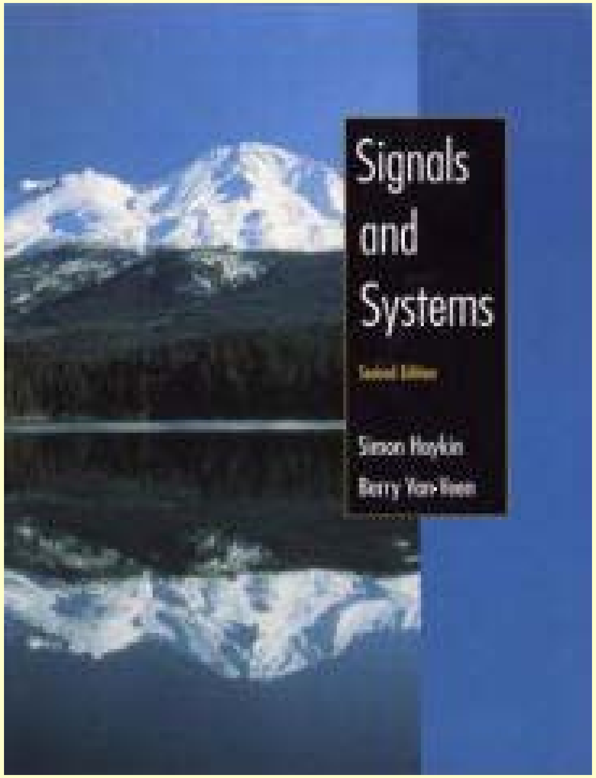
Audio & DSP Lab.

Signals and Systems
信號與系統

Lecture 1-1



Overview

- Signal ? System ?
- Overview of Specific Systems
- Classification of Signals
- Basic Operations on Signals
- Elementary Signals
- Serial and Parallel System Connections
- System Properties
- **Using MATLAB (optional)

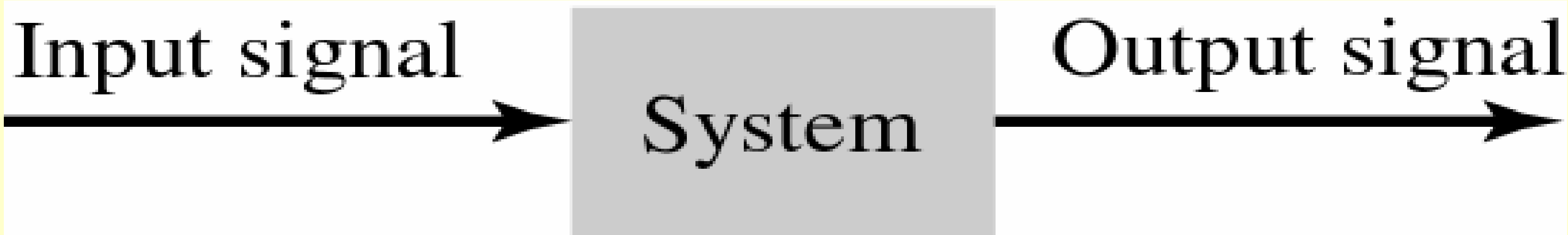
What is the Signal?

人與人間傳遞的訊息
自然界中溫度、 濕度…
…

What is the System?

處理訊號的機制
說明輸入和輸出間過程
…

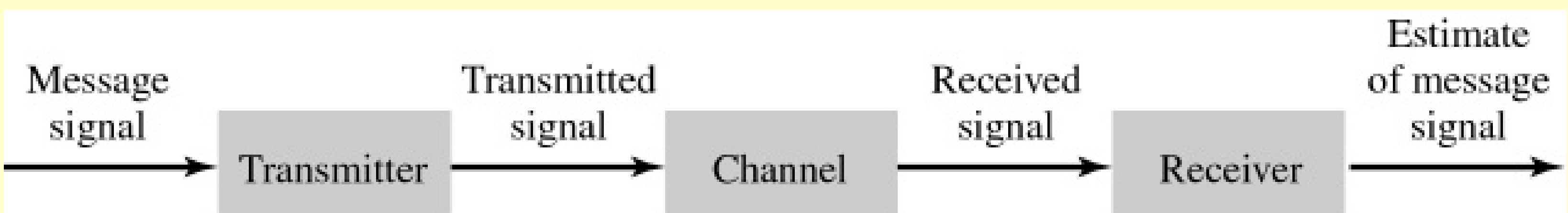
Signals and System Diagram

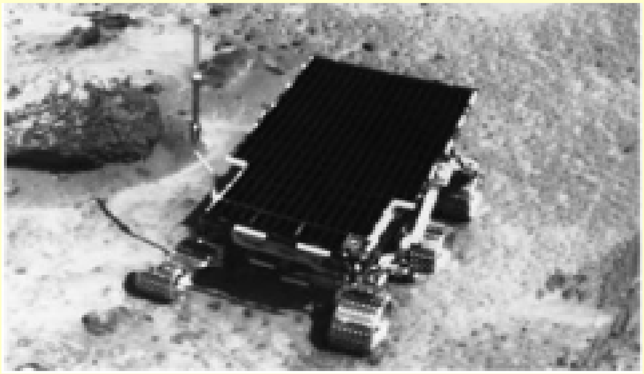


Overview of Specific Systems

- **Communication Systems**
- **Feedback Control Systems**
- **Micro-electro-mechanical Systems**
- **Remote Sensing Systems**
- **Biomedical Signal Systems**
- **Auditory Signal Systems**
- **…**

Communication System



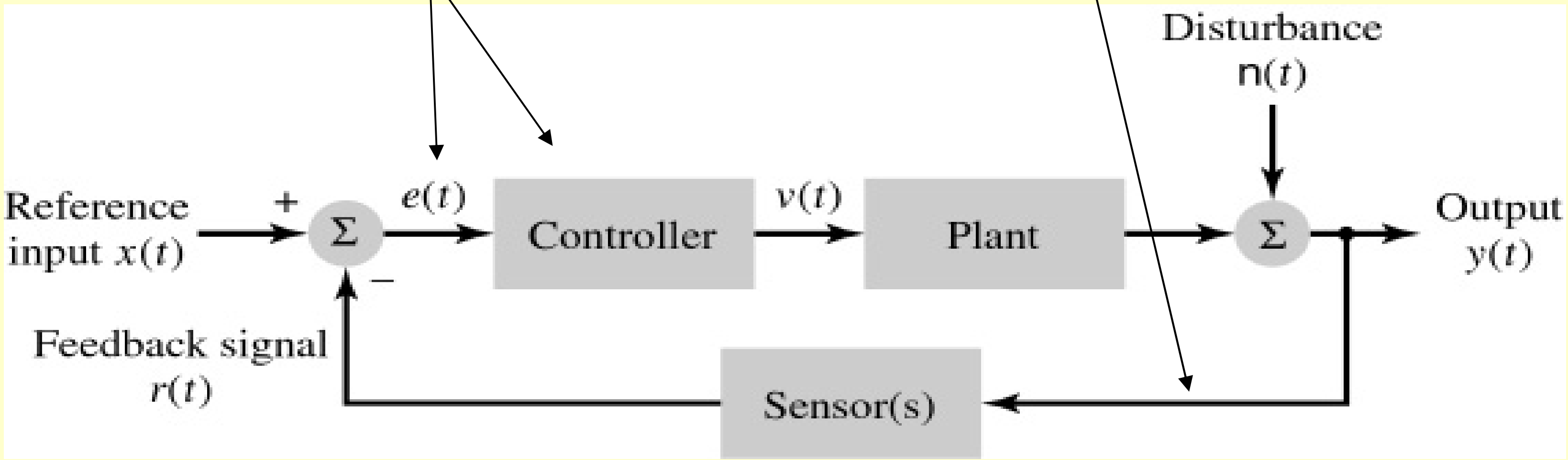


Pathfinder exploring the surface of Mars

The 70-meter (230-foot) diameter antenna located at Canberra, Australia
The surface of the 70-meter reflector must remain accurate within a fraction of the signal's wavelength. (Courtesy of Jet Propulsion Laboratory.)

Feedback Control System

The controller drives the plant, whose disturbed output drives the sensor(s). The resulting feedback signal is subtracted from the reference input to produce an error signal ***e(t)***, which, in turn, drives the controller. The feedback loop is thereby closed.



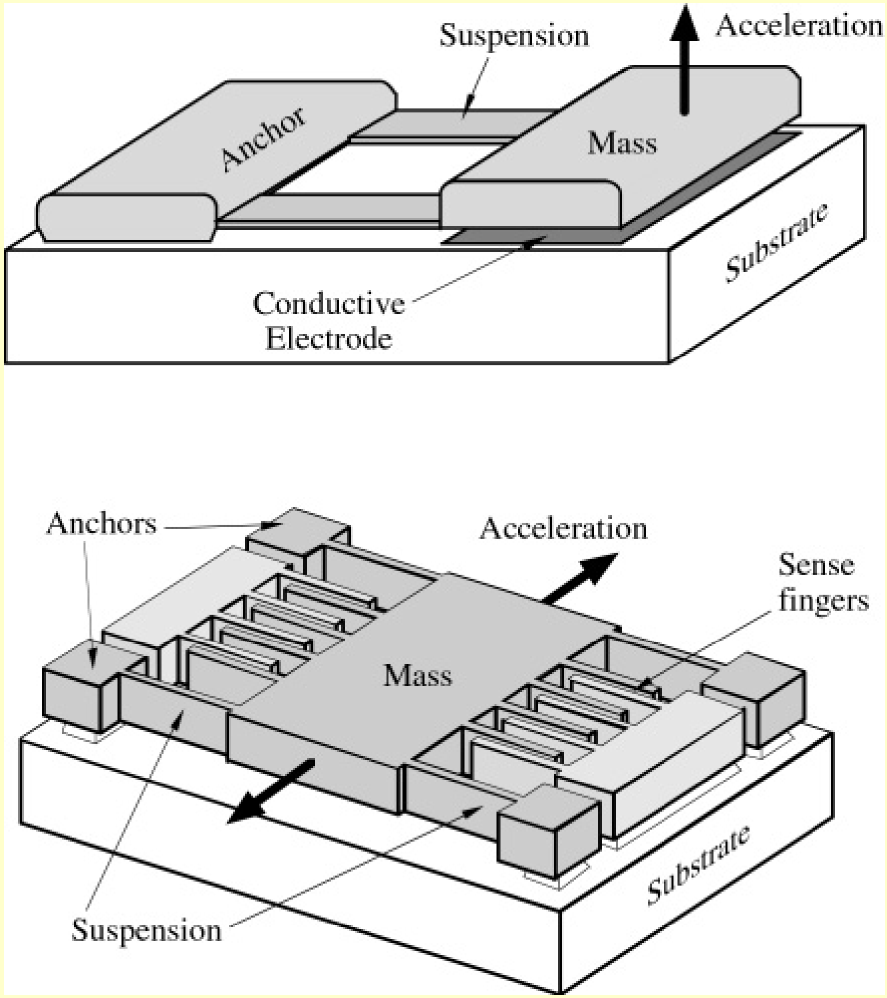
Example:

NASA space shuttle launch

(Courtesy of NASA.)
National ***A***eronautics & ***S***pace ***A***dministration

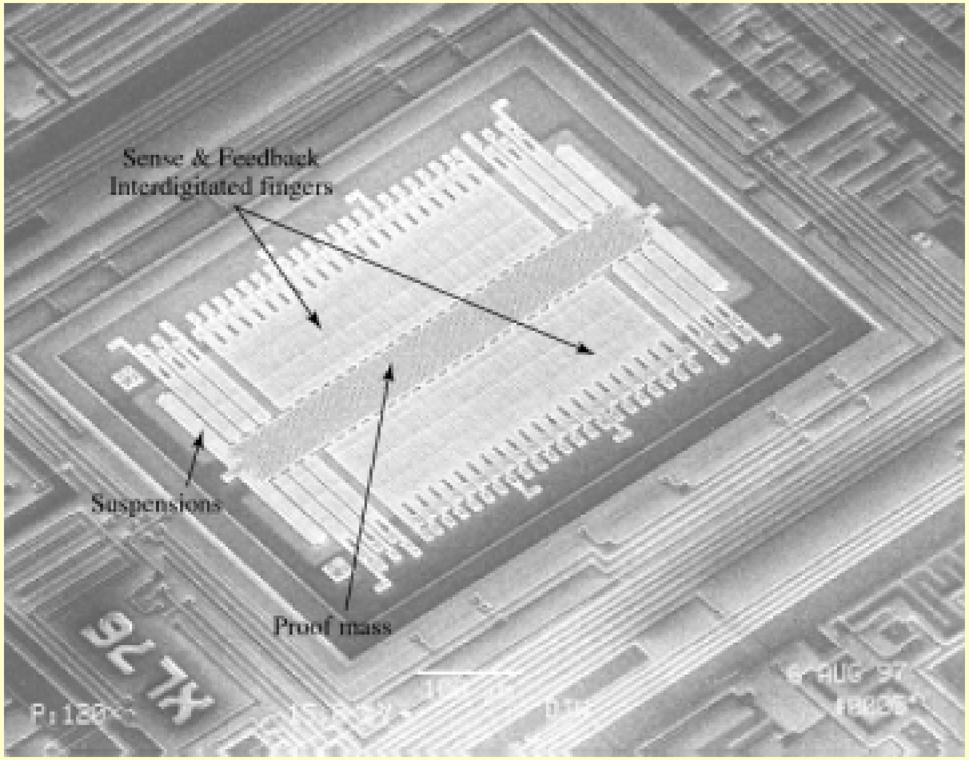
Micro-Electro-Mechanical System

MEMS:



