Basic Electronic Circuits (IEC-103)

Lecture-01

Course Overview

Course Objective

To build & analyze simple electronic circuits using operational amplifiers as basic building blocks.

Need for the Course

- Majority of engineering systems now have at least one electrical sub system in it.
- Many electrical systems are composed of electronic circuits.
- So, study of electronic circuits is essential to build many engineering systems.

Pre-requisite

Basic Circuit Analysis (ES-I)

Grading Plan

- Assignments/Quizzes – 10%
- Mid Exams – 35%
- End Semester Exam – 35%
- Lab – 20%

Office Hours

5:00 – 7:00 pm on Fridays

Electronics

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  - Physical electronics
  - Electronics Engineering

Classification of Electronics

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Deals with the motion of electrons and focuses on the physics of electronic devices.

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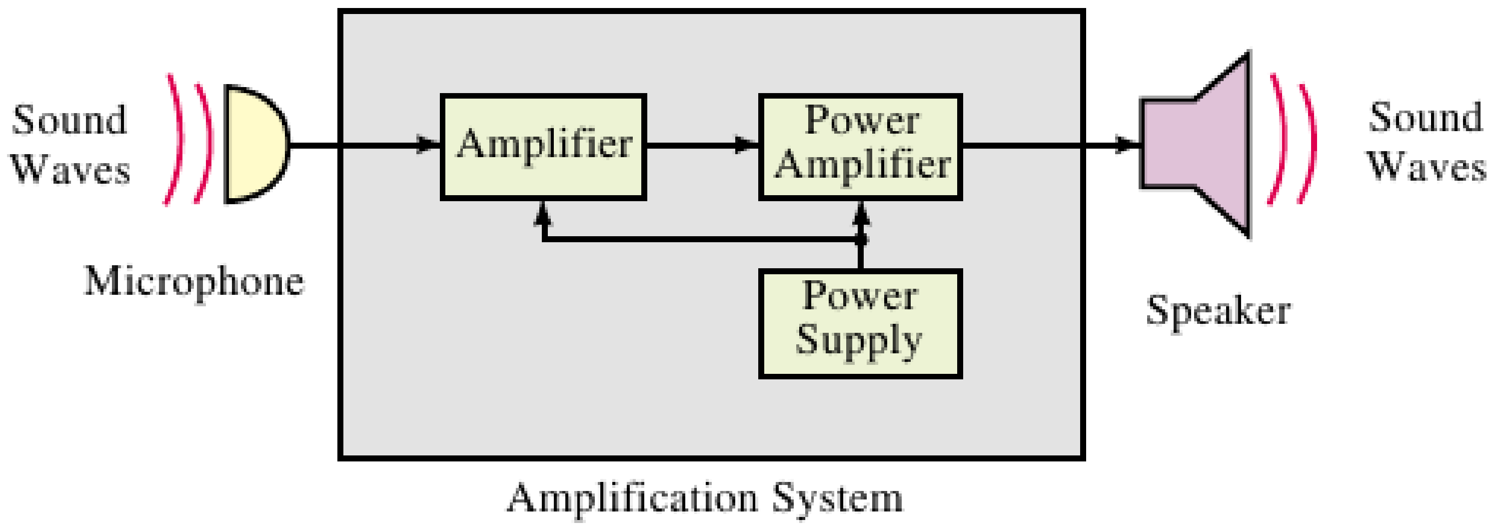
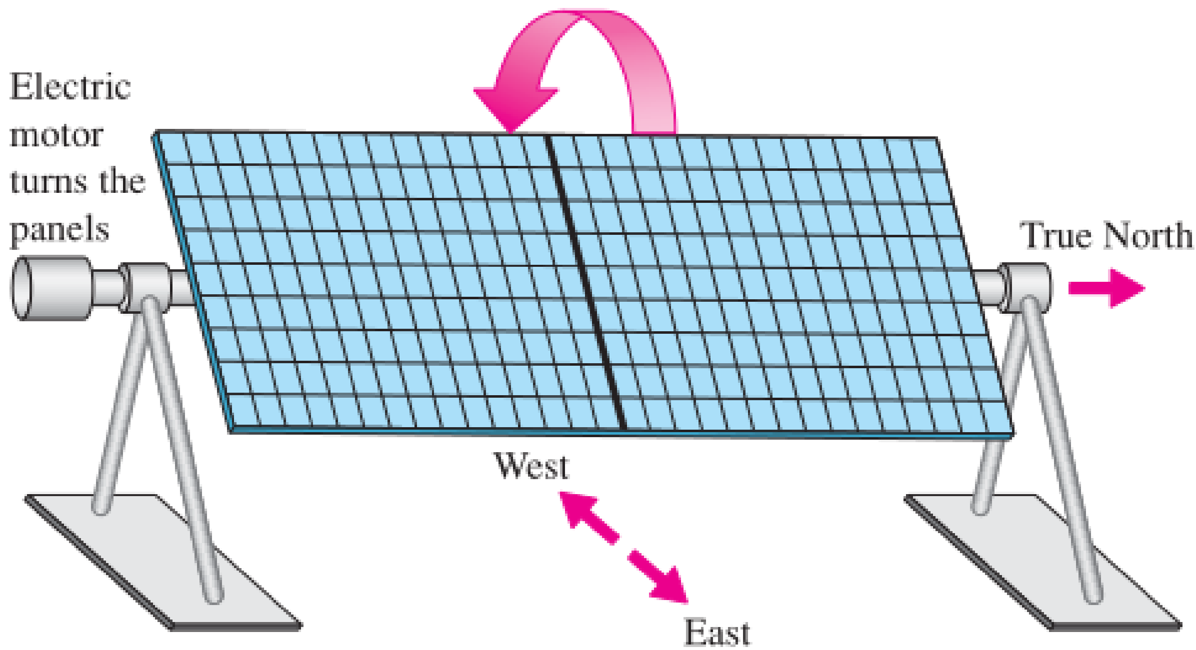
In this course we stick to the analysis of circuits containing electronic devices used in simple applications like amplifiers, converters, etc.

