Signal & System

Week-1:
Intro, Ref, Journey, Sinyal, Sistem, Transformasi, Terms, Symbol

“**There is no royal road to mathematics**” -Menaechmus

@btatmaja
Adopted from “Sistem Linear” by D. Prananto

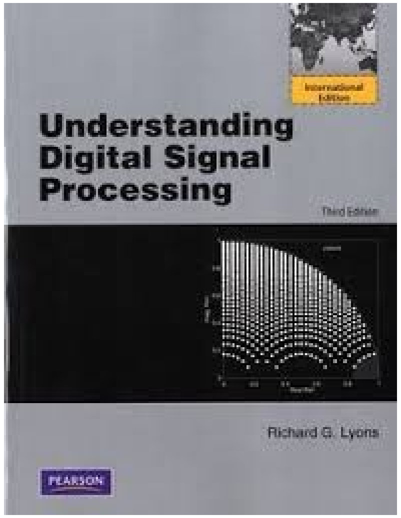
Referensi

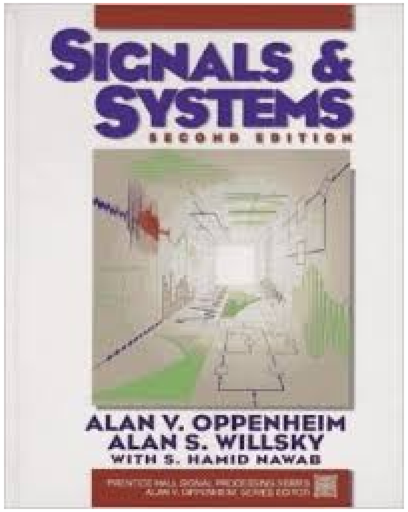
[1] Lyon, Understanding Digital Signal Processing.

[2] A. V. Oppenheim, A. S. Willsky, S. H. H. Nawab, *Sinyal dan Sistem jilid 1*, (Penerbit Erlangga, Jakarta, 2000)

[3] Wikipedia

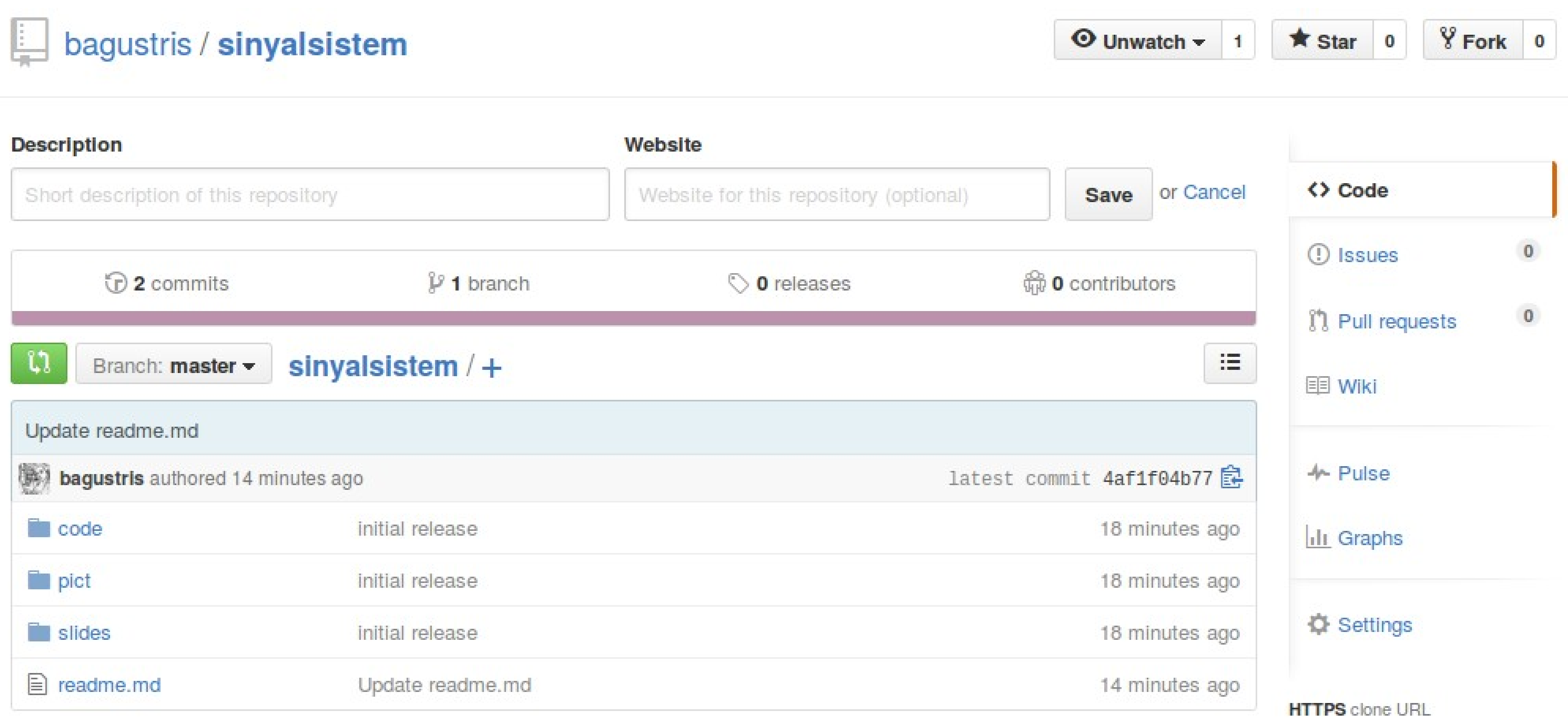
[4] Octave / MATLAB

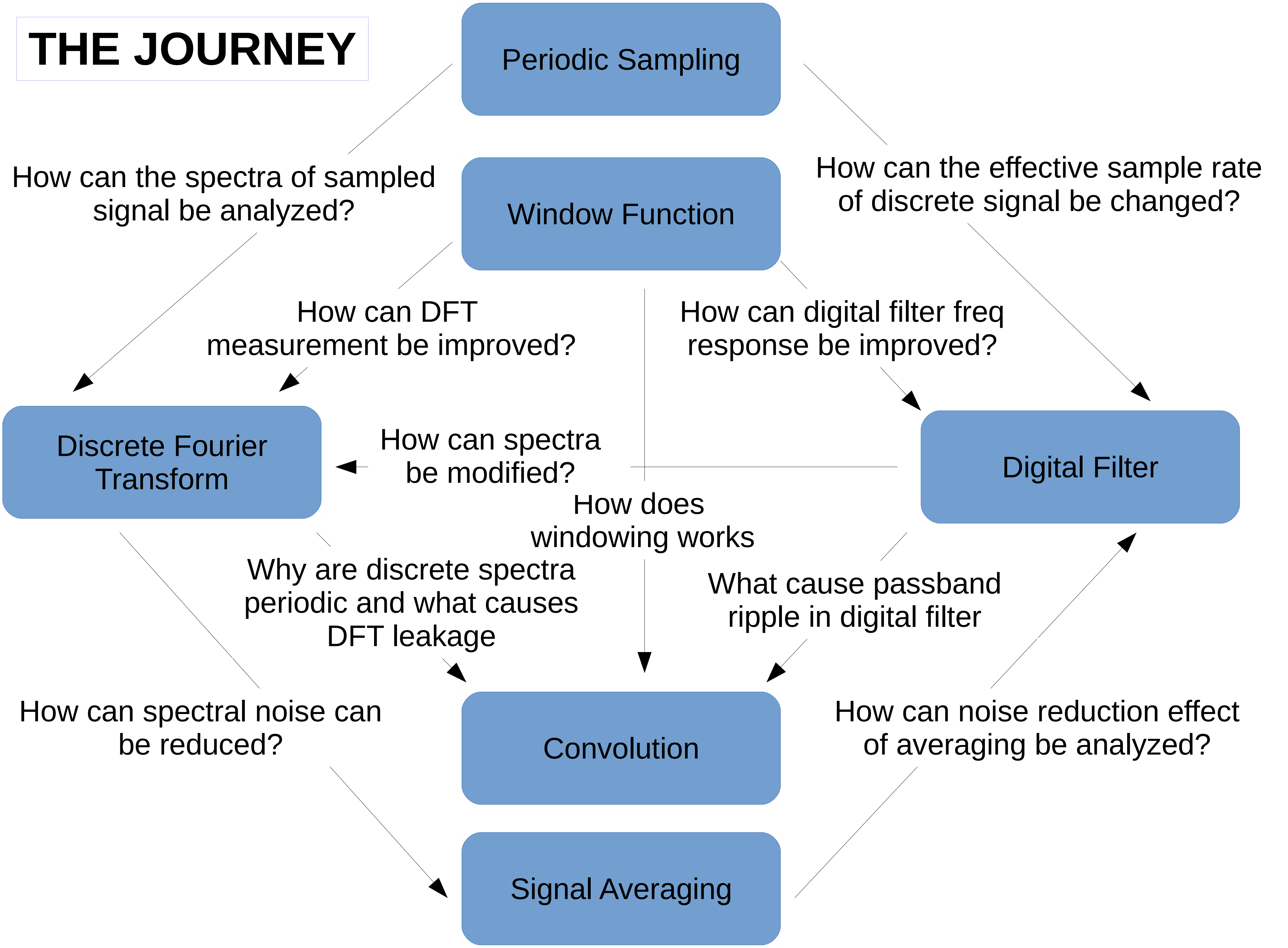




RESOURCES

https://github.com/bagustris/sinyalsistem

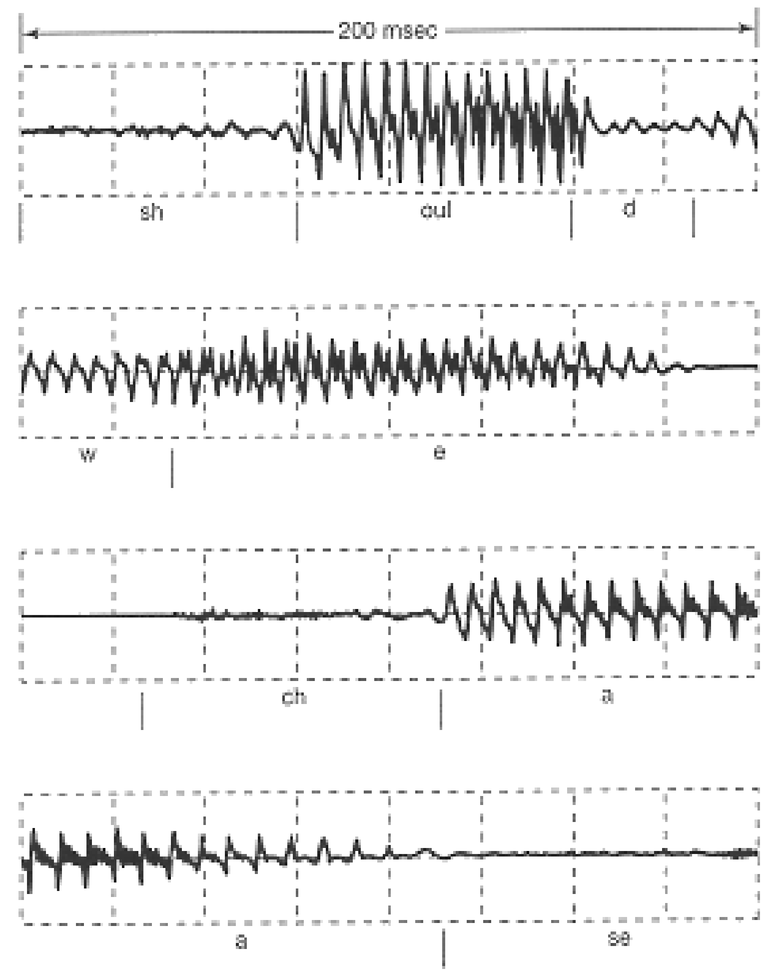



THE JOURNEY
Periodic Sampling
How can the spectra of sampled signal be analyzed?
Window Function
How can the effective sample rate of discrete signal be changed?
How can DFT measurement be improved?
How can digital filter freq response be improved?
Discrete Fourier Transform
How can spectra be modified?
Digital Filter
How does windowing works
Why are discrete spectra periodic and what causes DFT leakage
What cause passband ripple in digital filter
How can spectral noise can be reduced?
Convolution
How can noise reduction effect of averaging be analyzed?
Signal Averaging

Sinyal & sistem

SINYAL Pola-pola yang berubah/bervariasi terhadap satu atau lebih variabel bebas, yang di dalamnya terkandung informasi

Variasi tekanan akustik



Variasi kecerahan titik-titik terhadap posisi (2D)

Joseph Fourier (21 Maret 1768 – 16 Mei 1830)
(Kredit gambar: wikimedia commons)

Sinyal & sistem

SISTEM

Kumpulan beberapa komponen dengan fungsionalitas berbeda yang saling terhubung satu sama lain yang bekerja sama untuk mencapai suatu tujuan

