Audio & DSP Lab.

Signals and Systems
信號與系統

Lecture 1-3

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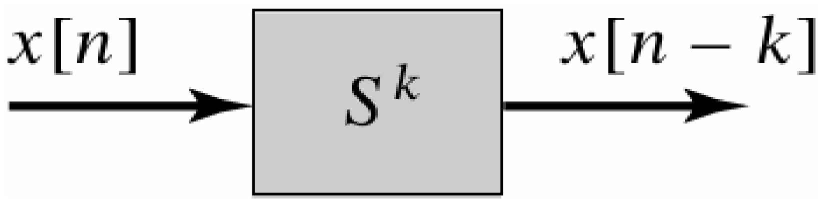
Cascading System

(系統串接方式)

(a) (b)

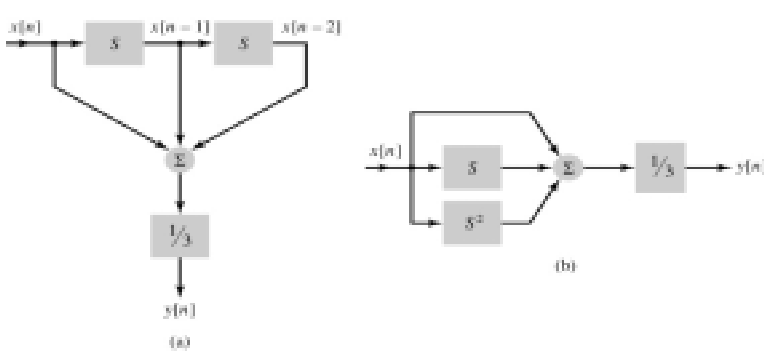
Discrete-time-shift operator S^k, operating on the discrete-time signal $x[n]$ to produce $x[n-k]$.



(離散時間延遲系統與離散時間時間平移運算元 S^k)

Two implementations of the moving-average system

(a) cascade form of implementation and
(b) parallel form of implementation.



Properties of Systems

- Stability 穩定性
- Memory 記憶性
- Causality 因果性
- Invertibility 可逆性
- Time Invariance 非時變性
- Linearity 線性

Stability

- **B**ounded **I**nput causes **B**ounded **O**utput (BIBO).
- 輸入與輸出需滿足:

$$|y(t)| \le M_y < \infty$$

$$|x(t)| \le M_x < \infty$$

for M_x, M_y are finite and positive numbers.

- Unstable Example:
  - "*Tacoma Narrows Suspension Bridge*"

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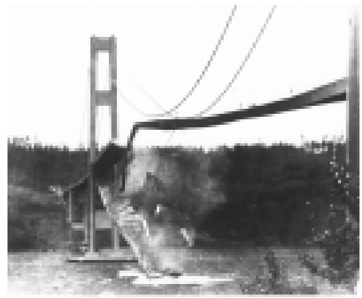
Dramatic photographs showing the collapse of the *<u>Tacoma</u>* Narrows suspension bridge on November 7, 1940.

(a) Photograph showing the twisting motion of the bridge's center span just before failure.
(b) A few minutes after the first piece of concrete fell, this second photograph shows a 600-ft section of the bridge breaking out of the suspension span and turning upside down as it crashed in Puget Sound, Washington. Note the car in the top right-hand corner of the photograph.

(Courtesy of the Smithsonian Institution.)



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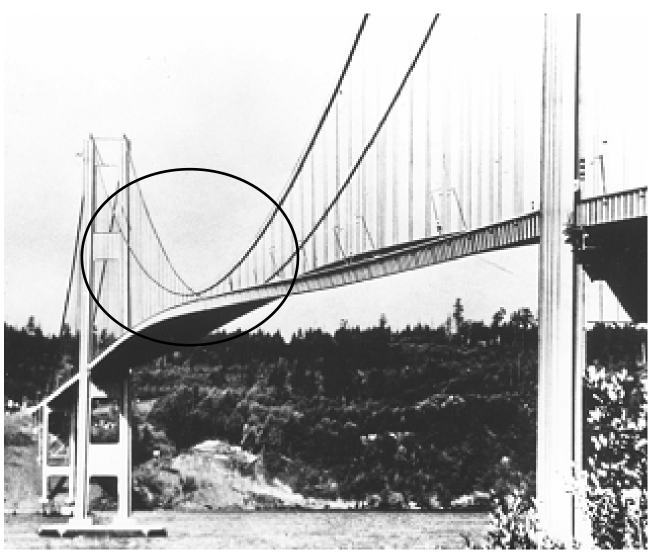

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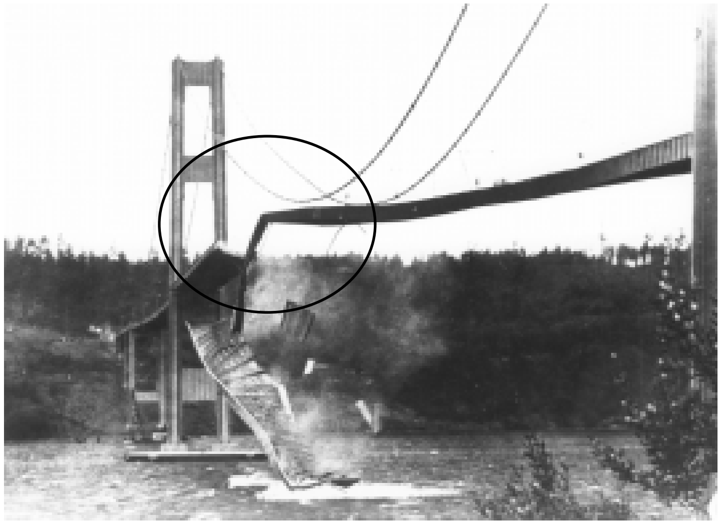