Examples

Public Addressing System



Solar Tracker



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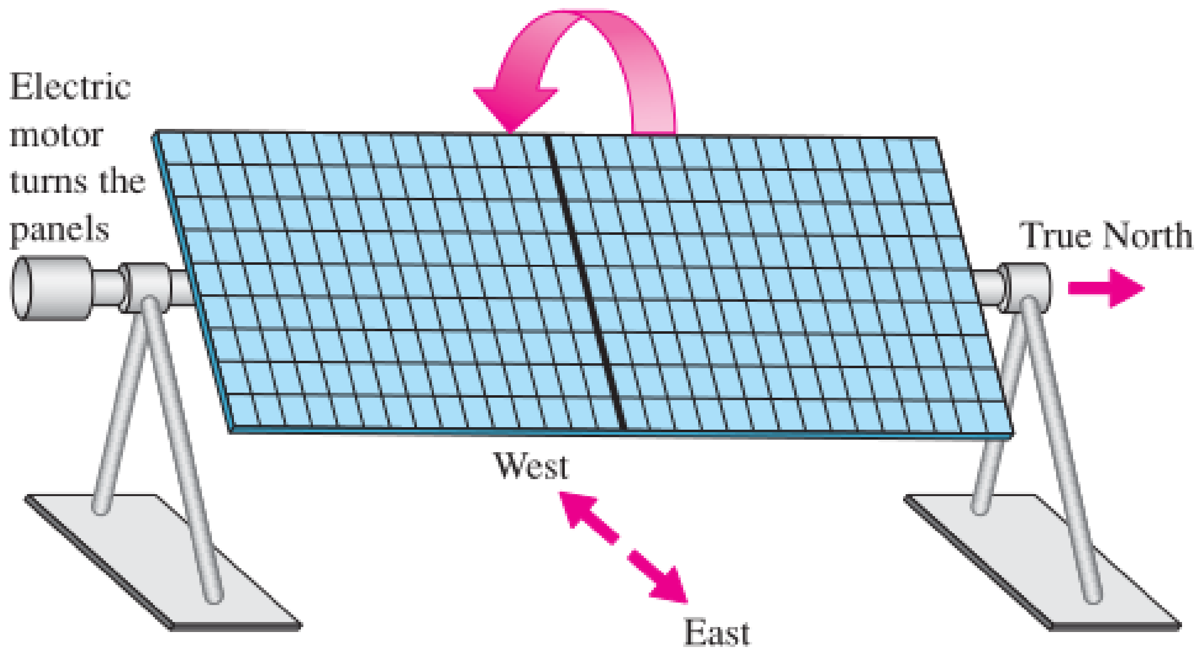
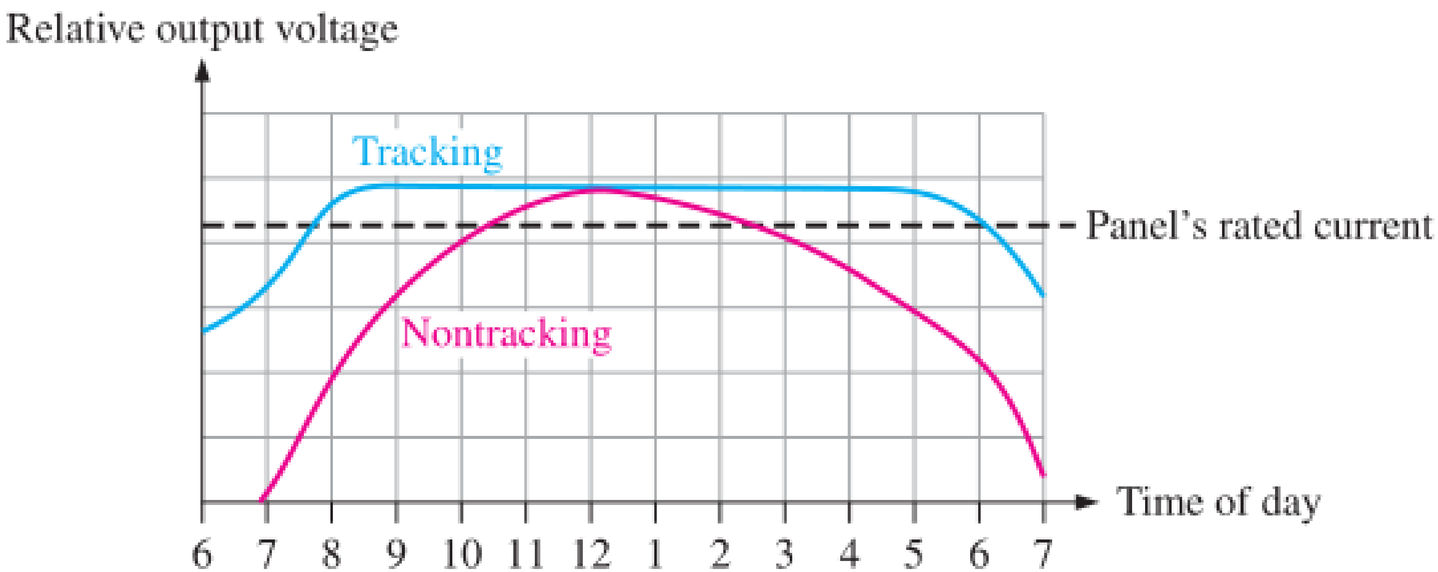
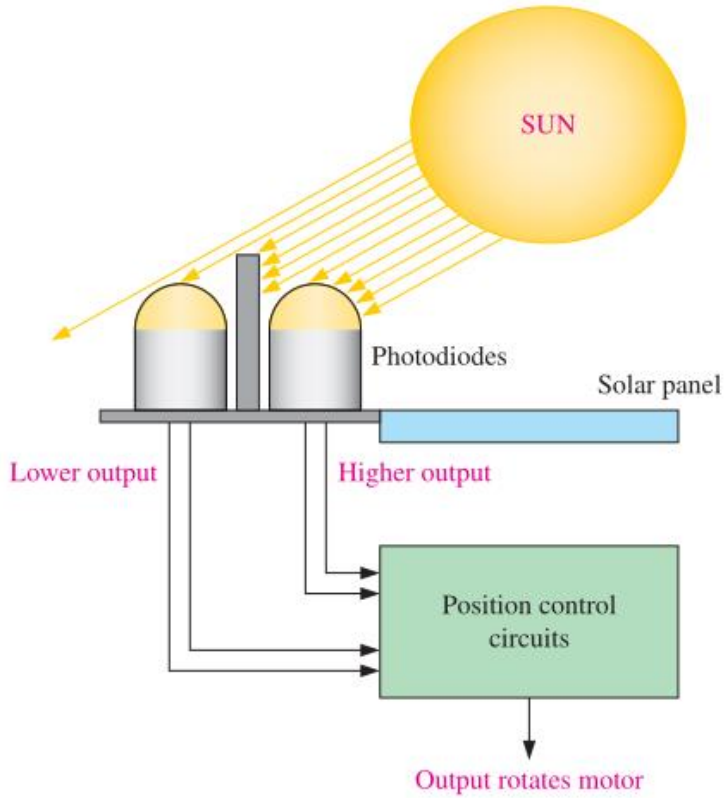


Position Control System

Solar Tracker

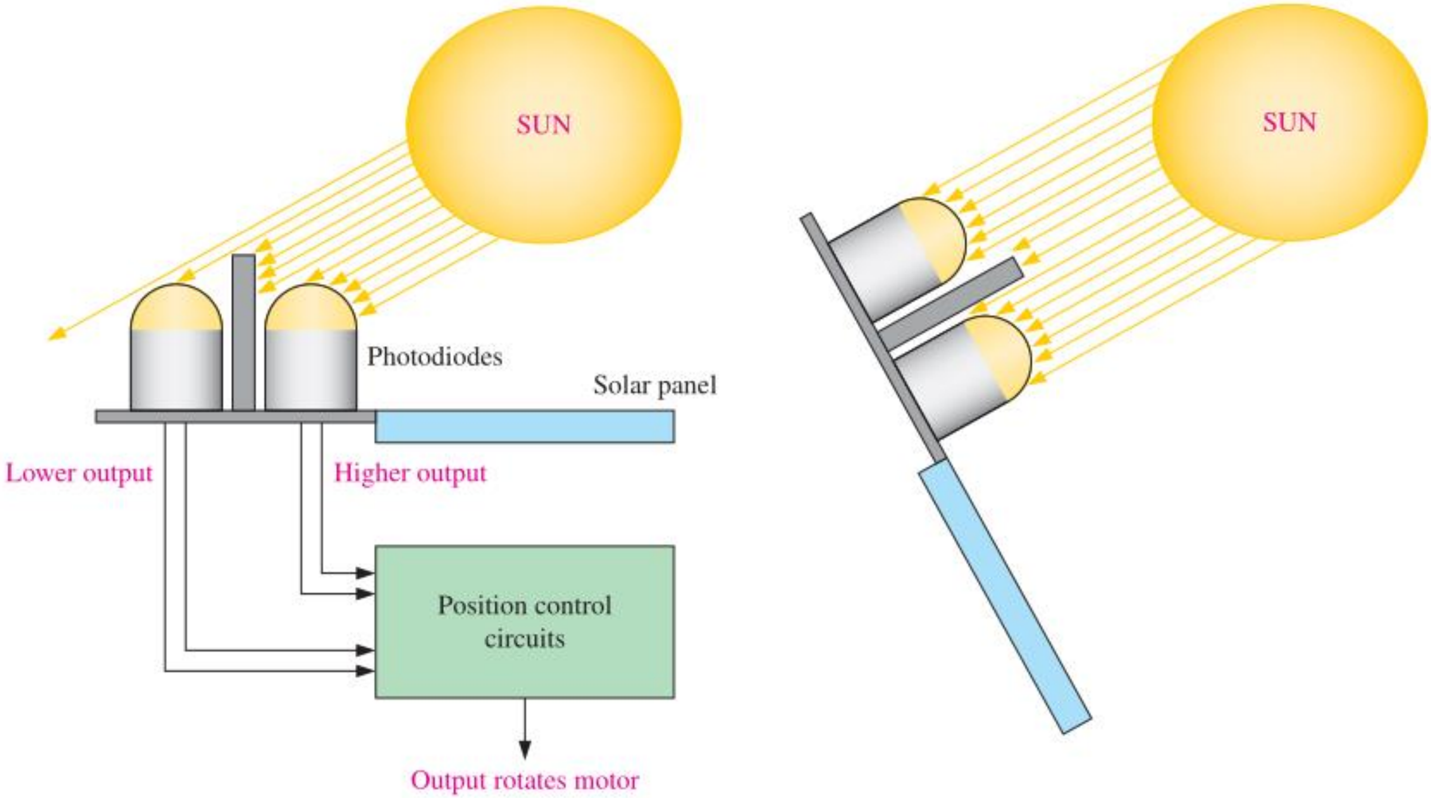


Solar Tracker



(a) Outputs of the photodiodes are unequal if solar panel is not directly facing the sun.