Analog Device's ADXLO5

surface-micro machined poly silicon accelerometer

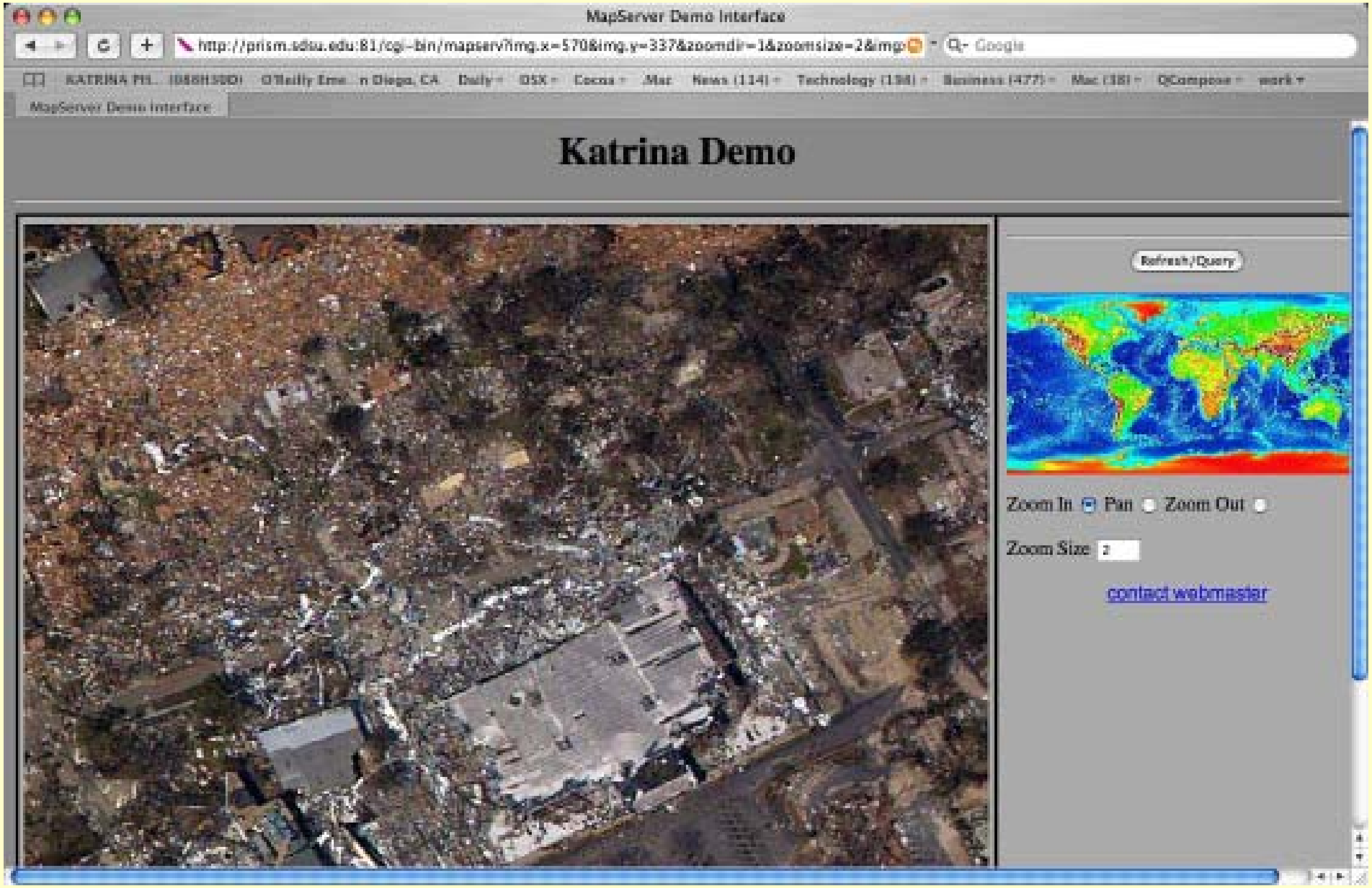


Remote Sensing System

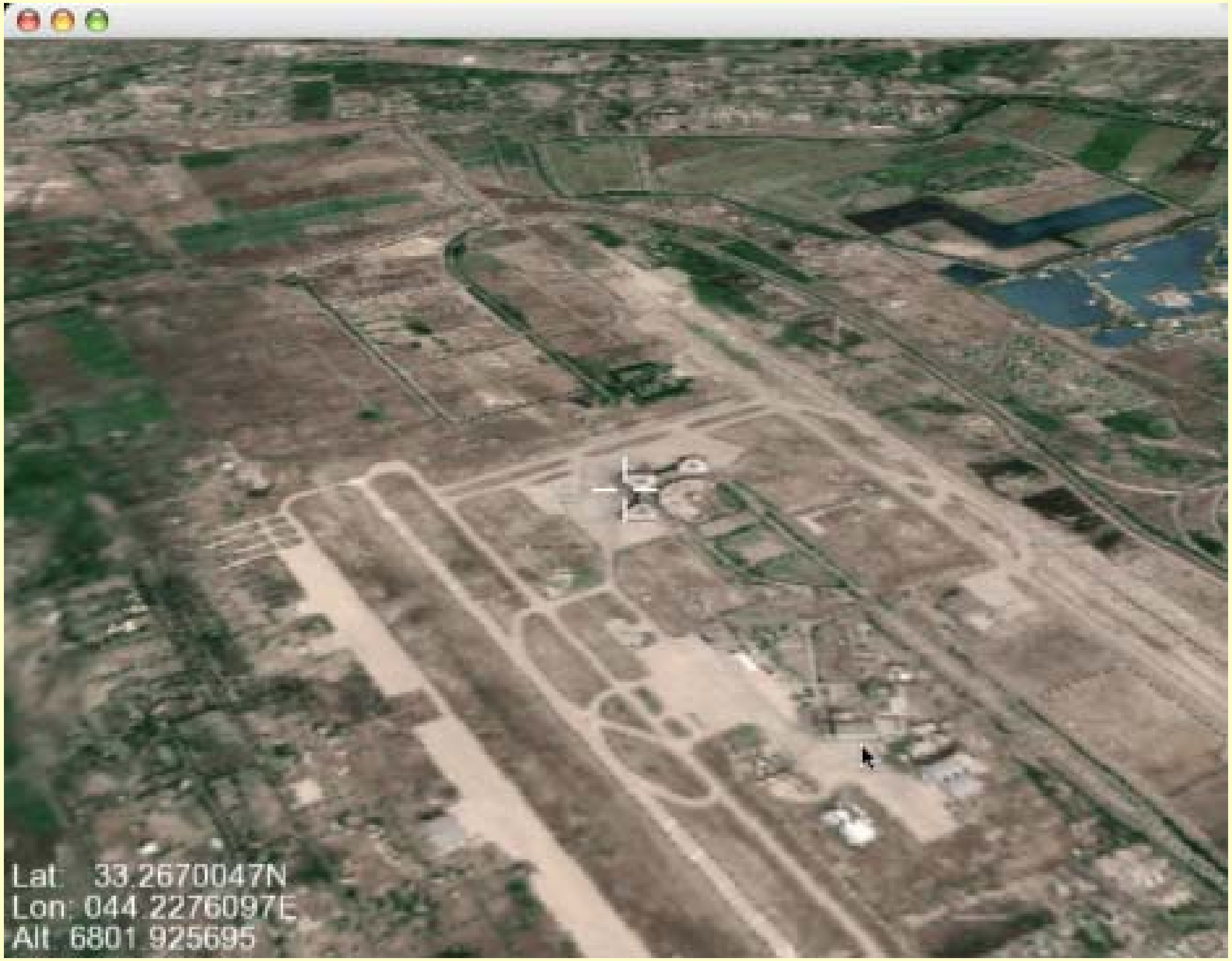
Mount Shasta (California)

derived from a pair of stereo radar images acquired from orbit with the shuttle Imaging Radar (SIR-B). (Courtesy of Jet Propulsion Laboratory.)

Example of the Remote Sensing



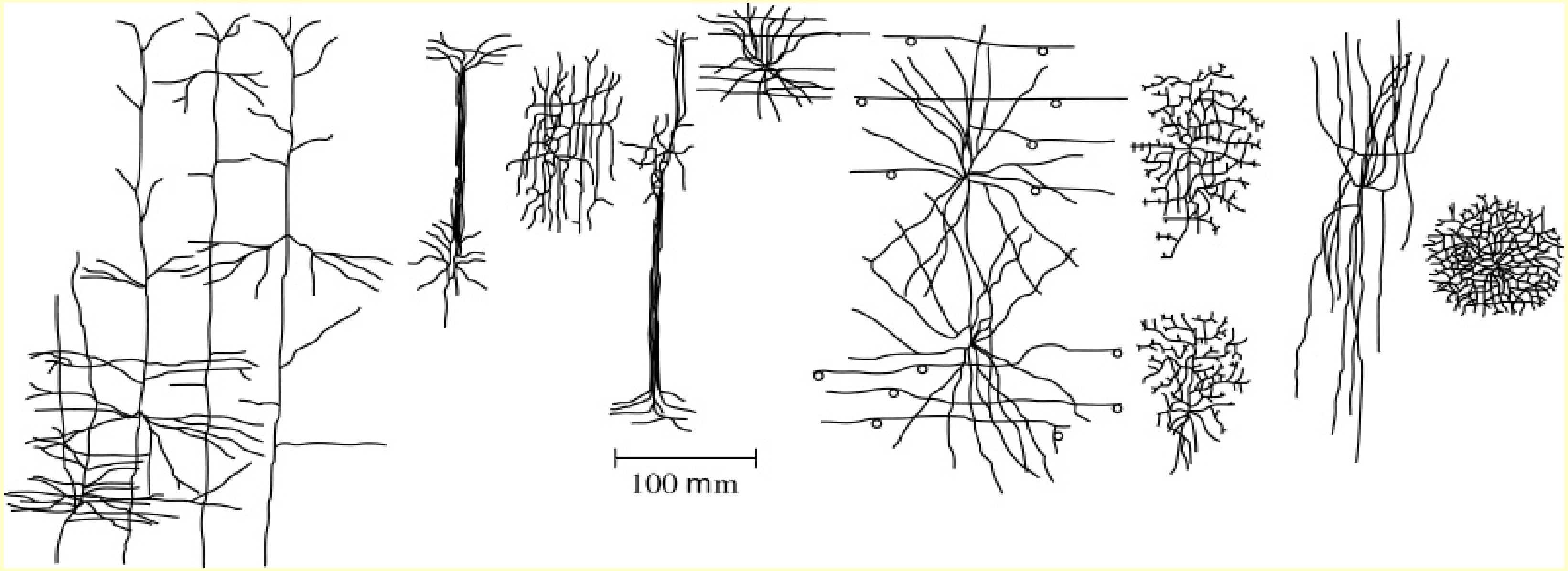
Example of the Remote Sensing



Biomedical Signal System

Morphological types of nerve cells (neurons)

identifiable in monkey cerebral cortex, based on studies of primary somatic sensory and motor cortices. (Reproduced from E. R. Kande, J. H. Schwartz, and T. M. Jessel, *Principles of Neural Science,* 3d ed., 1991; courtesy of Appleton and Lange.)