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Example of a Stable System

$Example:$ [Moving-average case]

$$y[n]=\frac{1}{3}\left(x[n]+x[n-1]+x[n-2]\right).$$

$$\left|y[n]\right|=\frac{1}{3}\left(\left|x[n]+x[n-1]+x[n-2]\right|\right)$$

$$\leq\frac{1}{3}\left(\left|x[n]\right|+\left|x[n-1]\right|+\left|x[n-2]\right|\right)\leq\frac{1}{3}\left(M_x+M_x+M_x\right)=M_x$$

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Example of an Unstable System

Example:

$$y[n] = r^n \; x[n], \quad \forall \; r > 1$$

$$even \; if \; |x[n]| \le M_x < \infty, \quad \forall all \; n$$

$$|y[n]| = |r^n \; x[n]| = |r^n| \cdot |x[n]|$$

$$if \;\; r > 1, \quad r^n \; divergences$$

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Memory or Memory-less

Memory :

若系統輸出取決於過去的訊號輸入時

Memory-less :

若系統輸出僅取決於現在的訊號輸入時

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Causality

Causal :

若系統輸出取決於目前或過去的訊號輸入時

$$Ex: \quad y[n] = x[n] + x[n-1]$$

Non-causal :

若系統輸出取決於一個或以上未來的訊號輸入時

$$Ex: \quad y[n] = x[n+1] + x[n]$$

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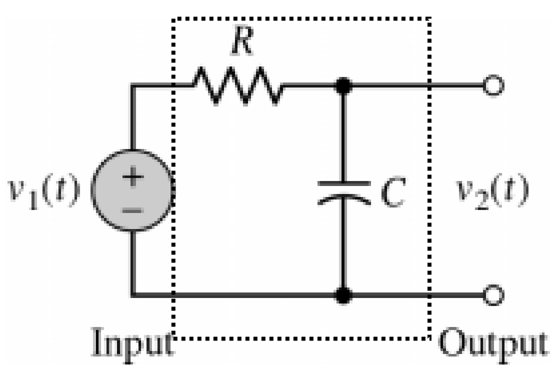
Example: Causal System ?

Series *RC* circuit driven from an ideal voltage source $v_1(t)$, producing output voltage $v_2(t)$



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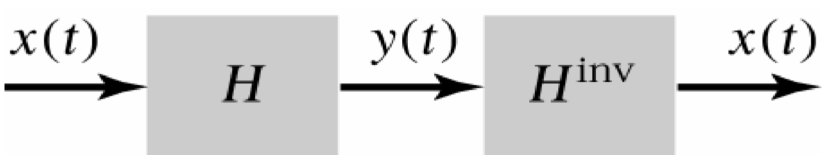
System Invertibility

The second operator *H*[inv] is the inverse of the first operator *H*. Hence, the input *x*(*t*) is passed through the cascade correction of *H* and *H*[-1] completely unchanged.

$$H^{inv} = H^{-1}$$



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Time Invariance

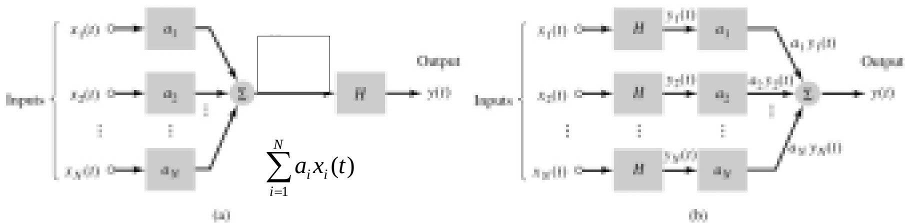
These two situations are equivalent, provided that *H* is time invariant.

$$y_2(t) = y_1(t - t_0)$$

(a) (b)

The Linearity Properties

If these two configurations produce the same output *y*(*t*), the operator *H* is linear.

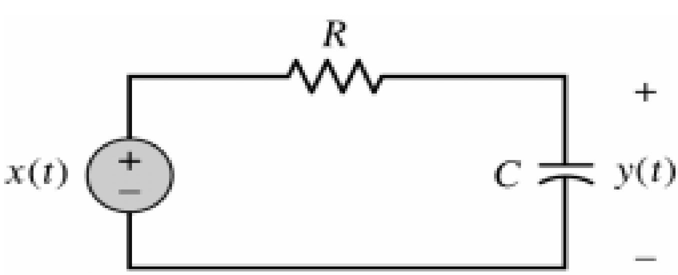


$$\sum_{i=1}^{N} a_i x_i(t)$$

EX: RC **circuit : *y*(*t*) = ? in response to the unit-impulse input *x*(*t*) = *δ*(*t*).**

回憶： $step\ response: \quad y(t) = \left(1 - e^{-t/RC}\right)u(t)$

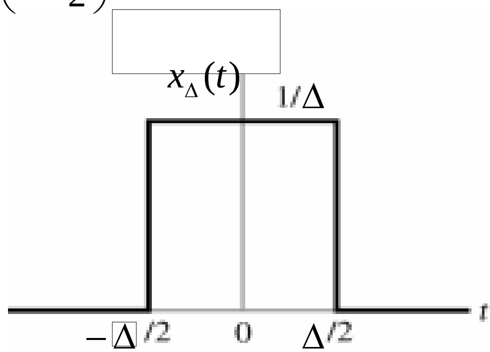
(電容充電 *y*(t) 電壓緩緩上升)



Rectangular pulse of unit area approaches a unit impulse as $\Delta \rightarrow 0$

$$x_\Delta(t) = \frac{1}{\Delta}u\left(t+\frac{\Delta}{2}\right) - \frac{1}{\Delta}u\left(t-\frac{\Delta}{2}\right)$$
$$= x_1(t) - x_2(t)$$

$$\delta(t) = \lim_{\Delta \rightarrow 0} x_\Delta(t)$$



System Output y(t), applying Linear property:

$$y_1(t) = H\{x_1(t)\}; \quad y_2(t) = H\{x_2(t)\};$$

$$y(t) = y_1(t) \pm y_2(t) = H\{x_1(t) \pm x_2(t)\}$$ (應用線性特性)

solution:

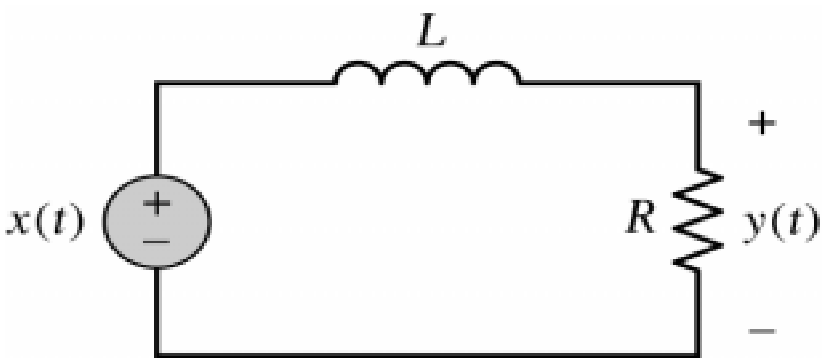
$$y_1(t) = \frac{1}{\Delta}\left(1 - e^{-(t+\Delta/2)/(\mathrm{RC})}\right)u(t+\Delta/2)$$

$$y_2(t) = \frac{1}{\Delta}\left(1 - e^{-(t-\Delta/2)/(\mathrm{RC})}\right)u(t-\Delta/2)$$

$\therefore$ (中間步驟請自行參考教科書並加以推導)

$$y(t) = y_1(t) - y_2(t) = \frac{1}{RC}e^{-t/RC}u(t)$$

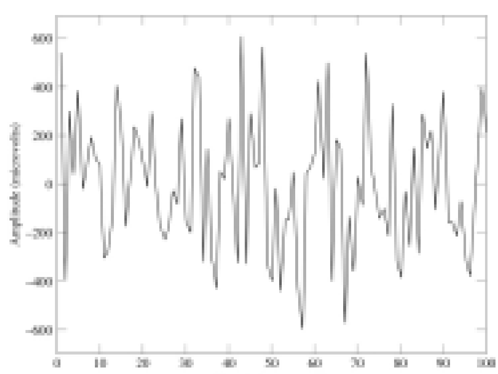
EX: RL circuit : $y(t)$ in response to the unit-impulse input $x(t) = \delta(t)$?



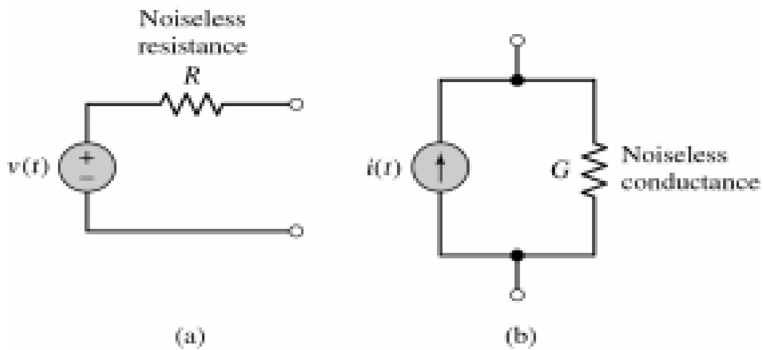
類似前題請自行參考並推導

Waveform of electrical noise generated by a thermionic diode with a heated cathode.

Note that the time-averaged value of the noise voltage displayed is approximately zero.



(a) Thévenin equivalent circuit of a noisy resistor.
(b) Norton equivalent circuit of the same resistor.



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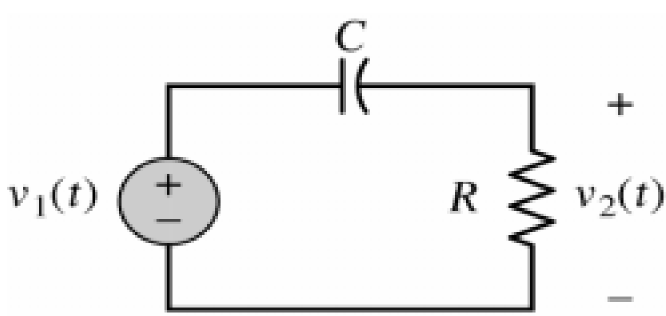
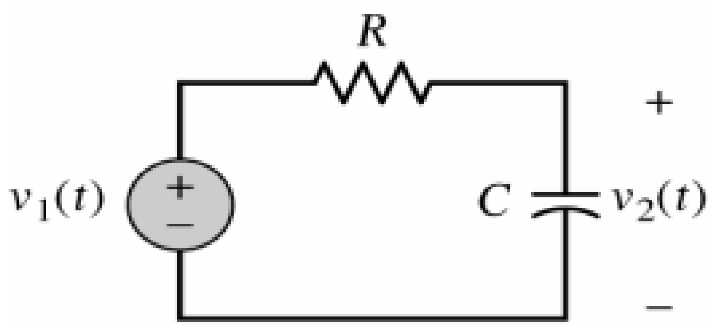
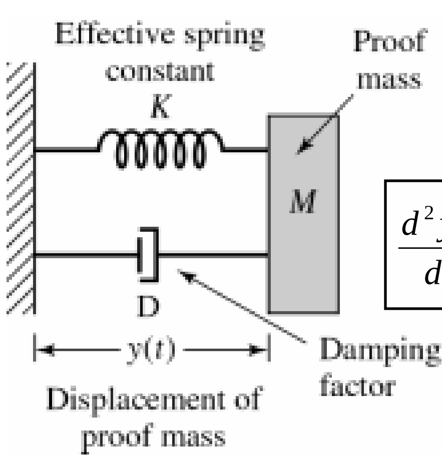
Simple *RC* circuit with small time constant, used as an approximator to a *differentiator*.



Simple *RC* circuit with large time constant used as an approximator to an *integrator*.