ADA DI SEKITAR KITA

Sinyal & sistem

SINYAL & SISTEM, HUBUGANNYA?

sinyal masukan

sistem

sinyal Keluaran/ tanggapan

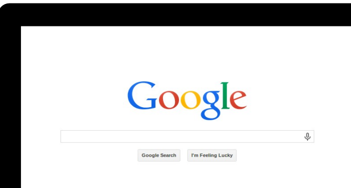
- *Car system*

Injakan Pedal gas

kecepatan

- *Google's Speech-to-text system*

Sinyal suara

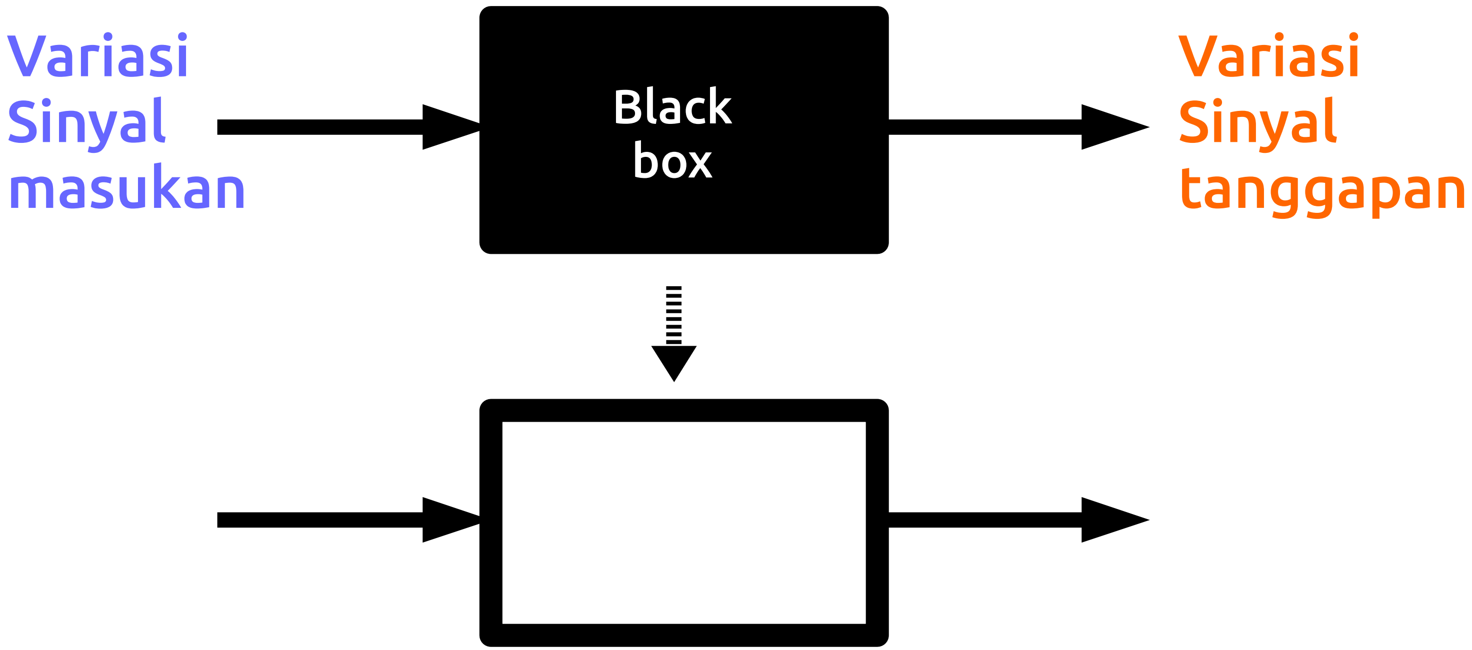


text

Sinyal & sistem

DENGAN KONSEP SINYAL & SISTEM,
Apa yang bisa diperbuat?

- Karakterisasi sistem

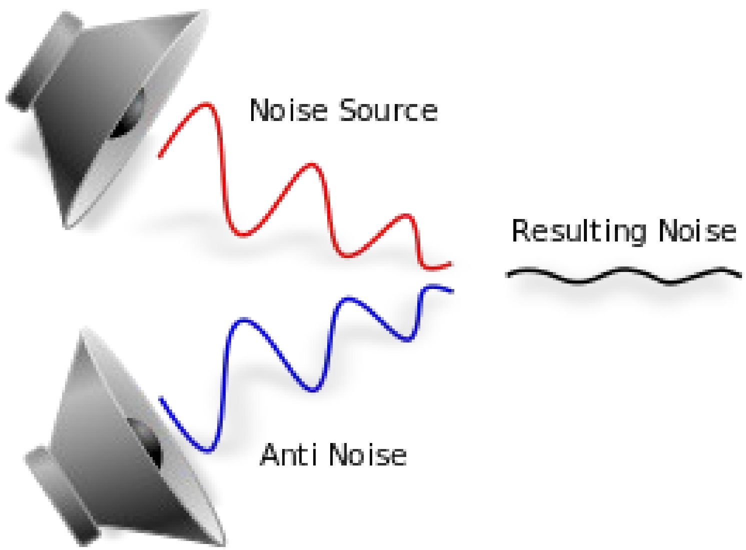


Sinyal & sistem

DENGAN KONSEP SINYAL & SISTEM,
Apa yang bisa diperbuat?

- Pemrosesan sinyal *(signal processing)*

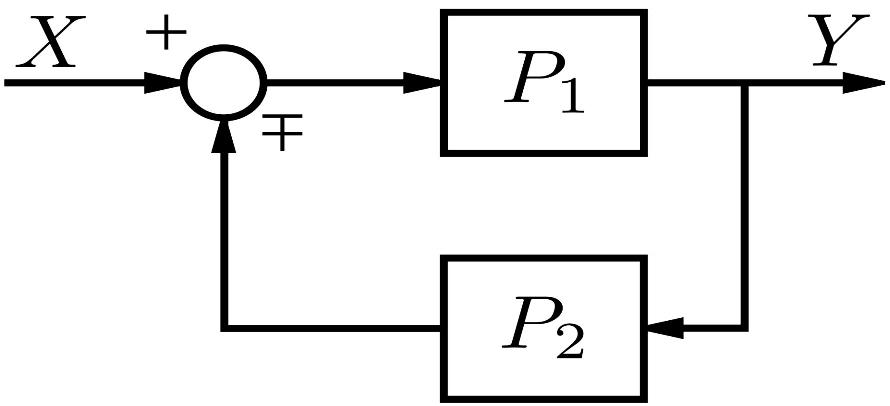
Active Noise Canceling



Sinyal & sistem

DENGAN KONSEP SINYAL & SISTEM,
Apa yang bisa diperbuat?

- Sistem kendali otomatik



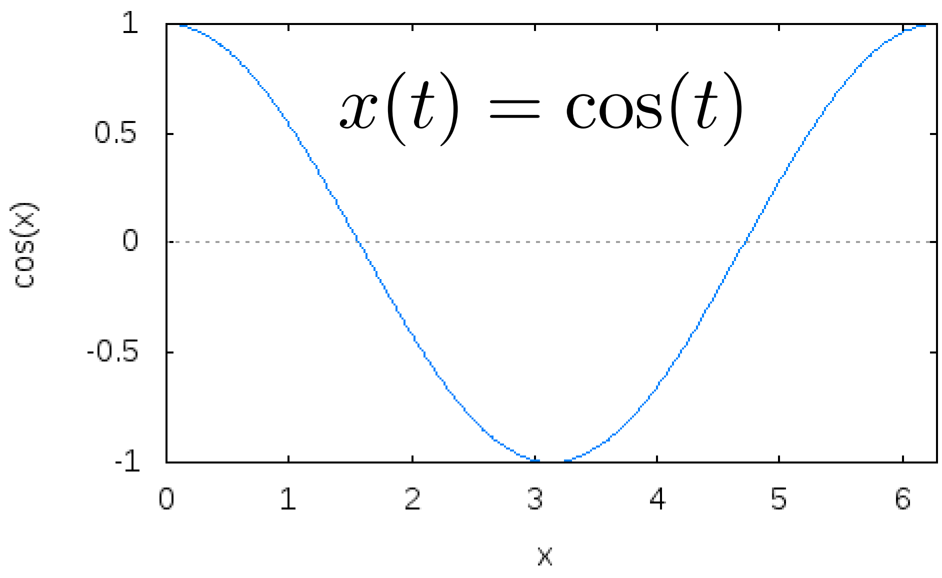
Sinyal & sistem

KATEGORI SINYAL

- Sinyal waktu-kontinu

Variabel bebas berubah secara kontinu

$x(t)$ ***t*** **merupakan variable bebas waktu-kontinu**



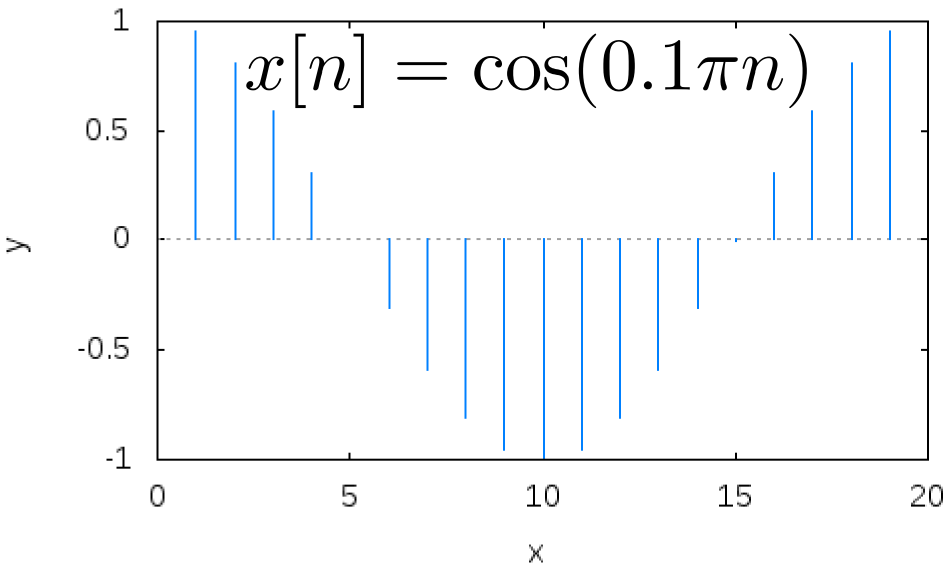
Sinyal & sistem

KATEGORI SINYAL

- Sinyal waktu-diskrit → Discrete Sequence

  Variabel bebas berubah secara diskrit

  $x[n]$ *n* merupakan variable bebas waktu-diskrit



Sinyal & sistem

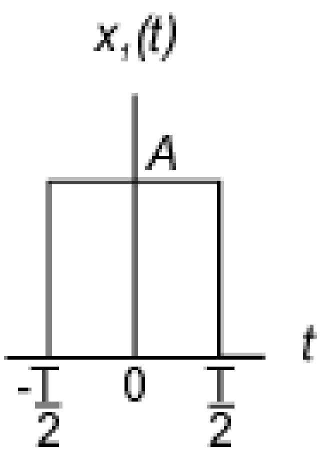
SINYAL GANJIL & GENAP

Sinyal genap

$$x(t)=x(t)$$ **Untuk semua *t***

Sinyal ganjil

$$x(t)=-x(t)$$ **Untuk semua *t***



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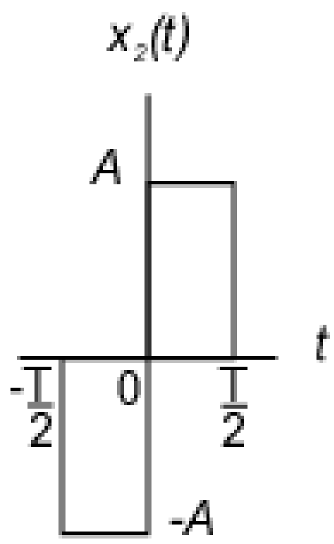


(b)