Structural & Functional Brain Research

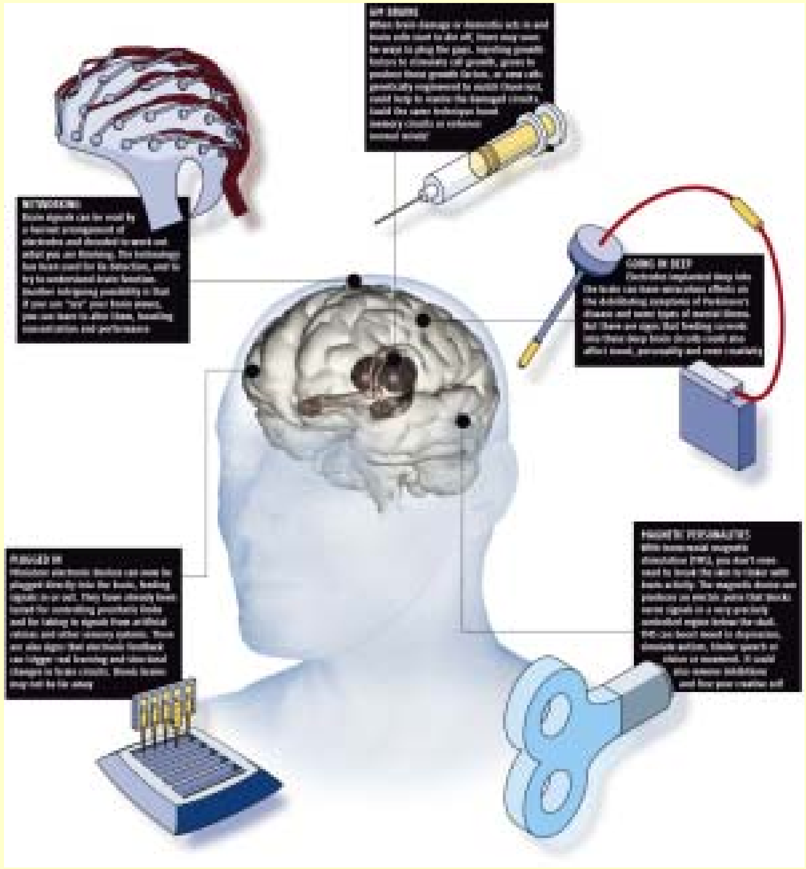
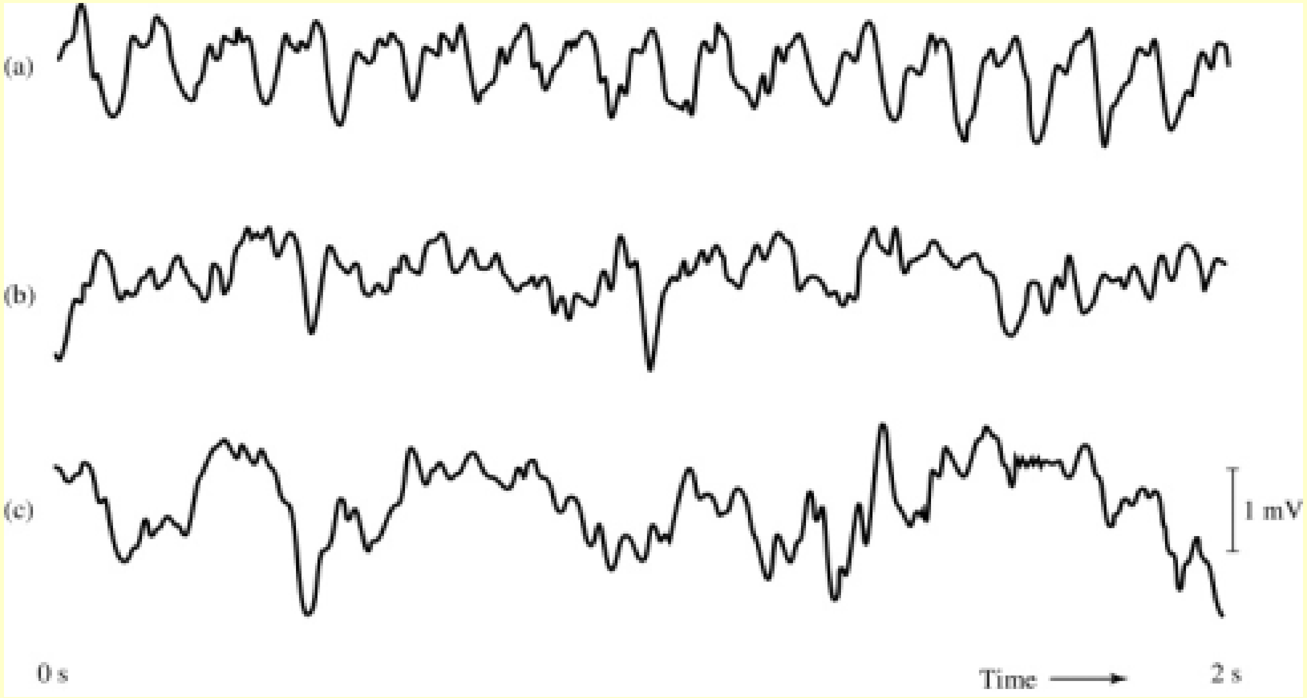


Photo from http://www.newscientist.com

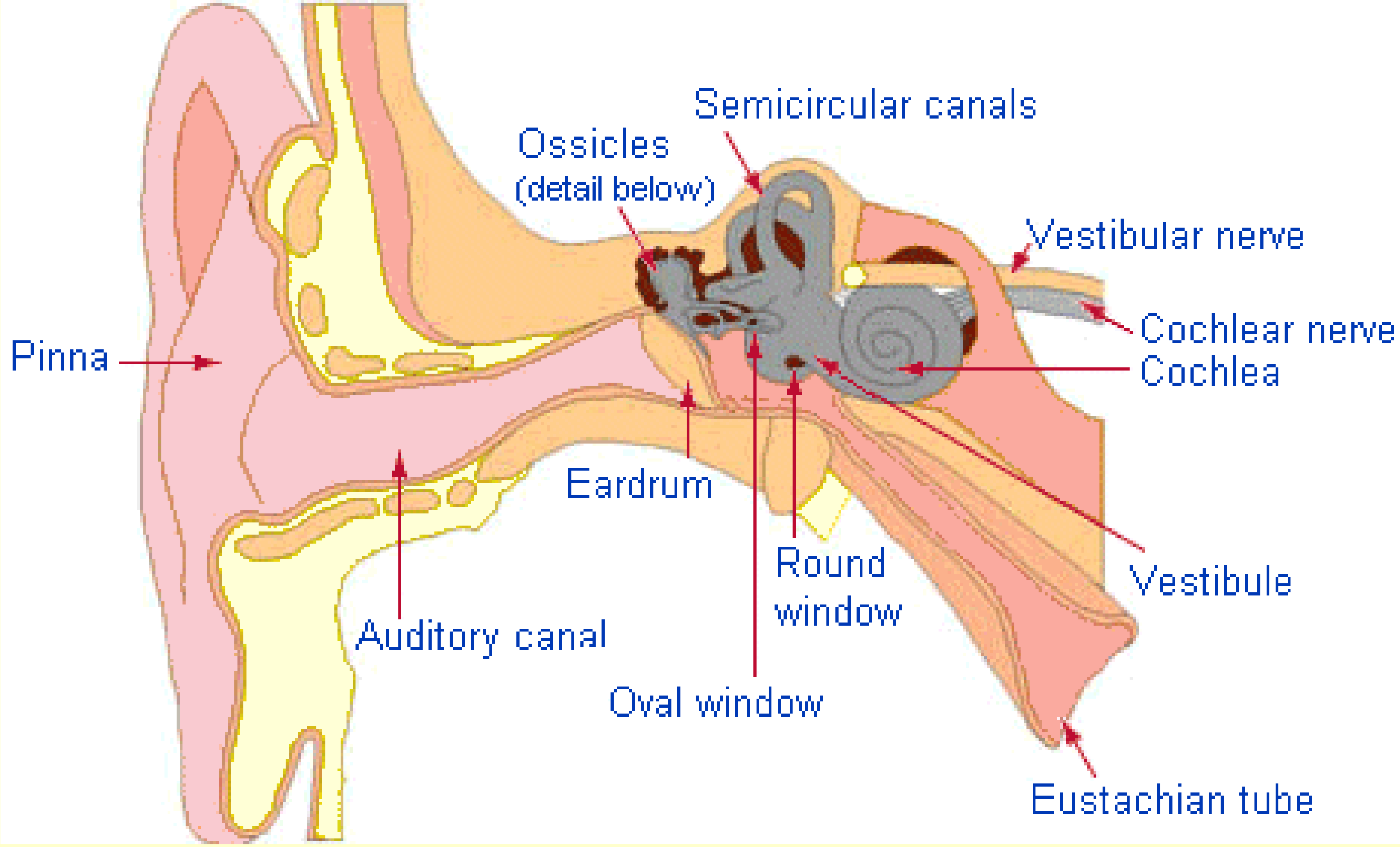
Examples of EEG signals recorded from the *hippocampus* of a rat

Neurobiological studies suggest that the *hippocampus* plays a key role in certain aspects of learning and memory.

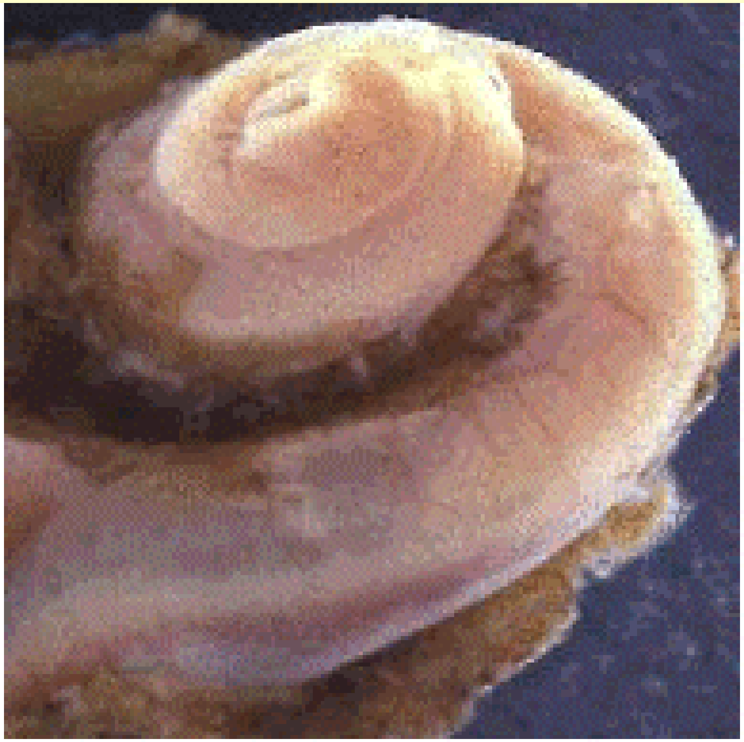


Example of Hippocampi

Auditory Signal System



Inner Ear - Cochlea



Cochlea. The bony labyrinth has been dissected out, showing the membranous labyrinth coils.

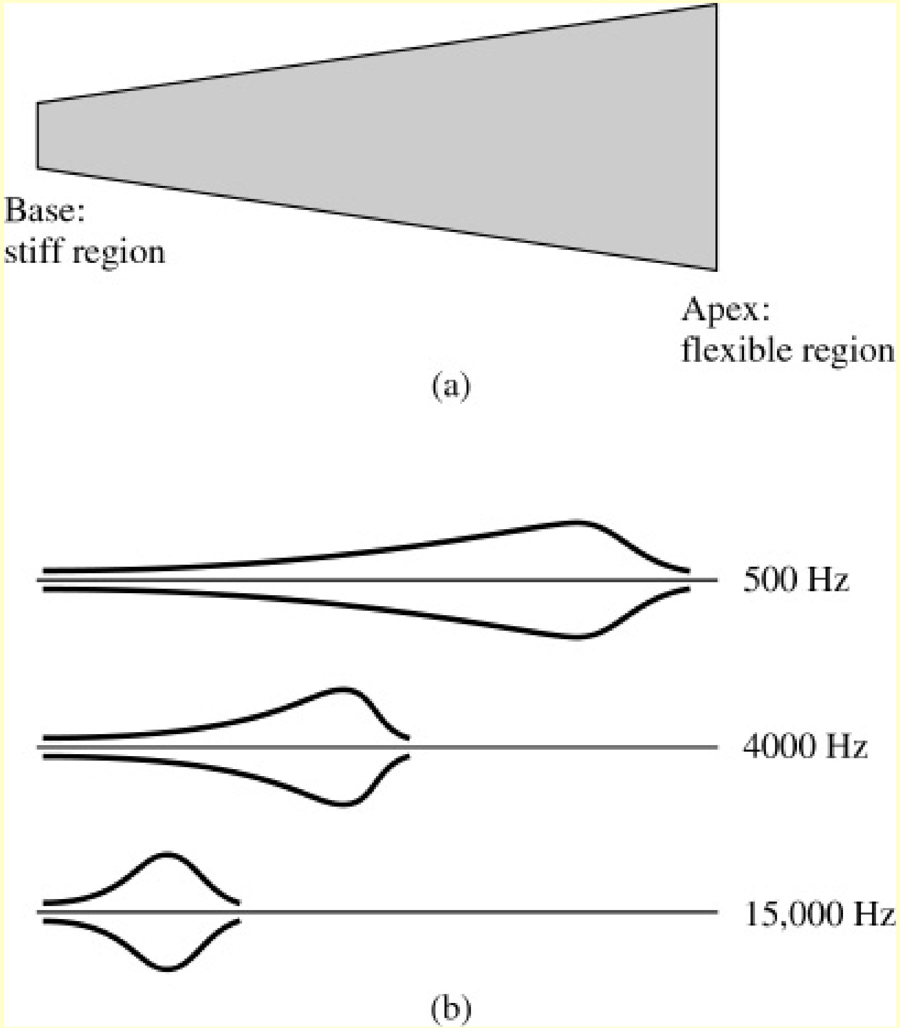
Source: Promenade 'round the Cochlea

Owner: Mireille Rebillard
(Unit 254 Inserm France)

