PENGOLAHAN SINYAL DIGITAL

Modul 3.

Sinyal Waktu Diskrit

PROGRAM SARJANA FAKULTAS TEKNIK
(Undergraduate Program of Engineering School)

Telkom University

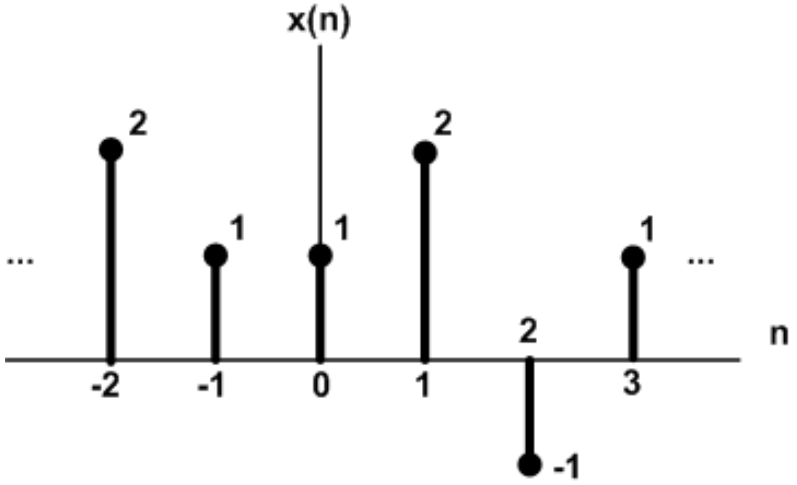
Content

- Overview Sinyal Waktu Diskrit
- Representasi Sinyal
- Sinyal-sinyal Dasar
- Klasifikasi Sinyal
- Operasi-operasi pada Sinyal

Representasi Sinyal

- Grafik (Graphical Representation)
- Fungsional (Functional Representation)
- Tabel (Tabular Representation)
- Deret (Sequence Representation)

- **Grafik (Graphical Representation)**



- n = integer (bilangan bulat) $-\infty < n < \infty$
- $x_a(t) \rightarrow x(n) = x_a(nT)$, T = perioda sampling
- x(n) = sinyal ke-n

- **Fungsional (Functional Representation)**

$$x(n) = \begin{cases} 1, & n = 0, -1, 3 \\ 2, & n = 1, -2 \\ -1, & n = 2 \\ 0, & n \ lainnya \end{cases}$$

- **Tabel (Tabular Representation)**

n	...	-2	-1	0	1	2	3	...
x(n)	...	2	1	1	2	-1	1	...

- **Deret (Sequence Representation)**

  - Deret dengan durasi tak terbatas

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

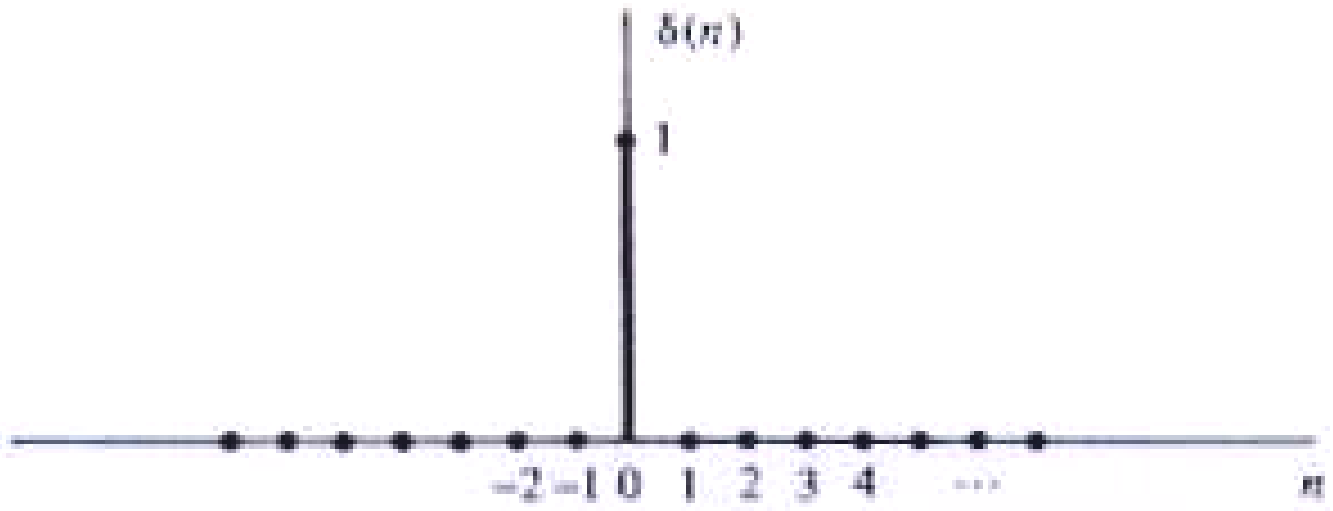
  - Deret dengan durasi terbatas

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

Sinyal-sinyal Dasar

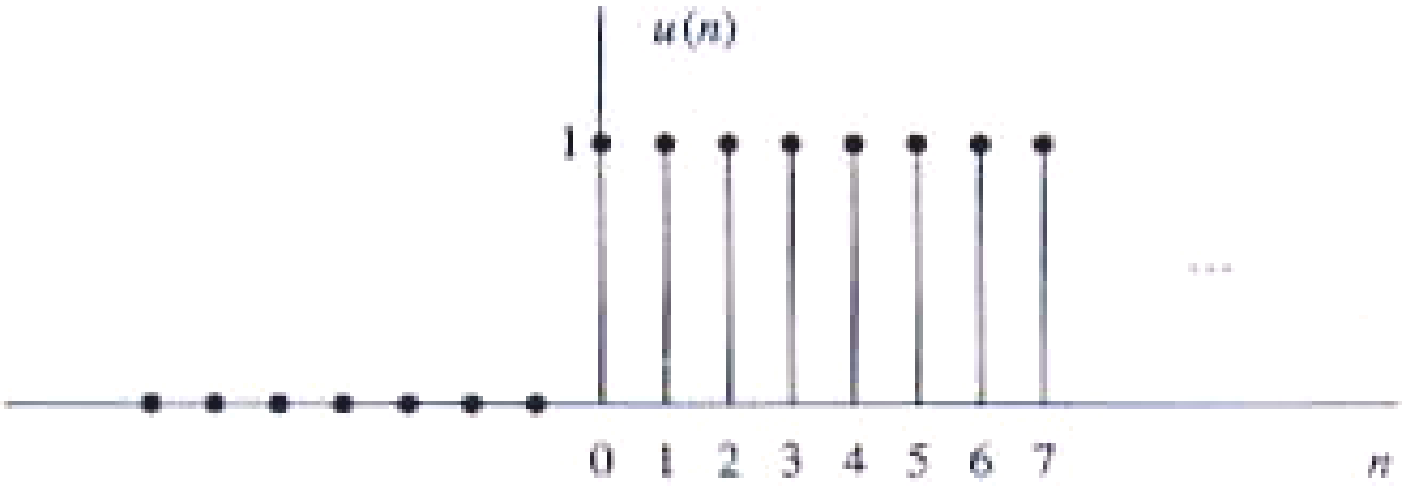
- Unit impuls sinyal
- Unit step signal
- Unit ramp signal
- Exponential signal

