Classification of Signals

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Classification of Signals

- Continuous-time and discrete-time signals
- **Even and Odd Signals**
- Periodic and aperiodic signals
- Power and energy signals
- Deterministic and random signals
- Causal and non-causal.

Continuous Time Signal

Signal that has a value for all points in time

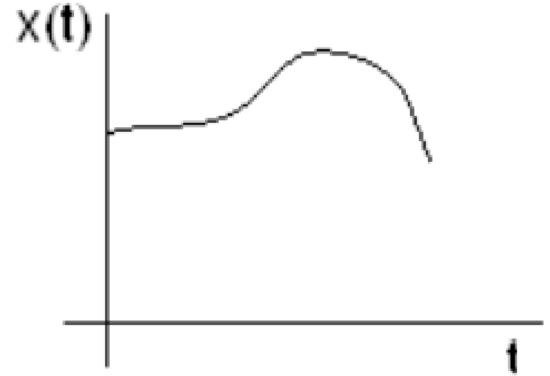
Function of time

Written as x(t) because the signal x is a function of time

Commonly found in the physical world

ex. speech Signal

Displayed graphically as a line



Discrete Time Signals

Signal that has a value for only specific points in time

Typically formed by "sampling" a continuous-time signal

- Taking the value of the original waveform at specific intervals in time

Function of the sample value, n

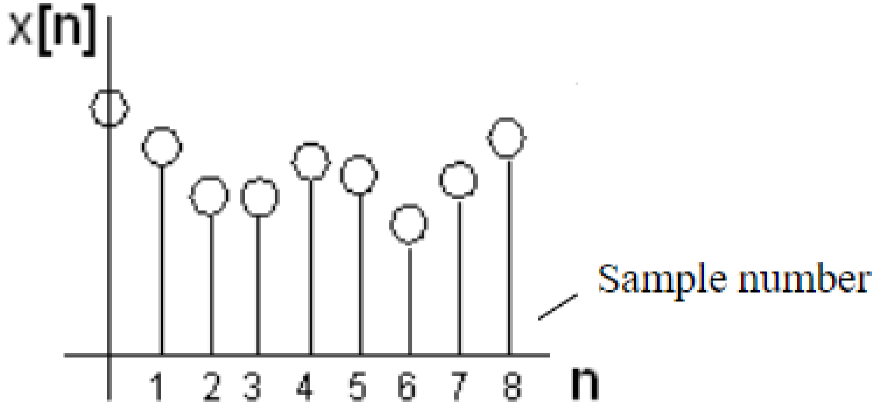
- Write as x[n]
- Often called a sequence