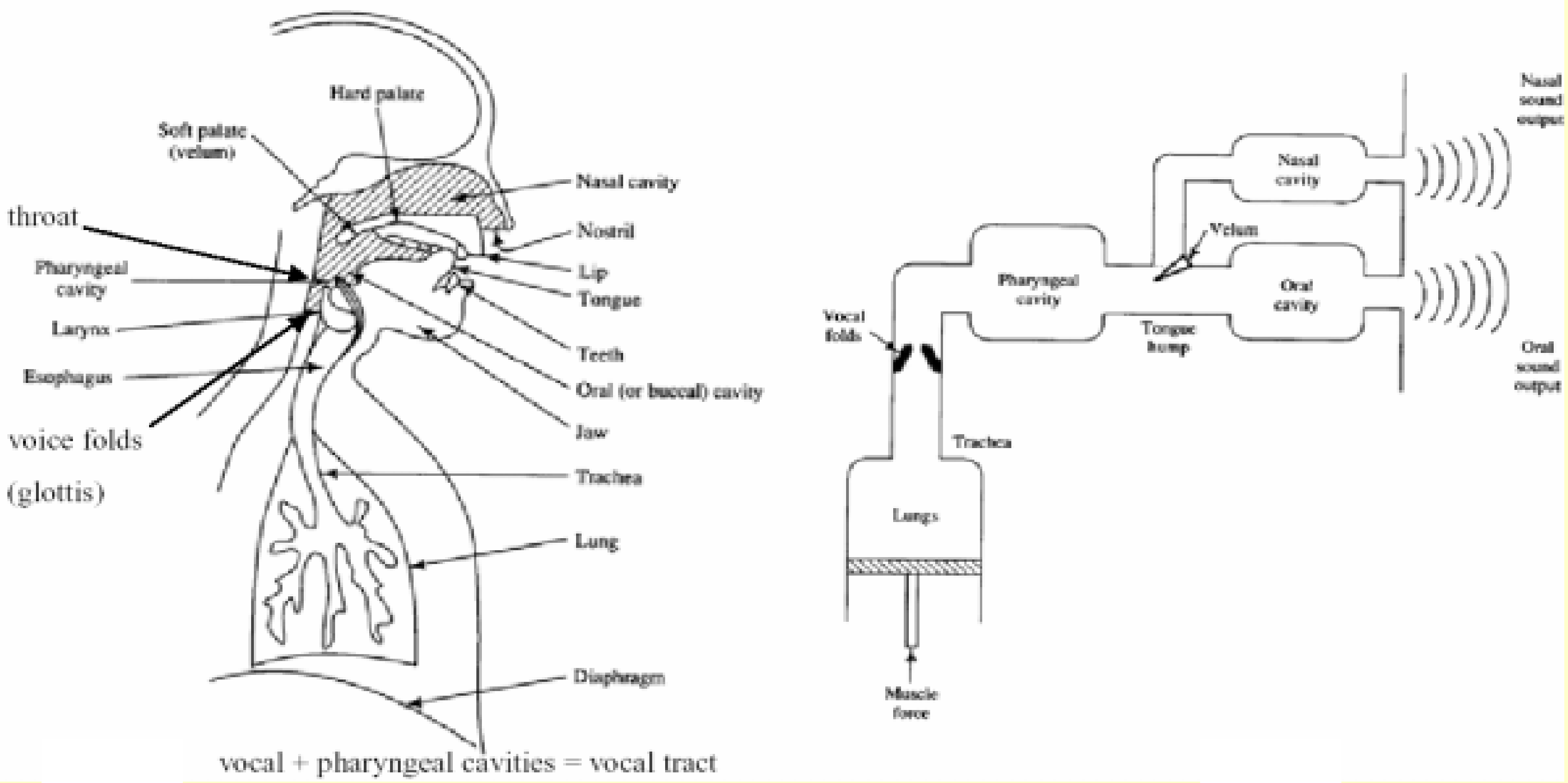
Basilar Membrane in the Cochlea

(a)*Basilar membrane* in the cochlea is depicted as if it were uncoiled and stretched out flat; the “base” and “apex” refer to the cochlea, but the remarks “stiff region” and “flexible region” refer to the basilar membrane.

(b) This diagram illustrates the traveling waves along the basilar membrane.

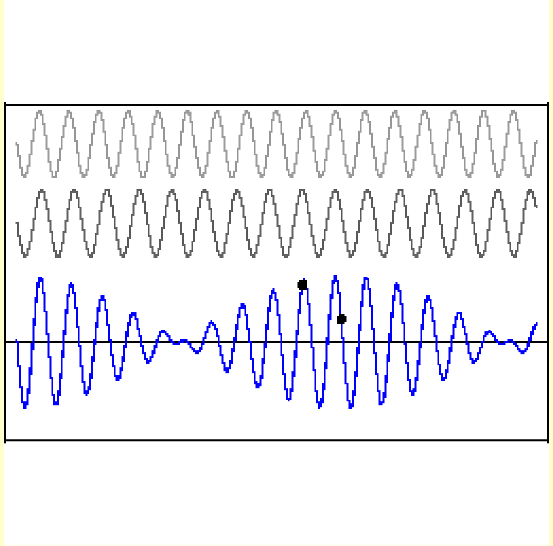


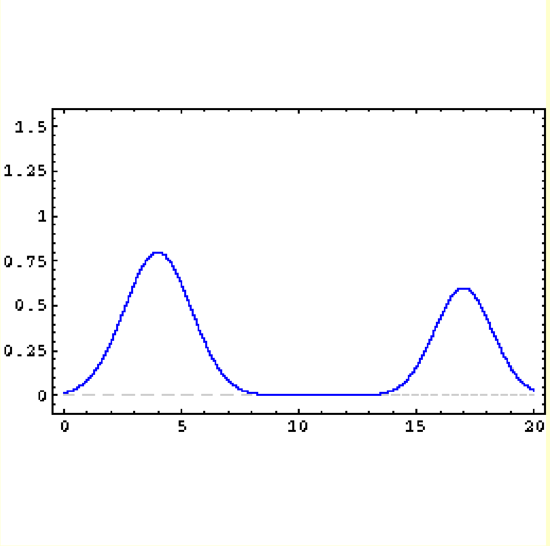
Voice Reproduction



Voice or Acoustics Web Sites

http://www.humnet.ucla.edu/humnet/linguistics/faciliti/demos/vocalfolds/vocalfolds.htm





http://www.kettering.edu/~drussell/Demos/copyright.html

Classification of Signals

1. Continuous-Time and Discrete-time Signals
2. Even and Odd Signals
3. Periodic and Non-periodic Signals
4. Deterministic and Random Signals
5. Energy and Power Signals

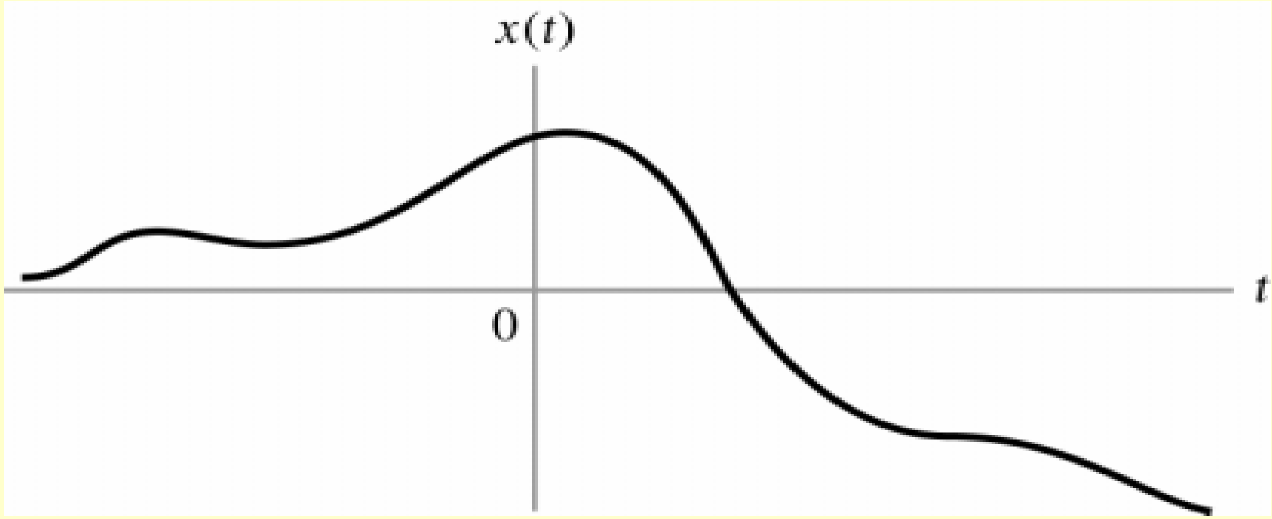
Continuous-time Signal x(t)

t : 自變數 (Independent variable)

t 是連續時間變數

x(t) : 應變數 (Dependent variable)

x(t) 也是連續時間變數



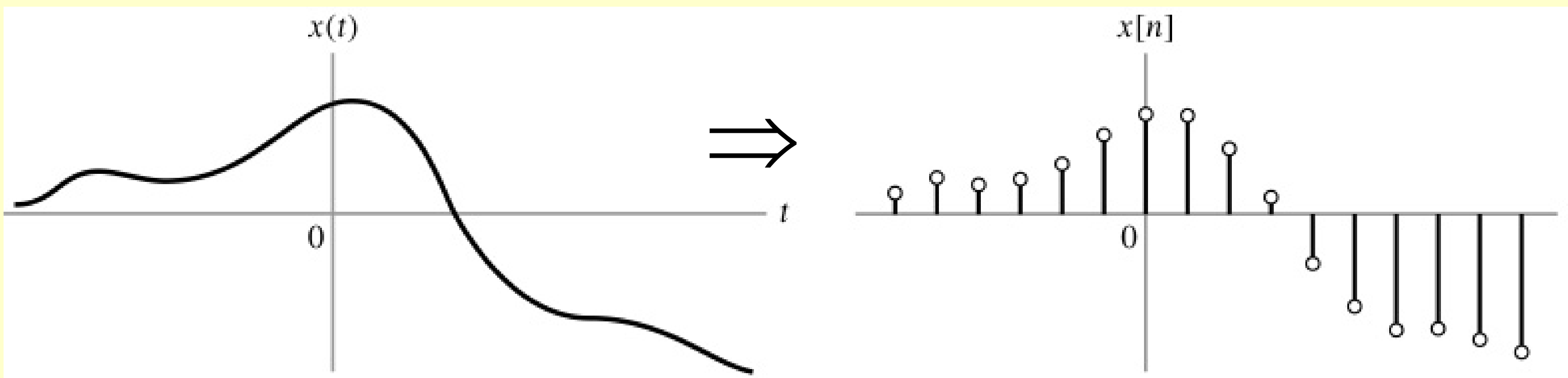
Discrete-time Signal x[n]

n : 自變數 (Independent variable)

n 是離散時間變數 (integer index 整數索引)

x[n] : 應變數 (Dependent variable)

x[n] 也是離散時間變數



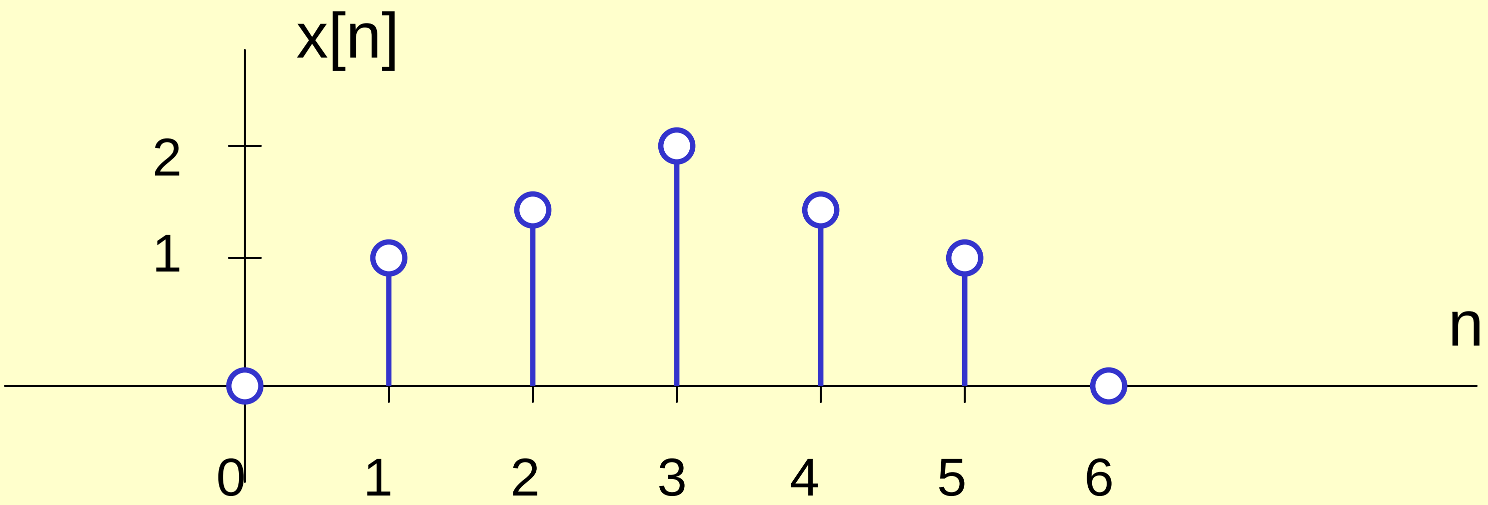
(a) 連續性訊號　　(b) 離散性訊號

Discrete-time Signal x[n] (cont.)