Mechanical lumped model of an accelerometer



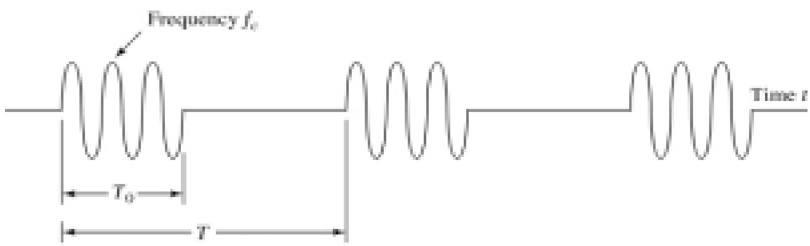
$$\frac{d^2y(t)}{dt^2}+\frac{D}{M}\frac{dy(t)}{dt}+\frac{K}{M}y(t)=x(t)$$

Radar Range Measurement

雷達與目標間距離：d

雷達脈波傳遞至目標並傳回所需時間 τ： $\tau = \dfrac{2d}{C}$

C：雷達脈波傳遞速度



Radar Range Measurement (cont.)

距離解析度 (Range Resolution)

脈波持續時間 T_0 限制可測量最短目標距離:

$$d_{\min} = \frac{cT_0}{2} \quad meters$$

距離模糊度 (Range Ambiguity)

脈波間週期 T 限制可測量最遠目標距離:

$$d_{\max} = \frac{cT}{2} \quad meters$$

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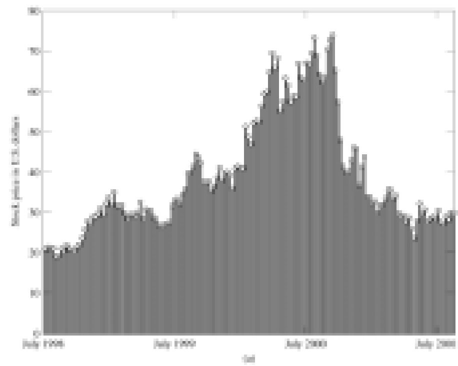
Moving Average System

Fluctuations in the closing stock price of Intel over a three-year period.



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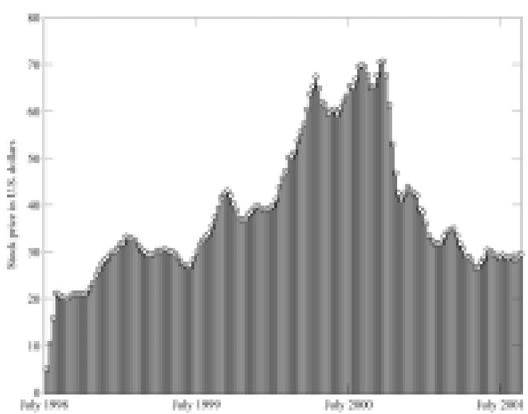
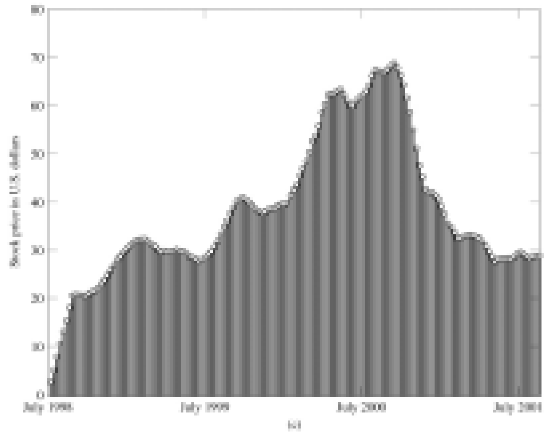
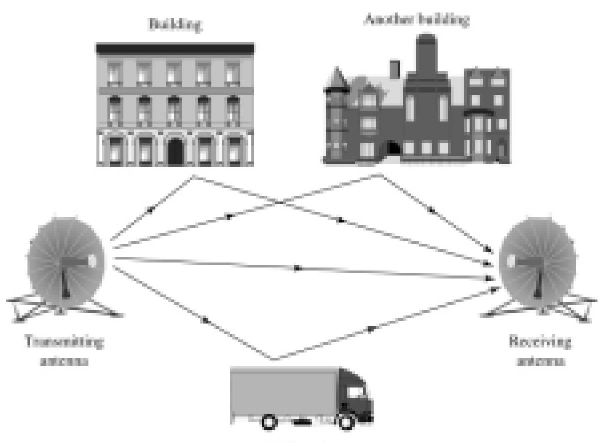
Output of a *4-point* moving-average system



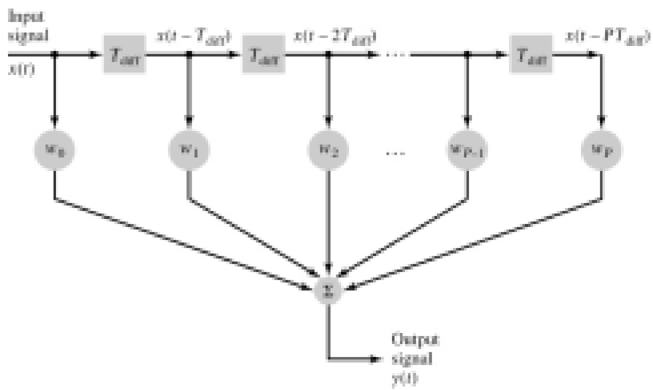
Output of an *8-point* moving-average system



Multiple propagation paths in a wireless communication environment

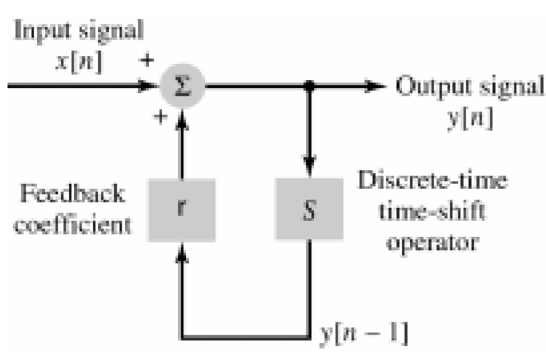


Tapped-delay-line model of a linear communication channel, assumed to be time-invariant

