Signals & Systems (CNET - 221)

Introduction to Systems

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Chapter Objective

Following are the objectives of Chapter-II

- System Definition, Classification, Representation of different systems including both Continuous and Discrete
- Basic System properties
- System verification for both Linearity and Time Invariance
- Linear Time-Invariant Systems
- Discrete-Time LTI Systems: The Convolution Sum
- Representation Of Discrete-Time Signals In Terms Of Impulse
- Discrete-Time Unit Impulse Response And The Convolution-Sum Representation Of LTI System

Outline-Chapter-2

Introduction to Systems

Introduction to Systems

What is a System?

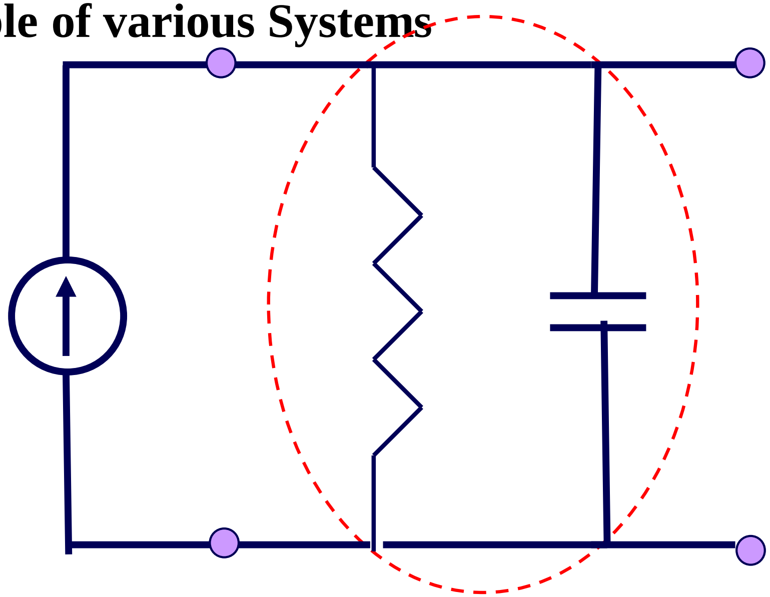
System is a device or combination of devices, which can operate on signals and produces corresponding response. Input to a system is called as excitation and output from it is called as response.

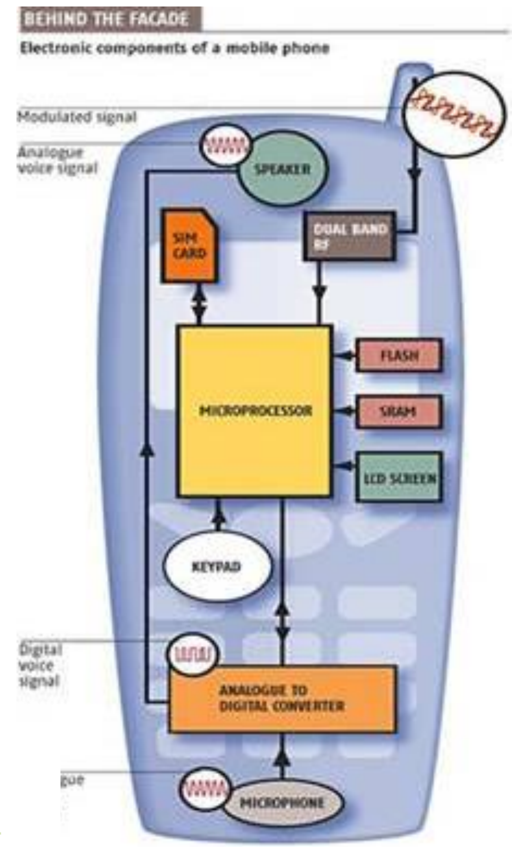
For one or more inputs, the system can have one or more outputs.

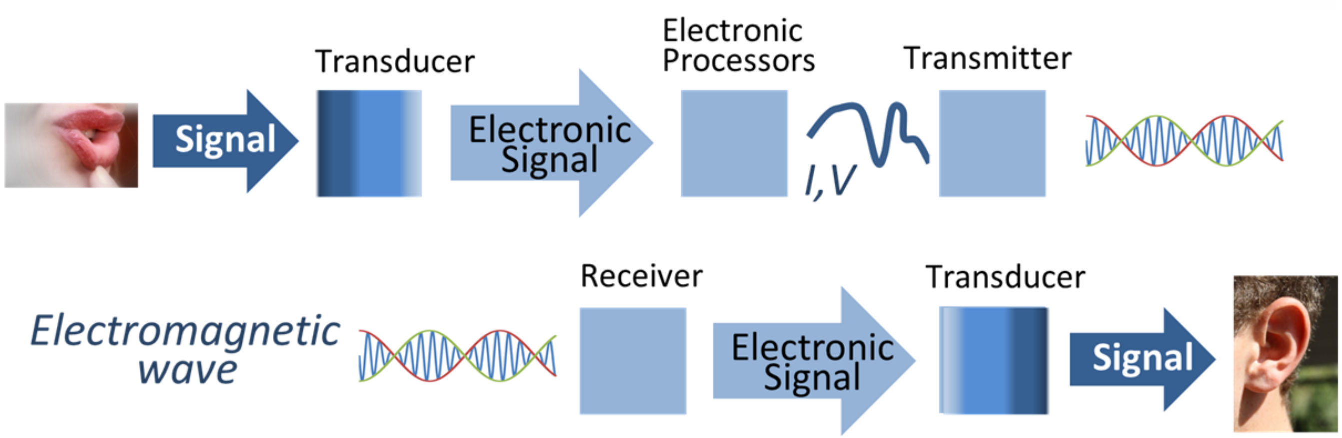
Example: Communication System

Introduction to Systems(Continued.....)

Example of various Systems



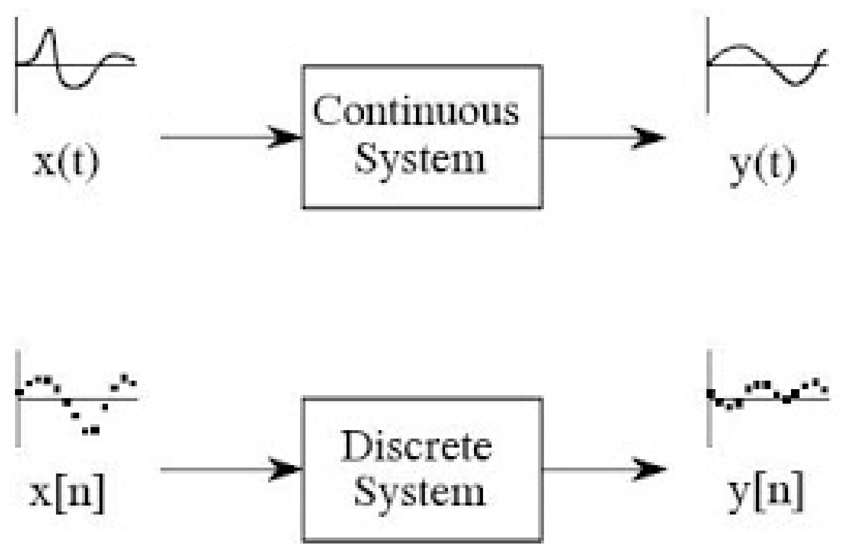




Introduction to Systems

Continuous-time System:- *is a system in which continuous –time input signals are applied and response a continuous-time output signals*.

Discrete-time System:- *is a system in which discrete –time input signals are applied and response a discrete-time output signals*.