x[n] 若以集合方式表示下圖 : 方法 一

x[n] = { 0, 1, 1.5, 2, 1.5, 1, 0} ,

預設第一個元素 (element) 所在位置 n = 0



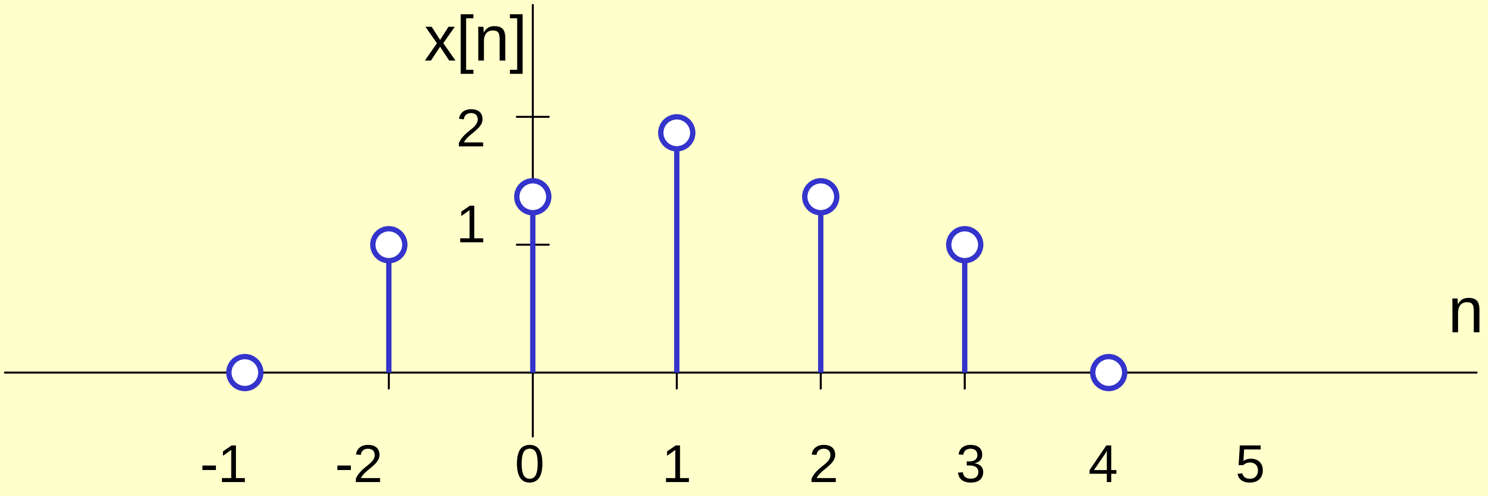
Discrete-time Signal x[n] (cont.)

x[n] 若以集合方式表示下圖 : 方法 二

x[n] = { 0, 1, 1.5, 2, 1.5, 1, 0} ,

↑ n=0

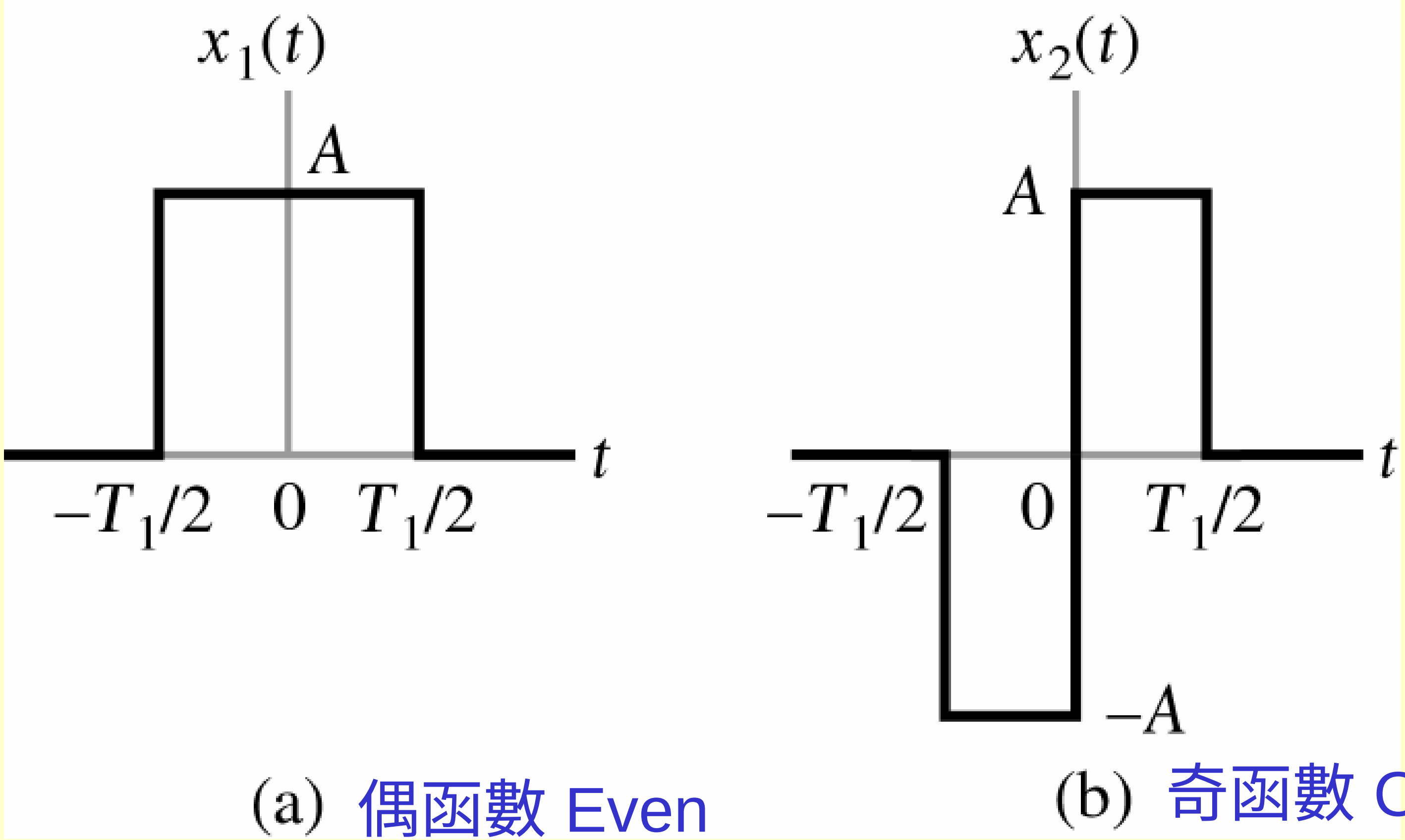
以特殊標示 元素 (element) 所在位置 n = 0



Even and Odd Signals

$$x_1(-t) = x_1(t)$$

$$x_2(-t) = -x_2(t)$$



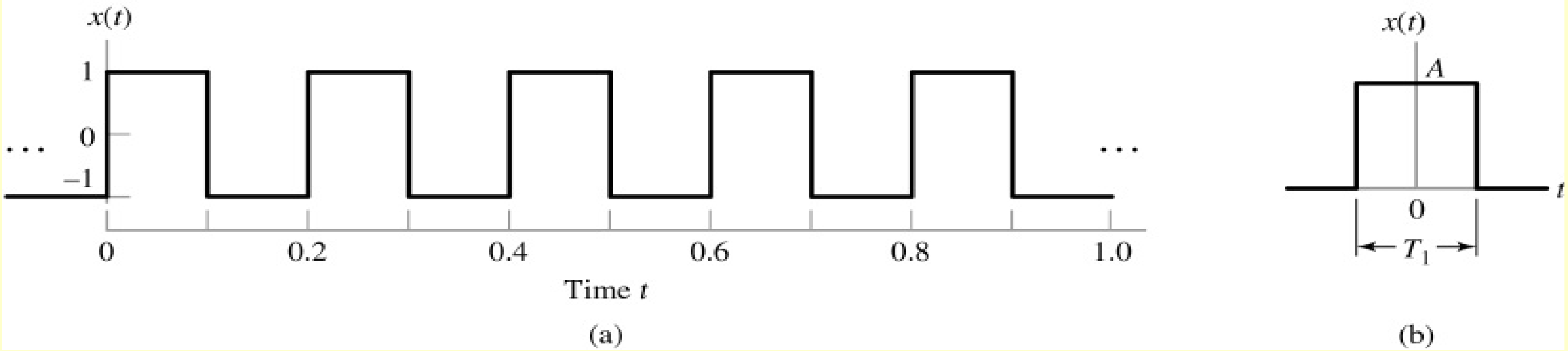
(a) 偶函數 Even

(b) 奇函數 Odd

Periodic and Non-Periodic Signals

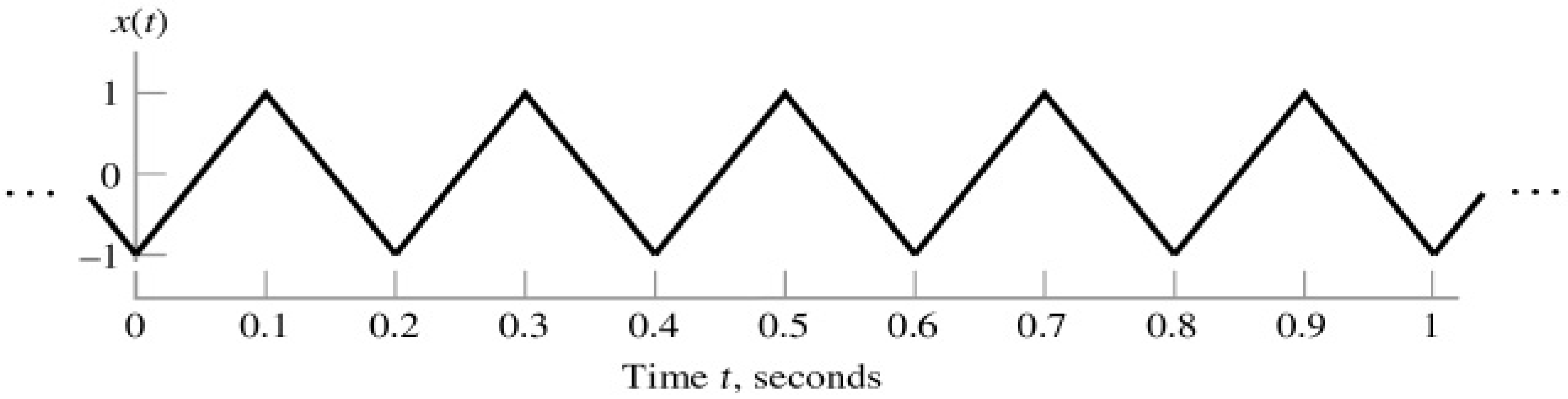
(a)Square wave with amplitude A = 1 and period T = 0.2s.
振幅: 1 ；週期性方波的週期: 0.2 秒

(b)Rectangular pulse of amplitude A and duration T_1.
振幅: A ；非週期方波的持續時間: 0.2 秒



Triangular wave alternative between –1 and +1

週期性三角波+1 和–1 間交互變化



x(t) 內含許多頻率分量

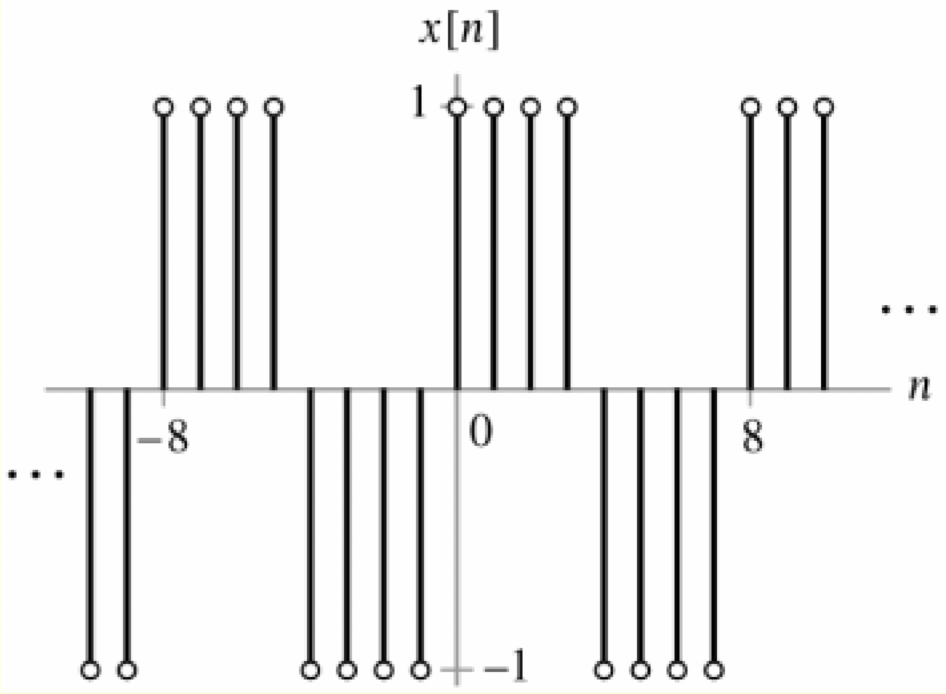
x(t)訊號基本週期：T = 0.2 秒

x(t)訊號基本頻率：f = 1/T = 5 cycles/sec = 5 Hz

Discrete-time square wave alternative between –1 and +1

x[n] = { …, 1,1,1,1, -1 -1,-1,-1,1,1,1,1,-1,-1,-1,-1,1,1…}

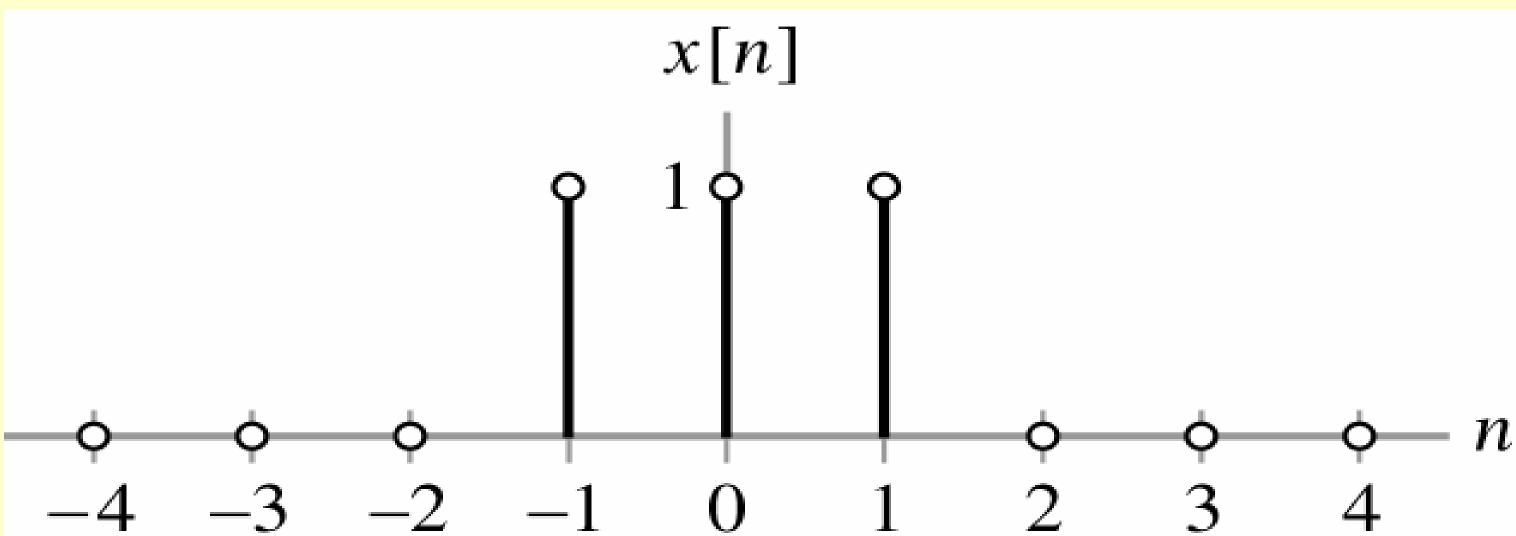
n = 0



Non-periodic discrete-time signal consisting of three nonzero samples

$x[n] = \{0, 0, 0, 1, 1, 1, 0, 0, 0\}$

↑ n = 0



Deterministic and Random Signals

- Deterministic Signal: (定性訊號)
  - 訊號在任何時間點不會有不確定之值
  - 能以明確的時間函數作為模型
- Random Signal: (隨機訊號)
  - 訊號在未產生前會有不確定之值
  - 訊號整體可視為一個“隨機過程(Random Process)”