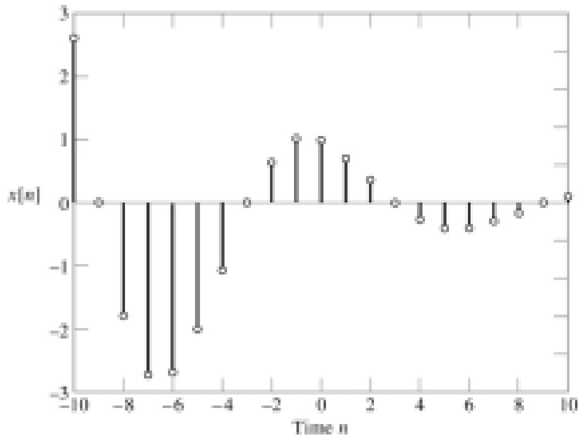


Block diagram of first-order recursive discrete-time filter

The operator *S* shifts the output signal *y*[*n*] by one sampling interval, producing *y*[*n* – 1]. The feedback coefficient *p* determines the stability of the filter.



Exponentially damped sinusoidal sequence



Exploring Concepts with MATLAB

- Periodic Signals
- Exponential Signals
- Sinusoidal Signals
- Exponentially Damped Sinusoidal Signals
- Step, Impulse and Ramp Functions
- User Defined Functions

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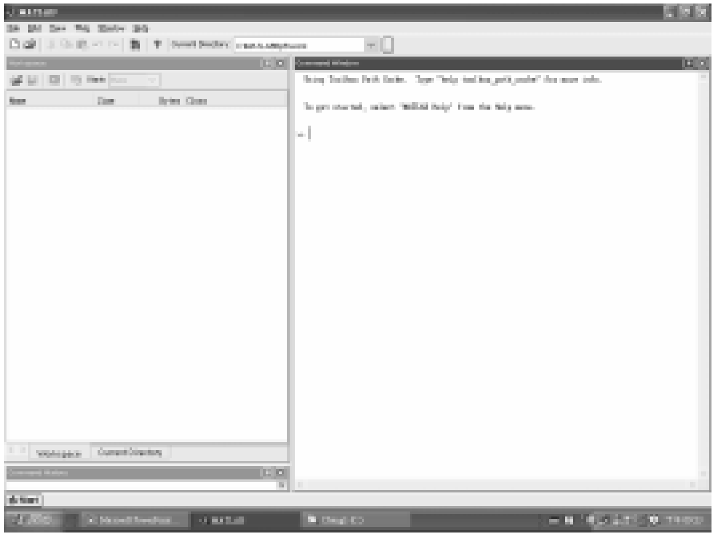
MATLAB Window 畫面



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Periodic Signal

- Generate Square Wave:

$$A = 1;$$

$$w0 = 10 * pi;$$

$$rho = 0.5;$$

$$t = 0 : 0.001 : 1;$$

$$sq = A * square(w0 * t, rho);$$

$$plot(t, sq)$$

$$axis([0 \quad 1 \quad -1.1 \quad 1.1])$$

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Exponential Signal

- Generate Function: x = b exp(-at)

$$b = 5;$$
$$a = 6;$$
$$t = 0:0.001:1;$$
$$x = b * \exp(-a * t);$$
$$plot(t, x)$$

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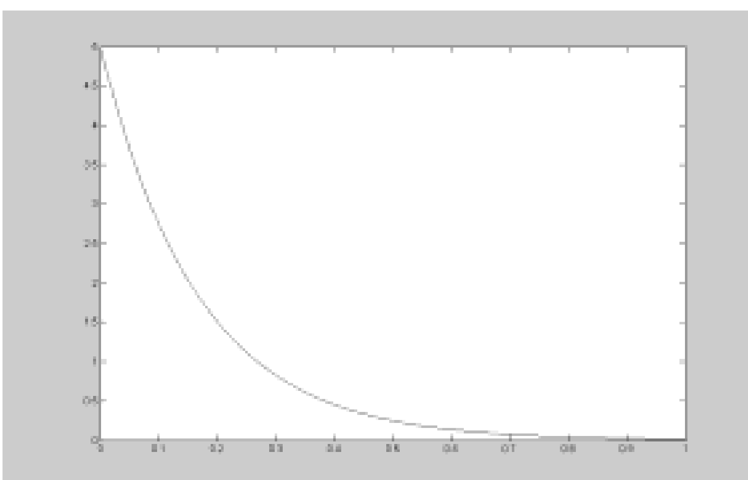
Exp Signal Plot

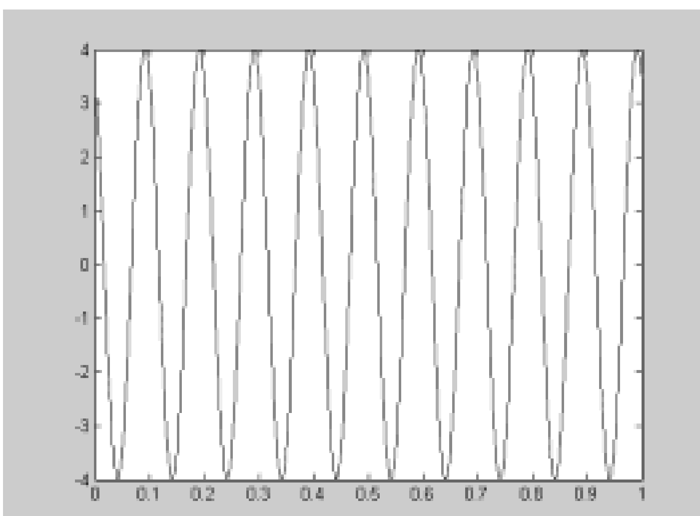


Sinusoidal Signal

- Generate Function: $x = A\cos(\omega_o t + \phi)$

$$A = 4;$$
$$w0 = 20 * pi;$$
$$phi = pi/6;$$
$$t = 0:0.001:1;$$
$$x = A * \cos(w0 * t + phi);$$
$$plot(t, x)$$