Solar Tracker



(a) Outputs of the photodiodes are unequal if solar panel is not directly facing the sun.

(b) Outputs of the photodiodes are equal when solar panel orientation is optimum.

Signals and Systems

Signals

- **Signal** can be represented as a function (generally of time).

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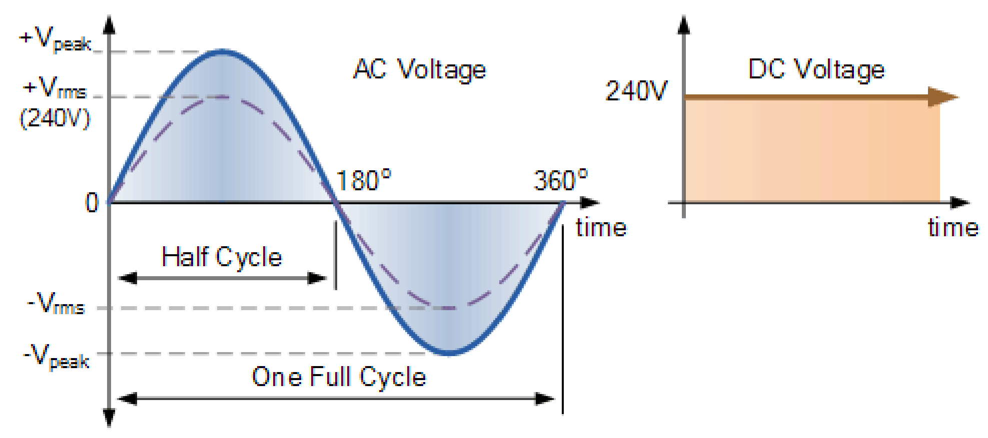
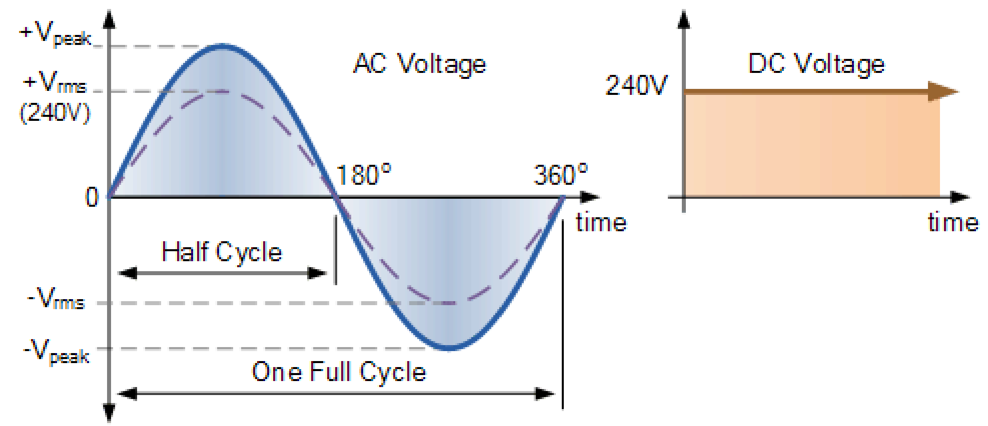
Example



AC & DC Power Supply Signals

Signals

- Signal can carry power or information.



AC & DC Power Supply Signals

Signals

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Speech Signal (Information)

Signals

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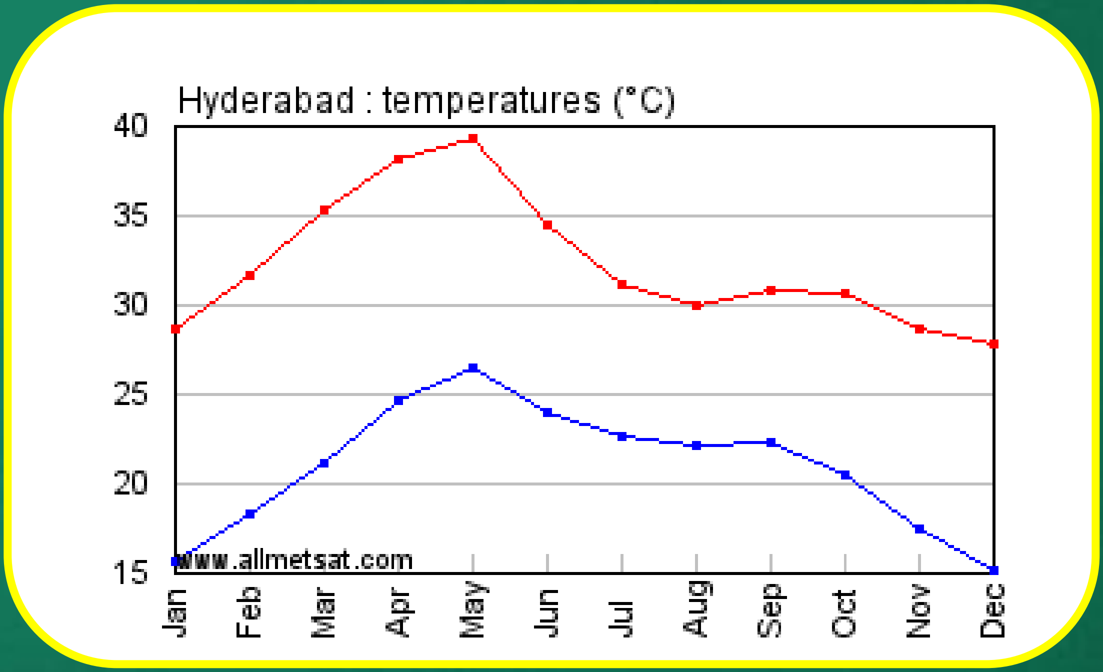

Monthly Temperature Data (Information)

Kinds of Signals

- **Analog Signal** : Function of continuous variable

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Examples:

$$s(t) = A\sin(2\pi f_0 t + \phi)$$

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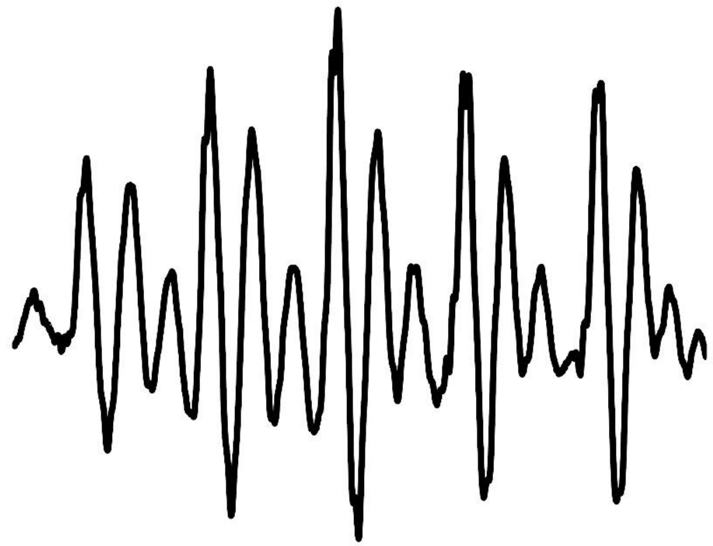

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- **Discrete Signal :** Function of discrete values of independent variable or a sequence of numbers.