Energy and Power Signals

瞬間功率(Instantaneous Power):

$$p(t) = \frac{v^2(t)}{R}$$

or

$$p(t) = i^2(t)\, R$$

連續時間總能量(total Energy):

$$E = \lim_{T \to \infty} \int_{-T/2}^{T/2} x^2(t)dt$$

$$= \int_{-\infty}^{+\infty} x^2(t)dt$$

Average Power

訊號 x(t) 在連續時間上的平均功率(Averaged Power):

$$P = \lim_{T \to \infty} \frac{1}{T} \int_{-T/2}^{T/2} x^2(t)\,dt$$

訊號 x(t) 在基本週期 T 的平均功率:

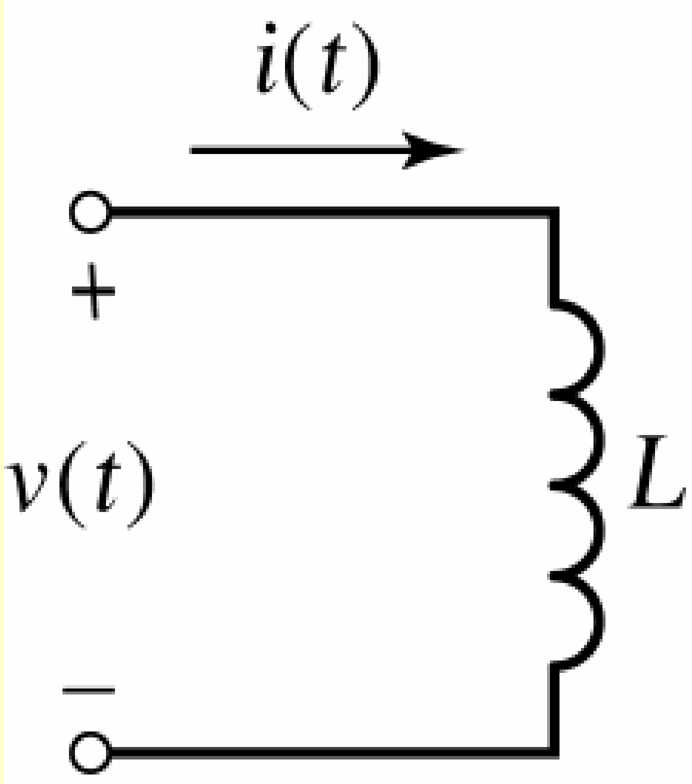
$$P = \frac{1}{T} \int_{-T/2}^{T/2} x^2(t)\,dt$$

Basic Operations on Signals

- Operations on Dependent Variables: (應變數運算)
  - ***Scaling***: 比例調整 $y(t) = c\,x(t)$ or $y[n] = c\,x[n]$
  - ***Addition***: $y(t) = x_1(t) + x_2(t)$ or $y[n] = x_1[n] + x_2[n]$
  - ***Multiplication:*** $y(t) = x_1(t)\,x_2(t)$ or $y[n] = x_1[n]\,x_2[n]$
  - ***Differentiation:*** $$y(t) = \frac{d}{dt}x(t)$$
  - ***Integration:*** $$y(t) = \int_{-\infty}^{t} x(\tau)\,d\tau$$

微分運算範例

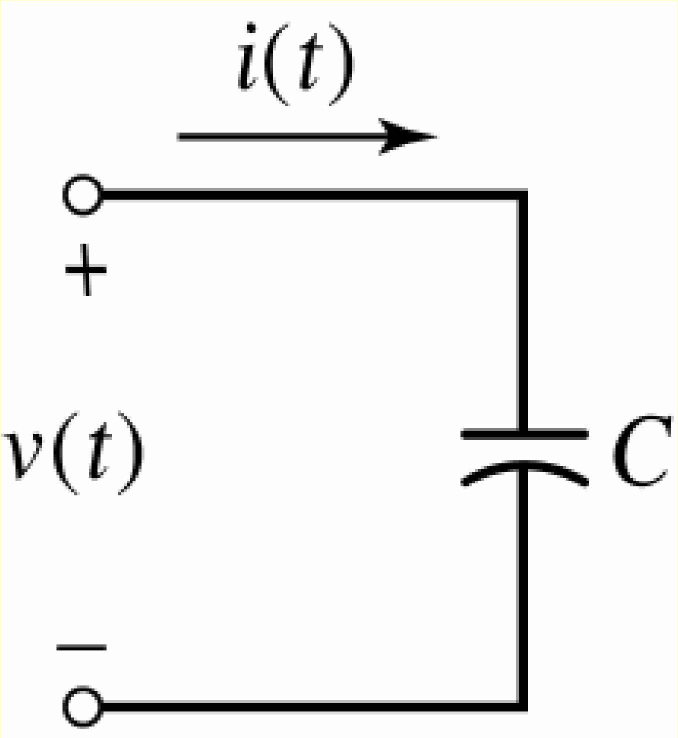
Inductor with current *i*(*t*), inducing voltage *v*(*t*) across its terminals.



$$v(t) = L\frac{d}{dt}i(t)$$

積分運算範例

Capacitor with voltage *v*(*t*) across its terminals, inducing current *i*(*t*).



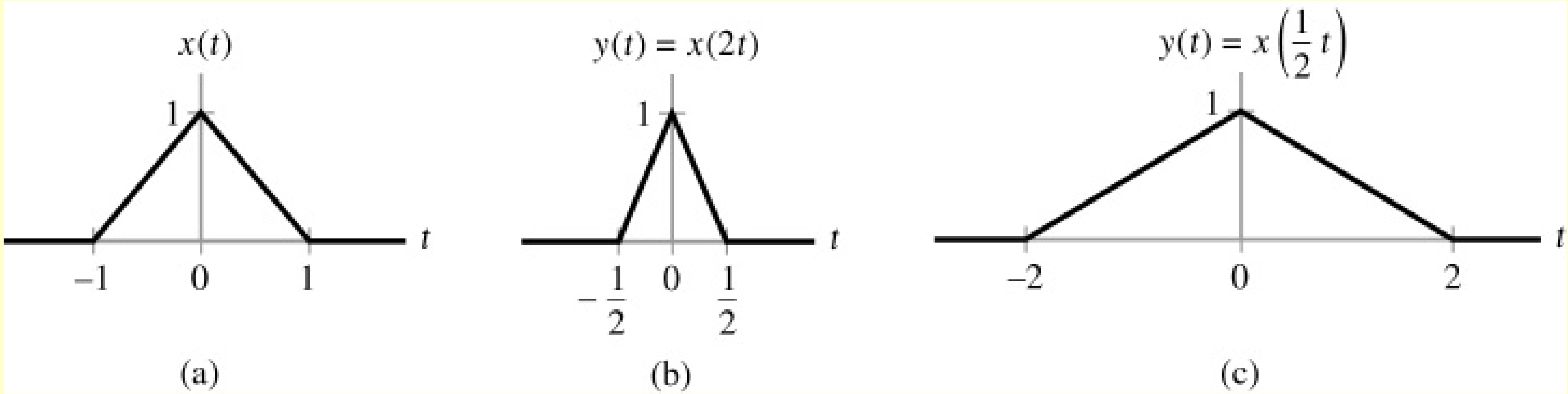
$$v(t) = \frac{1}{C}\int_{-\infty}^{t} i(\tau)\, d\tau$$

Operations on Independent Variables

- **Operations on Independent Variables: (自變數運算)**
  - ***Time Scaling:*** 時間比例調整
    - $y(t) = x(a\ t)$ or $y[n] = x[k\ n]$
  - ***Reflection:*** 反映射 (左、右反轉)
    - $y(t) = x(-t)$ or $y[n] = x[-n]$
  - ***Time Shifting:*** 時間位移
    - $y(t) = x(t-t_0)$ or $y[n] = x[n-n_0]$
  - ***Time Scaling and Shifting:***
    - $y(t) = x(a\ t - b)$ or $y[n] = x[k\ n - b]$
    - Procedure: (1) Shifting → (2) Scaling

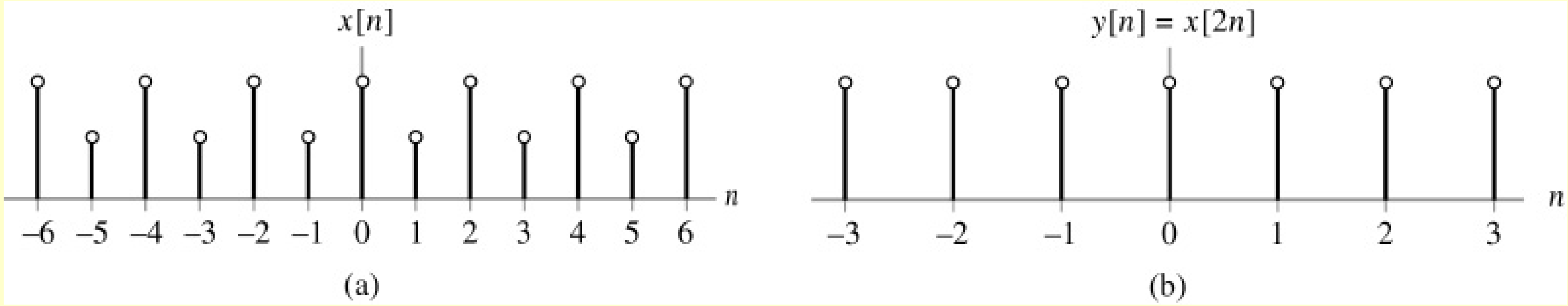
Time-scaling operation on a continuous-time signal

(a) original signal $x(t)$,
(b) $x(t)$ compressed by a factor of 2, and
(c) $x(t)$ expanded by a factor of 2.



Time scaling on a discrete-time signal

(a) discrete-time signal $x[n]$ and
(b) version of $x[n]$ compressed by a factor of 2, with some values of the original $x[n]$ lost as a result of the compression.