- **Unit impulse signal**



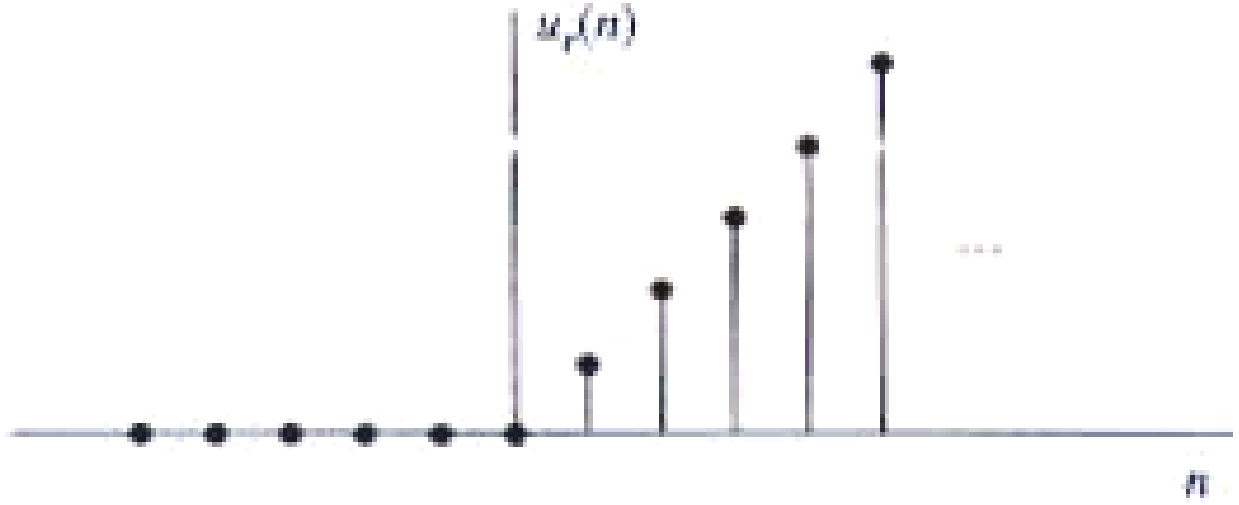
$$\delta(n) = \begin{cases} 1, & n = 0 \\ 0, & n \neq 0 \end{cases}$$

- **Unit step signal**



$$u(n) = \begin{cases} 1, & n \geq 0 \\ 0, & n < 0 \end{cases}$$

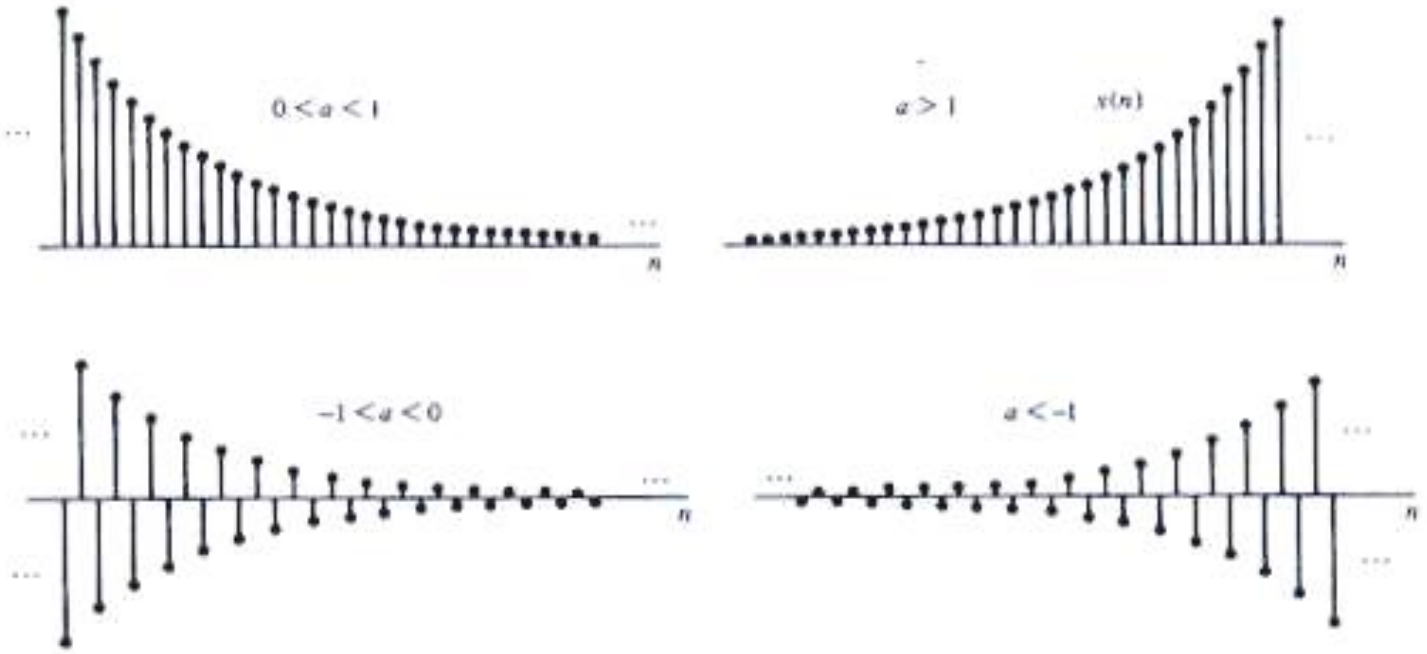
- **Unit ramp signal**



$$r(n) = \begin{cases} n, & n \geq 0 \\ 0, & n < 0 \end{cases}$$

- **Exponential signal (a nyata)**

$$x(n) = a^n$$



Klasifikasi Sinyal

- Sinyal energi
- Sinyal daya
- Sinyal genap (sinyal simetris)
- Sinyal ganjil (sinyal antisimetris)

- **Sinyal Energi dan Sinyal Daya**

Energi dari sinyal x(n) $\Longrightarrow$ $E = \sum_{n=-\infty}^{\infty} |x(n)|^2$

Bila E terbatas ($0 < E < \infty$) $\Longrightarrow$ x(n) = sinyal energi

Daya dari sinyal x(n) $\Longrightarrow$ $P = \lim_{N\to\infty} \frac{1}{2N+1} \sum_{n=-N}^{N} |x(n)|^2$

$E_N = \sum_{n=-N}^{N} |x(n)|^2 \Longrightarrow P = \lim_{N\to\infty} \frac{1}{2N+1} E_N$

Bila P terbatas dan $\neq 0$ $\Longrightarrow$ x(n) = sinyal daya

Bila x(n) adalah sinyal periodik :

x(n + N) = x(n) → N = perioda

$$x(n) = A\sin(2\pi\ f_o N) \longrightarrow f_o = \frac{k}{N}$$

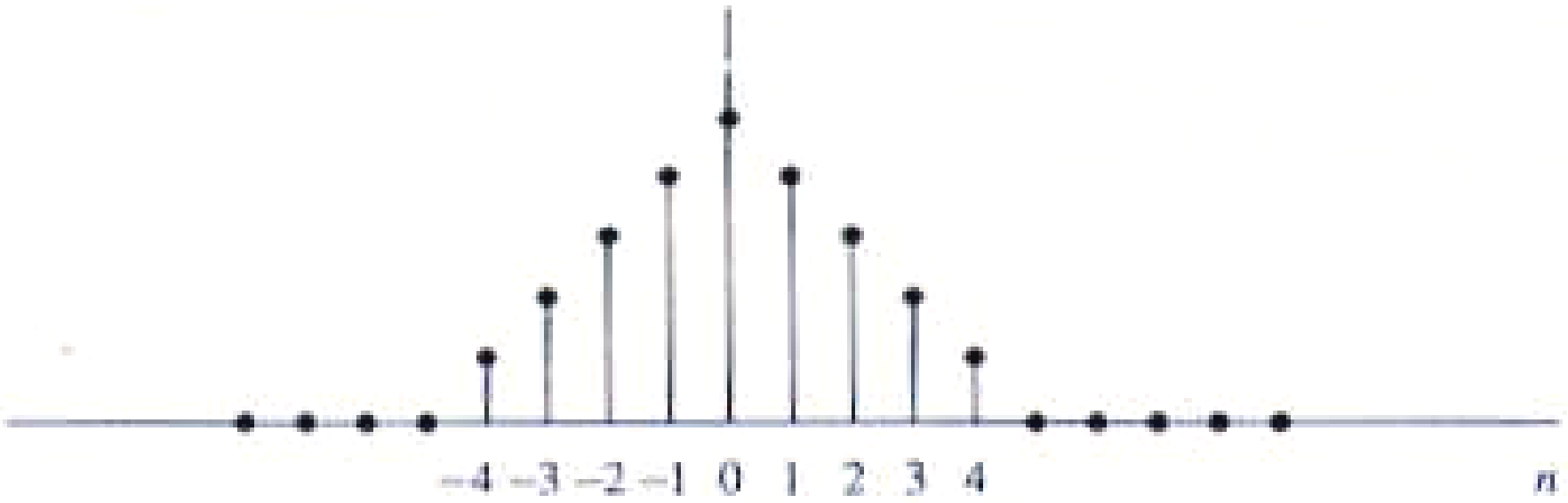
Daya dari sinyal x(n) $\longrightarrow$ $$P = \frac{1}{N}\sum_{n=0}^{N-1}\left|x(n)\right|^2$$