Sinyal genap
Simetris
Terhadap
Waktu asal

Sinyal ganjil
Tak-simetris
Terhadap
Waktu asal

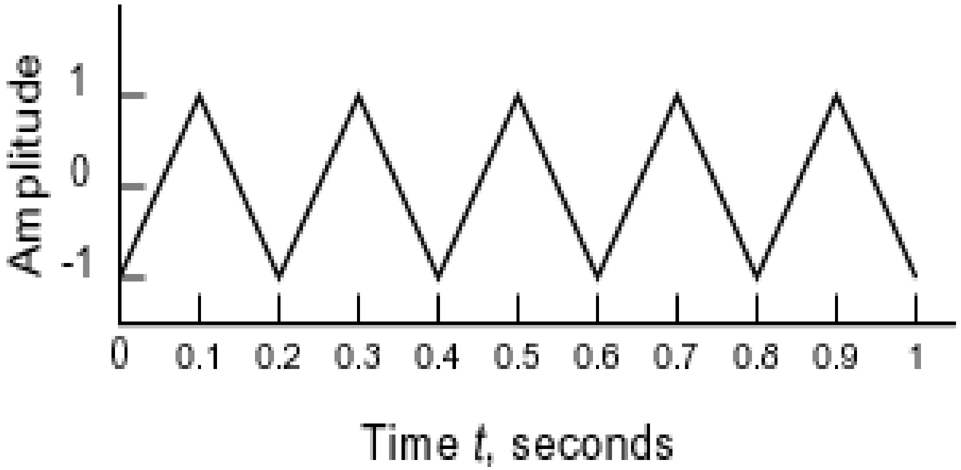
Sinyal & sistem

SINYAL PERIODIK

- Sinyal tak berubah dengan pergeseran waktu

kontinu

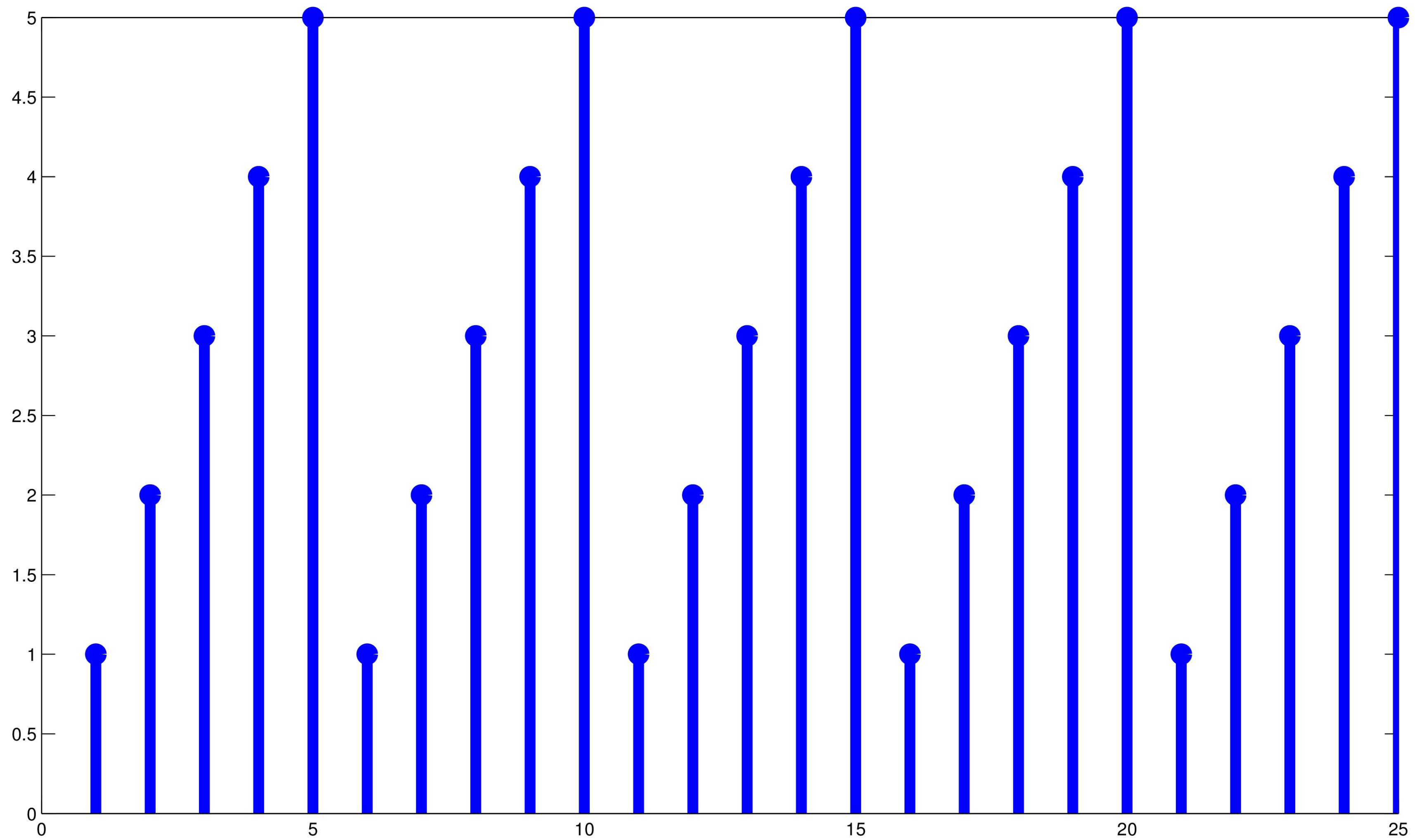
$$x(t) = x(t+T)$$ Untuk semua *t*



diskrit

$$x[n] = x[n+N]$$ Untuk semua *n*

Periodic Seq.



Sinyal & sistem

SINYAL EKSPONENSIAL REAL

- Bentuk umum

$$\boxed{x(t) = Ce^{at}}$$

- **C dan a bilangan real**

$a > 0 \rightarrow$ **Eksponensial meningkat**

$a < 0 \rightarrow$ **Eksponensi meluruh**

Plot:

$$x(t) = 4e^{0.5t}$$

dan

$$x(t) = 4e^{-0.5t}$$

Sinyal & sistem

SINYAL EKSPONENSIAL KOMPLEKS PERIODIK

Merupakan sinyal periodik

$$x(t) = e^{j\omega_0 t}$$

- **C bilangan real**
- **a bilangan imajiner**

Periode Dasar →

$$T = \frac{2\pi}{\omega_0}$$

Bukti periodik

$$x(t) = e^{j\omega_0 (t+T)}$$

$$x(t) = e^{j\omega_0 t} e^{j\omega_0 T}$$

Syarat periodik

$$e^{j\omega_0 T} = 1$$

Sinyal & sistem

SINYAL EKSPONENSIAL KOMPLEKS UMUM

- C dan a bilangan kompleks dengan bentuk berbeda

$$C = |C|e^{j\phi} \quad \rightarrow \text{bentuk polar}$$

$$a = r + j\omega_0 \quad \rightarrow \text{bentuk rektangular}$$

$$\boxed{Ce^{at} = |C|e^{j\phi}e^{(r+j\omega_0)t} = |C|e^{rt}e^{j(\omega_0 t+\phi)}}$$

Sinyal & sistem

SINYAL EKSPONENSIAL KOMPLEKS UMUM

Bentuk hubungan Euler

$$Ce^{at} = |C|e^{rt}\cos(\omega_0 t + \phi) + j|C|e^{rt}\sin(\omega_0 t + \phi)$$

Plot:

$$x(t) = 4e^{-0.5t}\cos(2\pi t) \quad r < 0 \rightarrow \text{sinyal sinusoidal meluruh}$$
$$x(t) = 4e^{0.5t}\cos(2\pi t) \quad r > 0 \rightarrow \text{sinyal sinusoidal meningkat}$$

Sinyal & sistem

KARAKTERISTIK SINYAL EKSPONENSIAL WAKTU-KONTINU

Karakteristik	C	a
Sinyal eksponensial real	real	real
Sinyal eksponensial kompleks periodik	real	imajiner
Sinyal eksponensial kompleks umum	kompleks	kompleks

Sinyal & sistem

SINYAL EKSPONENSIAL KOMPLEKS WAKTU-DISKRIT

- Bentuk umum

$$\boxed{x[n] = C\alpha^n} \quad \text{atau} \quad \boxed{x[n] = Ce^{\beta n}}$$

dimana $\alpha = e^{\beta}$

Sinyal & sistem

SINYAL EKSPONENSIAL REAL WAKTU-DISKRIT

$$\boxed{x[n] = C\alpha^n}$$

Karakteristik:

$\alpha > 1 \rightarrow$ Eksponensial meningkat

$0 < \alpha < 1 \rightarrow$ Eksponensial meluruh

$\alpha = 1 \rightarrow$ Konstan dengan amplituda +C

$\alpha = -1 \rightarrow$ Konstan dengan amplituda -C

$-1 < \alpha < 0 \rightarrow$ Eksponensial meluruh dengan amplituda bergantian antara +C dan -C

$\alpha < -1 \rightarrow$ Eksponensial meningkat dengan amplituda bergantian antara +C dan -C

Sinyal & sistem

SINYAL EKSPONENSIAL KOMPLEKS WAKTU-DISKRIT

C dan α bilangan kompleks dengan bentuk polar

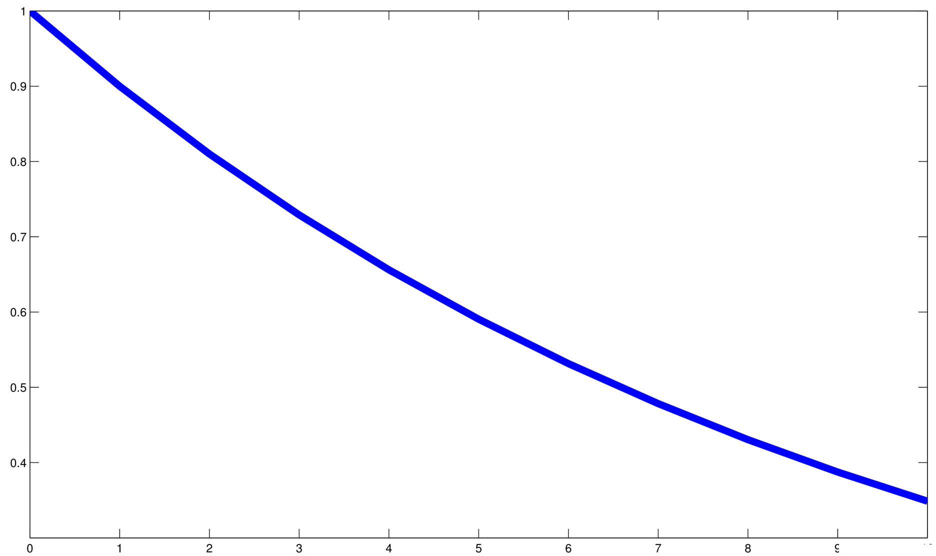
$$\boxed{\begin{aligned} C &= |C|e^{j\phi} \\ \alpha &= |\alpha|e^{j\omega_0} \end{aligned}}$$

$$\boxed{C\alpha^n = |C||\alpha|^n \cos(\omega_0 n + \phi) + j|C||\alpha|^n \sin(\omega_0 n + \phi)}$$

$$|\alpha| < 1 \ \rightarrow \ \text{Sinusoidal waktu-diskrit meluruh}$$

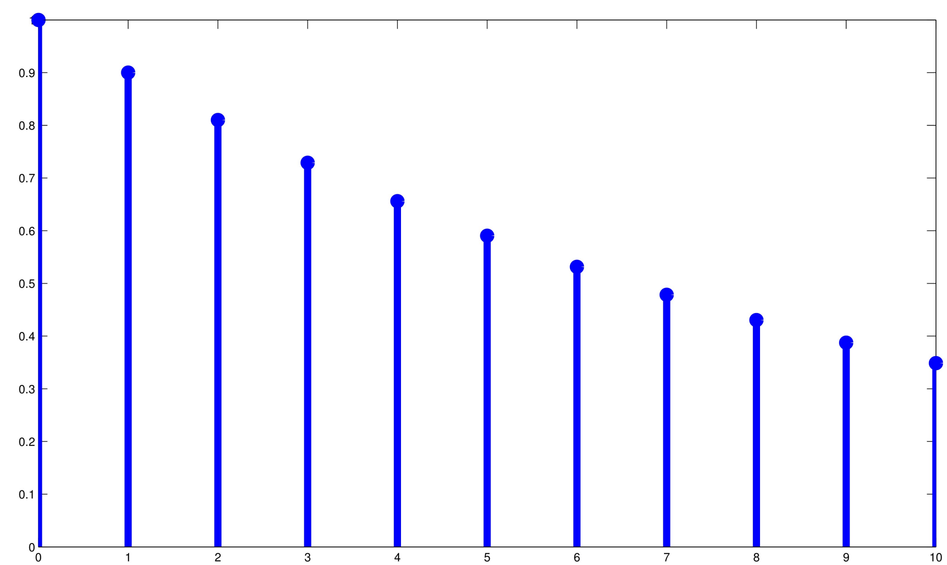
$$|\alpha| > 1 \ \rightarrow \ \text{Sinusoidal waktu-diskrit meningkat}$$