Basic system properties

1. System with or without memory
2. Invertible
3. Causality
4. Stability or Bounded-input Bounded-output (BIBO)
5. Linearity
6. Time invariance

1. System with or without memory

System with or without memory:

A system is said to be memory less if the output at any time depends on only the input at that same time. Otherwise, the system is said to have memory.

Let x(t) be system input, y(t) - system output.

For memory less system, y(t) = f(x(t)), where f is some function.

For systems with memory y(t) = ∫ f(τ)x(τ) dτ (integral from 0 to t), that is, the system output at the moment (t) depends not only on x(t), but also on all previous values of x.

- Examples of memoryless systems:

$$y(t) = Rx(t) \qquad \text{or} \qquad y[n] = \left(2x[n] - x^2[n]\right)^2.$$

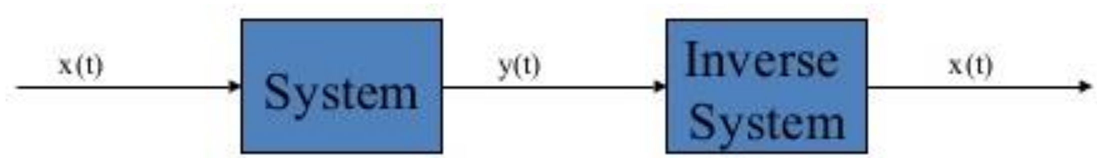
- Examples of systems with memory:

$$y(t) = \frac{1}{C}\int_{-\infty}^{t} x(\tau)d\tau \qquad \text{or} \qquad y[n] = x[n-1].$$

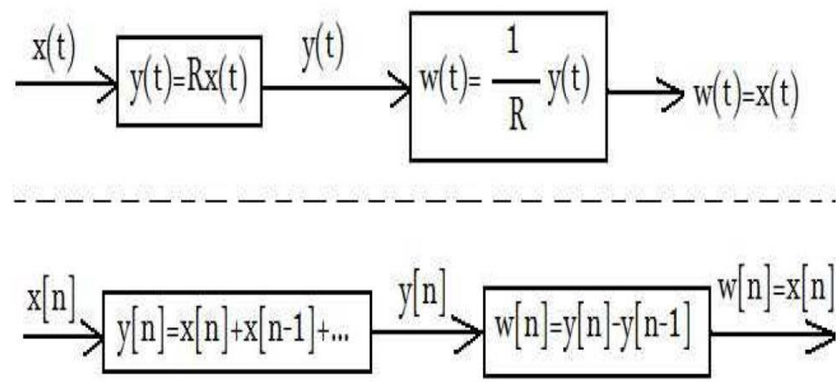
2. Invertible

Invertible:

A system is called **Invertible** if it produces distinct output signals for distinct input signals. If an invertible system produces the output y(t) for the input x(t), then its inverse produces the output x(t) for the input y(t):



Examples of invertible systems:



Examples of non-invertible systems:

$y(t) = x(t)^2$ or $y[n] = 0$:

3.Causality

Causality:

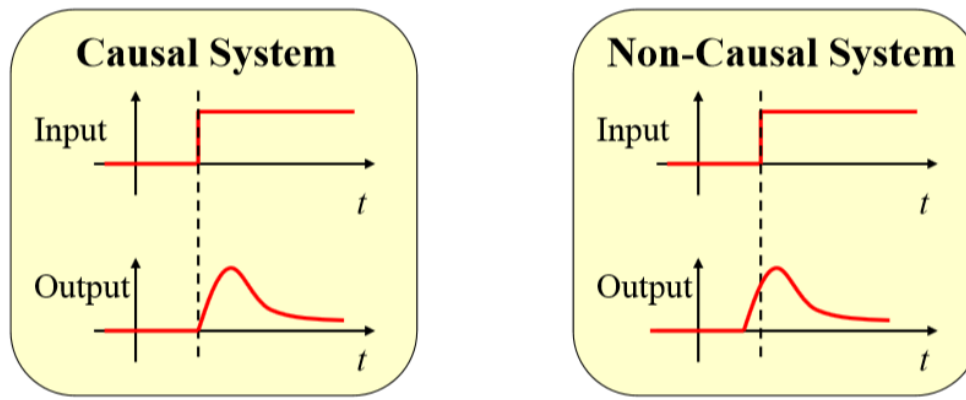
➢ A continuous-time or Discrete-time system is called **causal** if O/P depends upon Past and Present I/P but not Future.

Non Causal system :- A system whose present O/P depends on future values of the inputs is called as a non-causal system.

All memory less Systems are causal but vice-versa is not true.

Examples of causal systems:

$$y(t) = \frac{1}{C}\int_{-\infty}^{t} x(\tau)d\tau \quad \text{or} \quad y[n] = x[n-1].$$



Most systems in nature are causal

Examples of non-causal systems:

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

Ex. Planning commission, Weather forecasting.

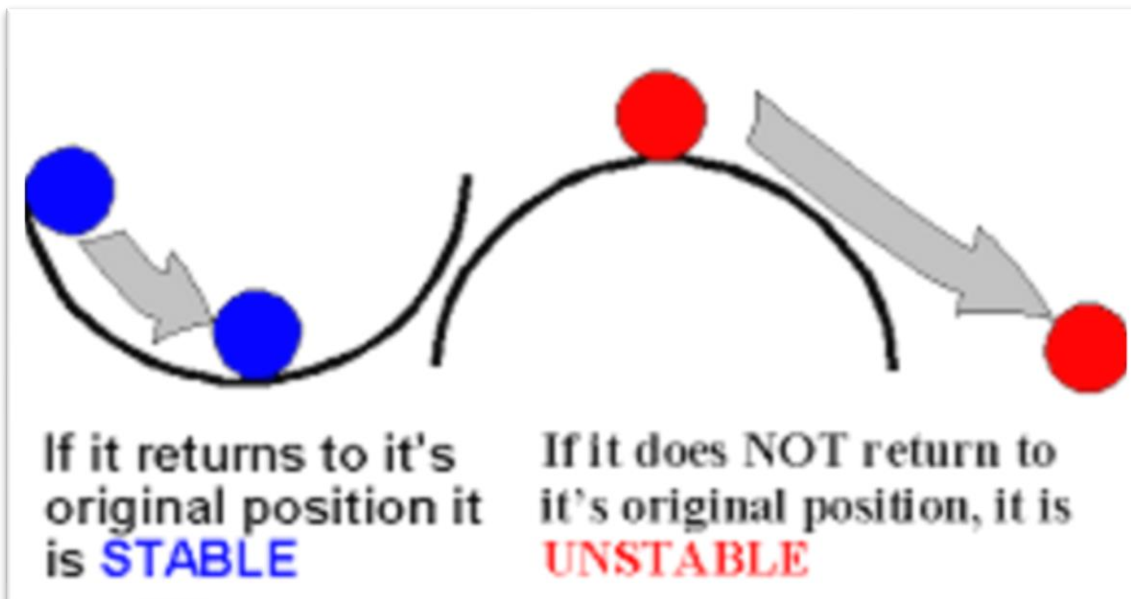
4. Stability or Bounded-input Bounded-output (BIBO)

Stability or Bounded-input Bounded-output (BIBO)

A system is called stable if it produces bounded outputs for all bounded inputs.

(A signal $x(t)$ is bounded if, for some $M < \infty$, $|x(t)| <= M$ for all t.)

Stability in a physical system generally results from the presence of mechanisms that dissipate energy, such as the resistors in a circuit, friction in a mechanical system, etc.