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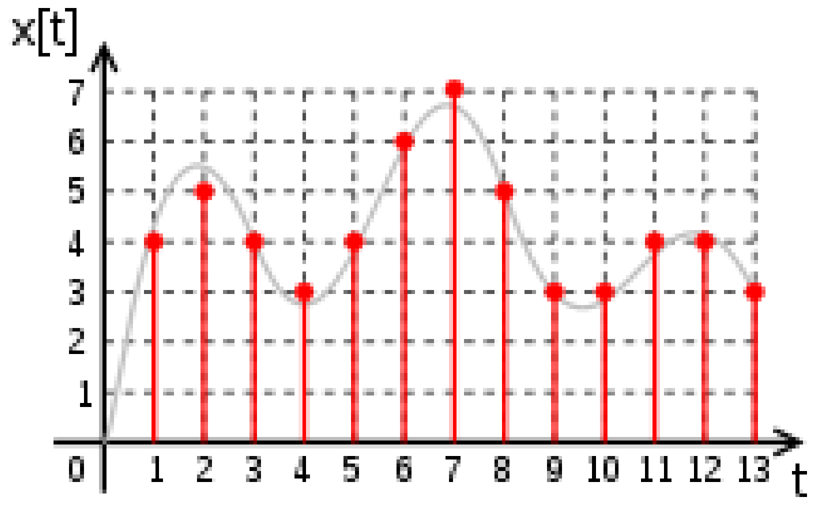
Example:

$$x[n] = 4,5,4,\ldots$$



Images

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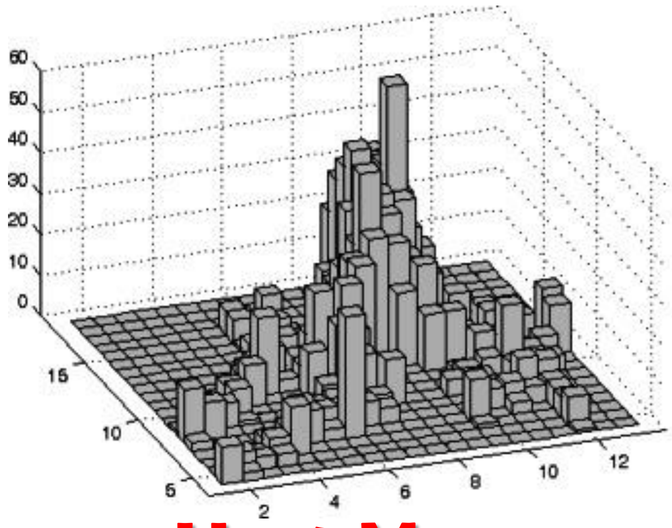
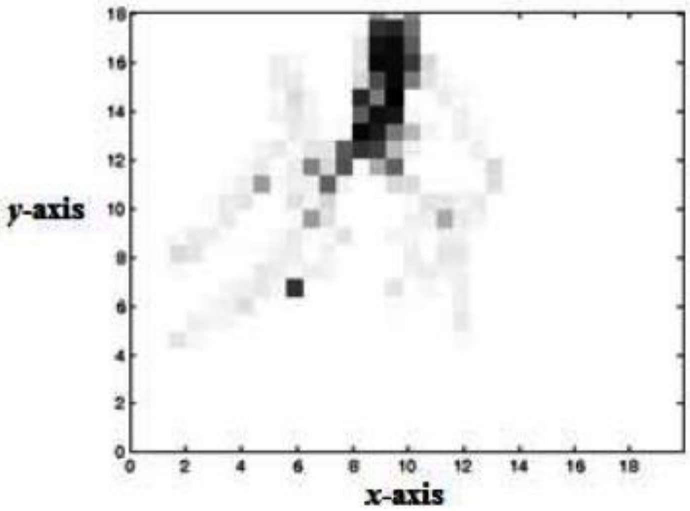


Heat Map



Image

Videos

- **Video** : Sequences of Images.

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$$s(x,y,t)=\begin{bmatrix} r(x,y,t) \\ g(x,y,t) \\ b(x,y,t) \end{bmatrix}$$

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- Number of independent variables is 3. It is a 3D signal.

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Signal and Information

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- So information cannot exist without a Signal to represent it.

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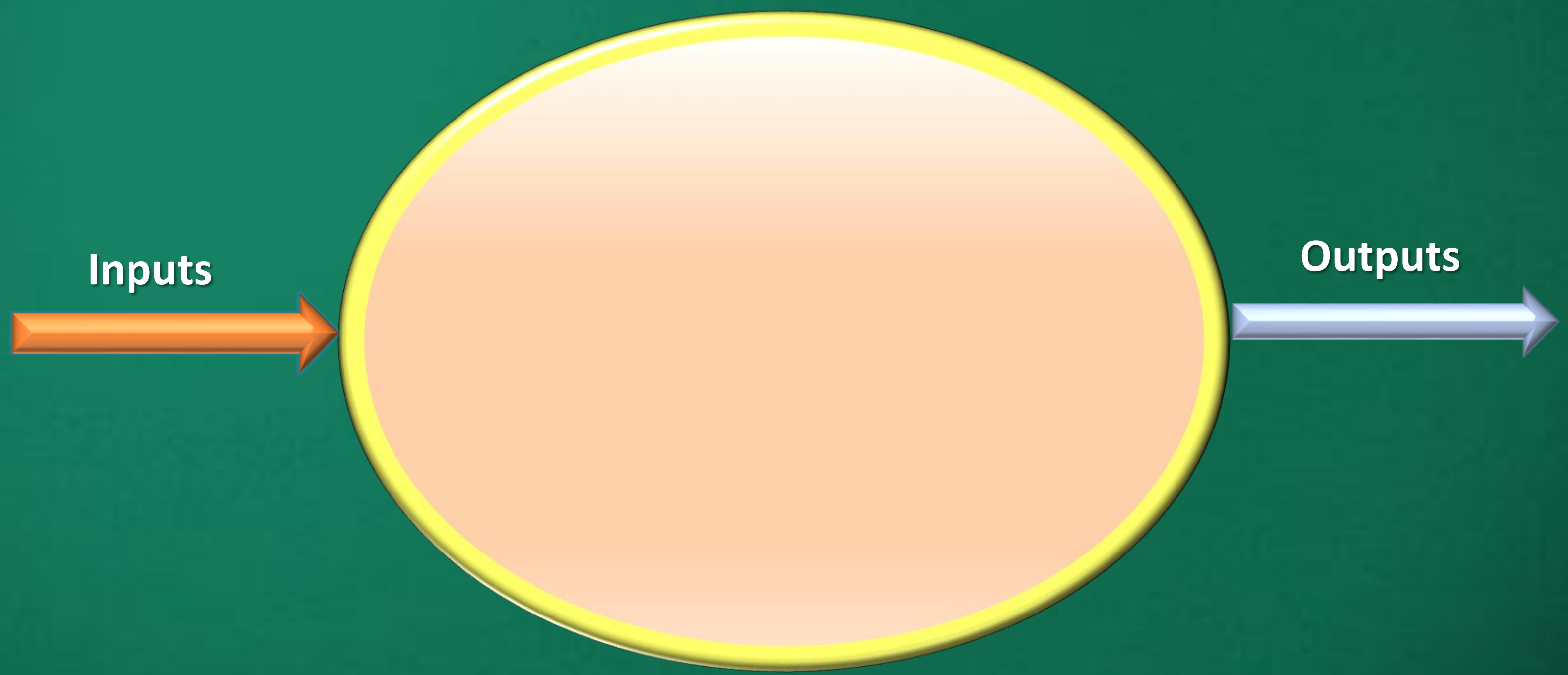
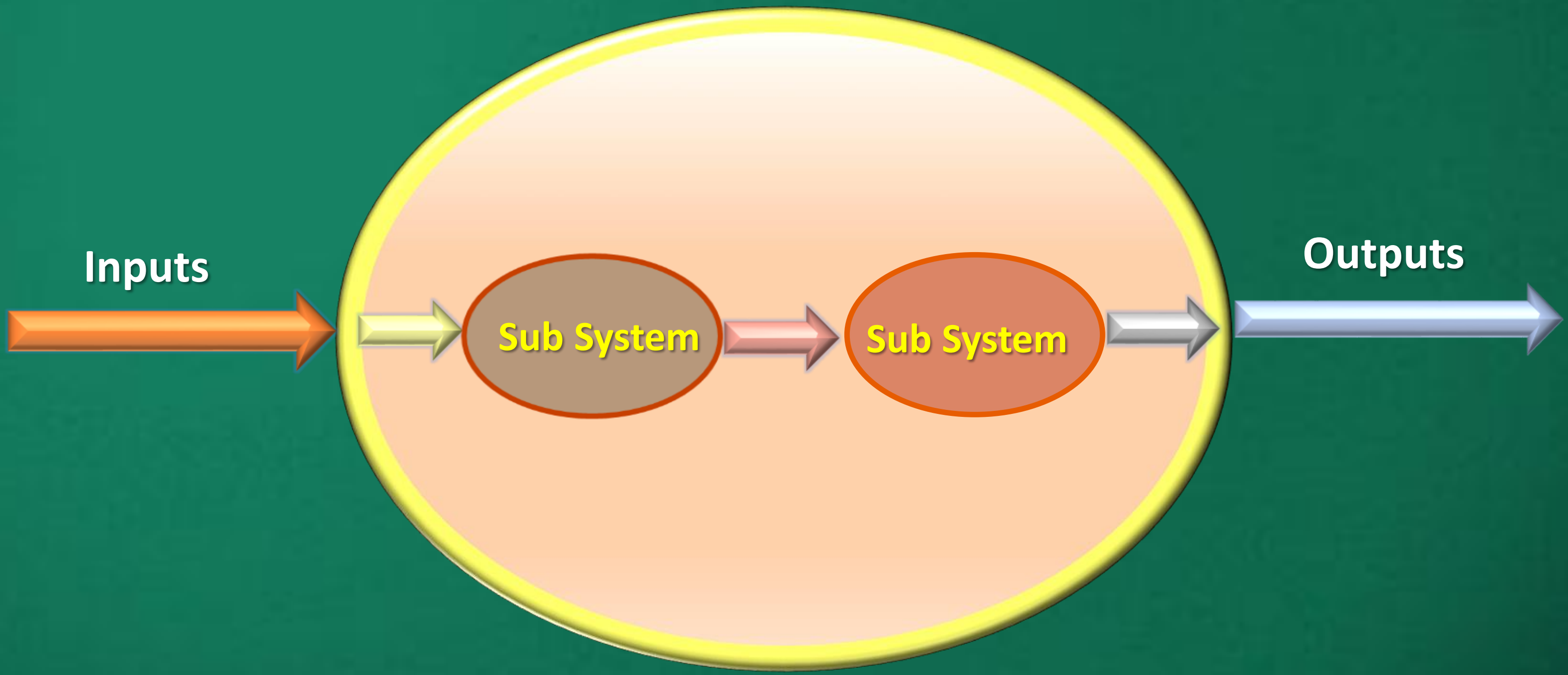
- Signals represent information.
- So information cannot exist without a Signal to represent it.
- There can be signals without any information.