Sine Signal Plot

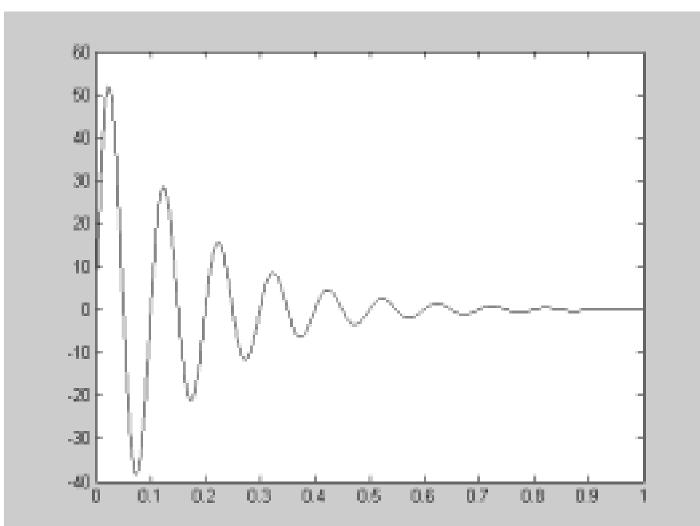


Exponentially Damped Sinusoidal Signal

- Generate Function: $x = A\, e^{-at} \sin(\omega_o t + \phi)$

$$A = 60;$$
$$w0 = 20 * pi;$$
$$phi = 0;$$
$$a = 6;$$
$$t = 0 : 0.001 : 1;$$
$$x = A * \sin(w0 * t + phi) .* \exp(-a * t);$$
$$plot(t, x)$$

Exp. Damped Sine Signal Plot



Step, Impulse and Ramp Function

- Generate Step Function:

$$u = [zeros(1,50), ones(1,50)];$$

- Generate Impulse Function:

$$delta = [zeros(1,49), 1, zeros(1,49)];$$

- Generate Ramp Function:

$$ramp = 0:0.1:10;$$

User Defined Function

- Generate ".m" file to define function:

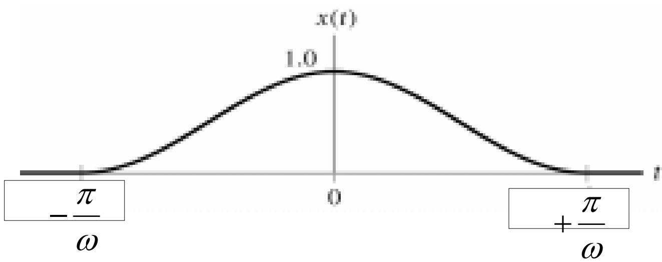
$$function\ g = rect(x)$$

$$g = zeros(size(x));$$
$$set = find(abs(x) <= 0.5);$$
$$g(set) = ones(size(set));$$

P1.46 試求下圖訊號能量總和 ？

$$E = \int_{-\pi/\omega}^{+\pi/\omega} x^2(t)\, dt$$

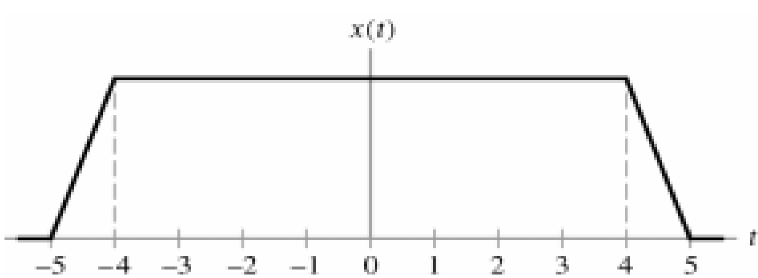
$$x(t) = \begin{cases} \frac{1}{2}\left[1 + \cos(\omega t)\right], & -\pi/\omega \le t \le \pi/\omega \\ 0, & others \end{cases}$$



P1.47 試求下圖訊號能量總和 ？

$$E = \int_{-5}^{+5} x^2(t)\, dt$$

$$x(t) = \begin{cases} 5 - t, & 4 \le t \le 5 \\ 1, & -4 \le t \le 4 \\ t + 5, & -5 \le t \le -4 \\ 0, & others \end{cases}$$



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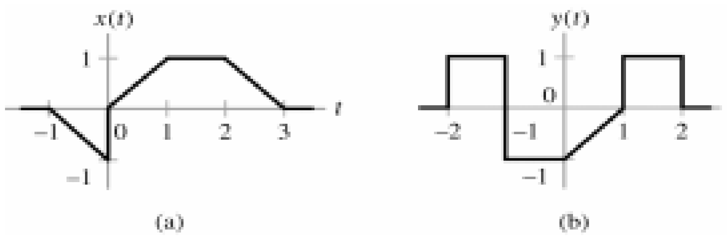
P1.52 請繪出下列訊號圖？

$$(a)\quad x(t)y(t-1)$$
$$(b)\quad x(t-1)y(-t)$$
$$(c)\quad x(t+1)y(t-2)$$



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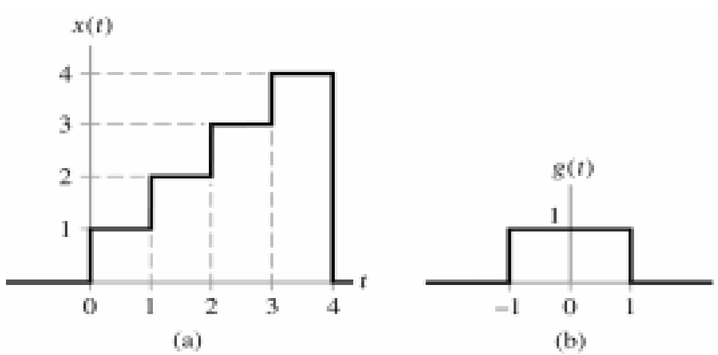
P1.53 試以 g(t) 表示 x(t)？