P terbatas :

Sinyal periodik = sinyal daya

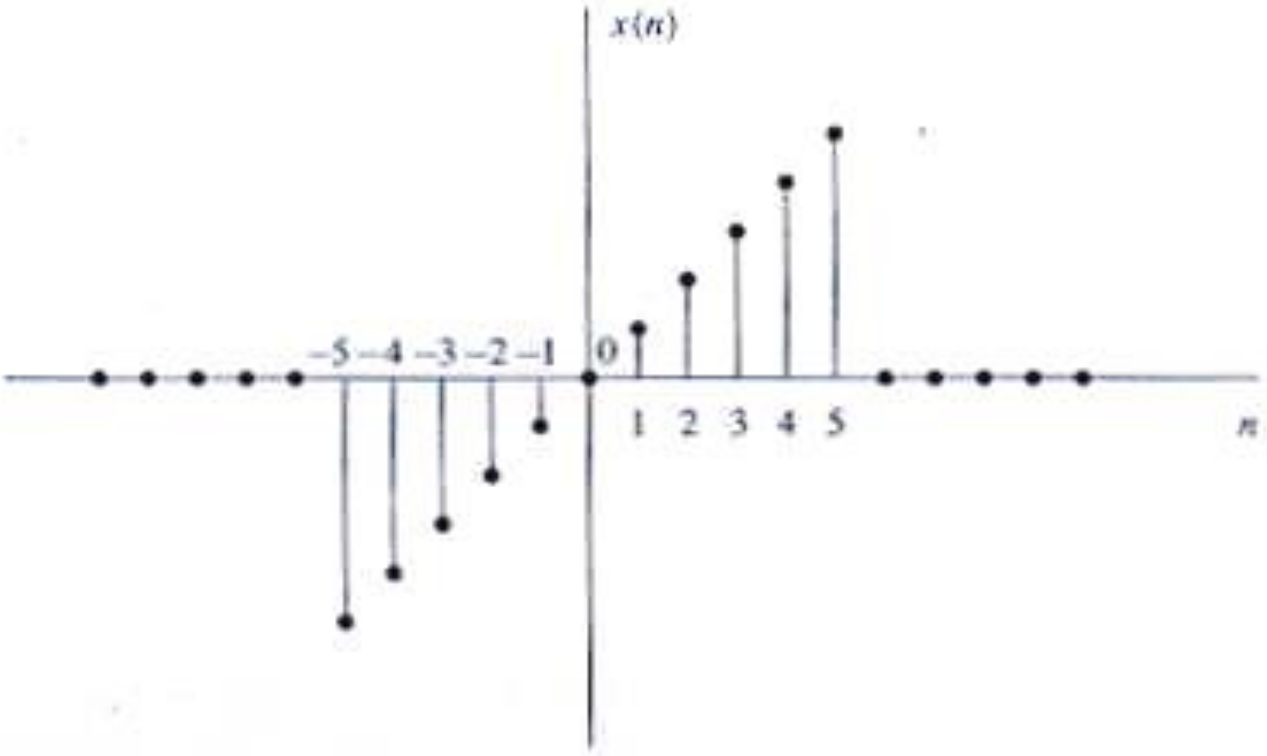
- **Sinyal Genap (Simetris)**

$$x(-n) = x(n)$$



- **Sinyal Ganjil (Antisimetris)**

$$x(-n) = -x(n)$$



Bila x(n) adalah sinyal sebarang :

$$x_e(n) = \frac{1}{2}[x(n) + x(-n)]$$

$$x_e(-n) = \frac{1}{2}[x(-n) + x(n)] = x_e(n)$$

$x_e(n)$ adalah sinyal genap

$$x_o(n) = \frac{1}{2}[x(n) - x(-n)]$$

$$x_o(-n) = \frac{1}{2}[x(-n) - x(n)] = -x_o(n)$$

$x_o(n)$ adalah sinyal ganjil

$$x_e(n) + x_o(n)$$

$$= \frac{1}{2}[x(n) + x(-n)] + \frac{1}{2}[x(n) - x(-n)]$$

$$= x(n)$$

Operasi-operasi Sinyal

- Time delay (pergeseran waktu)
- Folding (pencerminan)
- Time Scaling (skala waktu)

- **Time Delay**

$$y(n) = TD_k[x(n)]$$

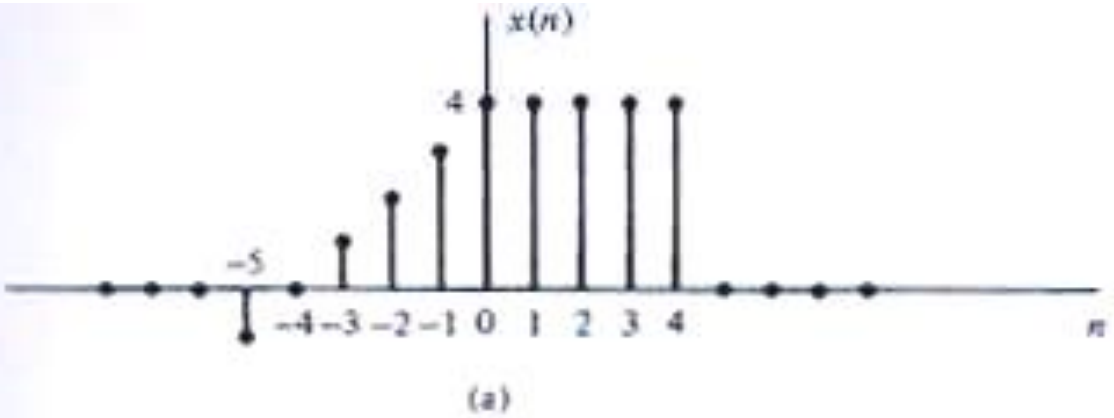
$$= x(n-k)$$

$$y(n) = TD_3[x(n)] = x(n-3)$$

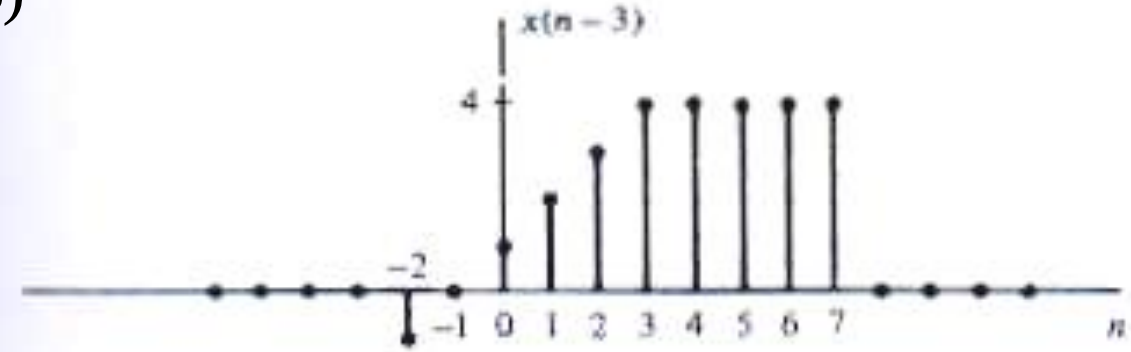
$$y(0) = x(0-3) = x(-3)$$

$$y(1) = x(1-3) = x(-2)$$

$x(n)$ **digeser ke kanan 3**



(a)