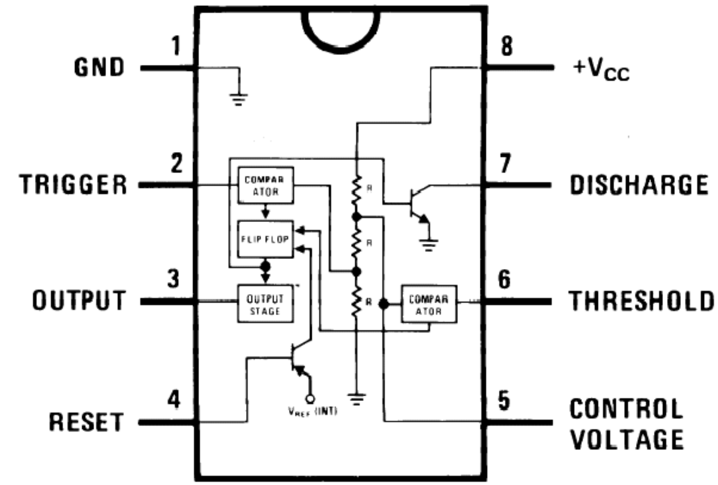


5. Linearity

Linearity

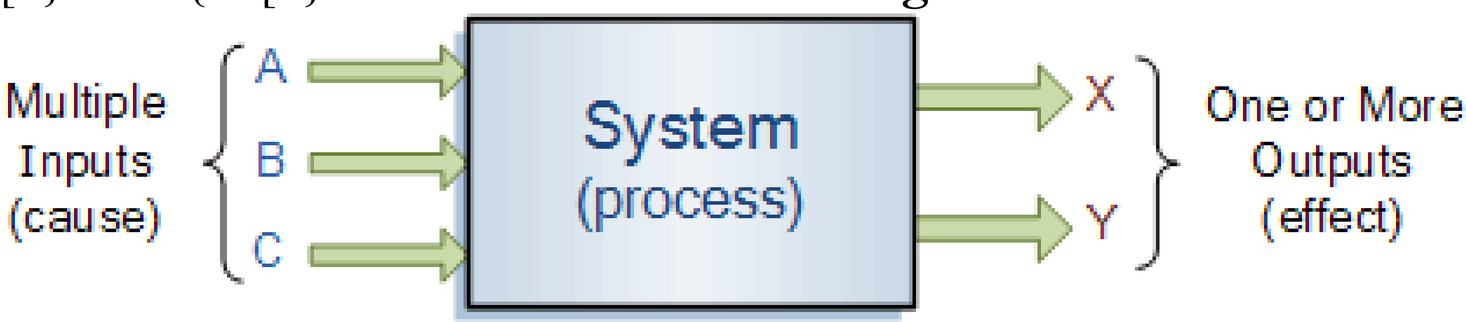
A system is called linear if its I/O behavior satisfies the **Additivity** and **Scaling** properties:

Note:- Linear systems have the property that the output is linearly related to the input. Changing the input in a linear way will change the output in the same linear way.



$T\{x_1[n]+x_2[n]\}=T\{x_1[n]\}+T\{x_2[n]\}$ ………………**Additivity**

$T\{a * x[n]\}= a\,T\{x[n]\}$ ……………………**Scaling**



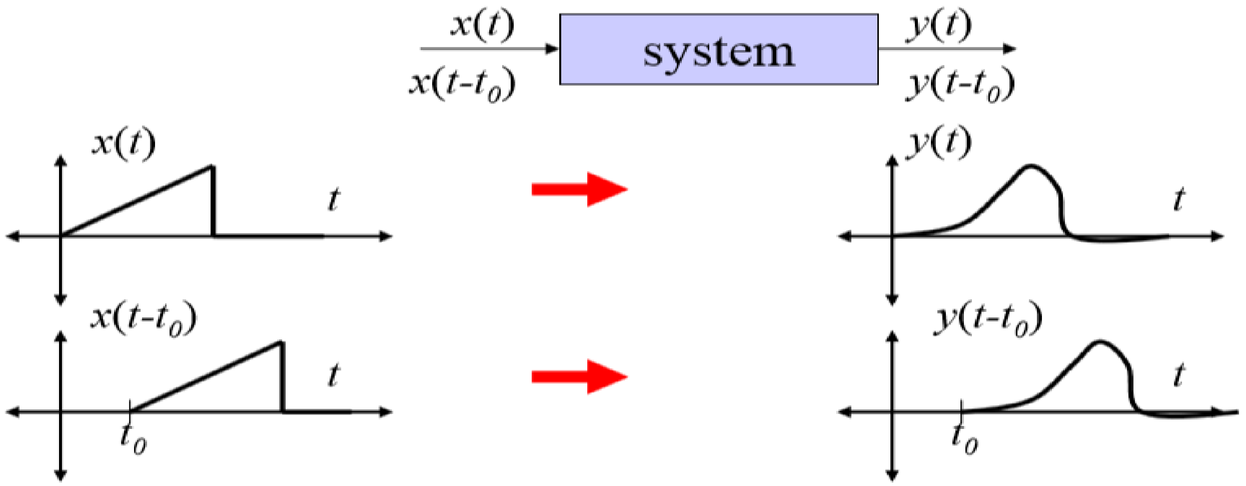
6. Time invariant

Time invariance:-

A system is called time-invariant if the way it responds to inputs does not change over time:

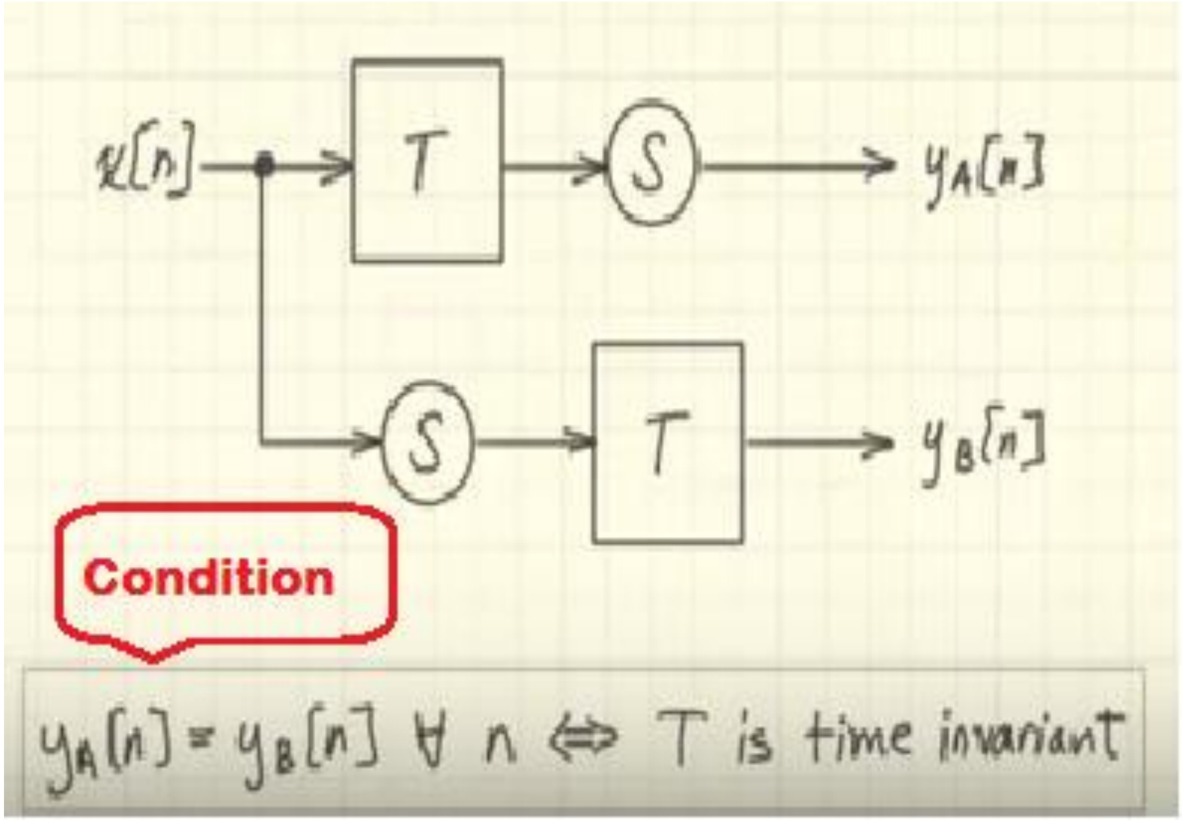
$$x(t) \rightarrow y(t) \quad \Rightarrow \quad x(t-t_0) \rightarrow y(t-t_0), \quad \text{for any } t_0$$

$$x[n] \rightarrow y[n] \quad \Rightarrow \quad x[n-n_0] \rightarrow y[n-n_0], \quad \text{for any } n_0.$$