Exponential Signal



Sinyal Eksponensial Real Kontinyu

Sinyal Eksponensial Real Diskrit



Sinyal & sistem

SINYAL SINUSOIDAL

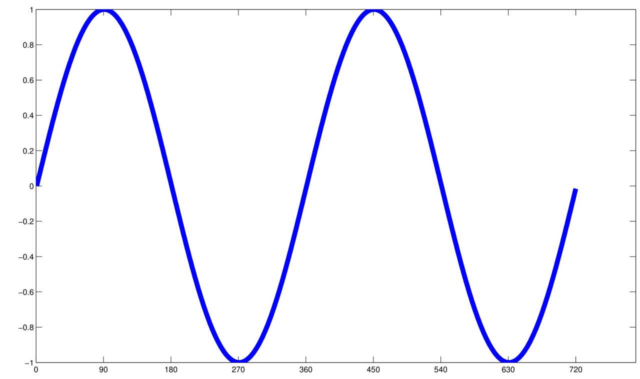
- **Bentuk umum**

$$\boxed{x(t) = A\cos(\omega_0 t + \phi)}$$

A → Amplituda

ω_0 → Frekuensi sudut (rad/s)

ϕ → Fase (rad)



Plot:

$$x(t)=2\cos(2\pi t+\pi/6)$$

Hubungan Euler

$$\boxed{e^{j\omega_0 t} = \cos\omega_0 t + j\sin\omega_0 t}$$

Sinyal & sistem

SINYAL SINUSOIDAL WAKTU-DISKRIT

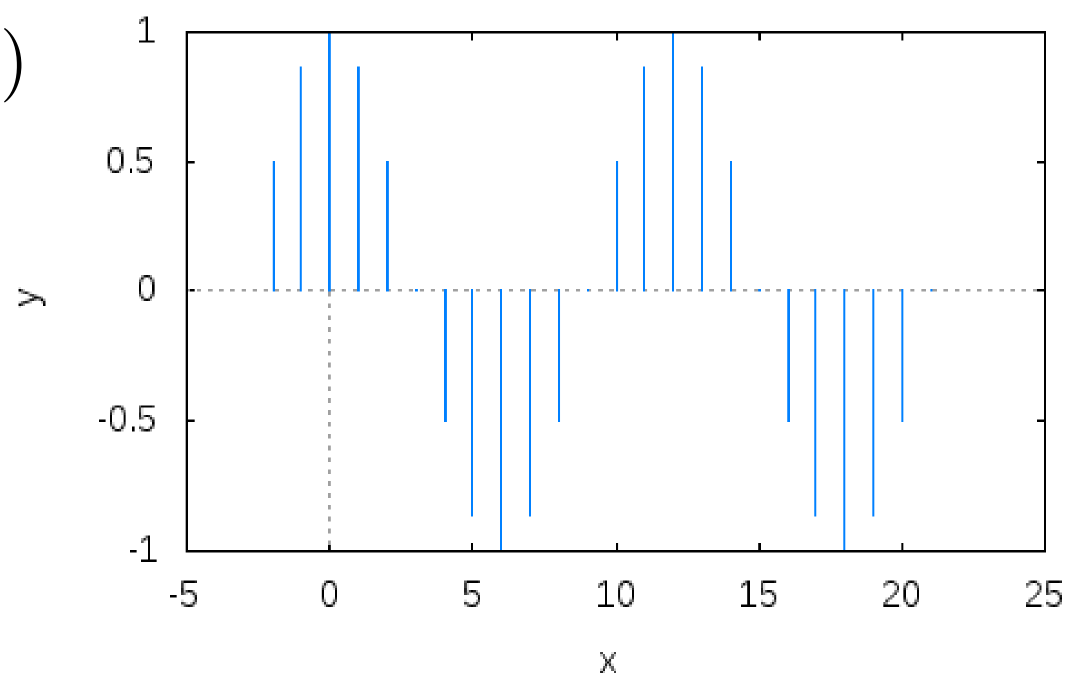
$$\boxed{x[n] = A\cos(\omega_0 n + \phi)}$$

Hubungan Euler

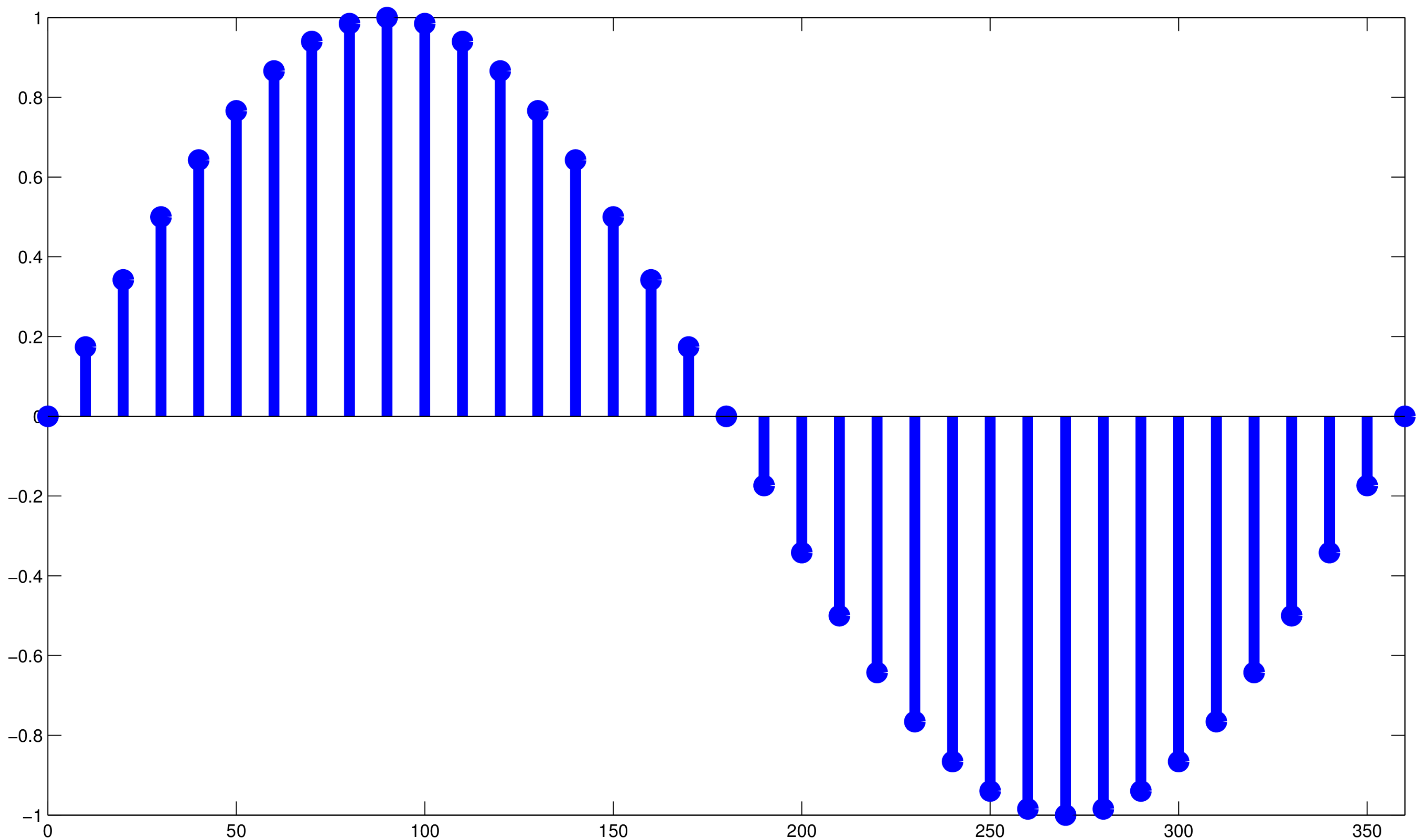
$$x[n] = e^{j\omega_0 n} = \cos\omega_0 n + j\sin\omega_0 n$$

$$\text{periode dasar} \;\rightarrow\; N = m\left(\frac{2\pi}{\omega_0}\right)$$

$$x[n] = \cos(2\pi n/12)$$



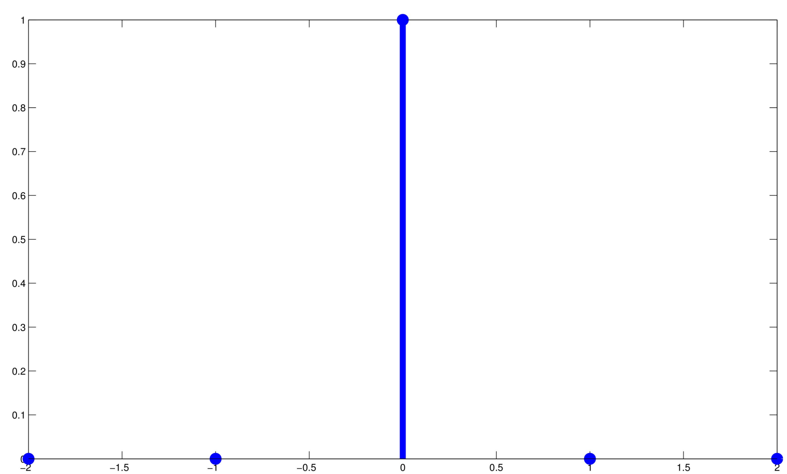
Sinusoidal Seq.

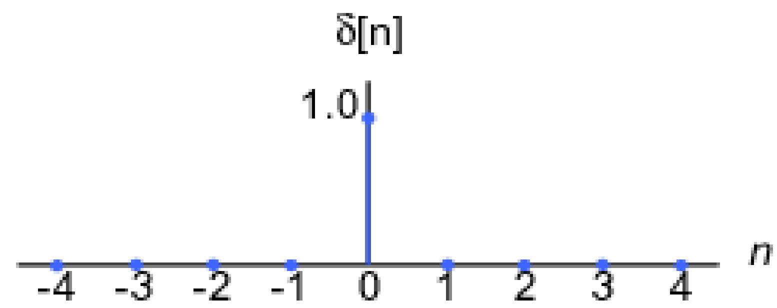


Sinyal & sistem

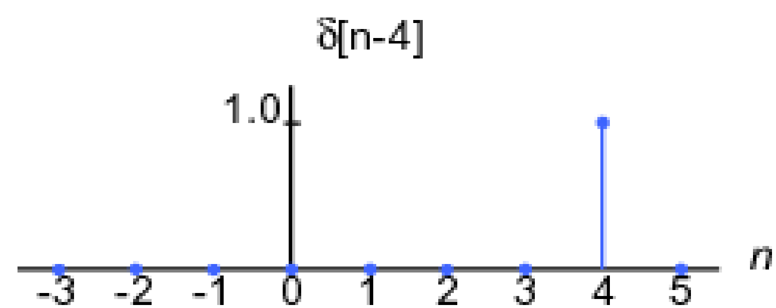
SINYAL IMPULS WAKTU-DISKRIT

$$\delta[n] = \begin{cases} 0, & n \neq 0 \\ 1 & n = 0 \end{cases}$$



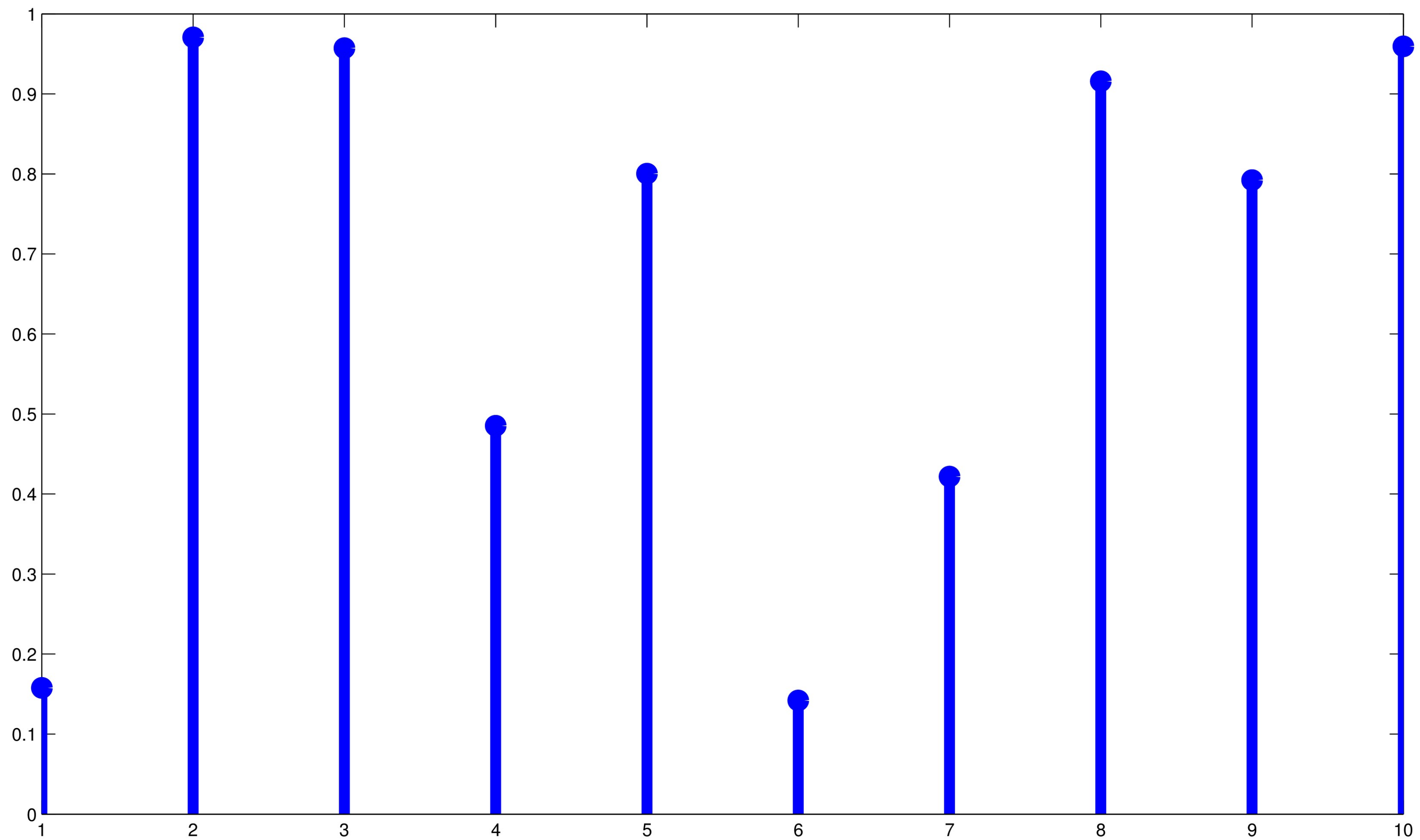


(a)