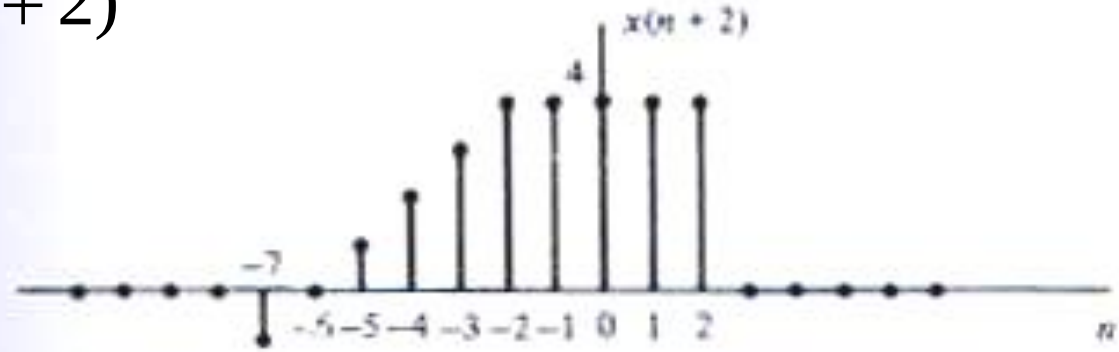
(b)

$$y(n) = TD_{-2}[x(n)] = x(n+2)$$

$$y(0) = x(0+2) = x(2)$$

$$y(1) = x(1+2) = x(3)$$

$x(n)$ **digeser ke kiri 2**



(c)

- **Folding**

$$y(n) = FD[x(n)] = x(-n)$$

$$y_1(n) = FD[x(n)] = x(-n)$$

$$y(1) = x(-1) = 2$$

$$y(-1) = x(1) = 1$$

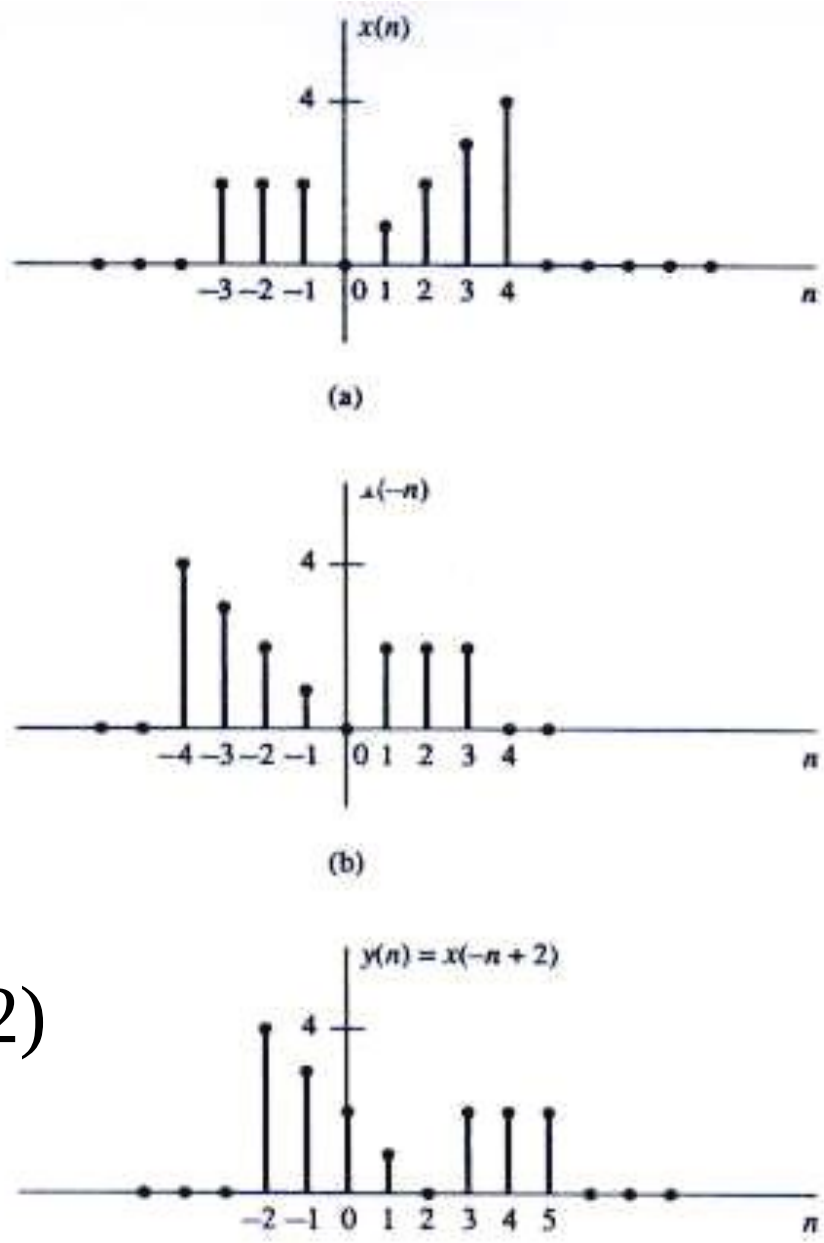
$x(n)$ **dicerminkan sumbu vertikal**

$$y_2(n) = TD_{-2}[y_1(n)]$$

$$= TD_{-2}[x(-n)]$$

$$= x(-n-(-2)) = x(-n+2)$$

$x(n)$ **dicerminkan, kemudian digeser ke kanan 2 satuan**



- **Time Scaling**

$$y(n) = x(\mu n)$$

$$y(n) = x(2n)$$

Contoh :