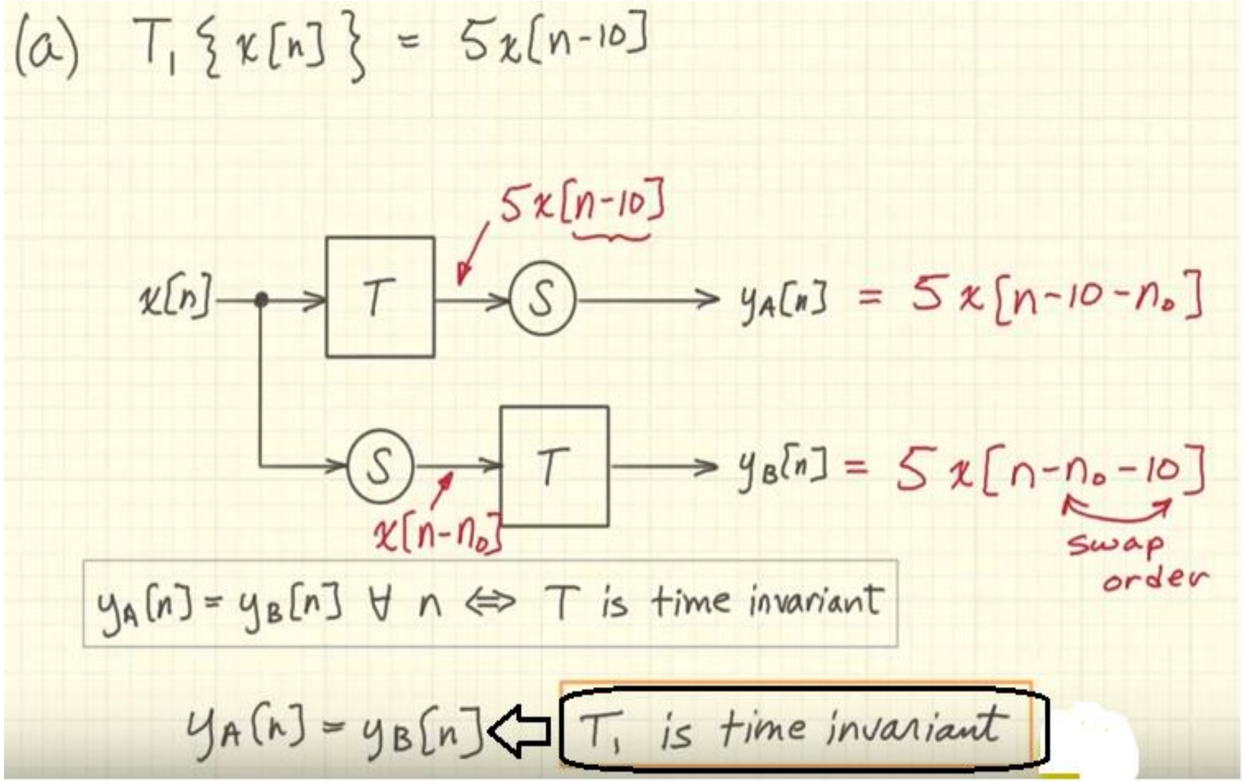


Example: - TV remote control, Keyboard, Microphone.