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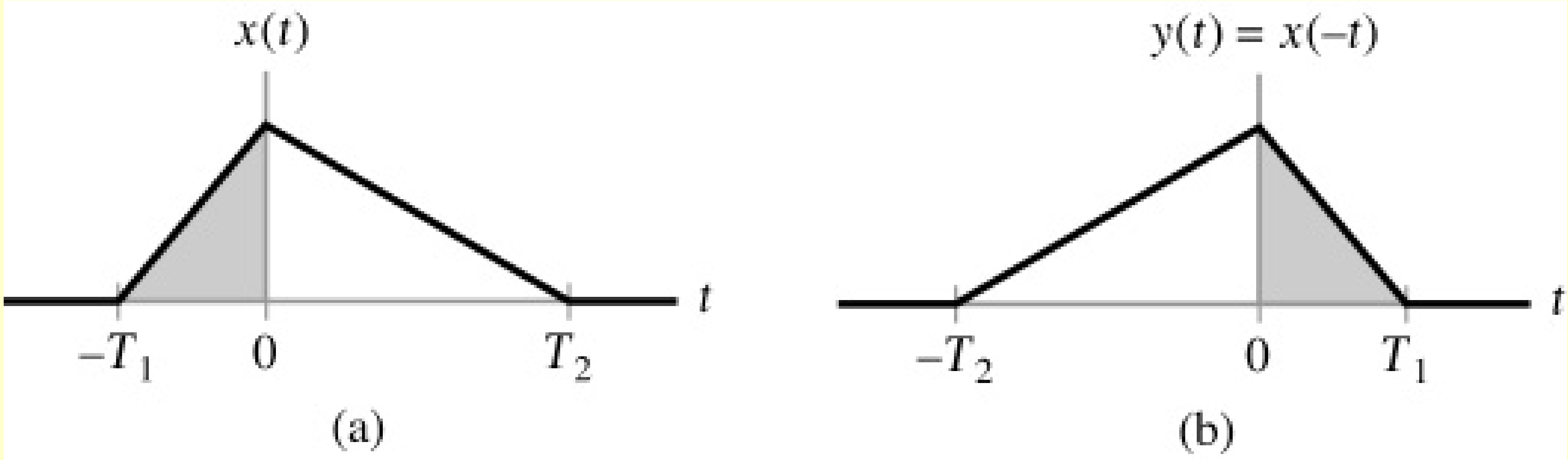
Operation of reflection

(a) continuous-time signal $x(t)$ and

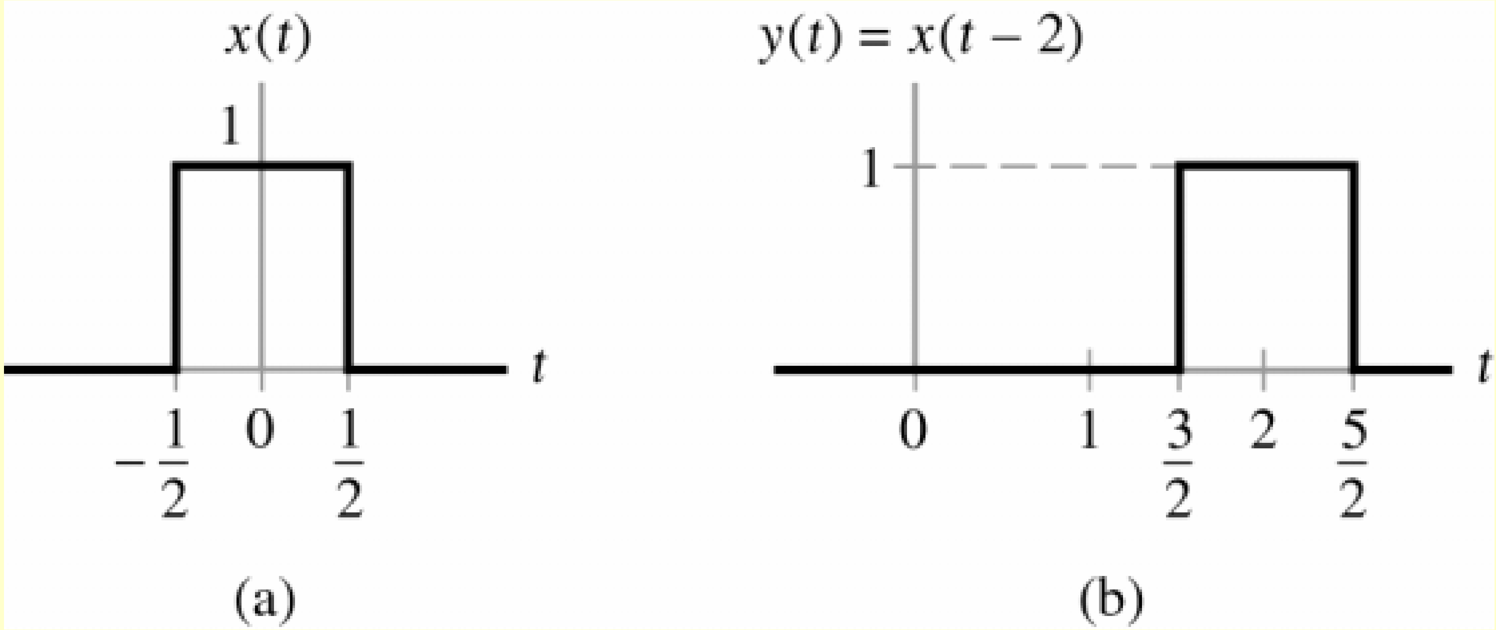
(b) reflected version of $x(t)$ about the origin.



Operation of Time-shifting

(a) continuous-time signal in the form of a rectangular pulse of amplitude 1.0 and duration 1.0, symmetric about the origin; and

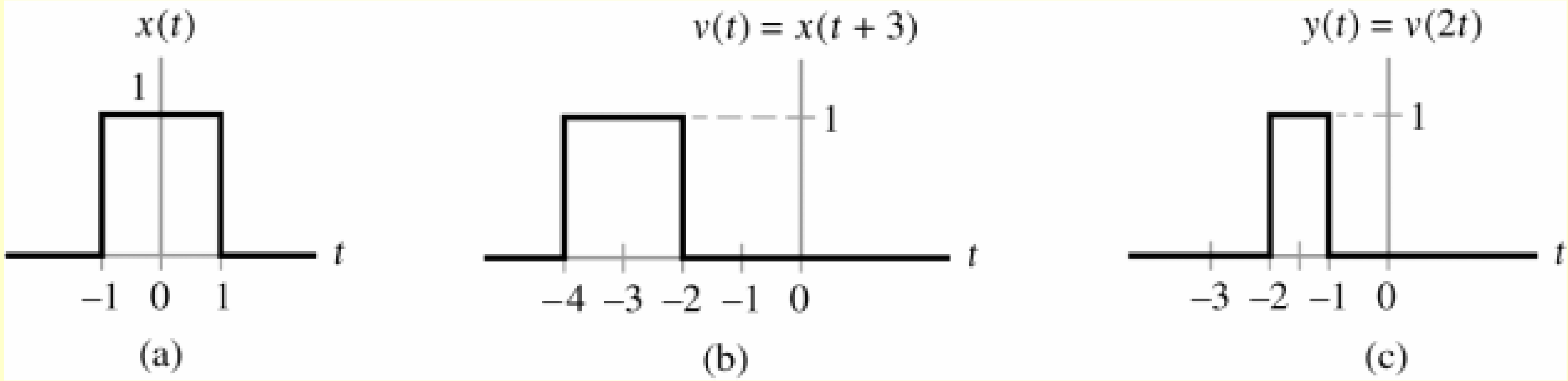
(b) time-shifted version of $x(t)$ by 2 time shifts.



Scaling and Shifting Operations

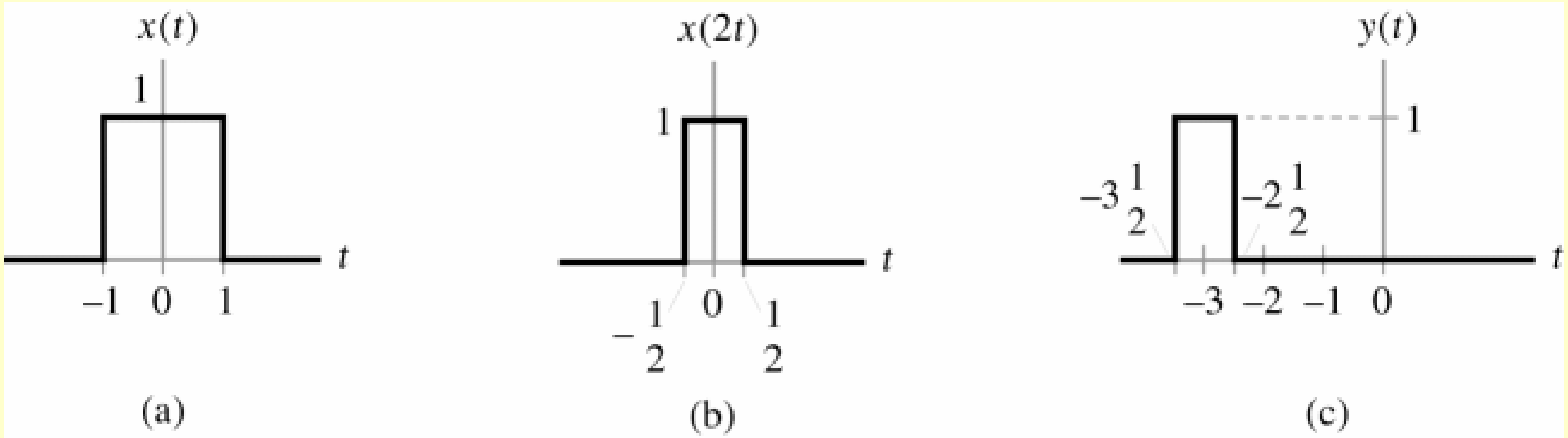
(a) $x(t)$ of amplitude 1.0 and duration 2.0, symmetric about the origin.
(b) Intermediate pulse $v(t)$, representing a time-shifted version of $x(t)$.
(c) Desired signal $y(t)$, resulting from the compression of $v(t)$ by a factor of 2.

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

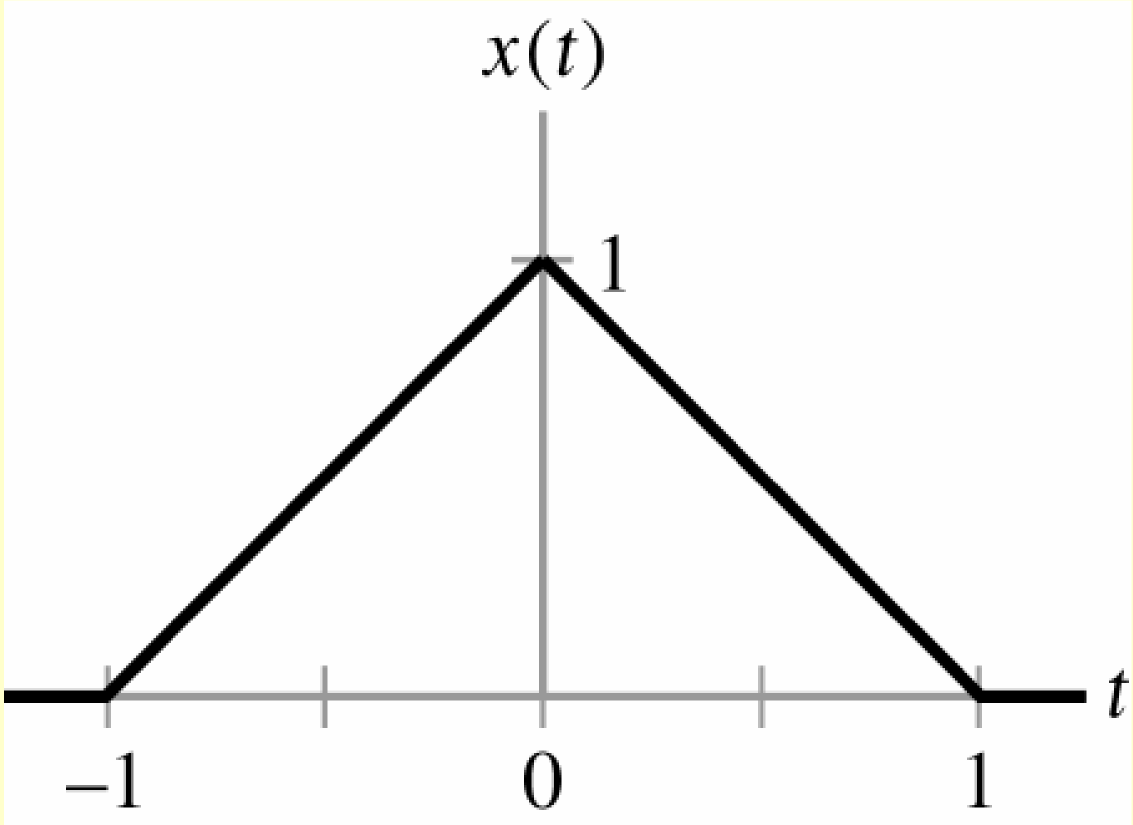


The incorrect way of applying the precedence rule (錯誤作法)

(a) Signal $x(t)$.
(b) Time-scaled signal $v(t) = x(2t)$.
(c) Signal $y(t)$ obtained by shifting $v(t) = x(2t)$ by 3 time units, which yields $y(t) = x(2(t + 3))$.