(b)

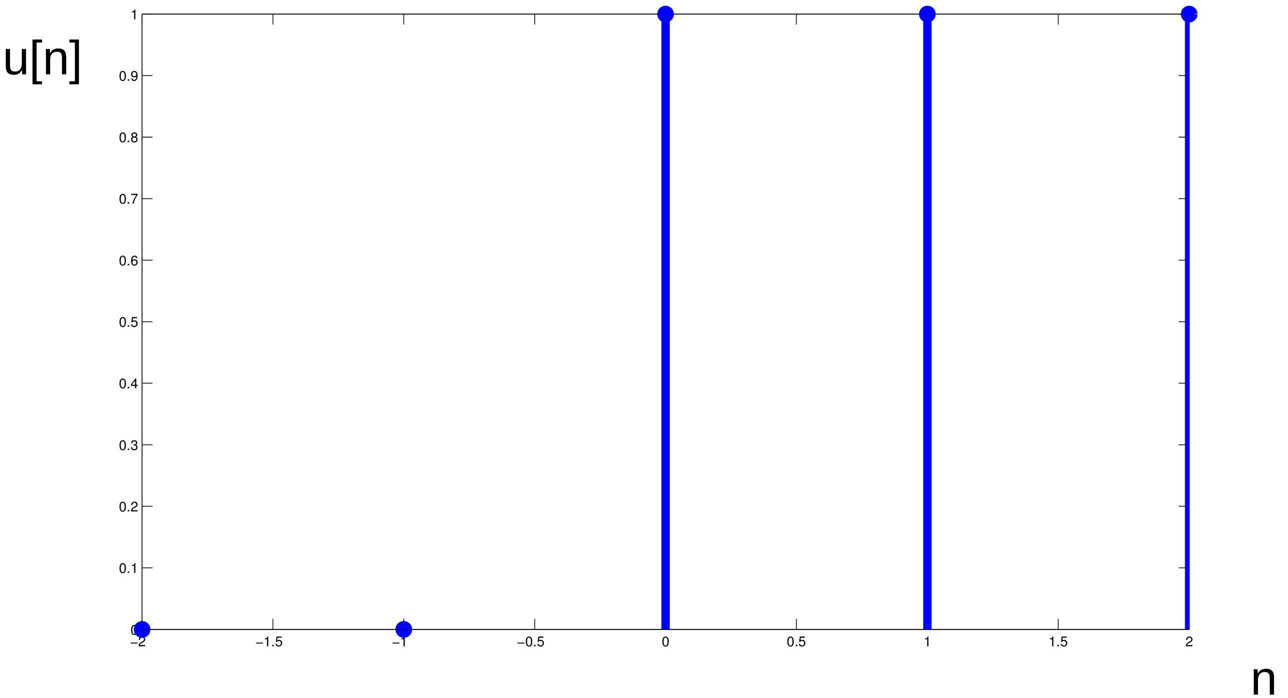
Random Seq.



Sinyal & sistem

SINYAL STEP WAKTU-DISKRIT

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



Sinyal & sistem

HUBUNGAN SINYAL IMPULS & STEP WAKTU-DISKRIT

- **Sinyal impuls adalah perbedaan pertama dari sinyal step**

$$\delta[n] = u[n] - u[n-1]$$

- **Sinyal step adalah jumlahan sinyal impuls**

$$u[n] = \sum_{m=-\infty}^{n} \delta[m] = \sum_{k=0}^{\infty} \delta[n-k]$$

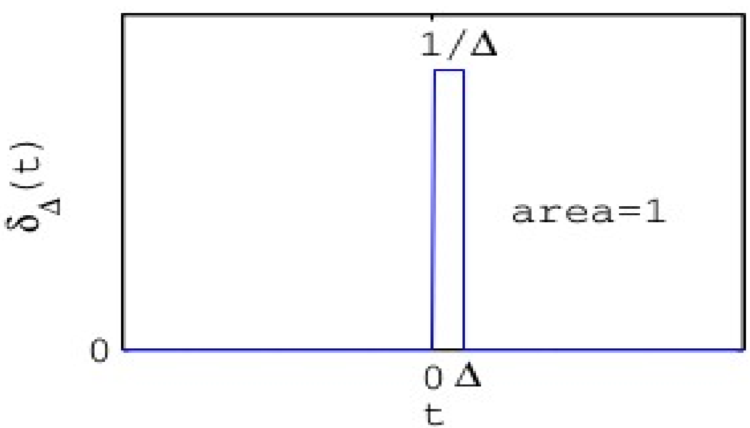
Sinyal & sistem

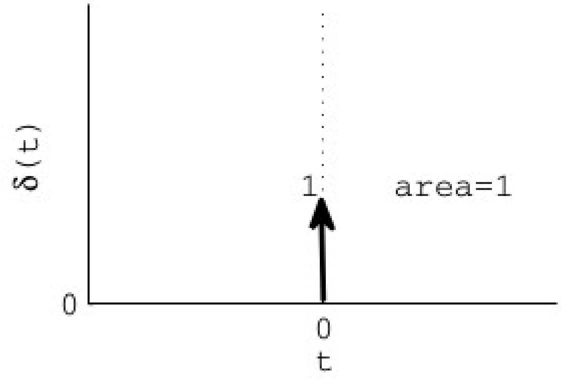
SINYAL IMPULS WAKTU-KONTINU

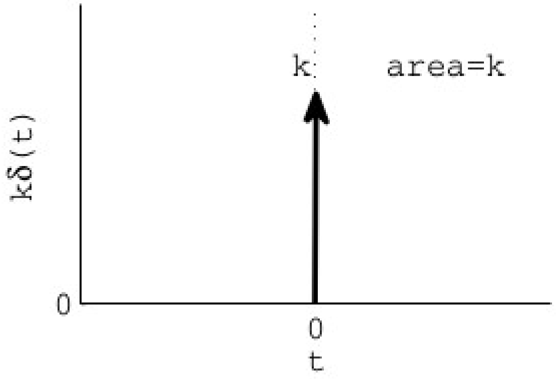
$$\boxed{\delta(t) = \lim_{\Delta \to 0} \delta_{\Delta}(t)}$$

dimana

$$\delta_{\Delta t} = \frac{u(t) - u(t-\Delta)}{\Delta}$$



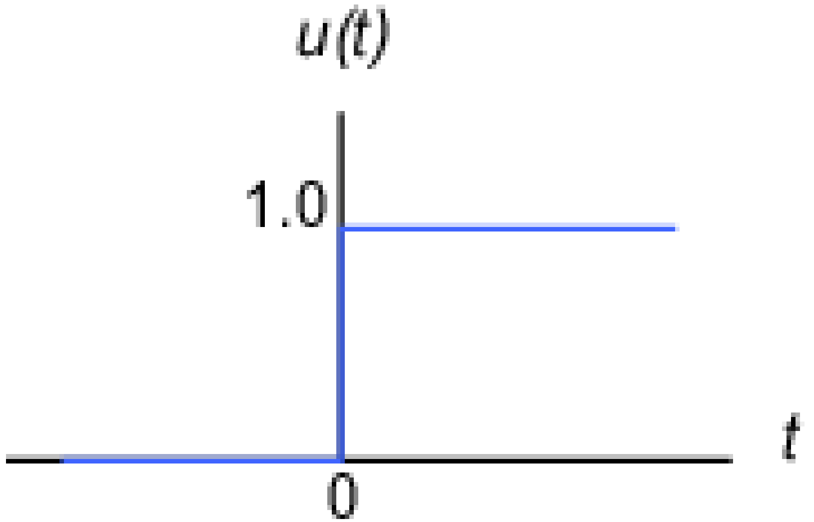




Sinyal & sistem

SINYAL STEP WAKTU-KONTINU

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



Sinyal & sistem

HUBUNGAN SINYAL IMPULS & STEP WAKTU-KONTINU

- **Sinyal step adalah integrasi sinyal pulsa**

$$u(t) = \int_{-\infty}^{t} \delta(\tau)d\tau = \int_{0}^{\infty} \delta(t-\tau)d\tau$$