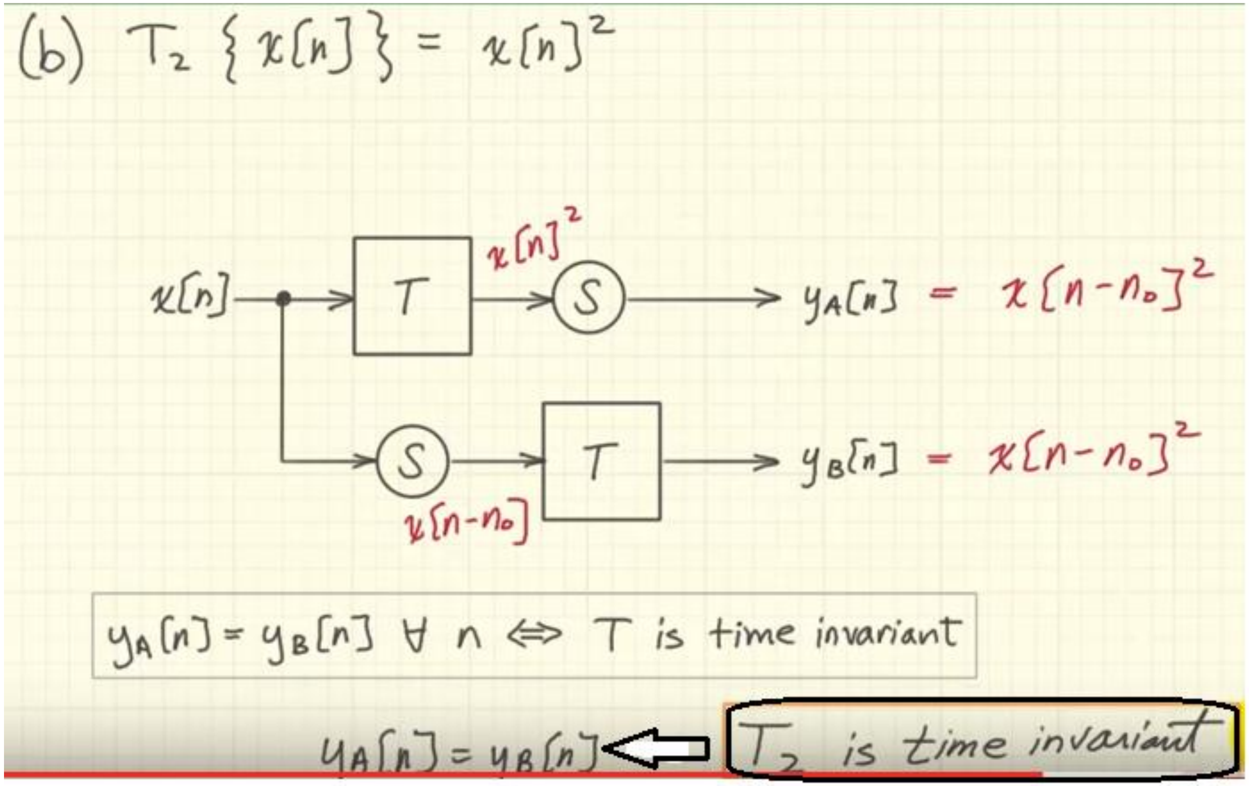
Time Invariance-Condition



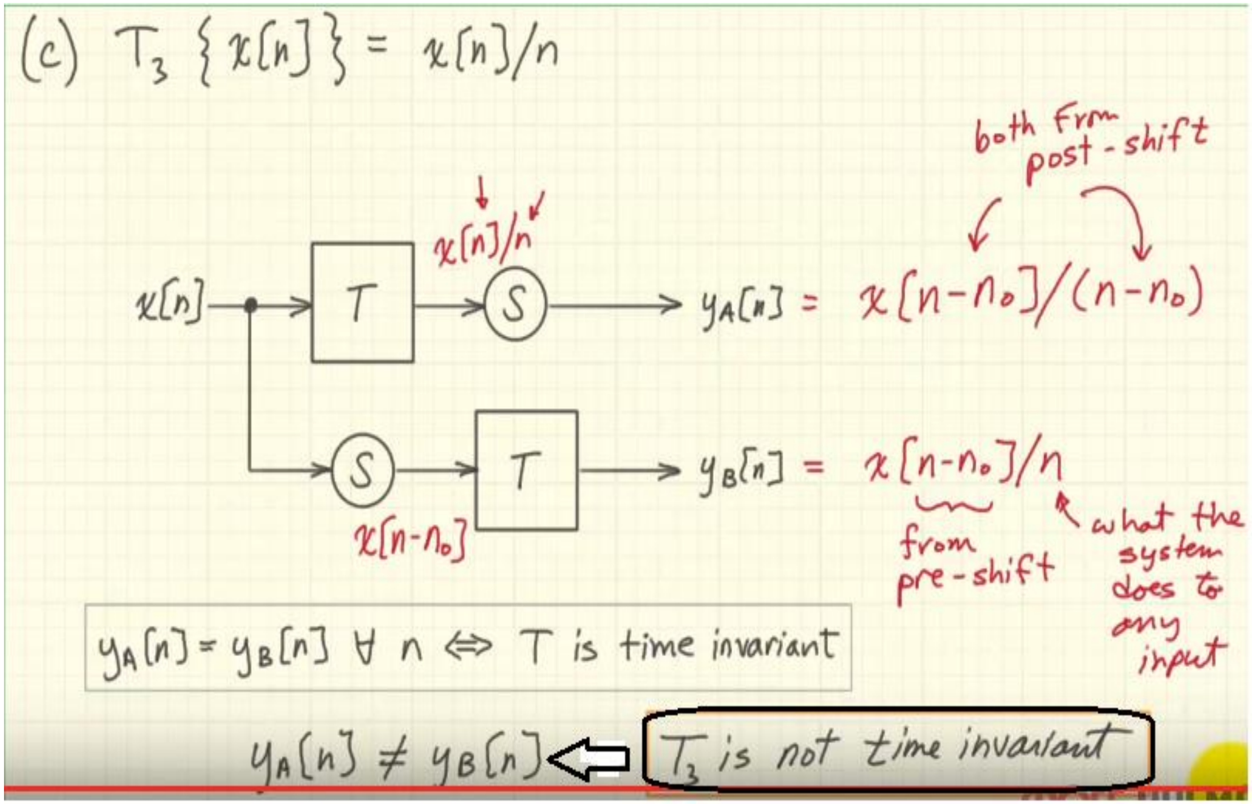
Time Invariance-Numerical Example-1



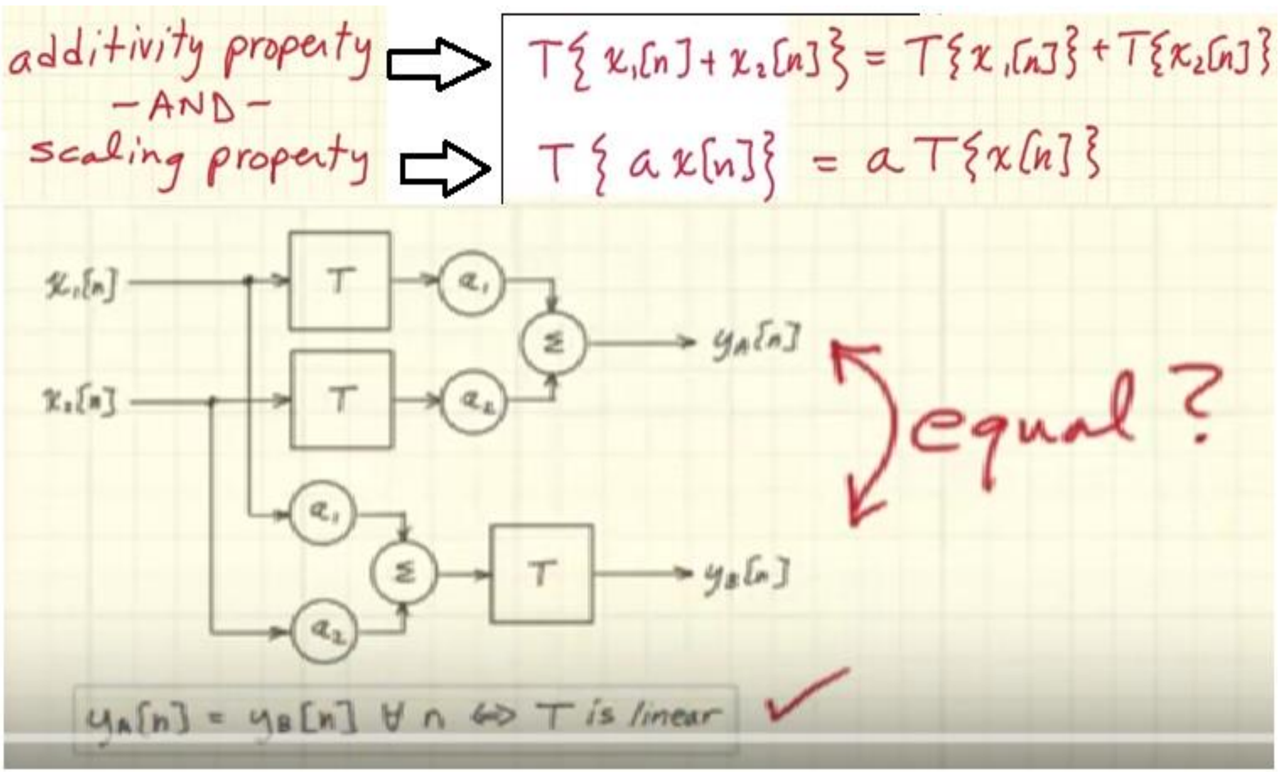
Time Invariance-Numerical Example-2



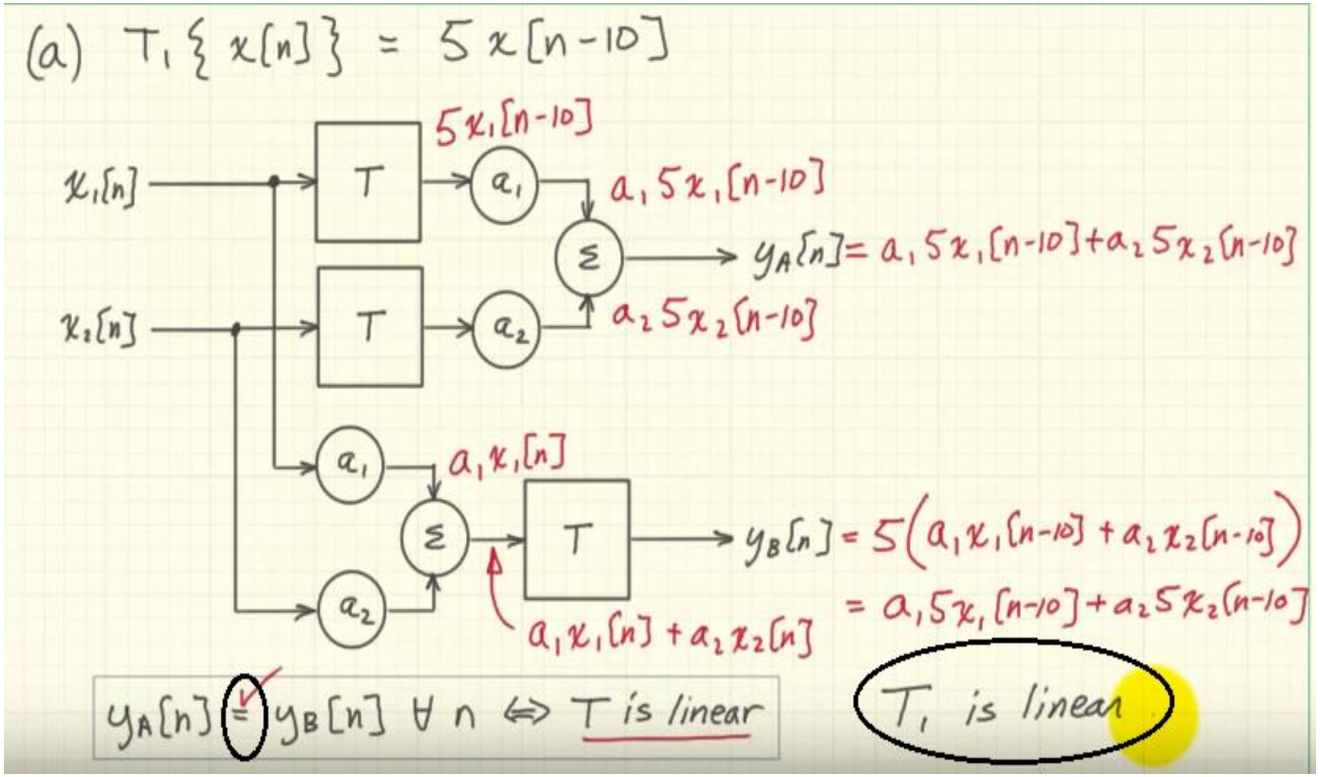
Time Invariance-Numerical Example-3



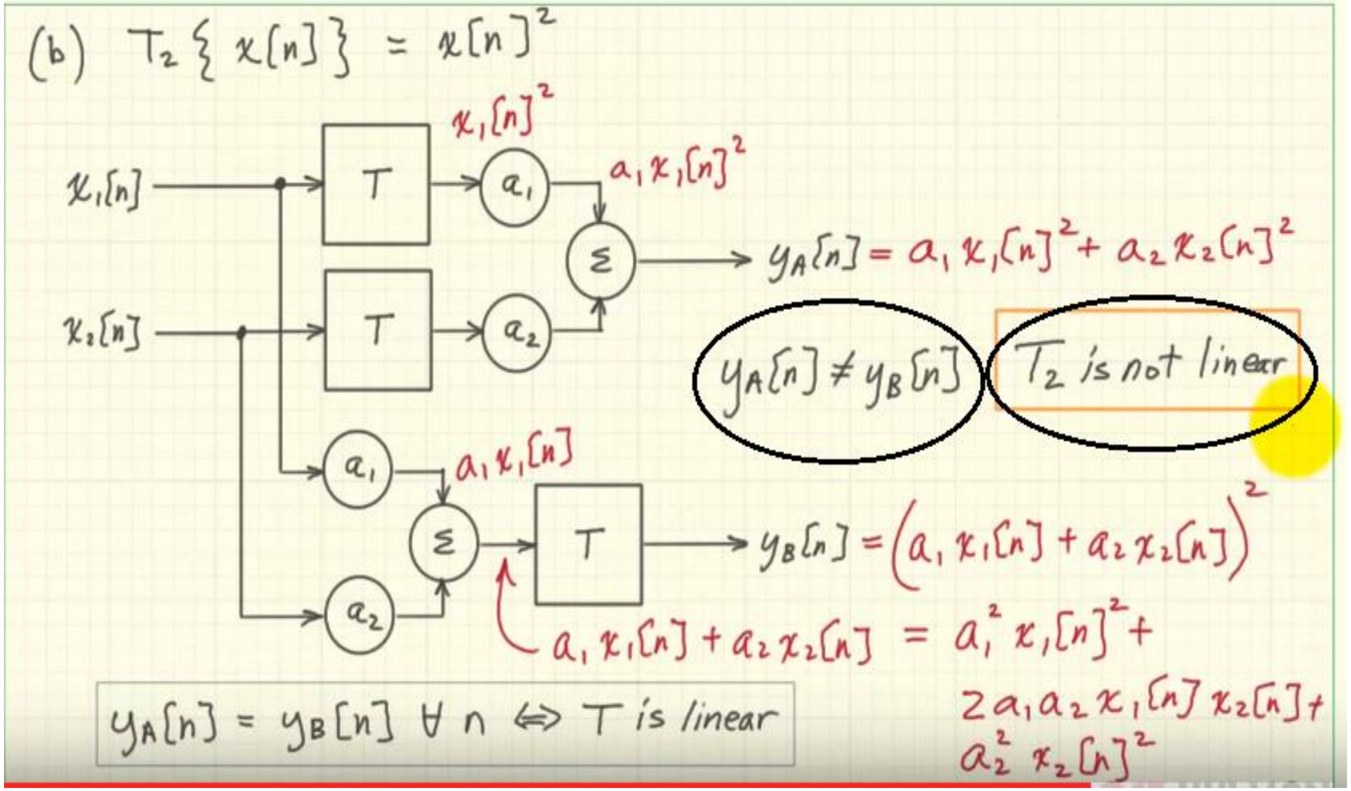
Linearity-Condition