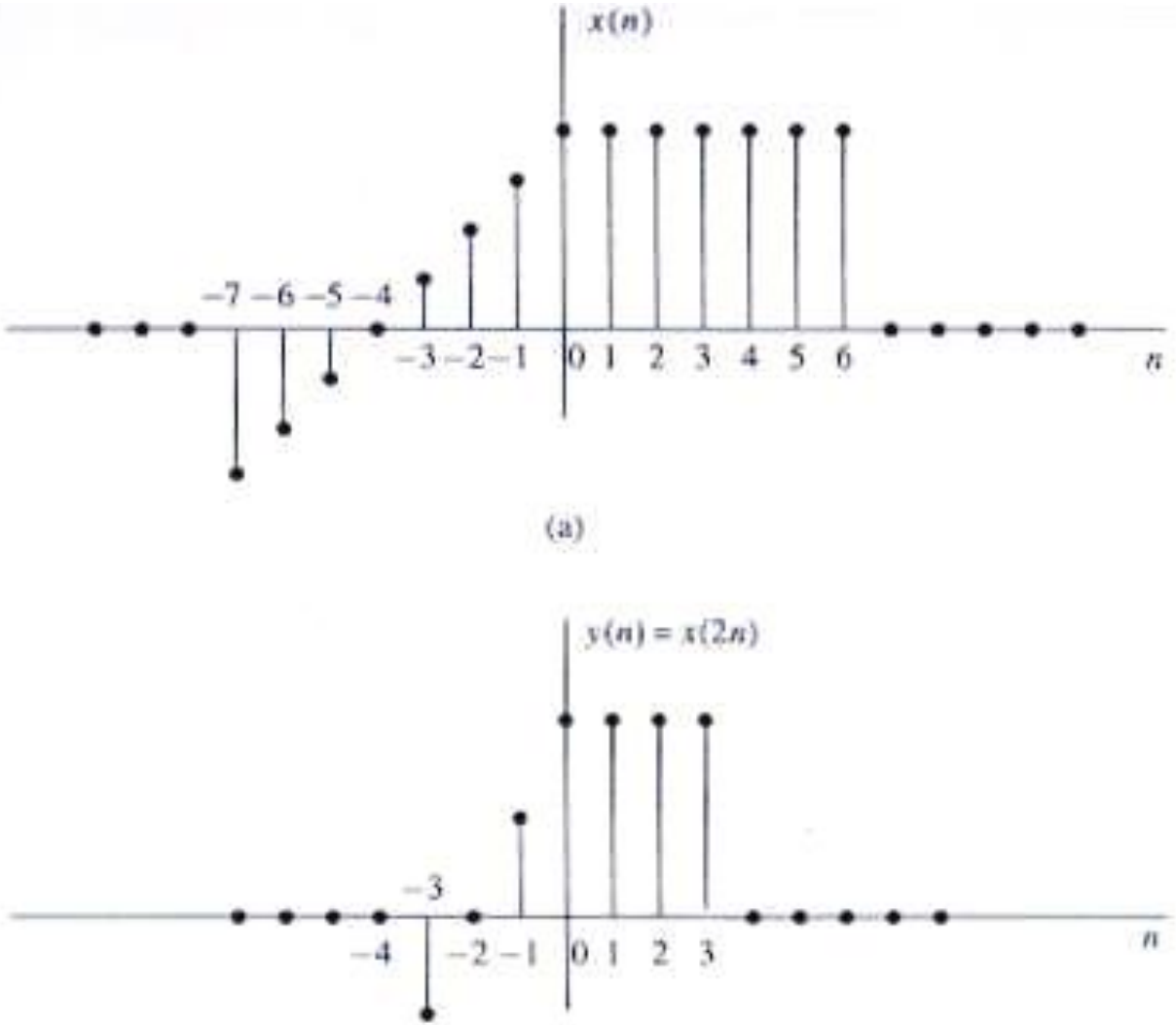
$$y(0) = x(0)$$

$$y(1) = x(2)$$

$$y(-1) = x(-2)$$

$$y(-2) = x(-4)$$

... dst



Contoh Soal 1

Diketahui suatu sinyal diskrit yang didefinisikan sebagai :

$$x(n) = \begin{cases} -n, & -2 \le n \le -1 \\ n-1, & 0 \le n \le 3 \\ 0, & n \ lainnya \end{cases}$$

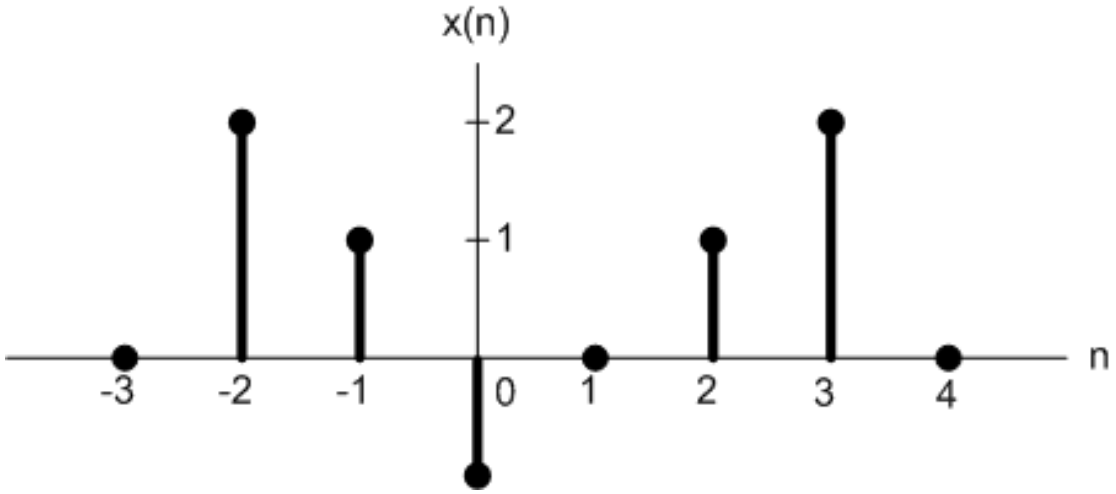
Gambarkan :

a. x(n) b. x(-n-2) c. x(-2n+4)

Jawab :

a.