- **Sinyal pulsa adalah derivatif sinyal step**

$$\delta(t) = \frac{du(t)}{dt}$$

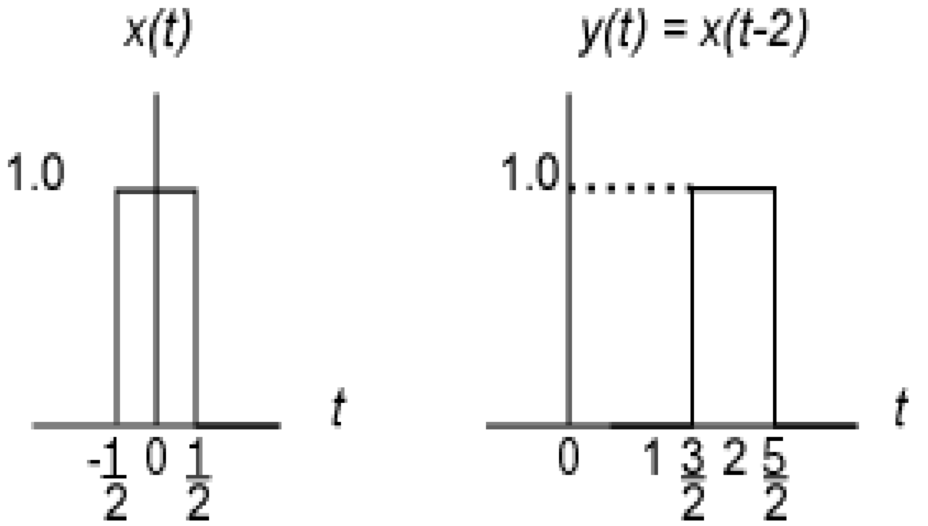
Sinyal & sistem

TRANSFORMASI SINYAL

- Pergeseran waktu *(time shift)*

$$\boxed{x'(t) = x(t - t_0)}$$

Sinyal kontinu



$t_0 > 0$ →	Geser ke kanan (*time delay*)
$t_0 < 0$ →	Geser ke kiri

Sinyal & sistem

TRANSFORMASI SINYAL

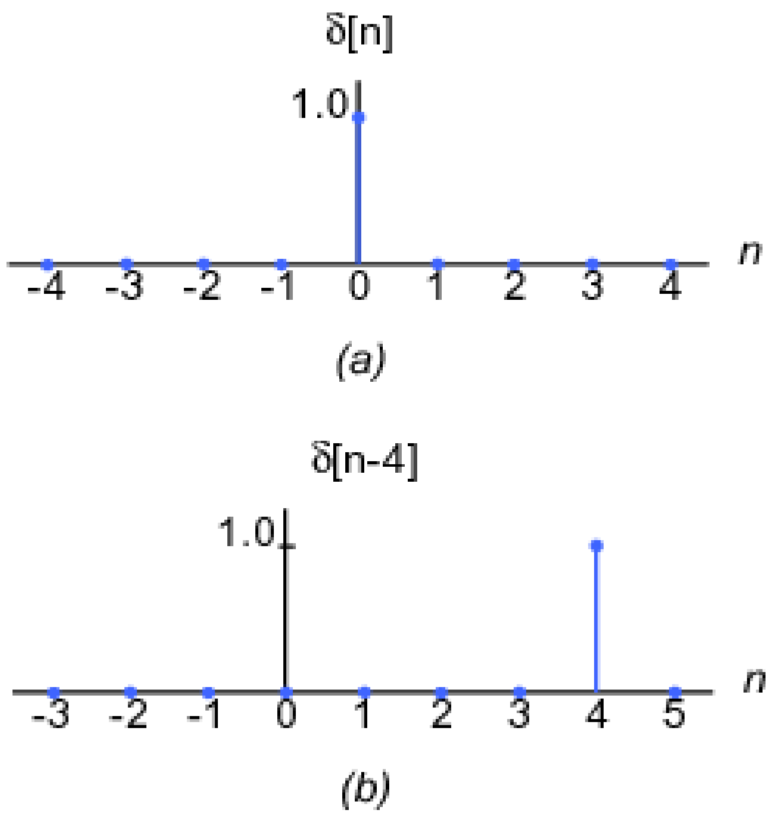
- Pergeseran waktu *(time shift)*

Sinyal diskrit

$$x'[n]=x[n-n_0]$$

$n_0>0$ → **Geser ke kanan (*time delay*)**

$n_0<0$ → **Geser ke kiri**

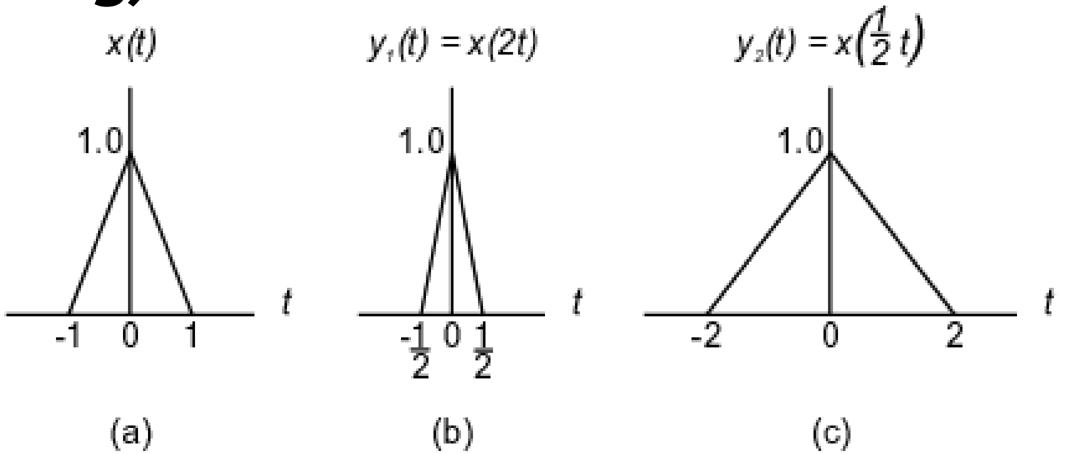


Sinyal & sistem

TRANSFORMASI SINYAL

- Penskalaan waktu *(time scaling)*

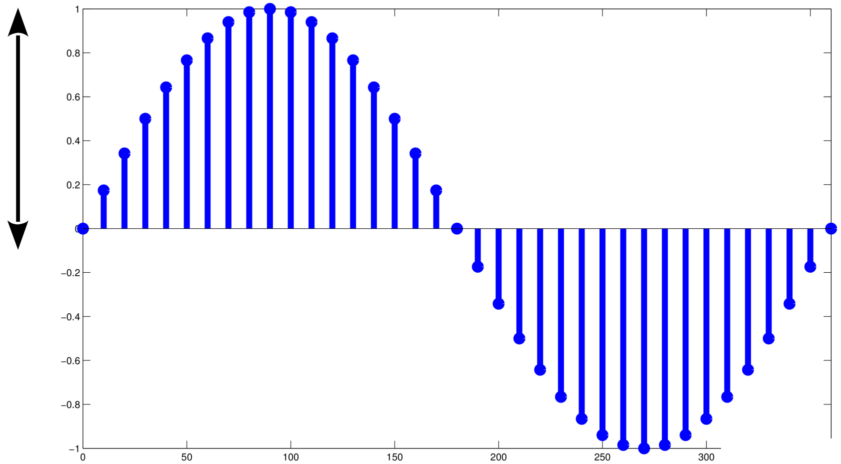
$$\boxed{x'(t)=x(at)}$$



$a>1$ → Sinyal terkompresi

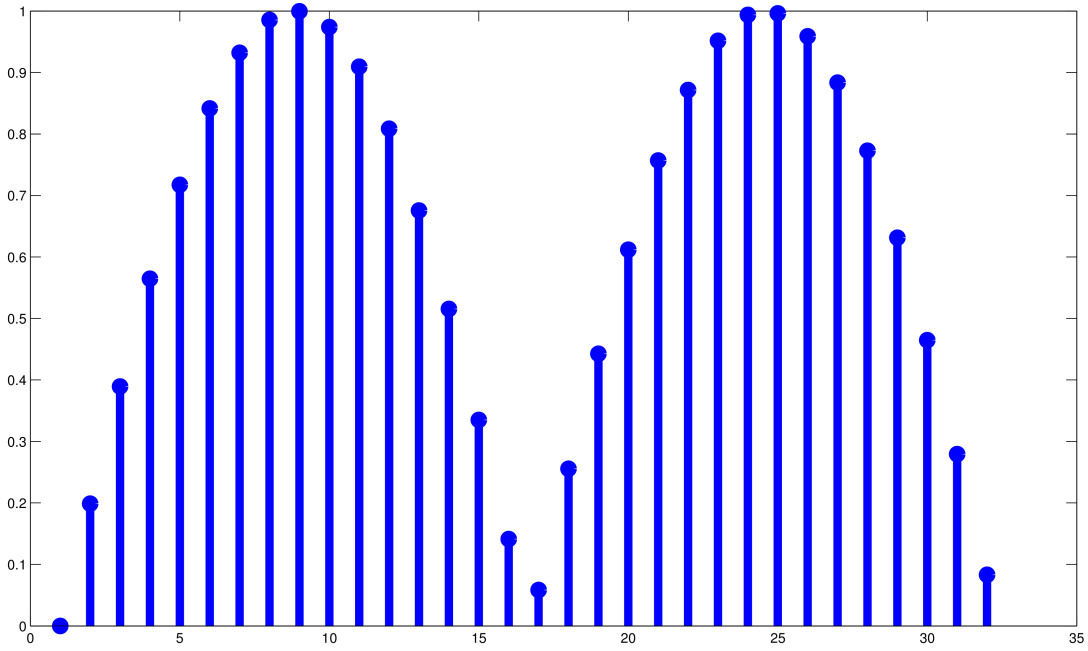
$0<a<1$ → Sinyal melar

Amplitude Vs Magnitud



Amplitude → 1

Magnitude :
Absolute Value
of amplitude



Signal Power

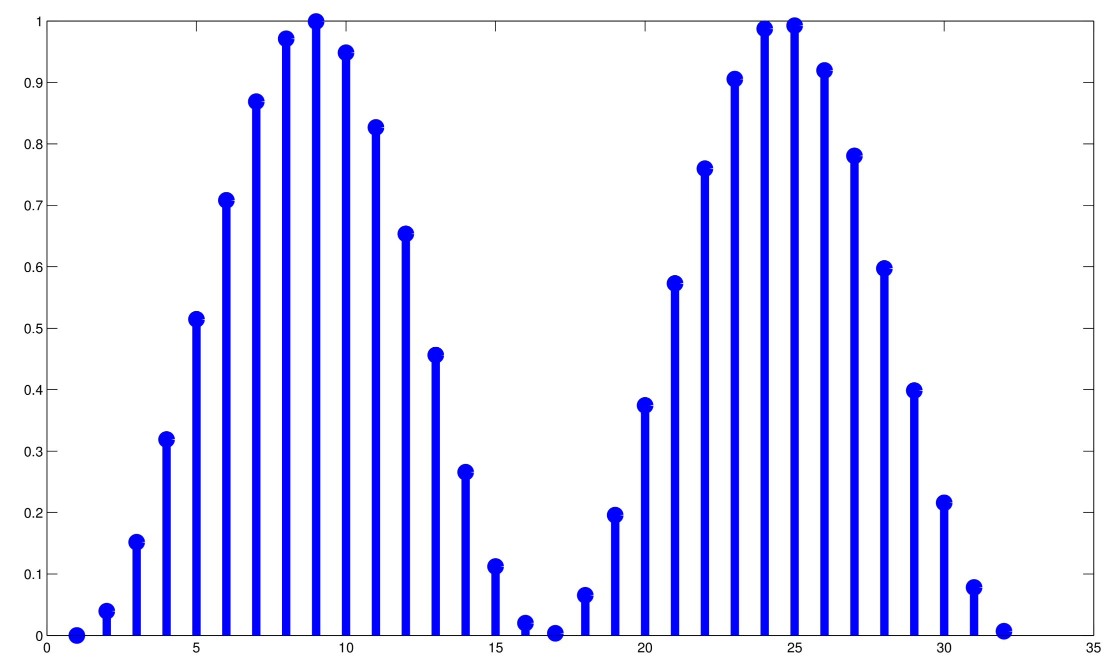
The power of signal is proportional to its amplitude/magnitude squared

$$x_{\text{pwr}}(n) = x(n)^2 = |x(n)|^2 ,$$

$$X_{\text{pwr}}(m) = X(m)^2 = |X(m)|^2 .$$

Average power:

$$\mathcal{P}_x = \frac{1}{N}\sum_{0}^{N-1} |\tilde{x}(n)|^2$$



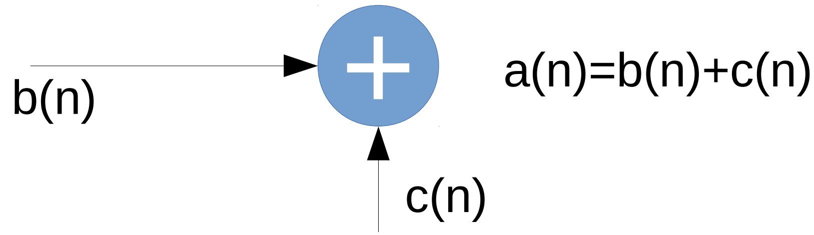
Signal Energy

$$\mathcal{E}_x = \sum_{-\infty}^{\infty} x(n)x^*(n) = \sum_{-\infty}^{\infty} |x(n)|^2$$

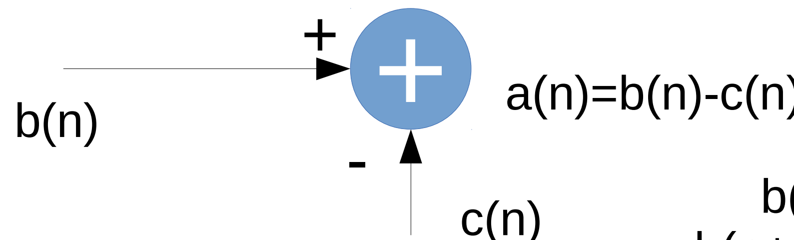
```
>> load laughter;
>> x=y;
>> Ex1 = sum(x .* conj(x)); % one approach
>> Ex2 = sum(abs(x) .^ 2); % another appr
```