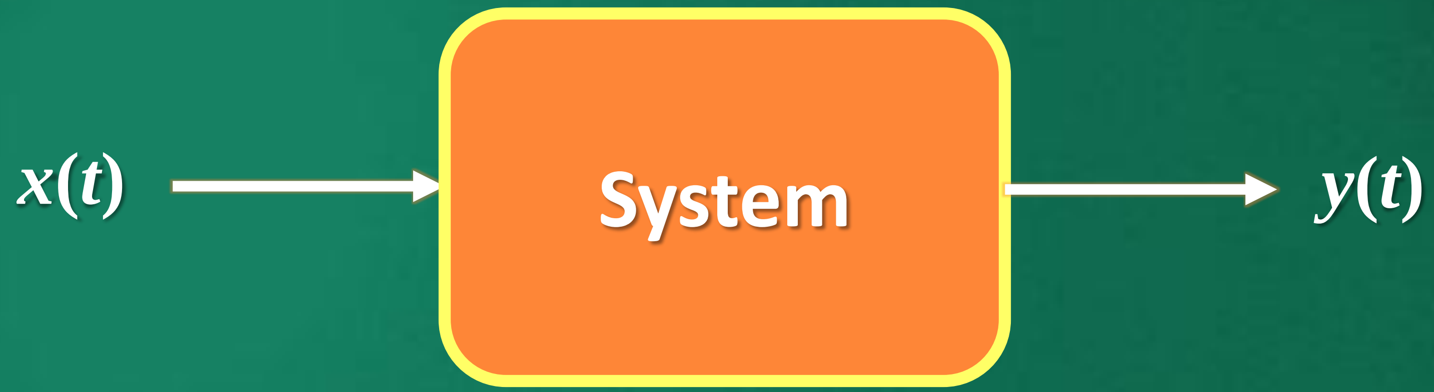
System



System



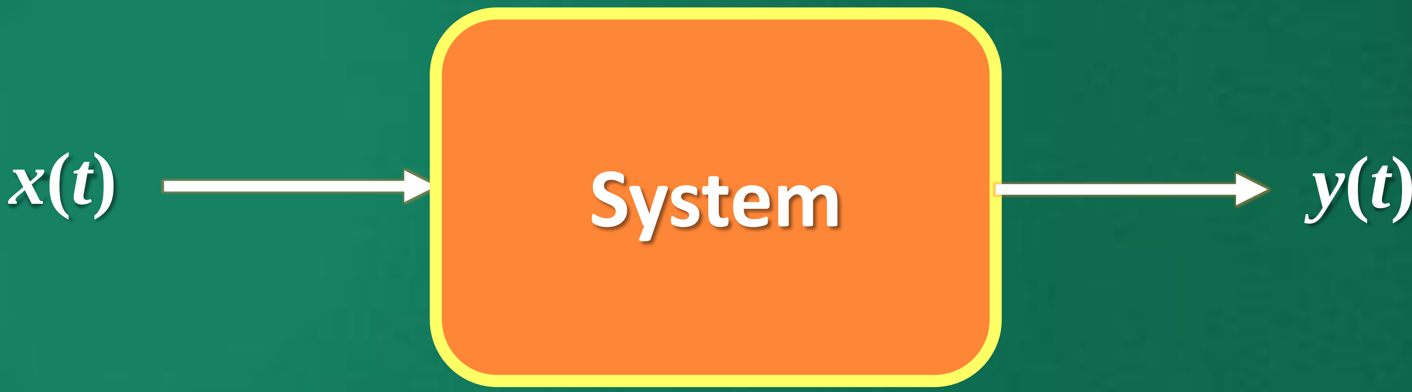
Systems



Systems

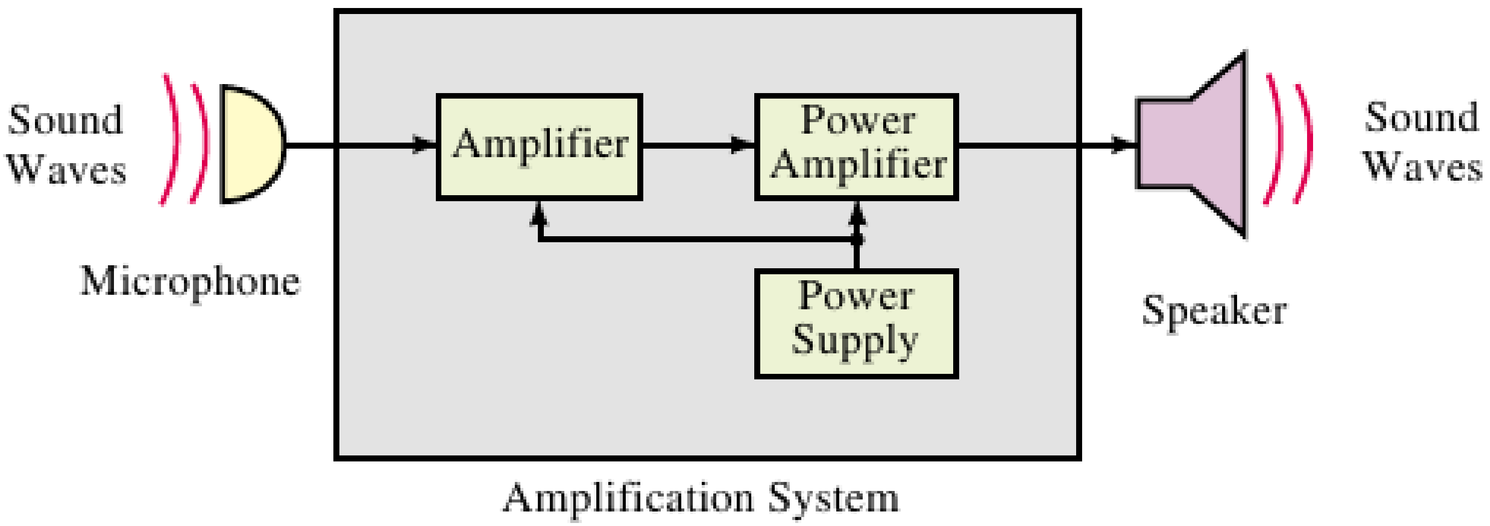
- Systems operate on signals to produce a modified signal.