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



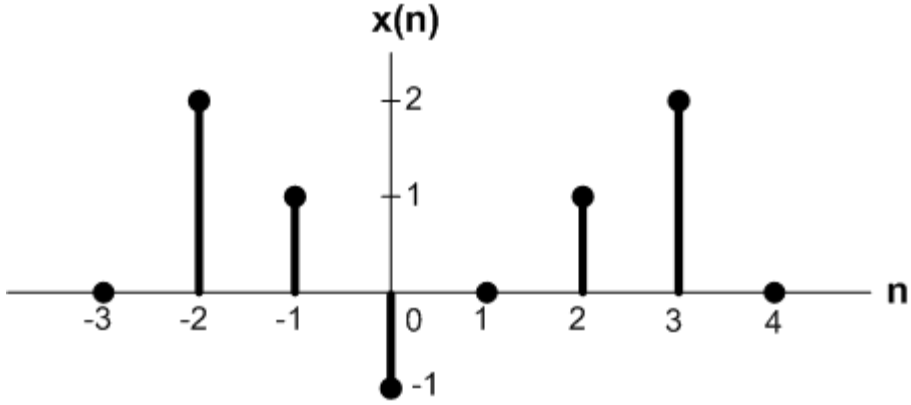
b. Gambarkan $x(-n-2)$

Cara 1. operasi sinyal

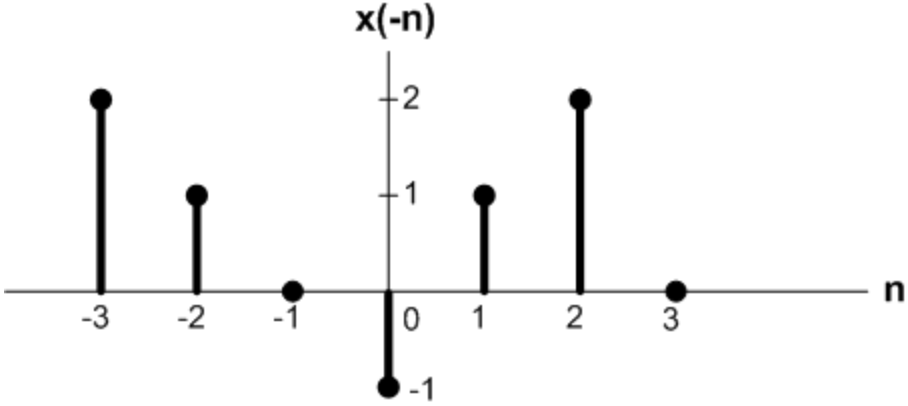
$$x(-n-2) = x(-(n+2))$$

cerminkan

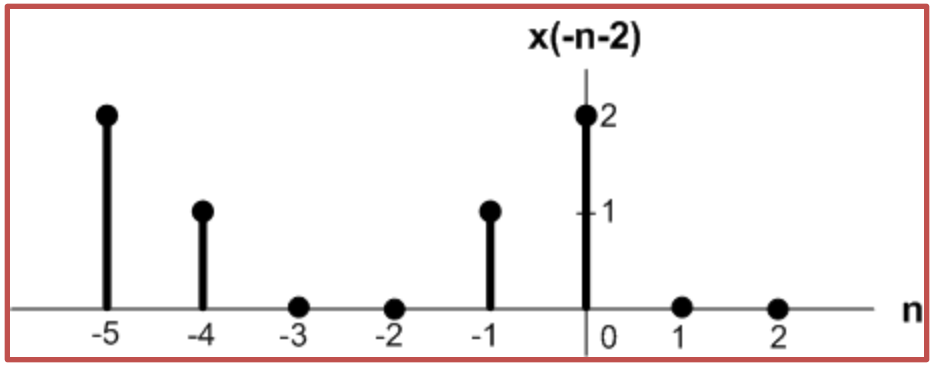
geser ke kiri 2 satuan



cerminkan



geser ke kiri 2 satuan



Cara 2. perhitungan

$$y(n) = x(-n-2)$$

$$y(-5) = x\big(-(-5)-2\big) = x(3) = 2$$

$$y(-4) = x(2) = 1$$

$$y(-3) = x(1) = 0$$

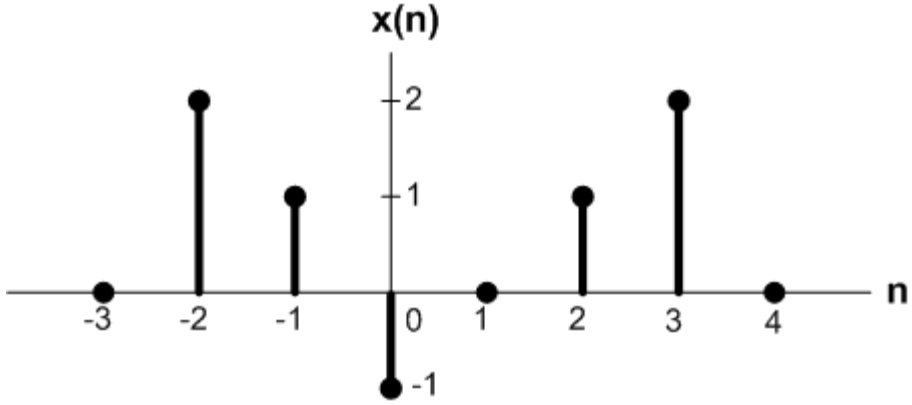
$$y(-2) = x(0) = -1$$

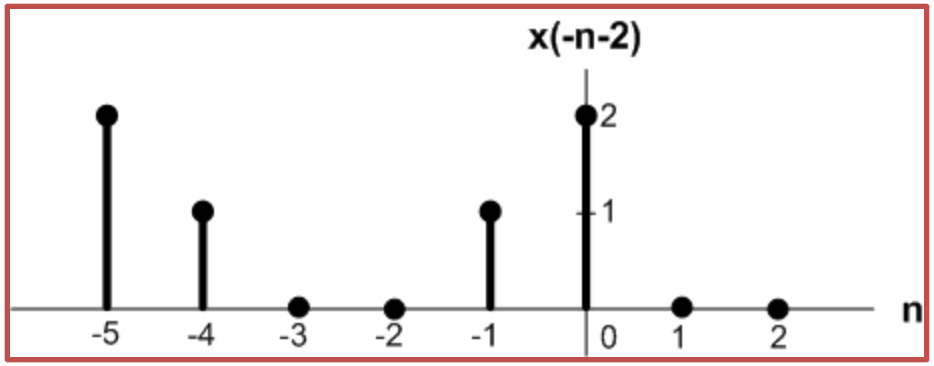
$$y(-1) = x(-1) = 1$$

$$y(0) = x(-2) = 2$$

$$y(1) = x(-1) = 0$$

$$y(2) = x(-4) = 0$$





c. Gambarkan $x(-2n+4)$

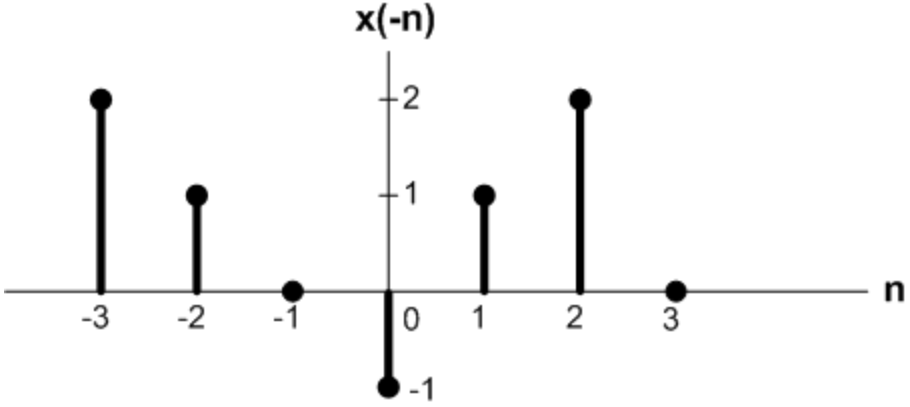
Cara 1. operasi sinyal

$$x(-2n+4) = x(-2(n-2))$$

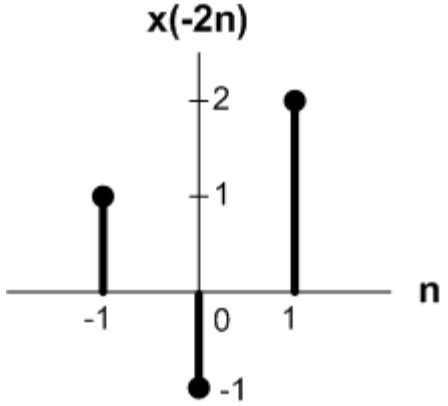
cerminkan

kompresi 2x

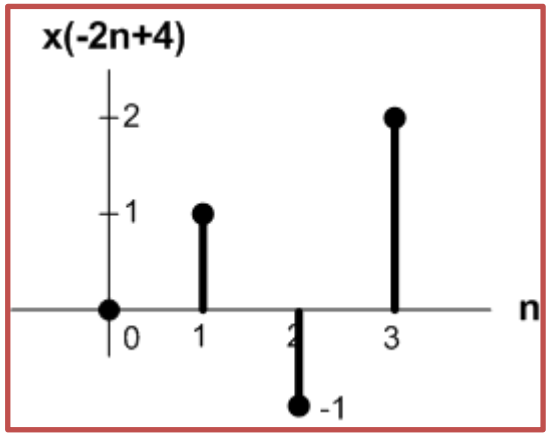