Operational & Symbol

- Adder

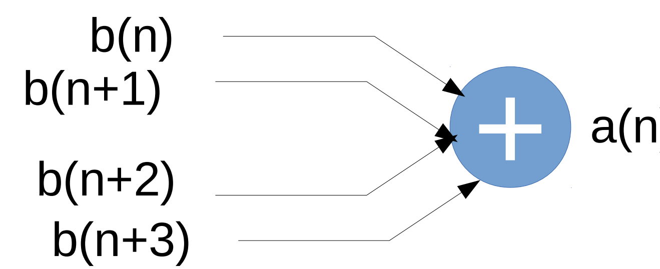


- Substractor

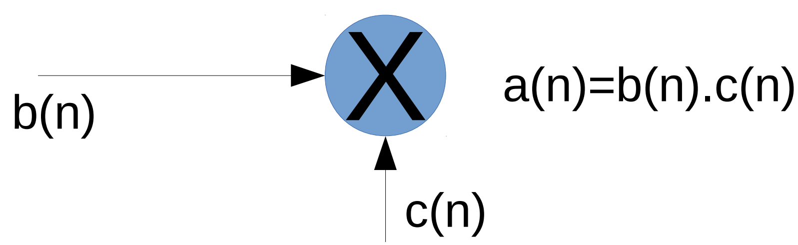


- Summation

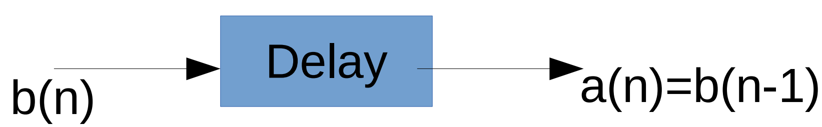
$a(n)=b(n)+b(n+1)+b(n+2)+b(n+3)$

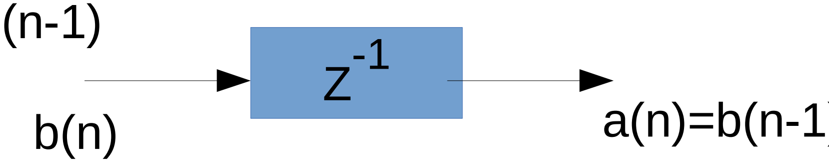


- Multiplication

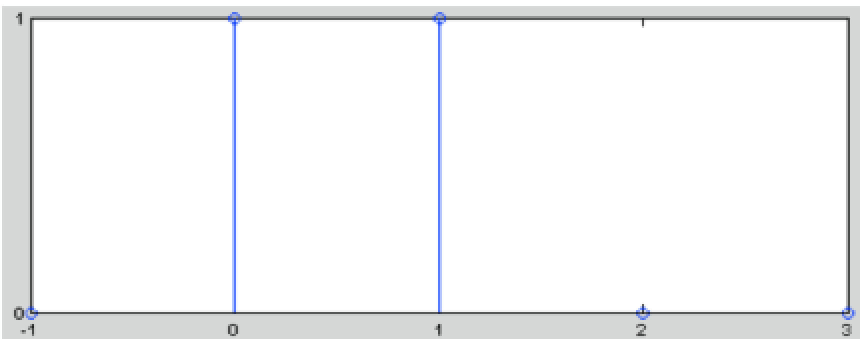


- Unit delay

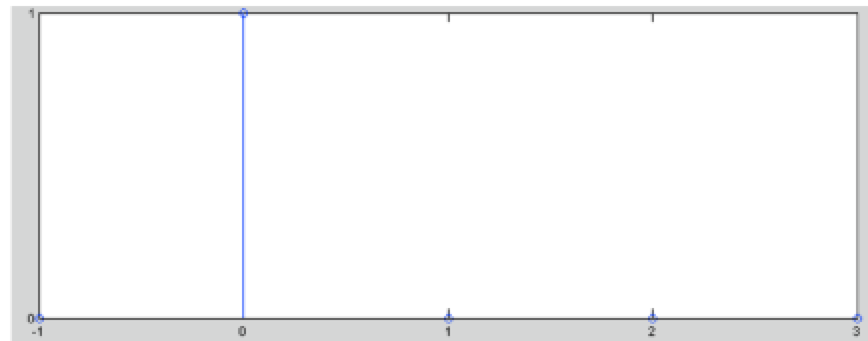




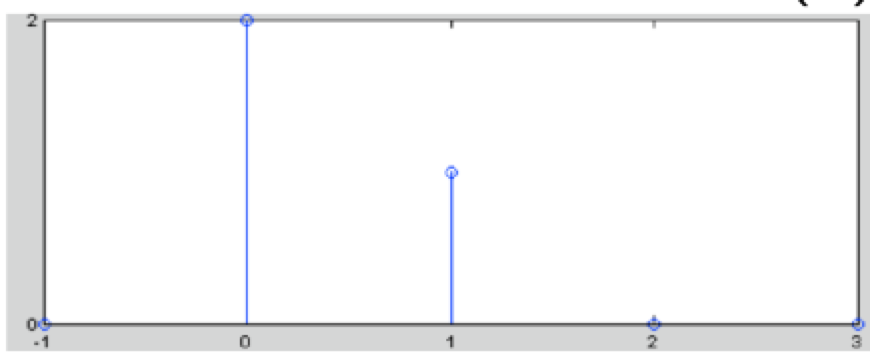
Addition



$x_1(n)$



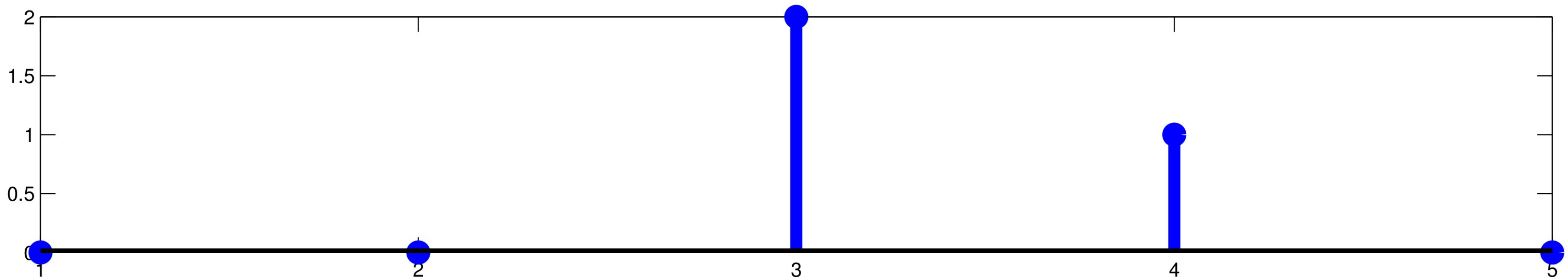
$x_2(n)$



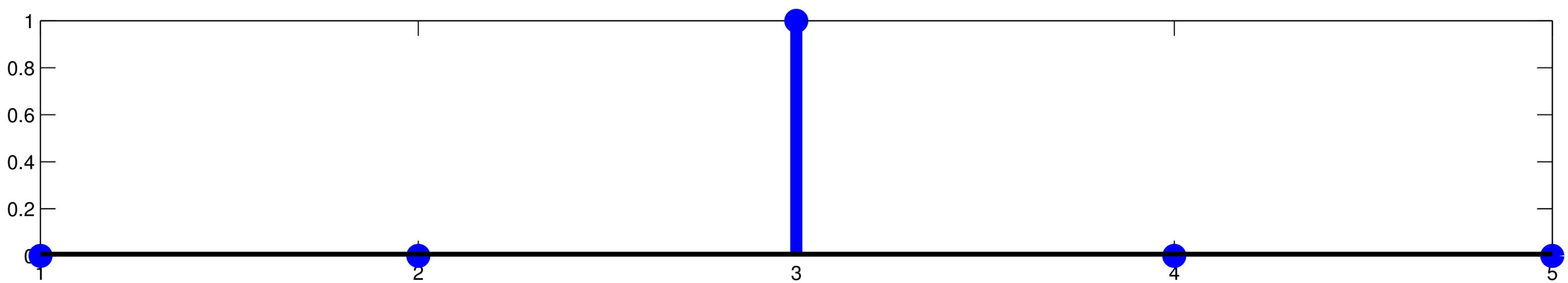
$$y(n) = x_1(n) + x_2(n)$$

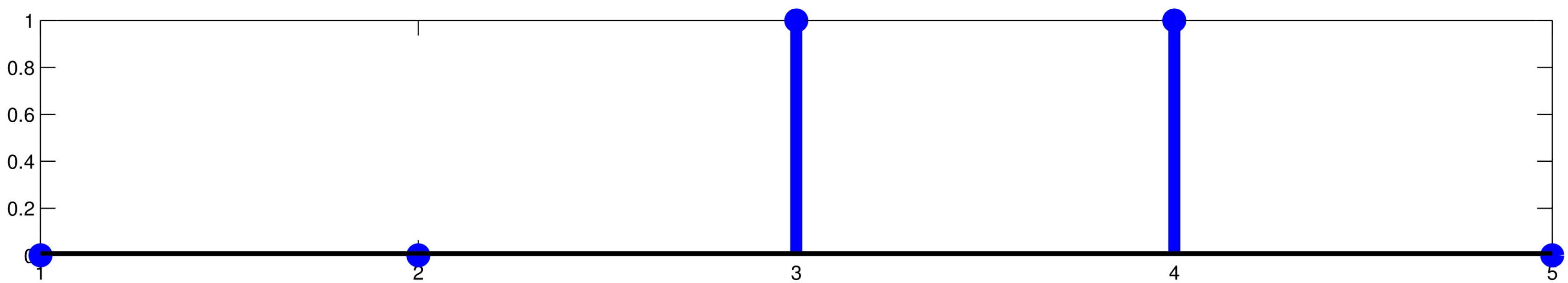
Substraction

$x_1[n]$



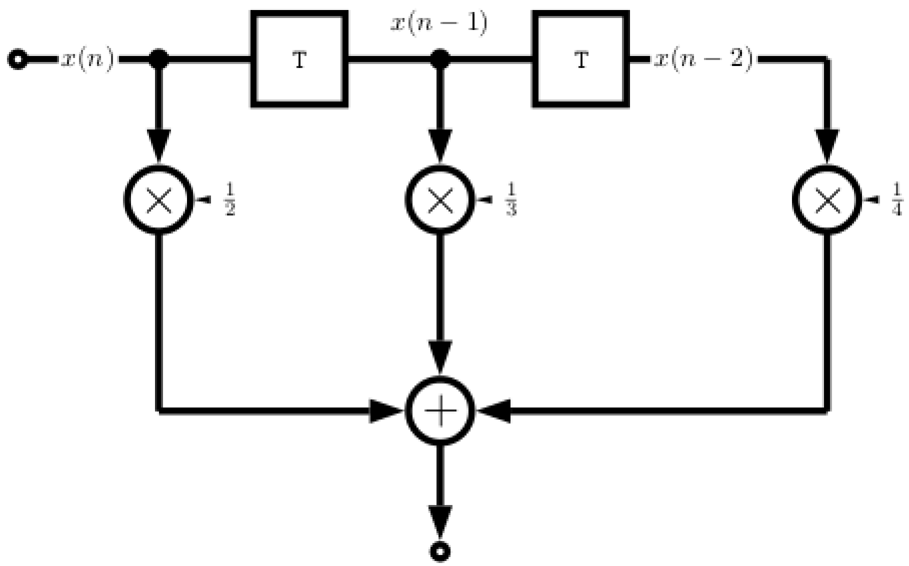
$x_2[n]$

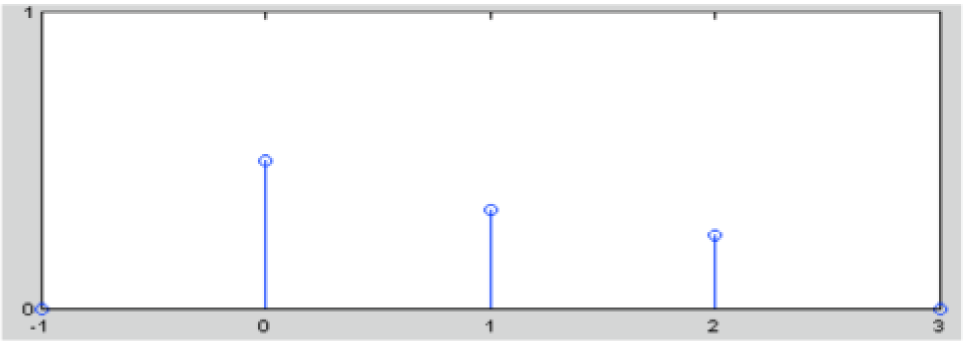




$x_3 = x_1[n] - x_2[n]$

Summation



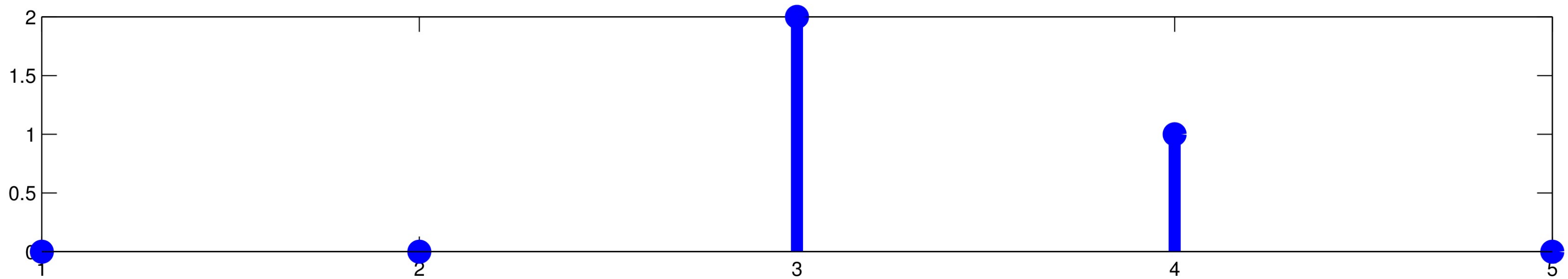


$x(n)$

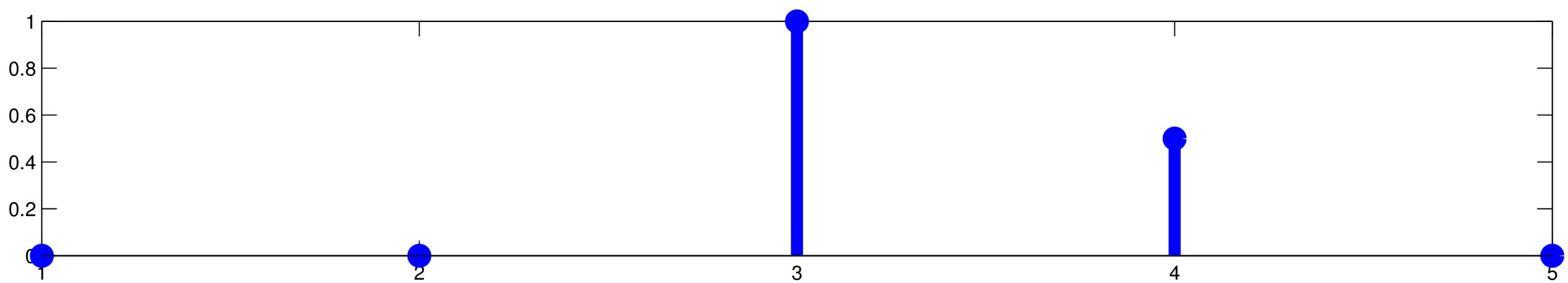
$$y(n) = \frac{1}{2}x(n) + \frac{1}{3}x(n-1) + \frac{1}{4}x(n-2)$$