Systems

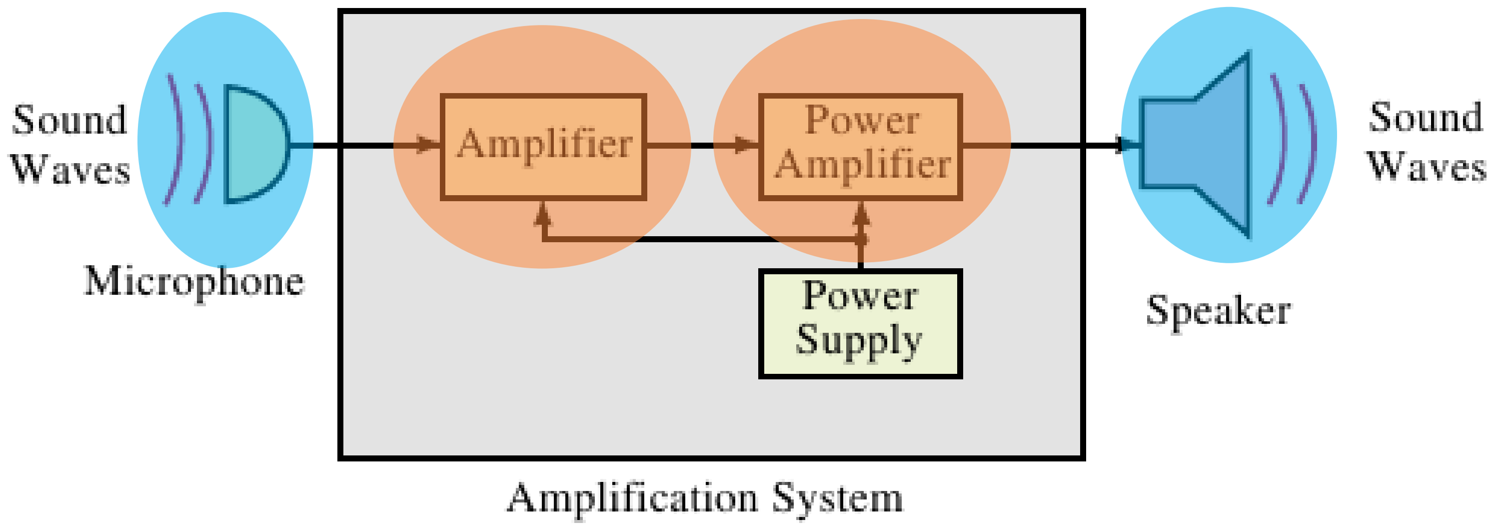


- Systems operate on signals to produce a modified signal.
- Electronic systems process electric signals.

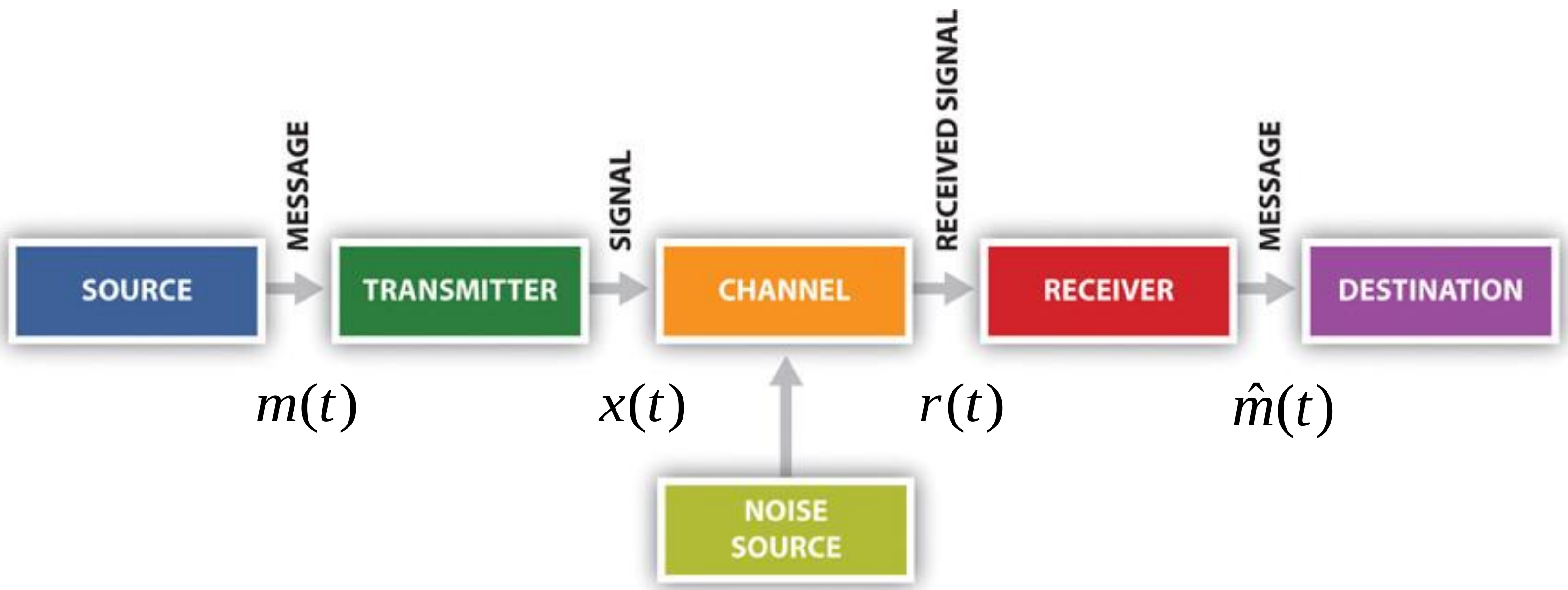
Public Addressing System



Public Addressing System



Fundamental Model of a Communication System



Important Signals

- Sinusoids and related signals
- Pulse-like signals
- Constructing and deconstructing a signal.