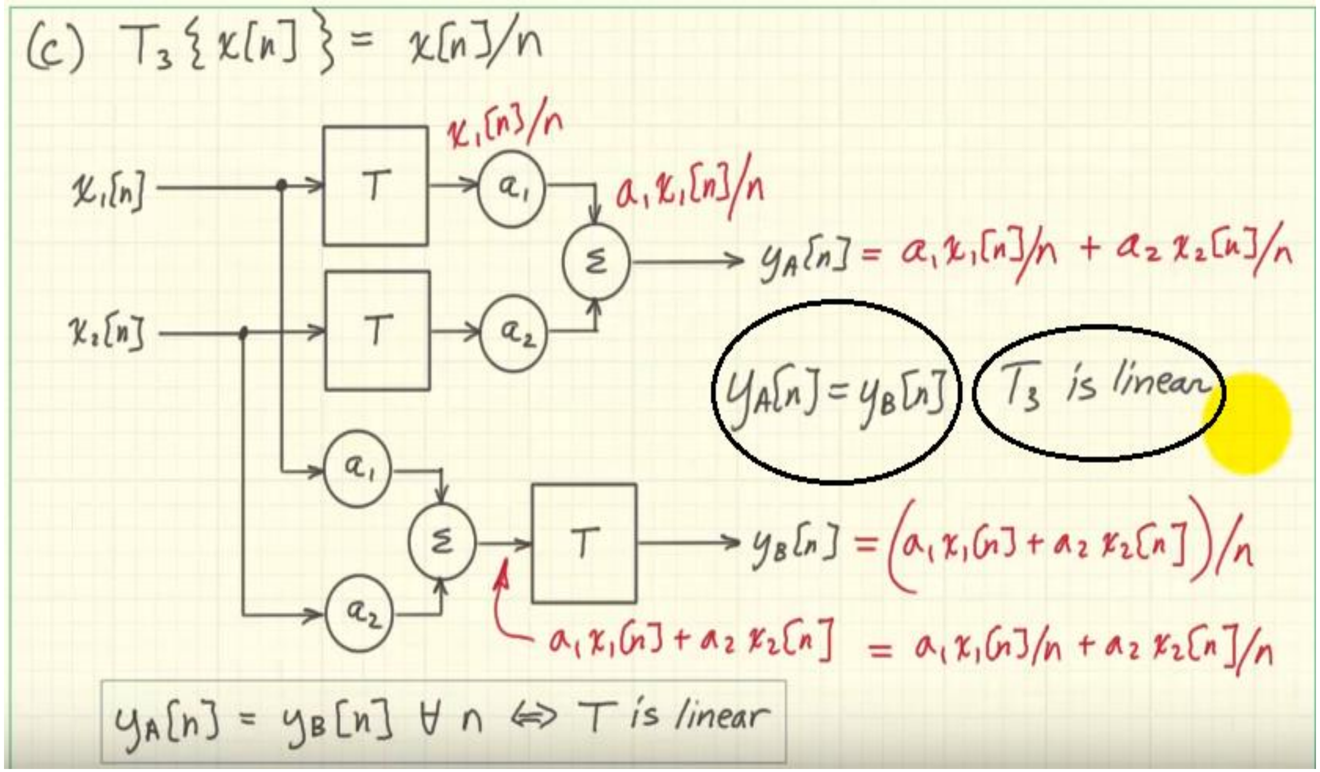
Linearity-Numerical Example-1



Linearity-Numerical Example-2



Linearity-Numerical Example-3



Linear Time Invariant (LTI) Systems

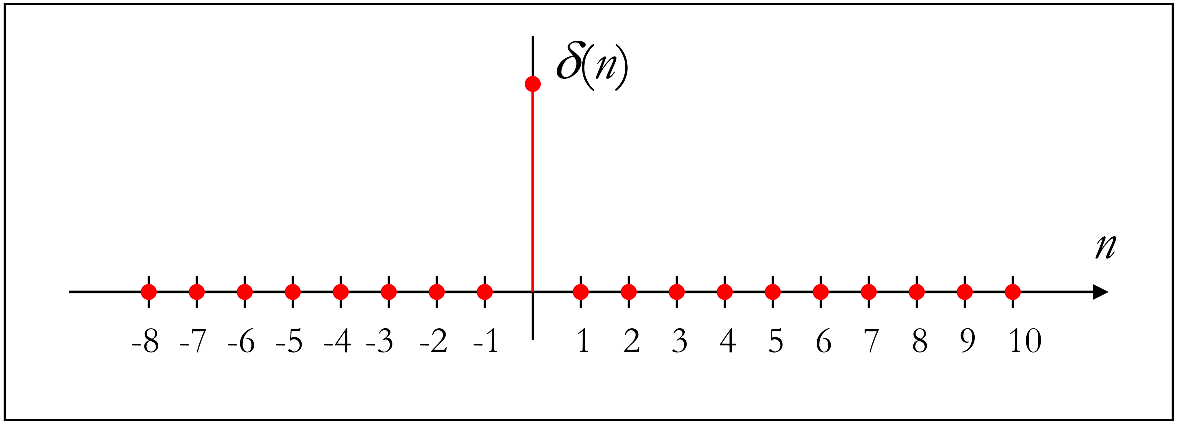
- **Linearity** – Linear system is a system that possesses the property of *superposition*.

- **Time Invariance** – A system is time invariant if the behavior and characteristics of the system are *fixed over time*.

