R_{12}(k)$ for $k = -2$.

We have $$R_{12}(-2) = \sum_{n=0}^{2} x_1(n)\, x_2(n+2)$$
$$= x_1(0)\, x_2(2) + x_1(1)\, x_2(3) + x_1(2)\, x_2(4)$$
$$= (2 \times 3) + (3 \times 0) + (4 \times 0) = 6$$

3. $R_{12}(k)$ for $k = -1$.

We have $$R_{12}(-1) = \sum_{n=0}^{2} x_1(n)\, x_2(n+1)$$
$$= x_1(0)\, x_2(1) + x_1(1)\, x_2(2) + x_1(2)\, x_2(3)$$
$$= (2 \times 2) + (3 \times 3) + (4 \times 0) = 13$$

4. $R_{12}(k)$ for $k = 0$.

We have $$R_{12}(0) = \sum_{n=0}^{2} x_1(n)\, x_2(n)$$
$$= x_1(0)\, x_2(0) + x_1(1)\, x_2(1) + x_1(2)\, x_2(2)$$
$$= (2 \times 1) + (3 \times 2) + (4 \times 3) = 20$$

5. $R_{12}(k)$ for $k = 1$.

We have $$R_{12}(1) = \sum_{n=0}^{2} x_1(n)\, x_2(n-1)$$
$$= x_1(0)\, x_2(-1) + x_1(1)\, x_2(0) + x_1(2)\, x_2(1)$$
$$= (2 \times 0) + (3 \times 1) + (4 \times 2) = 11$$

6. $R_{12}(k)$ for $k = 2$.

We have $$R_{12}(2) = \sum_{n=0}^{2} x_1(n)\, x_2(n-2)$$
$$= x_1(0)\, x_2(-2) + x_1(1)\, x_2(-1) + x_1(2)\, x_2(0)$$
$$= (2 \times 0) + (3 \times 0) + (4 \times 1) = 4$$

7. $R_{12}(k)$ for $k = 3$.

$$R_{12}(3) = \sum_{n=0}^{2} x_1(n)\, x_2(n-3)$$
$$= x_1(0)\, x_2(-3) + x_1(1)\, x_2(-2) + x_1(2)\, x_2(-1)$$
$$= (2 \times 0) + (3 \times 0) + (4 \times 0) = 0$$

The value of $R_{12}(k) = 0$ for $k \ge 3$

Plot of $R_{12}(k)$.

Figure 7.22 shows the plot of $R_{12}(k)$ with respect to k.

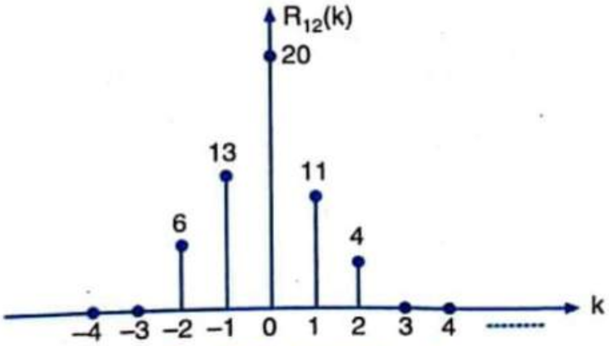


Fig. 7.22. Plot of $R_{12}(k)$

$R_{12}(k)$ in the sequence form.

$R_{12}(k)$ in the sequence form is as under:

$$R_{12}(k) = (6, 13, 20, 11, 4)$$
$$\uparrow$$

(Online exam) shortcut

Q) Obtain cross-correlation between, (Tabular method)

$$x(n) = [\underset{\uparrow}{0}, 1, 2, 3]$$

$$y(n) = [\underset{\uparrow}{1}, 1, 2\ 1]$$

Sol: $y(-n) = \{1\ 2\ 1\ \underset{\uparrow}{1}]$

n=0

x(n) \ y(-n)	1	2	1	1
n=0 → 0	0	0	0	0
1	1	2	1	1
2	2	4	2	2
3	3	6	3	1

Answer

$$R_{xy}(n) = \{0, 1, 4, \underset{\uparrow}{8}, 9, 5, 1\}$$

n=0