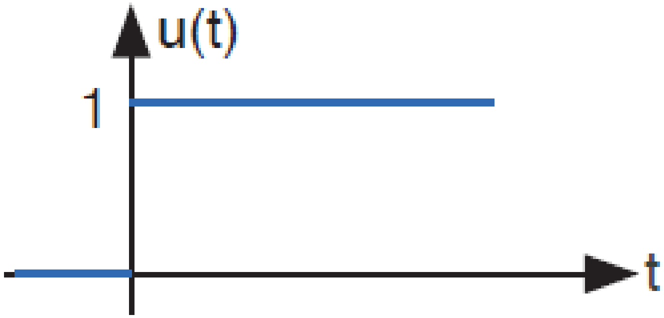
Pulse-like Signals

- Unit Step

Pulse-like Signals

- Unit Step

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



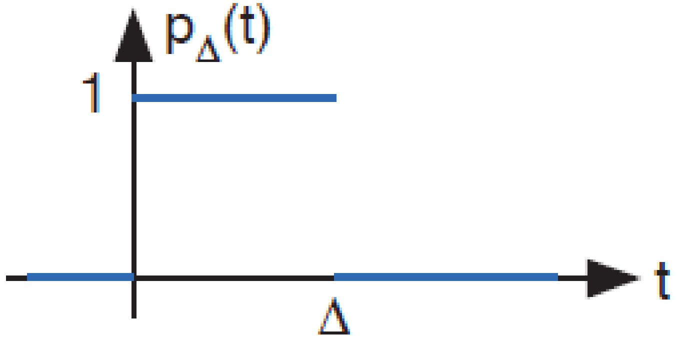
Pulse-like Signals

- Unit Pulse

Pulse-like Signals

- Unit Pulse

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



Pulse-like Signals

- Square Wave

Pulse-like Signals

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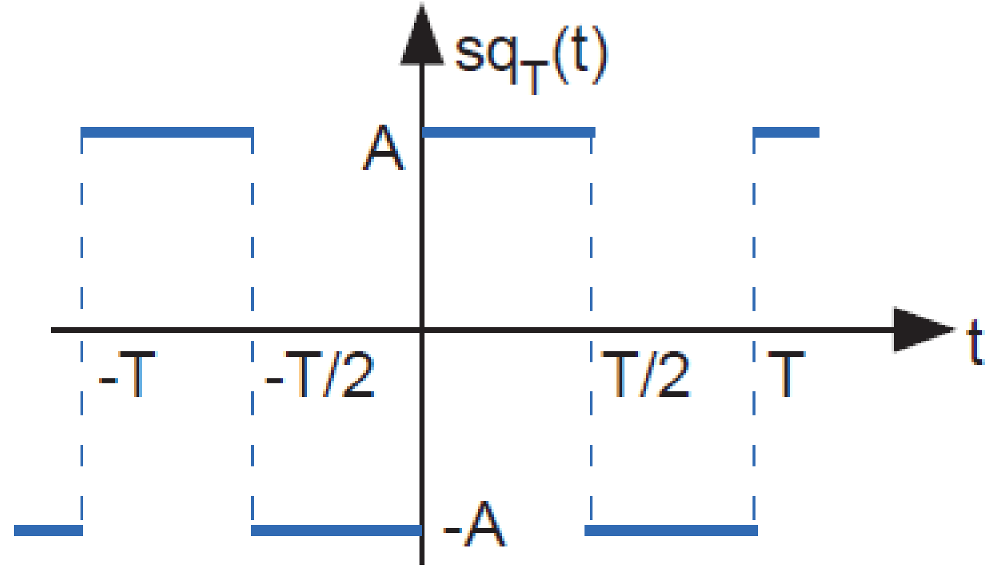
$$\mathrm{sq}_T(t)$$



Building Signals

- Signal delay $s(t-\tau)$

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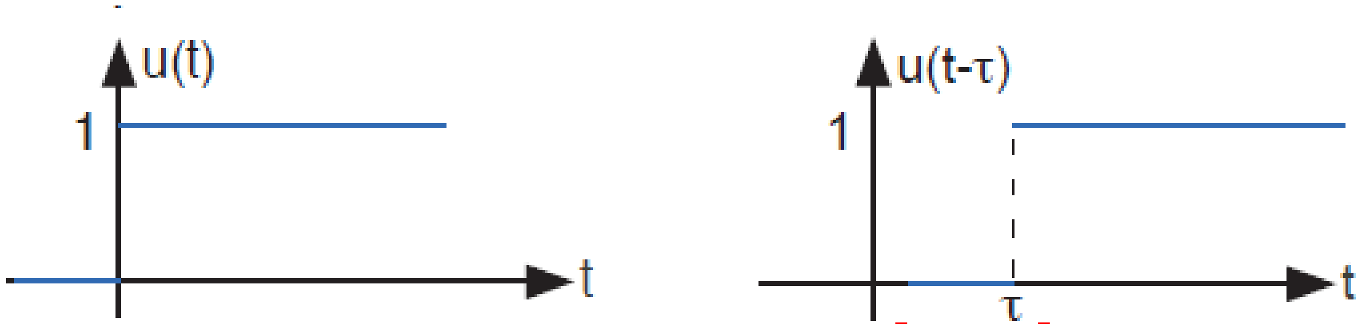

Unit Step

Delayed Unit Step

Building Signals

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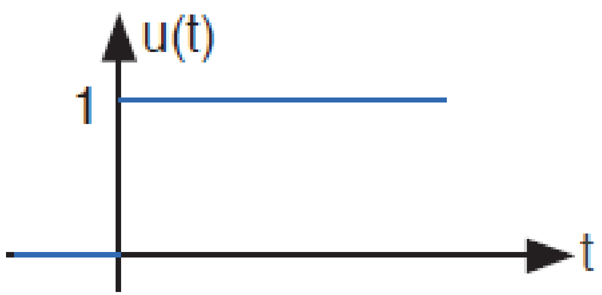
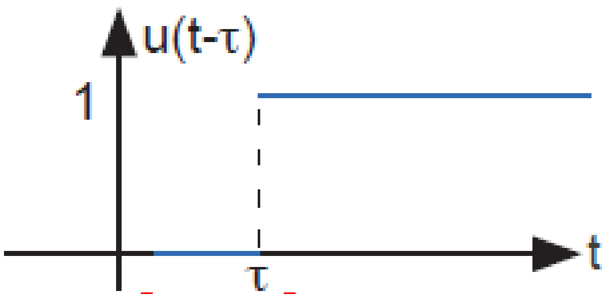


Unit Step

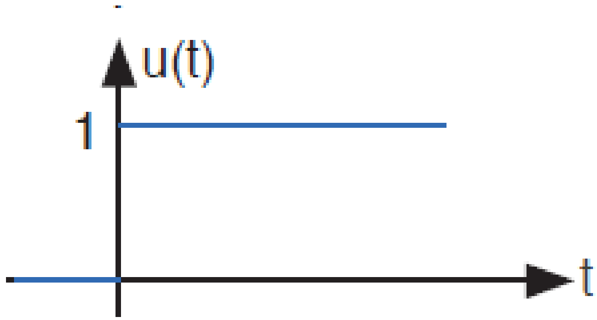


Delayed Unit Step

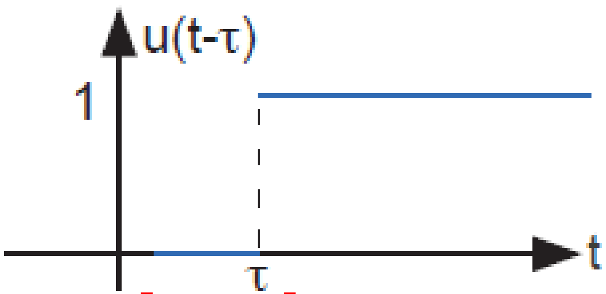
What is $u(t)-u(t-\Delta)$

Building Signals

- Signal delay $s(t-\tau)$



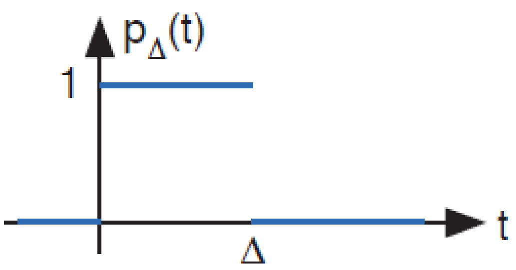
Unit Step



Delayed Unit Step

What is $u(t)-u(t-\Delta)$

$$u(t)-u(t-\Delta)=p_{\Delta}(t)$$



Building Signals

Signal construction as sum or difference of a simpler signals is called signal superposition.