Unit Impulse Signal $\delta(n)$ and Unit Step Sequence $u(n)$

1. Unit-Impulse Signal $\delta(n)$

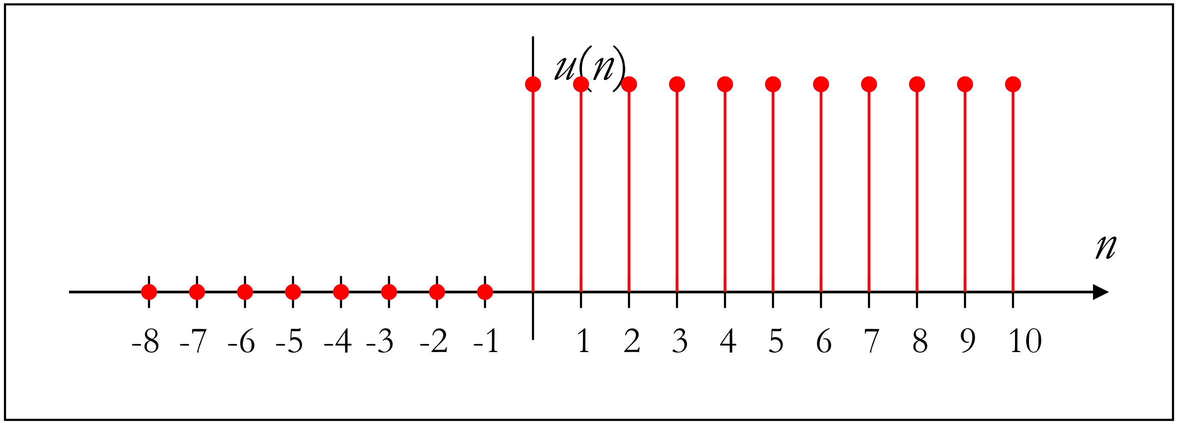
$$\delta(n) = \begin{cases} 1 & n = 0 \\ 0 & n \neq 0 \end{cases}$$



2. Unit-step sequence *u*(*n*)

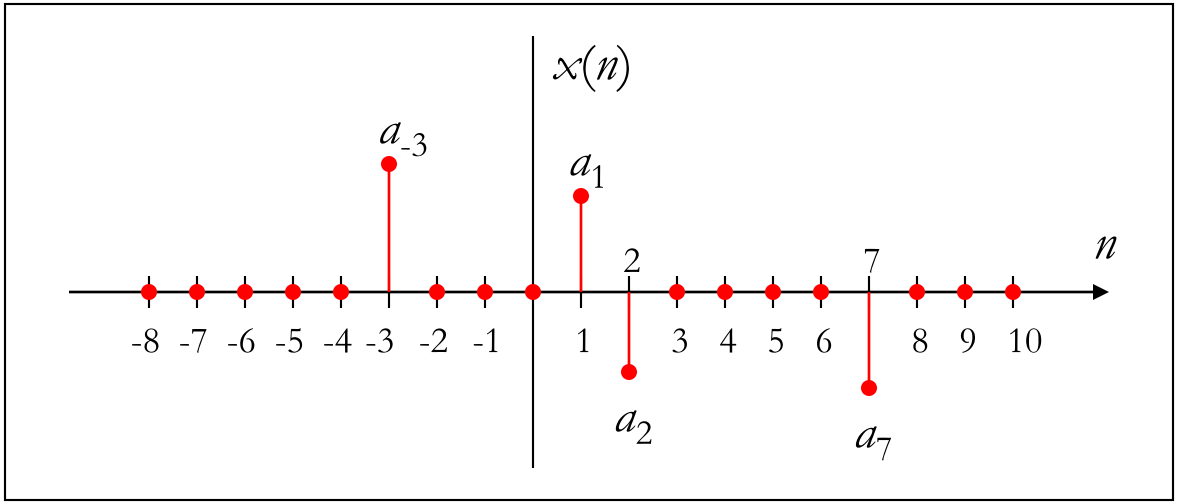
$$u(n) = \begin{cases} 1 & n \geq 0 \\ 0 & n < 0 \end{cases}$$