Commonly found in the digital world

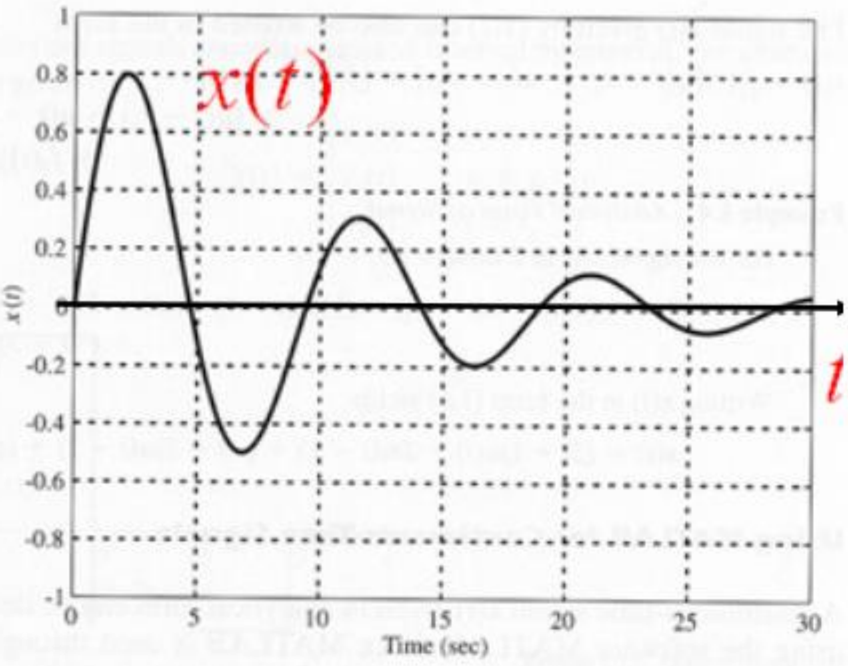
- ex. mp3

Displayed graphically as individual values

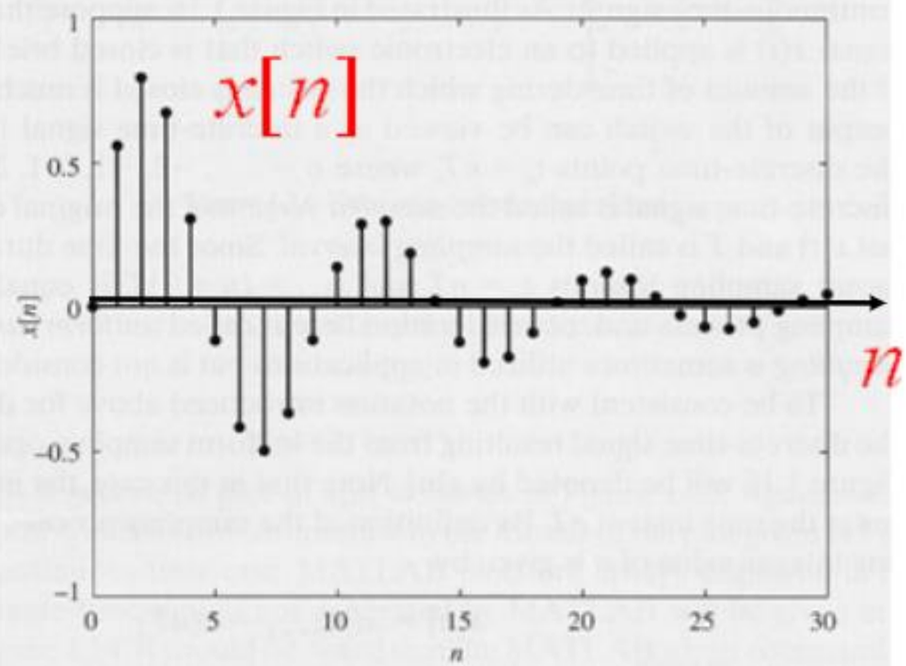
- Called a "stem" plot



Example of CT & DT Signal



MATLAB plot of the signal $x(t) = e^{-0.1t} \sin \frac{2}{3} t$.

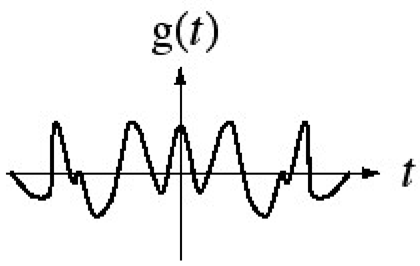


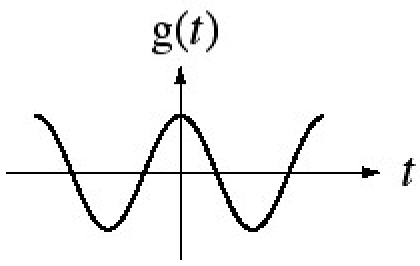
Sampled continuous-time signal.

Even And Odd Signals

Even function

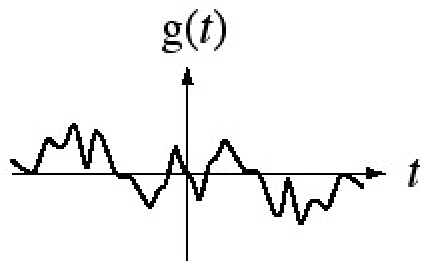
$g(t) = g(-t)$

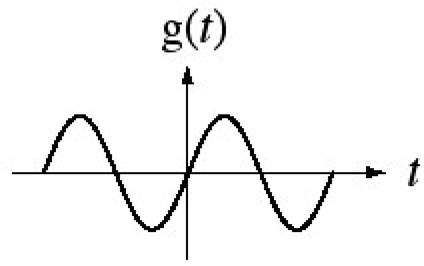




Odd function

$g(t) = -g(-t)$





Even & Odd parts are Calculated as

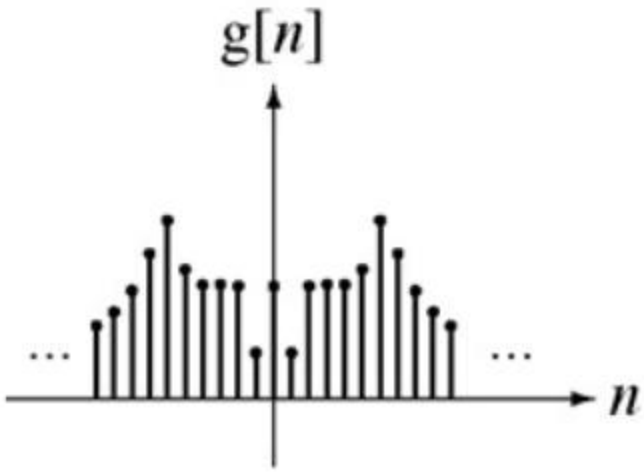
The **even part** of a function is $g_e(t) = \dfrac{g(t) + g(-t)}{2}$