geser ke kanan 2 satuan



kompresi 2x



geser ke kanan 2 satuan



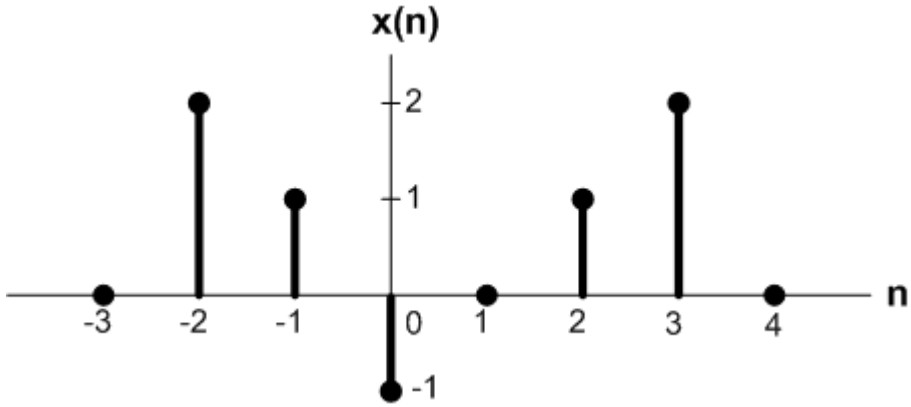
Cara 2. perhitungan

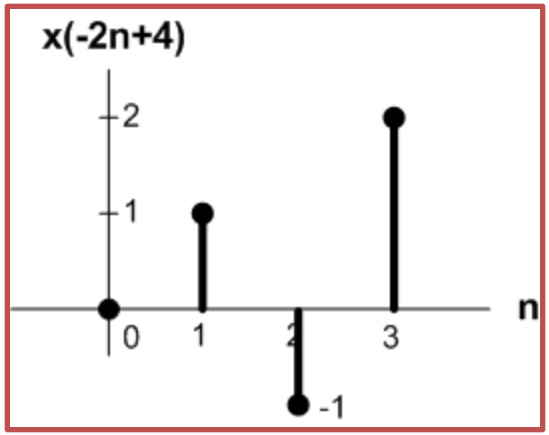
$$y(n) = x(-2n+4)$$

$$y(1) = x(-2.1+4) = x(2) = 1$$

$$y(2) = x(0) = -1$$

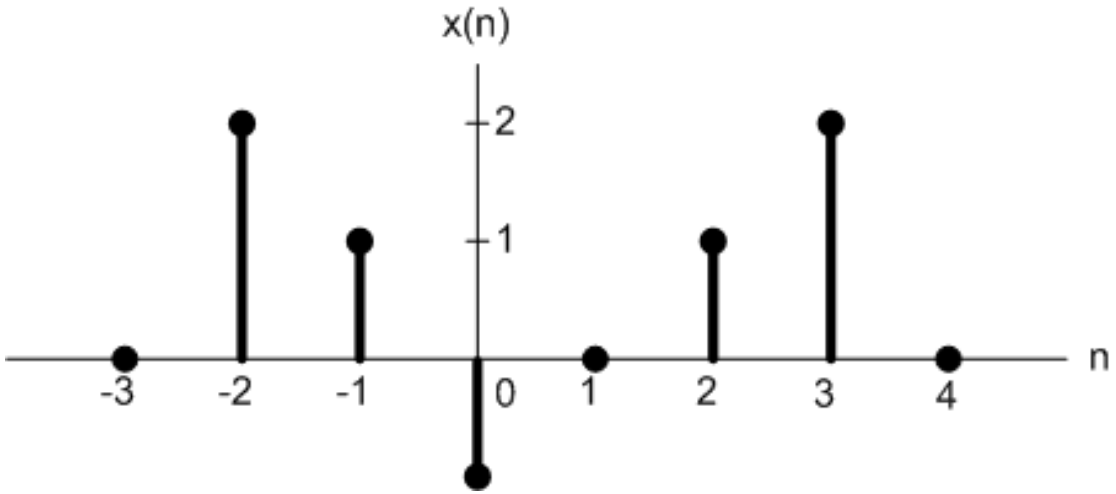
$$y(3) = x(-2) = 2$$





Contoh Soal 2

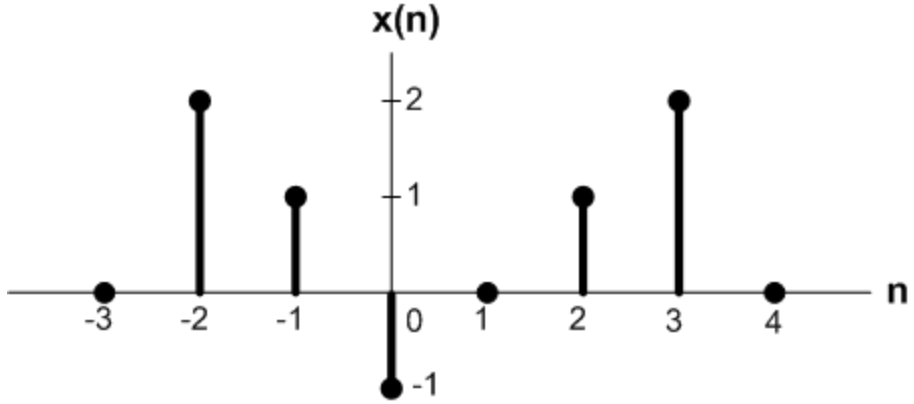
Diketahui suatu sinyal diskrit sebagai berikut :

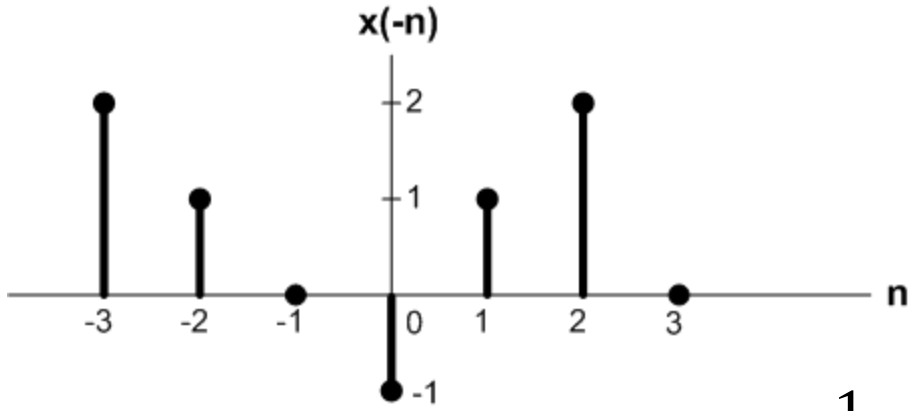


a. Gambarkan bagian genap dari $x(n)=x_e(n)$

b. Gambarkan bagian ganjil dari $x(n)=x_o(n)$

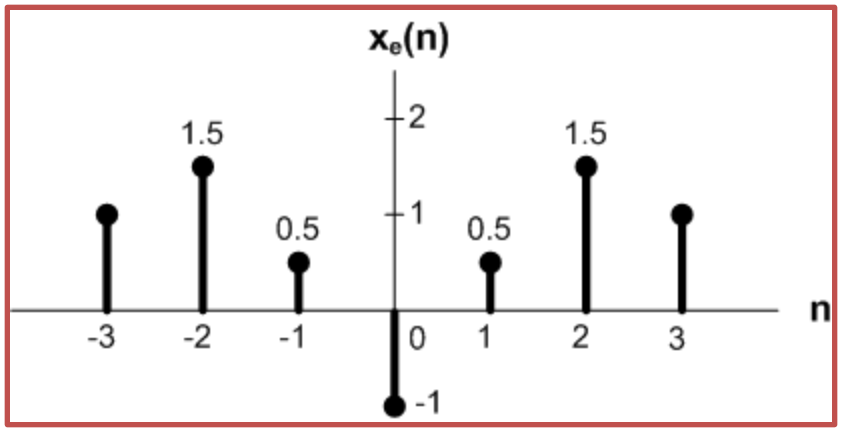
c. Jumlahkan kedua bagian ini, apakah sama dengan x(n)?

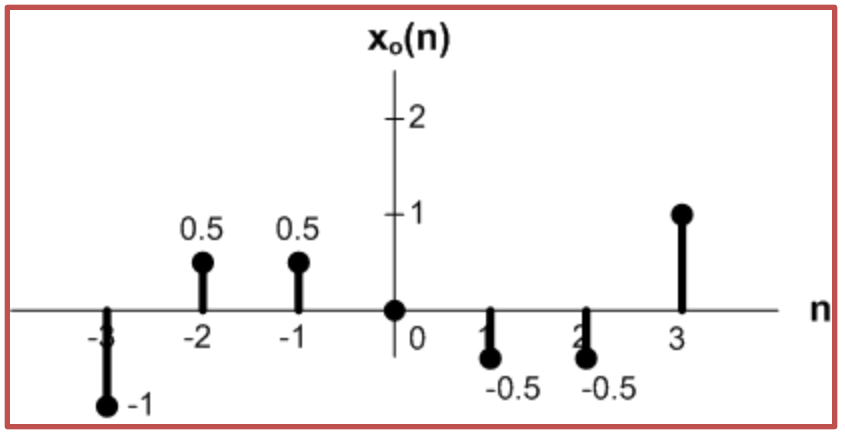


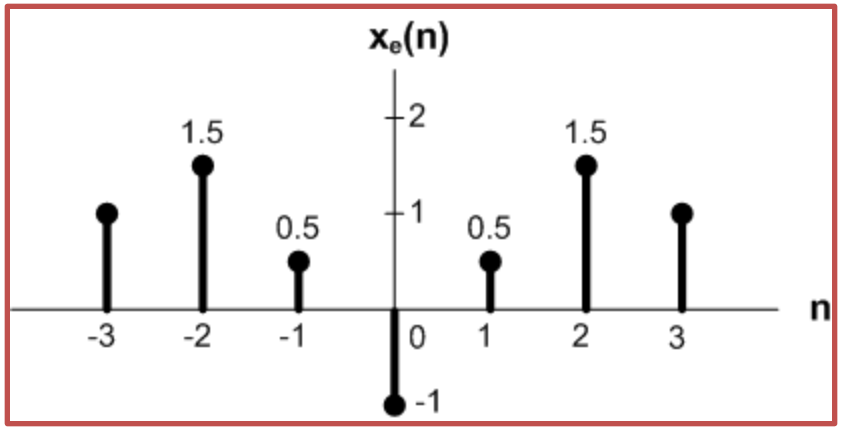


$$x_e(n) = \frac{1}{2}\left[x(n) + x(-n)\right]$$

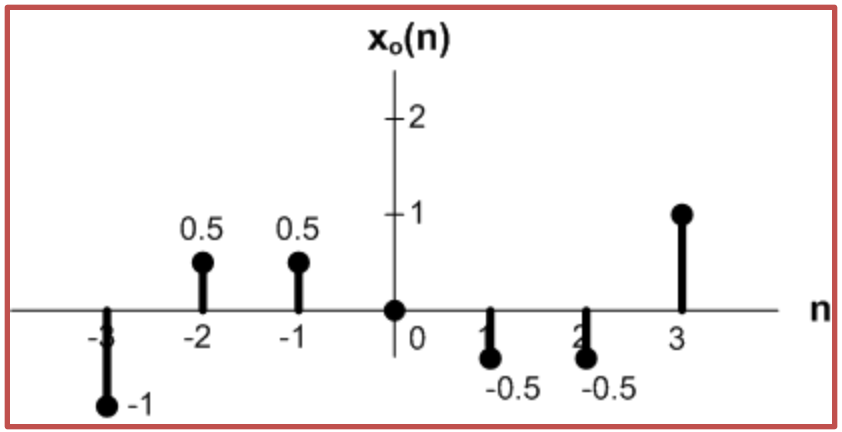
$$x_o(n) = \frac{1}{2}\left[x(n) - x(-n)\right]$$