- Fact: $\delta(n) = u(n) - u(n-1)$



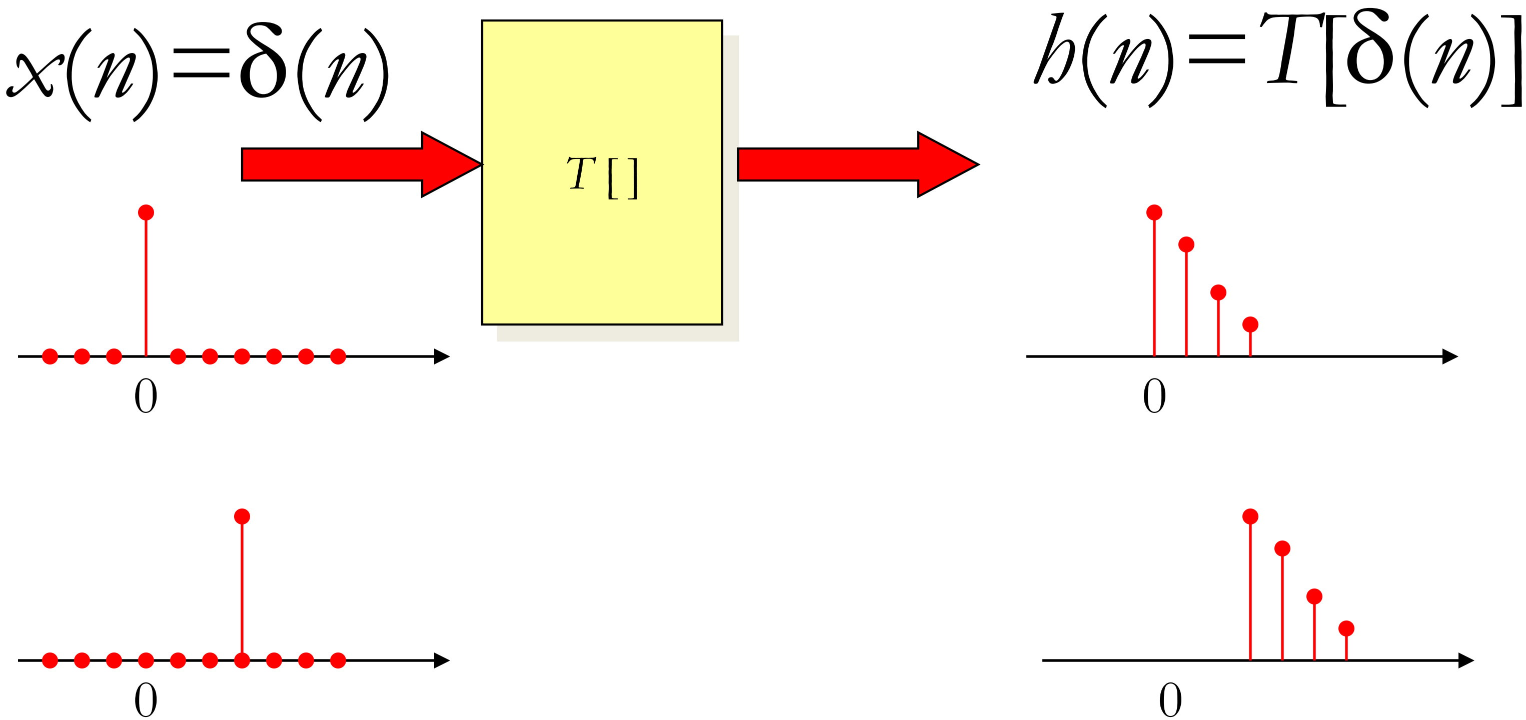
Representation of Discrete-Time Signals in Terms of Impulse

$$x(n) = \sum_{k=-\infty}^{\infty} x(k)\delta(n-k)$$

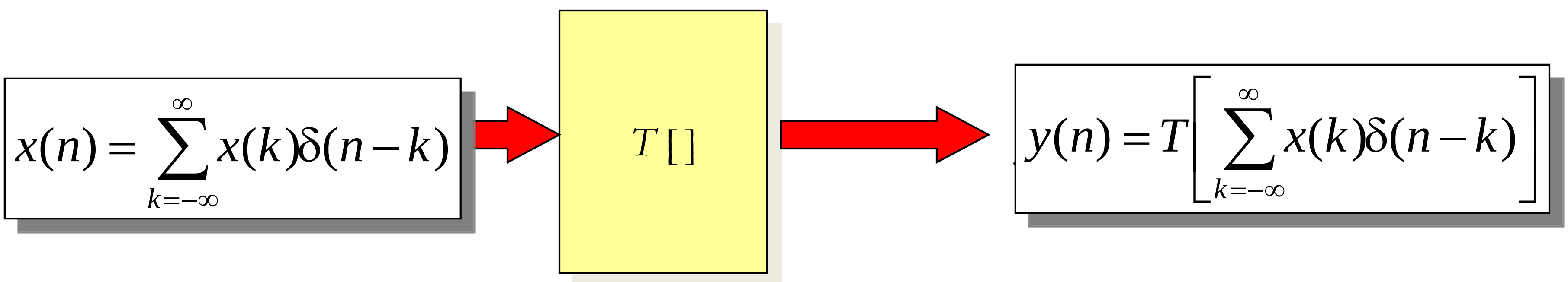


$$x(n) = a_{-3}\delta(n+3) + a_1\delta(n-1) + a_2\delta(n-3) + a_7\delta(n-7)$$

Impulse Response



Linear time-Invariant Systems



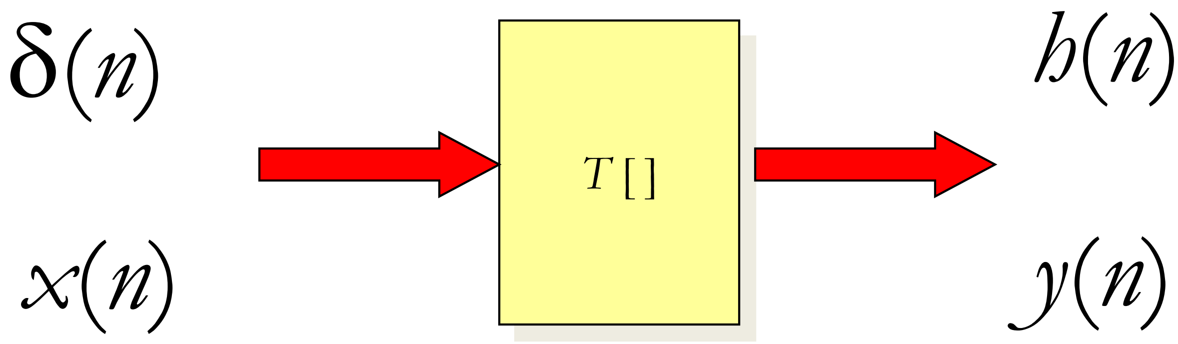
$$y(n) = \sum_{k=-\infty}^{\infty} x(k)\underbrace{T[\delta(n-k)]} = \sum_{k=-\infty}^{\infty} x(k)\underbrace{h(n-k)}$$

Time k impulse
The output value at time n

Only with the time difference

Where h is the impulse response

Convolution Sum



$$y(n)=\sum_{k=-\infty}^{\infty}x(k)h(n-k)=\underbrace{x(n)*h(n)}_{\text{convolution}}$$

A linear shift-invariant system is completely characterized by its impulse response.

Videos

1. https://www.youtube.com/watch?v=7Z3LE5uM-6Y&list=PLbMVogVj5nJQQZbah2uRZIRZ_9kfoqZyx

2. Signals & Systems Tutorial

https://www.youtube.com/watch?v=yLezP5ziz0U&list=PL56ED47DCECCD69B2