The **odd part** of a function is $g_o(t) = \dfrac{g(t) - g(-t)}{2}$

Discrete Time Even and Odd Signals

$$g[n] = g[-n]$$

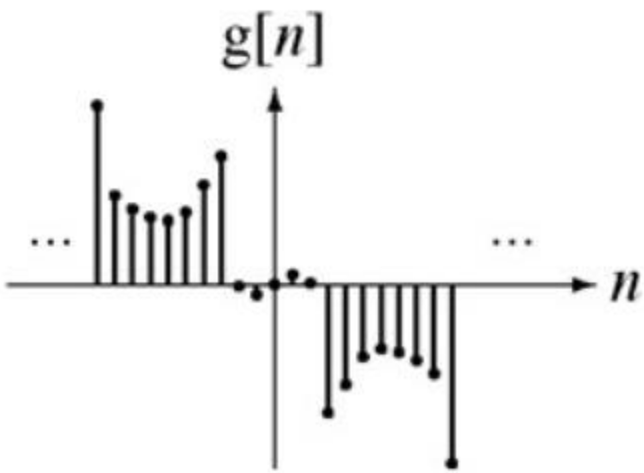
Even Function



$$g_e[n] = \frac{g[n] + g[-n]}{2}$$

$$g[n] = -g[-n]$$

Odd Function



$$g_o[n] = \frac{g[n] - g[-n]}{2}$$

Derivatives and Integrals of Functions

Function type	Derivative	Integral
Even	Odd	Odd + constant
Odd	Even	Even

Periodic Non-Periodic Signal

Given x(t) is a continuous time signal

x (t) is periodic if $x(t) = x(t+T_o)$ for any T and any integer n

Example

$$x(t) = A\cos(\omega t)$$

$$x(t+T_o) = A\cos[\omega(t+T_o)] = A\cos(\omega t+\omega T_o) = A\cos(\omega t+2\pi)$$

$$= A\cos(\omega t)$$

Note: $T_o = 1/f_o$; $\omega = 2\pi f_o$

Non-Periodic Signal

For non-periodic signals

$$x(t) \neq x(t+T_o)$$

A non-periodic signal is assumed to have a period T = Infinite

Example of non periodic signal is an exponential signal

Condition of periodicity for Discrete Time Signal

A discrete time signal is periodic if

$$x(n) = x(n+N)$$

For satisfying the above condition the frequency of the discrete time signal should be ratio of two integers

$$f_o = k/N$$

Sum of Two periodic Siognals

$$X(t) = x1(t) + X2(t)$$

$$X(t+T) = x1(t+m_1T_1) + X2(t+m_2T_2)$$

$m_1T_1=m_2T_2 = T_o =$ Fundamental period

Example: $\cos(t\pi/3)+\sin(t\pi/4)$

- $T1=(2\pi)/(\pi/3)=6$; $T2 =(2\pi)/(\pi/4)=8$
- $T1/T2=6/8 = 3/4 =$ (rational number) $= \frac{m_2}{m_1}$
- $m_1T_1=m_2T_2$ → Find m1 and m2 →
- $6.4 = 3.8 = 24 = T_o$

Energy and Power Signals

Energy Signal

- A signal with finite energy and zero power is called Energy Signal i.e.for energy signal

$$0 < E < \infty \text{ and } P = 0$$

- Signal energy of a signal is defined as the *area under the square of the magnitude of the signal*.

$$E_x = \int_{-\infty}^{\infty} |x(t)|^2 \, dt$$

- The units of signal energy depends on the unit of the signal.

Energy and Power Signals

•A signal is referred to as an energy signal, if and only if the total energy of the signal satisfies the condition
$0 < E < \infty$

•On the other hand, it is referred to as a power signal, if and only if the average power of the signal satisfies the condition
$0 < P < \infty$

•An energy signal has zero average power, whereas a power signal has infinite energy.

•Periodic signals and random signals are usually viewed as power signals, whereas signals that are both deterministic and non-periodic are energy signals.