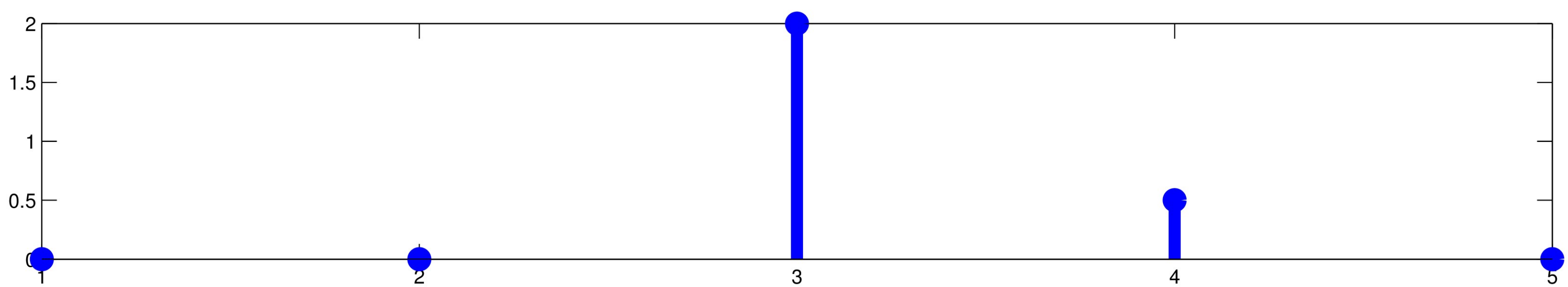
Multiplication

$x_1[n]$



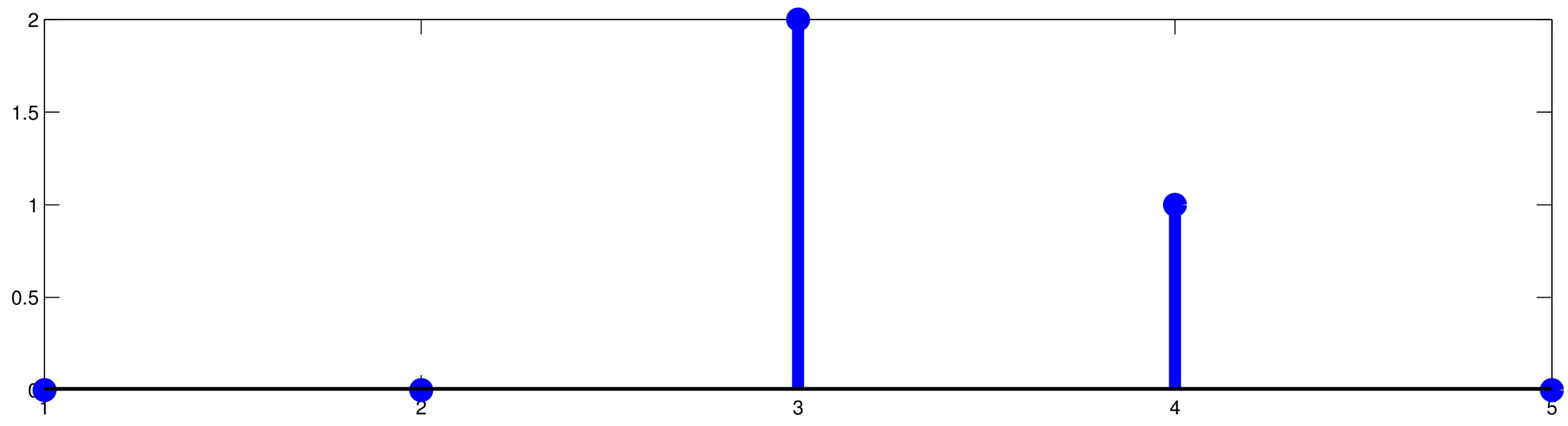
$x_2[n]$



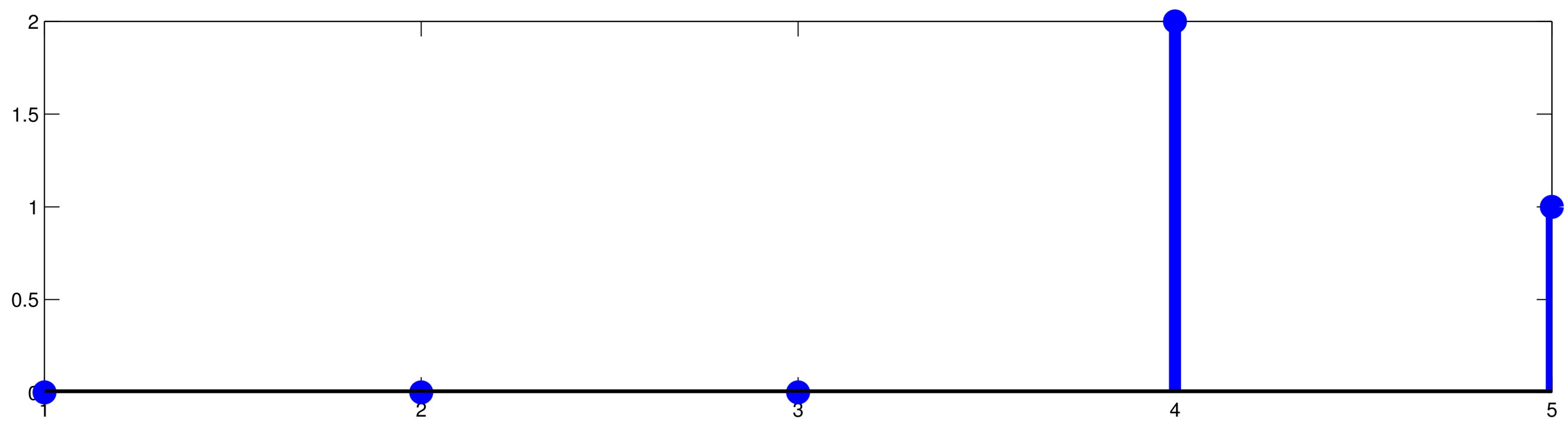


$x_3 = x_1[n] .* x_2[n]$

Delay



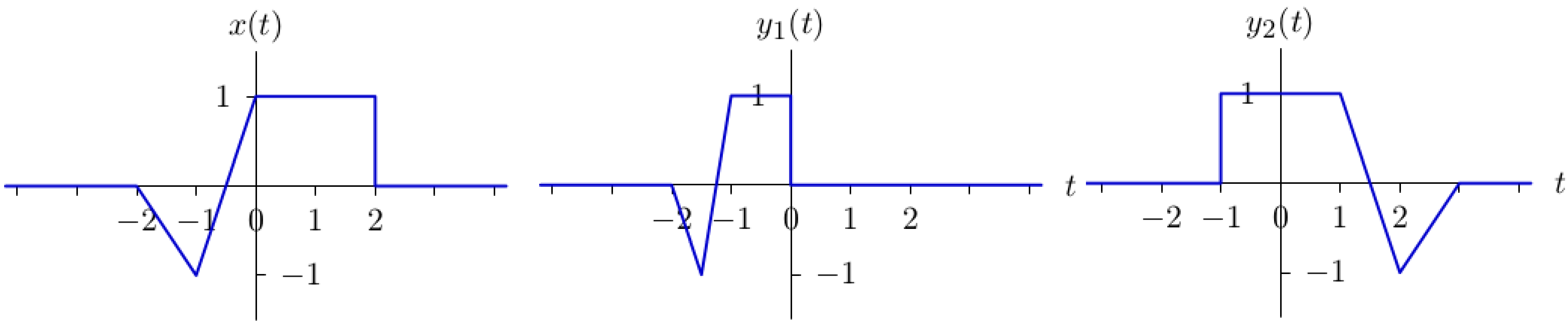
x[n]



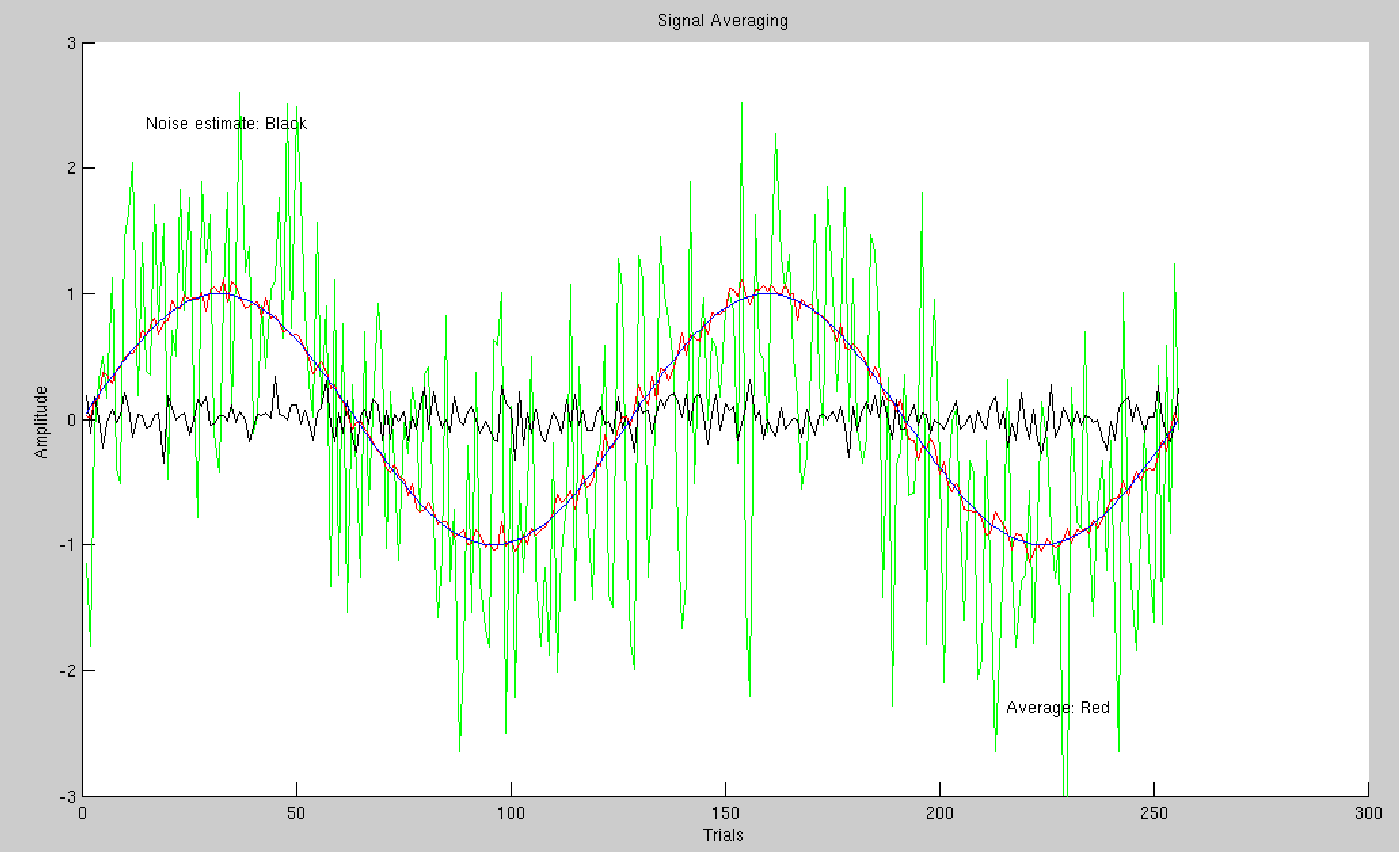
x[n - 1]

HOMEWORK #1

- Jelaskan perbedaan **differential equation** dan **difference equation**, berilah contoh masing-masing satu soal beserta solusinya.
- Apa fungsi kedua persamaan tersebut dalam sinyal dan sistem ?
- Tentukan $y_1(t)$ & $y_2(t)$ dalam fungsi $x(t)$ sbb:



Signal Averaging



Signal averaging is a signal processing technique applied in the time domain, intended to increase the strength of a signal relative to noise that is obscuring it