Triangular pulse

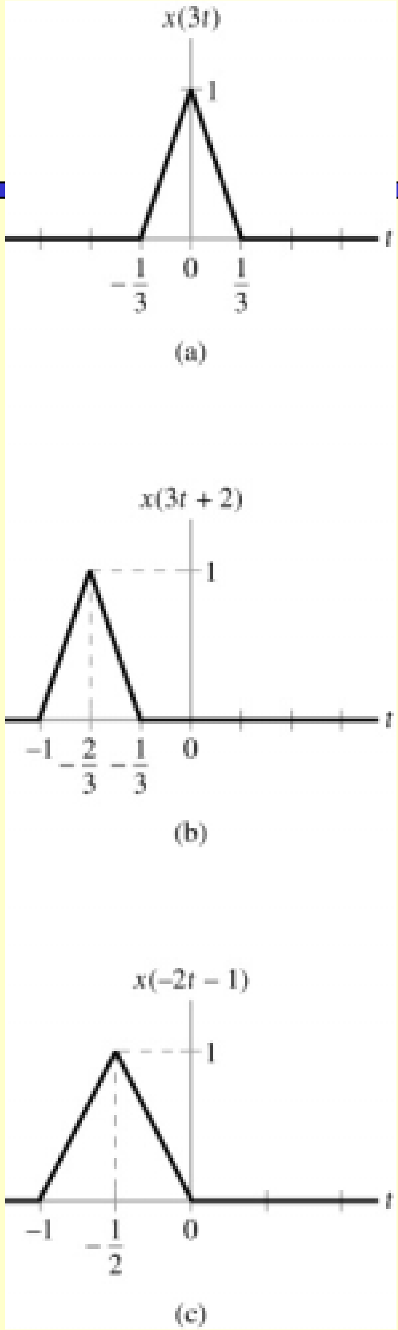


Scaling & Shifting Operations

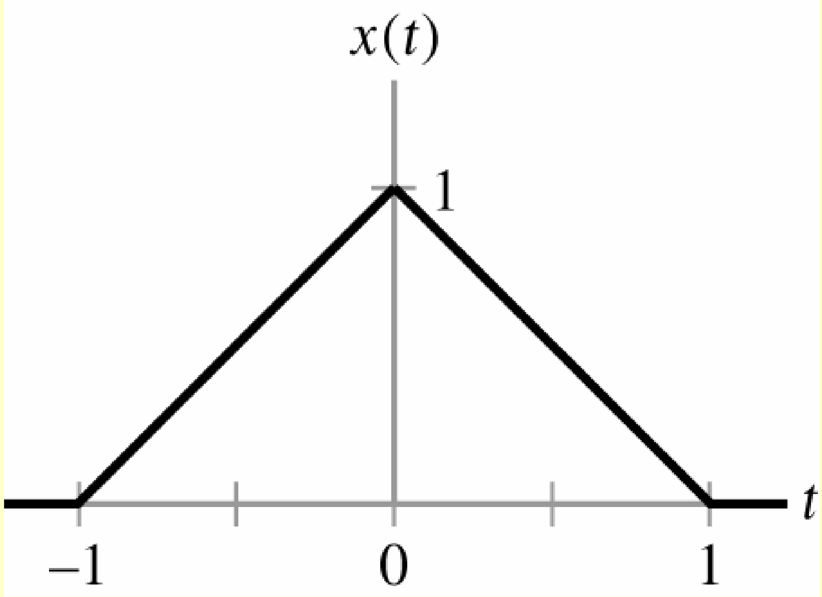
$$x(3t)$$

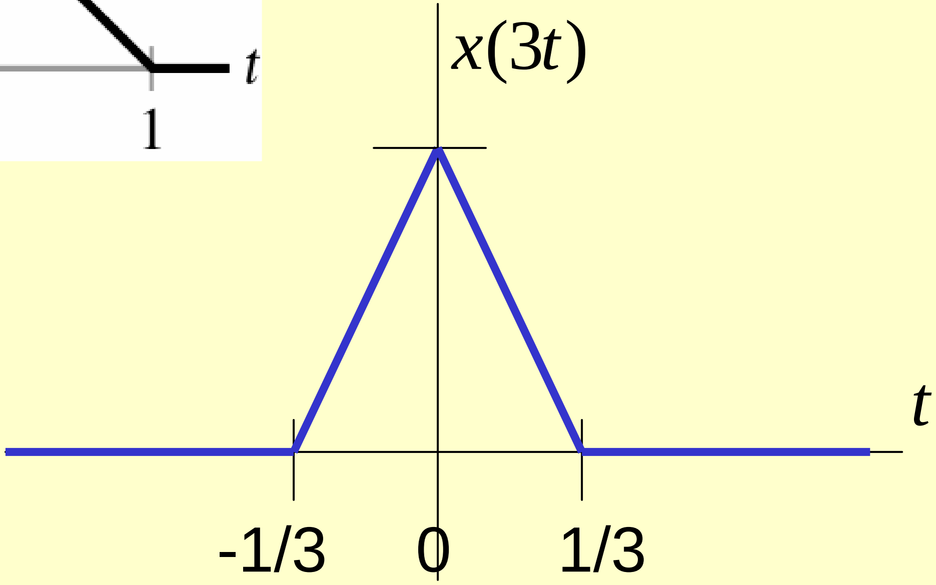
$$x(3t+2)$$

$$x(-2t-1)$$



Time-Scaling with factor of 3





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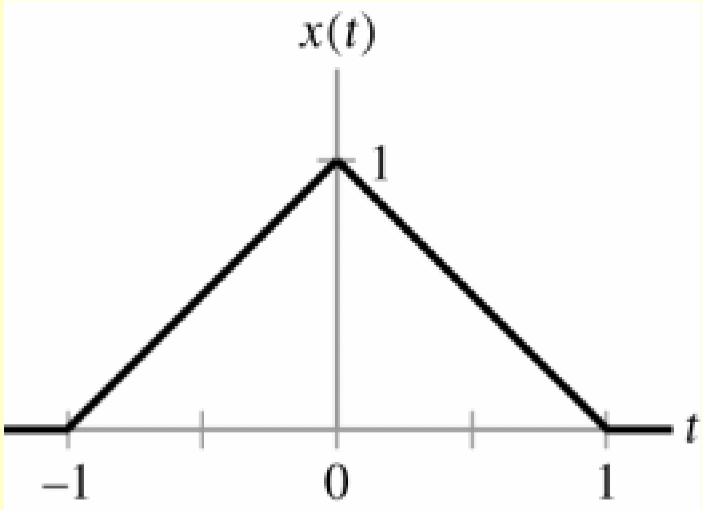
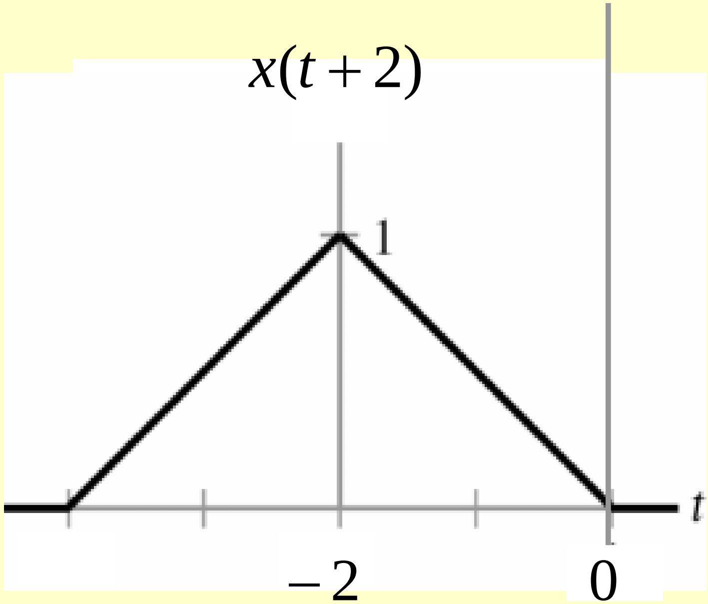
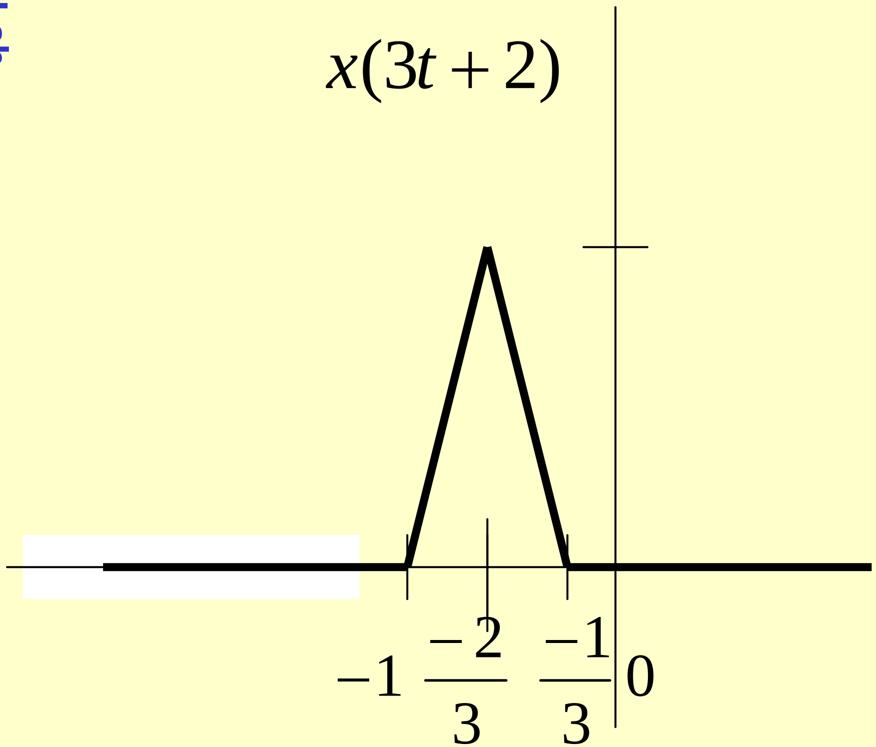
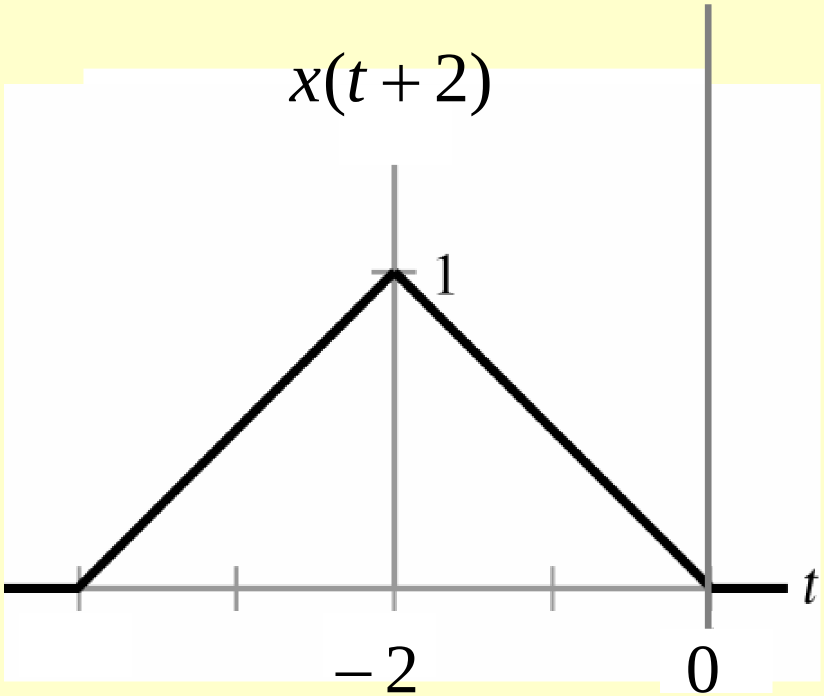
Time-Shifting with factor of -2



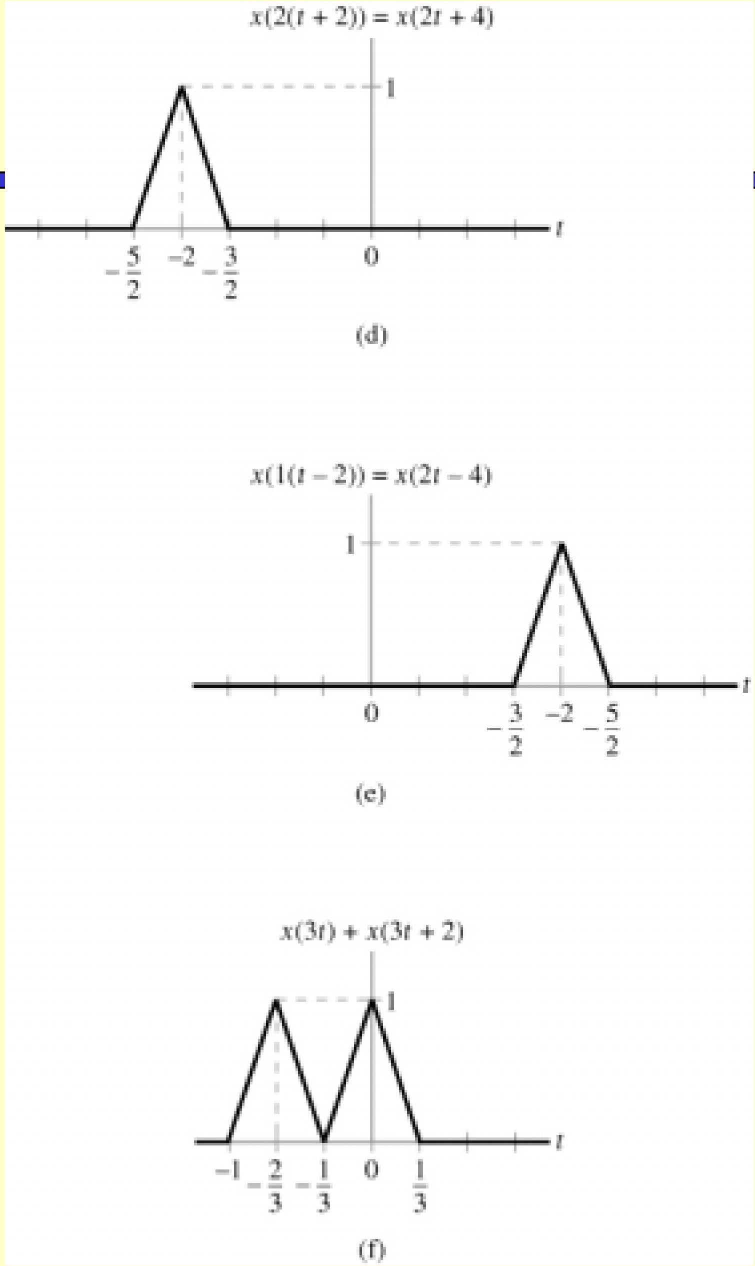


Time-Scaling with factor of 3





Scaling and Shifting Operations



Scaling and Shifting of $x[n]$

$$y[n] = x(2n+3)$$