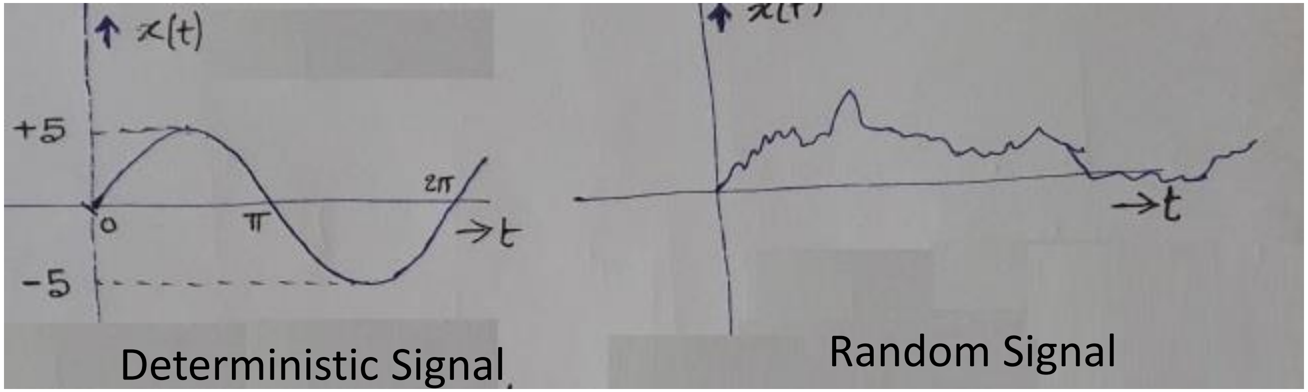
Power Signal	Energy Signal
• Infinite Duration	• Finite Duration
• Normalized Power is finite and non-zero.	• Normalized energy is finite and non-zero.
• Normalized energy averaged over infinite time is infinite.	• Normalized Power averaged over infinite time is zero.
	• Physically realizable

Deterministic Signal

- Any signal can be predictable or described in advance or by mathematical expression
- e.g. Sinusoidal signal

Random Signal

- Signals that cannot be described by is known as Random signal
- e.g- seismic signal , speech signal

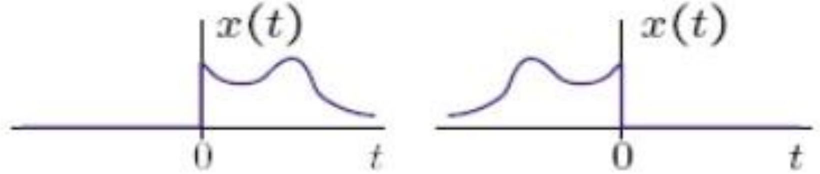


Deterministic Signal

Random Signal

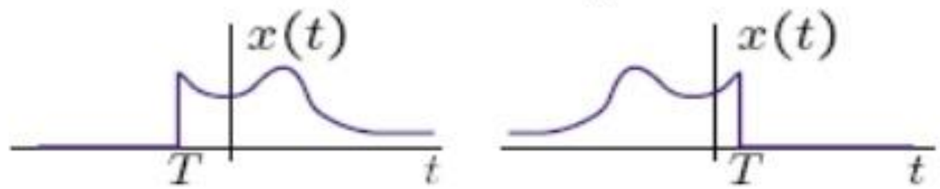
Causal vs. Non-causal

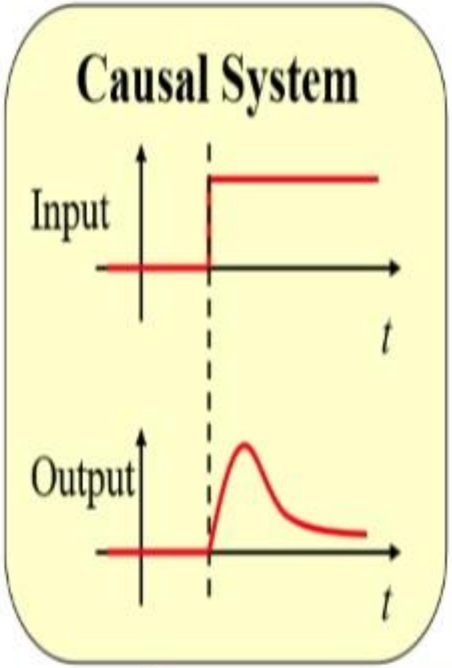
- A **causal** signal is zero for $t < 0$ and an **non-causal** signal is zero for $t > 0$

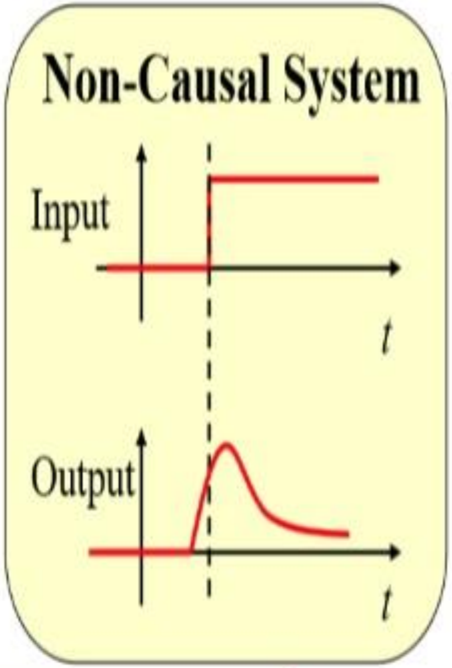


- **Right- and left-sided signals**

A right-sided signal is zero for $t < T$ and a left-sided signal is zero for $t > T$ where T can be positive or negative.







Most systems in nature are causal

Thank You!