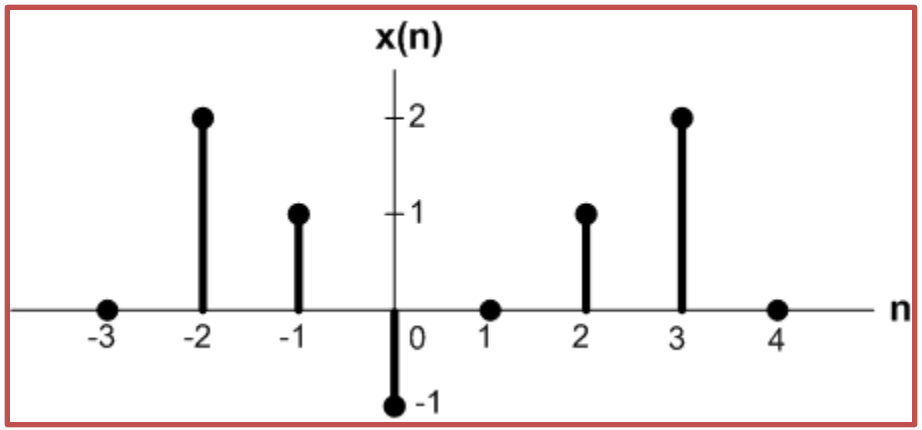



$x_e(n)$
2
1
1.5
1.5
0.5
0.5
-3
-2
-1
0
1
2
3
-1
n

+


$x_o(n)$
2
1
0.5
0.5
-2
-1
0
3
-1
-0.5
-0.5
n

=


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

$$x_e(n) + x_o(n) = x(n)$$

Contoh Soal 3

Gambarkan sinyal-sinyal berikut :

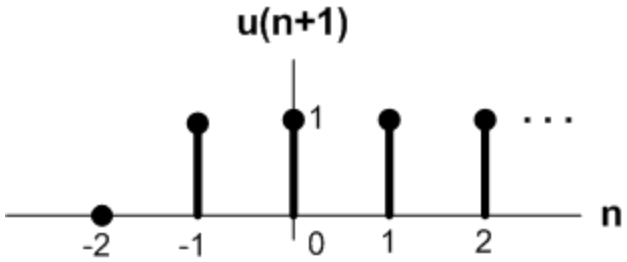
a. $x_1(n) = -u(-n-1)$

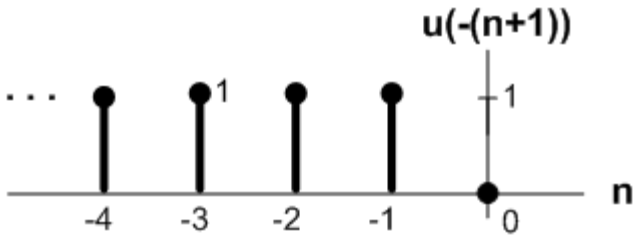
b. $x_2(n) = u(n) - u(n-2)$

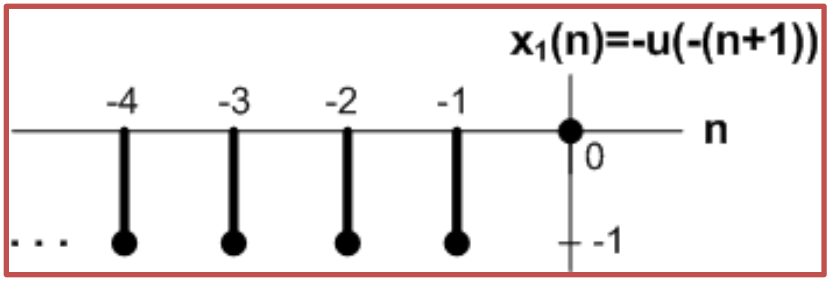
c. $x_3(n) = u(n+2) - u(n-1)$

a. $x_1(n) = -u(-n-1)$

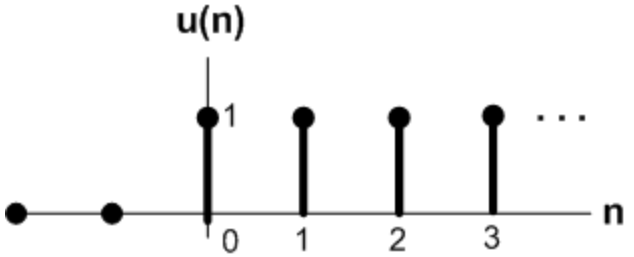
$= -u(-(n+1))$







b. $x_2(n) = u(n) - u(n-2)$



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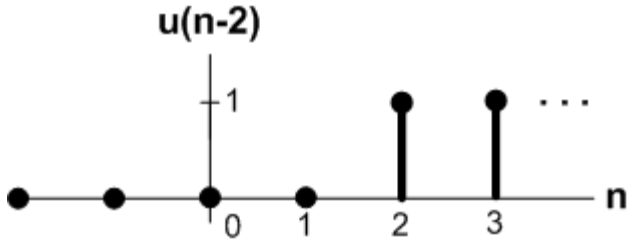

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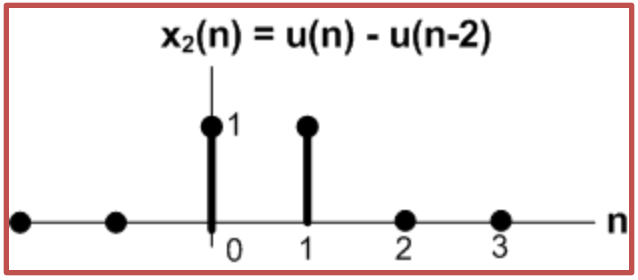
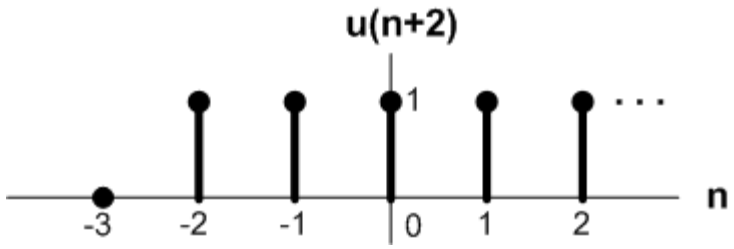


c. $x_3(n) = u(n+2) - u(n-1)$



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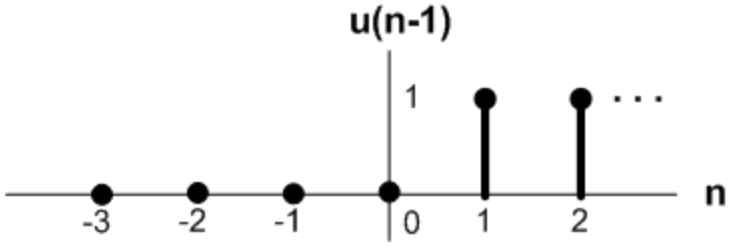

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