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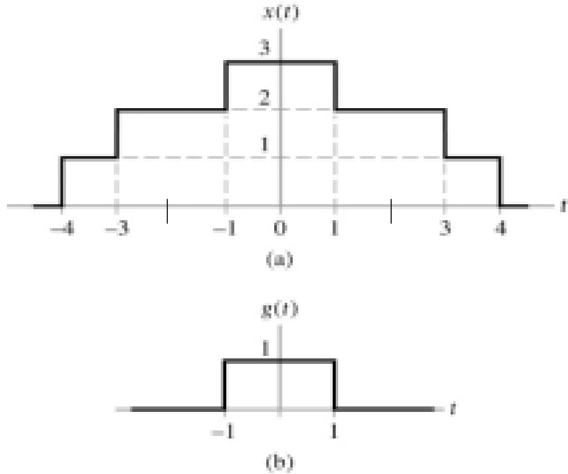
P1.55 試以 g(t) 表示 x(t) ？



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P1.56 請繪出下列訊號圖？

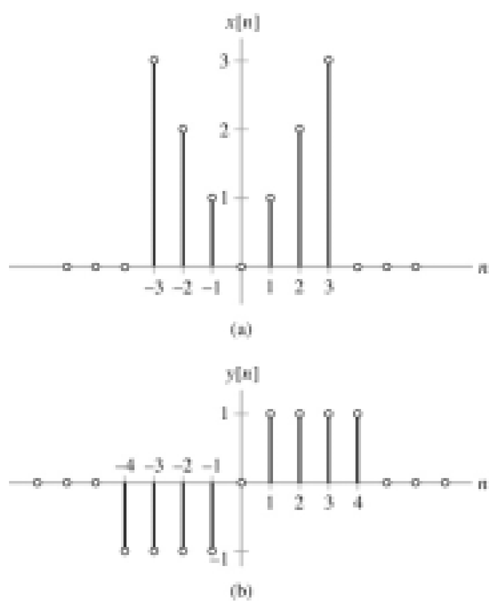
(1) $x[2n]$

(2) $x[3n-1]$

(3) $y[1-n]$

(4) $y[2-2n]$

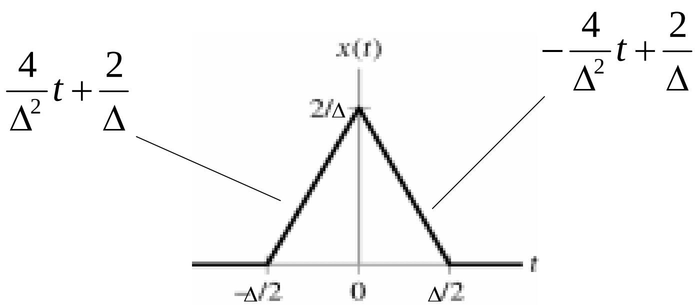
(5) $x[n-2]+y[n+2]$



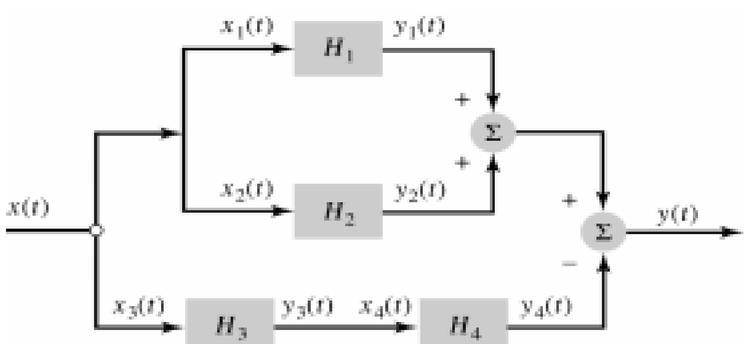
P1.62 將下面三角訊號送入一微分器，回答下列問題

(a) 微分器輸出 y(t) 為何？

(b) 當Δ 趨近於零時，輸出 y(t) 變化為何？以 δ(t) 說明



P1.63 試求出總系統？



P1.75

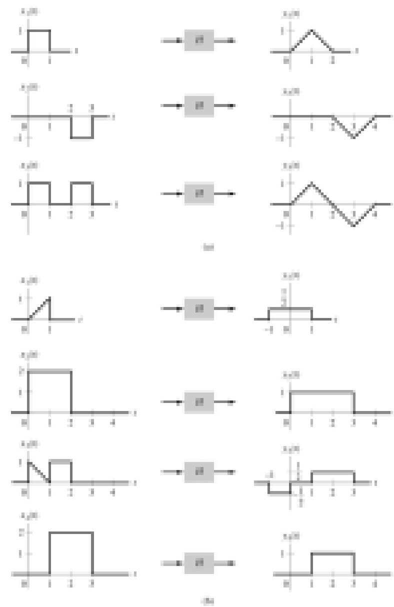
說明右圖各系統特性？

記憶性？

因果性？

線性？

(非)時變性？



P1.76

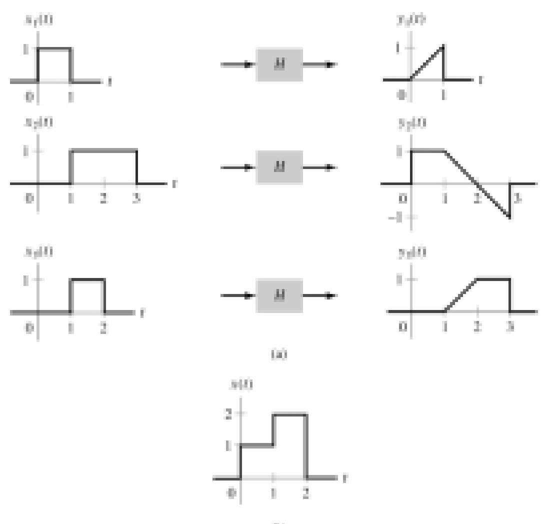
說明右圖各系統特性？

記憶性？

因果性？

線性？

(非)時變性？



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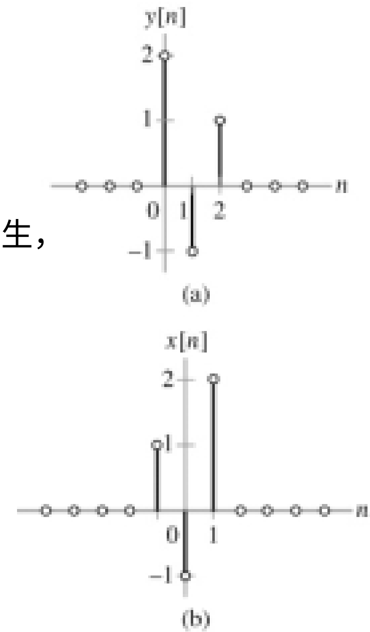
P1.77

若 (a) 輸出 y[n] 是 x[n] = δ[n] 所產生，
現以 (b) x[n] 輸入 則 y[n] 為何？



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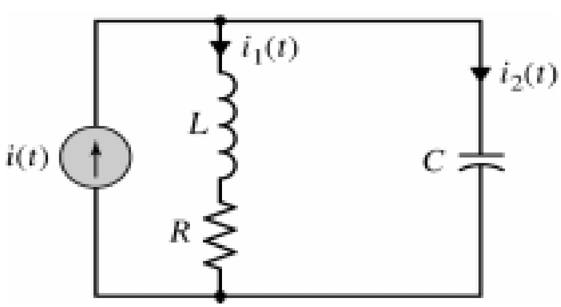
P1.79 試寫出微分方程式來描述下列電路？



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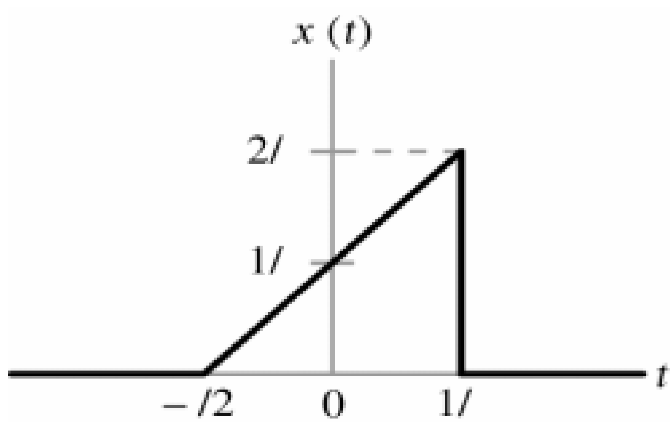
P1.80



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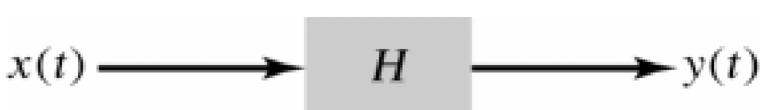
P1.81 若下圖 H 為線性非時變系統，請舉例說明？



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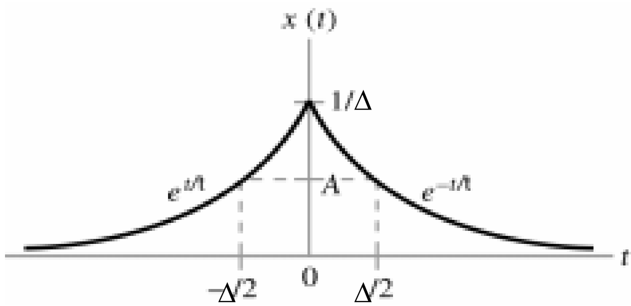
P1.82

試求 A = ?

$$x_{\Delta}(t) = \frac{1}{\Delta}\left(e^{+t/\tau}u(-t) + e^{-t/\tau}u(t)\right)$$



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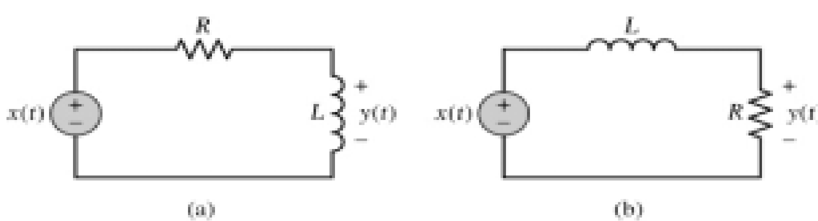
P1.83 電路 (a) 和 (b) 是否互為反運算 ？

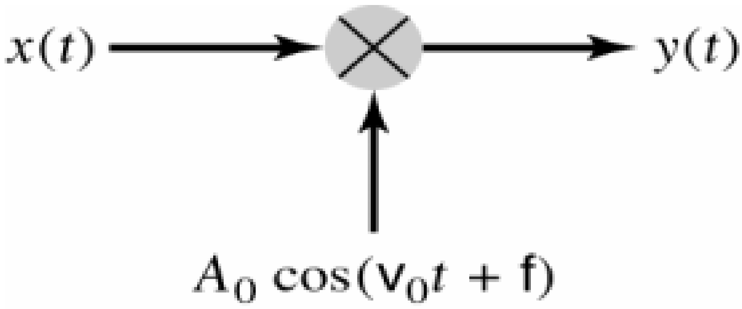


$$y(t) = A_0 \cos(\omega_0 t + \phi)\, x(t)$$

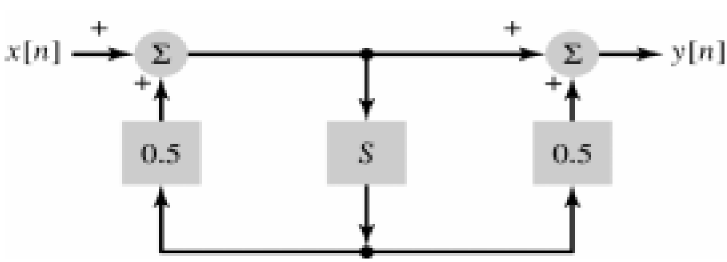
P1.84 系統輸出:

(a) 證明此系統為線性

(b) 證明此系統為時變性



P1.89 以輸入 x[n] 寫出輸出 y[n] 表示式？



P1.92 試繪出下圖中方塊圖？