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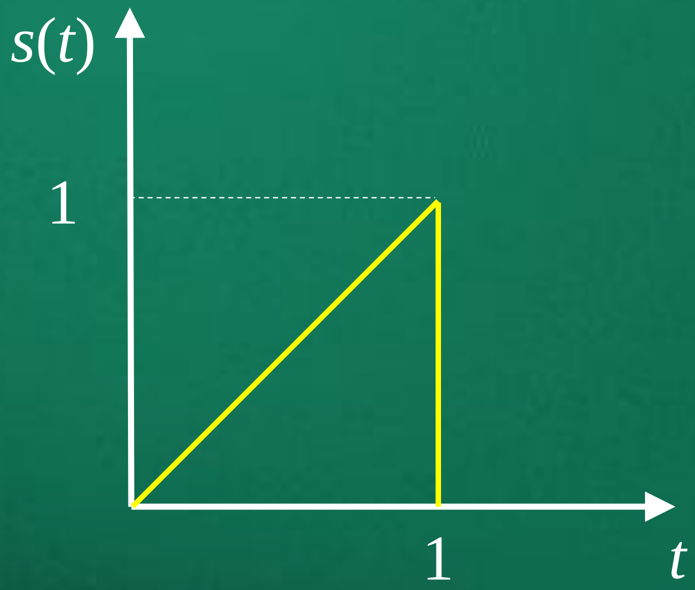
Example



Building Signals

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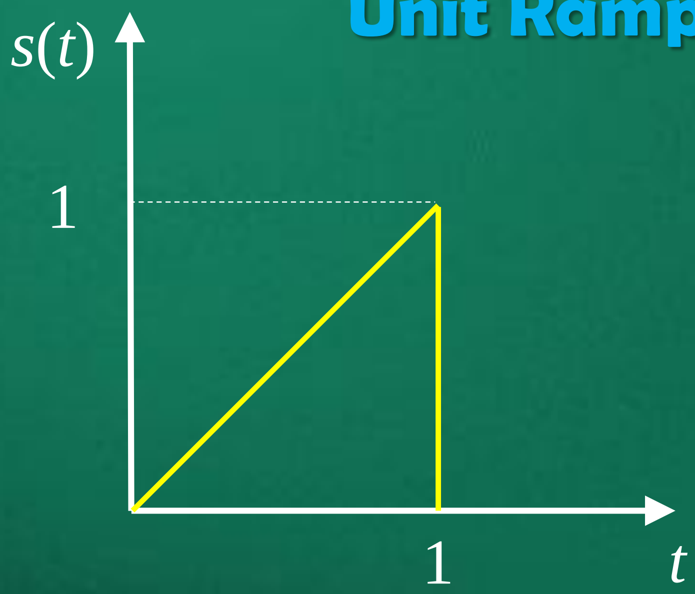
Example

Unit Ramp

$$r(t) = \int_{-\infty}^{t} u(\alpha)\, d\alpha$$



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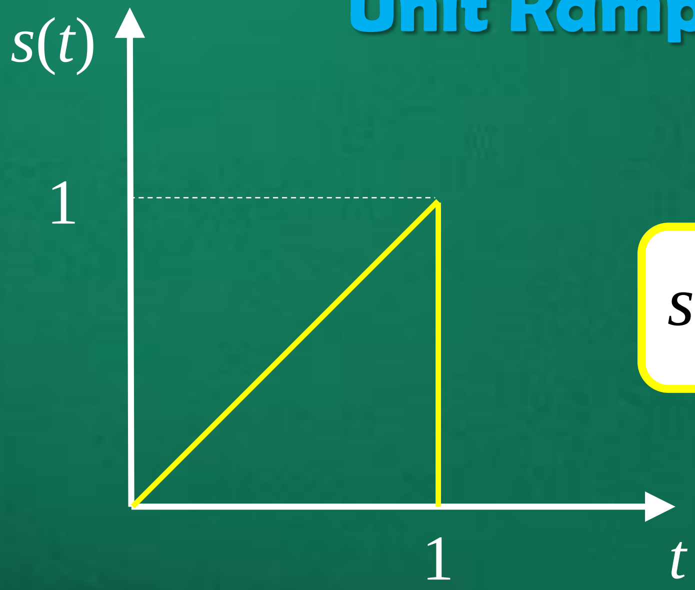
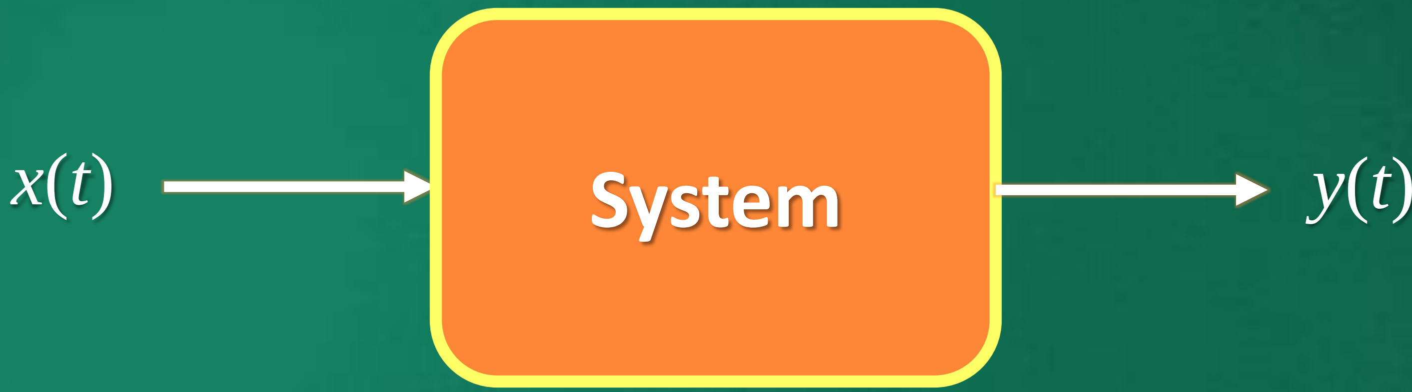


$$s(t) = r(t) - r(t-1) - u(t-1)$$

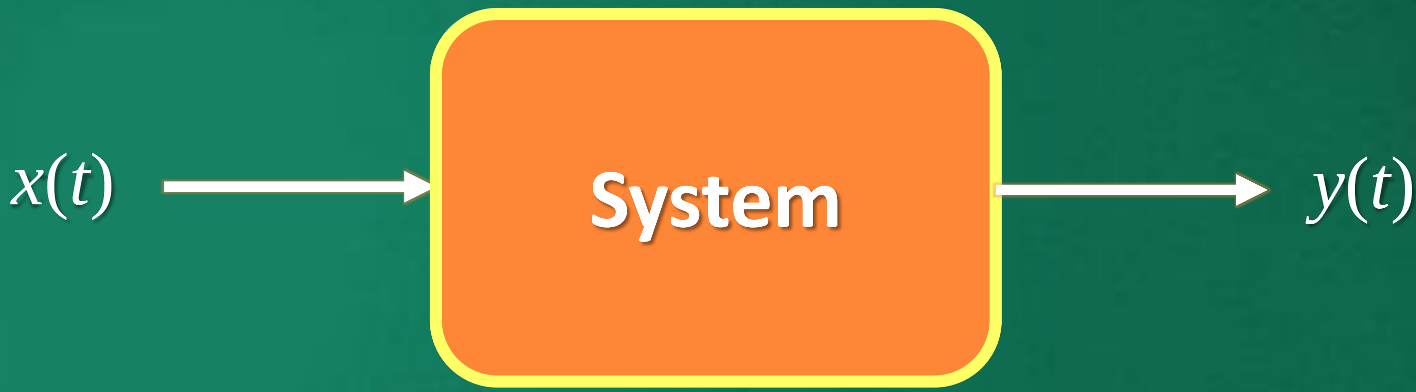
Basics of Systems

- Simple Systems
- System Structures
- Linear Time Invariant (LTI) Systems

Simple Systems



Simple Systems



- Gain

Simple Systems

$$x(t) \longrightarrow \boxed{\text{System}} \longrightarrow y(t)$$

- **Gain** $\boxed{y(t) = Gx(t)}$

Simple Systems

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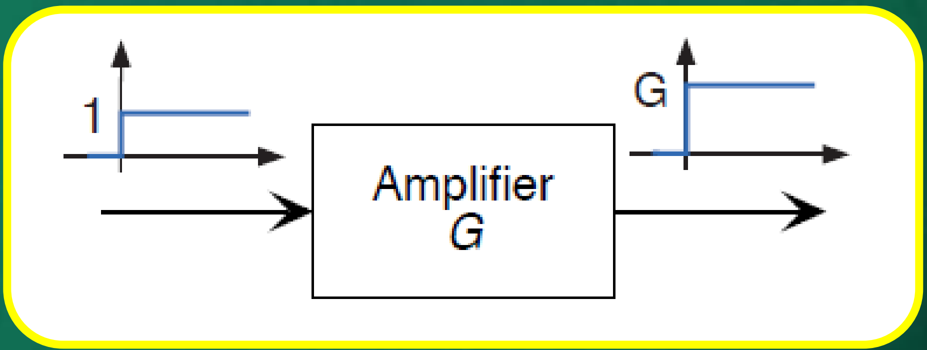
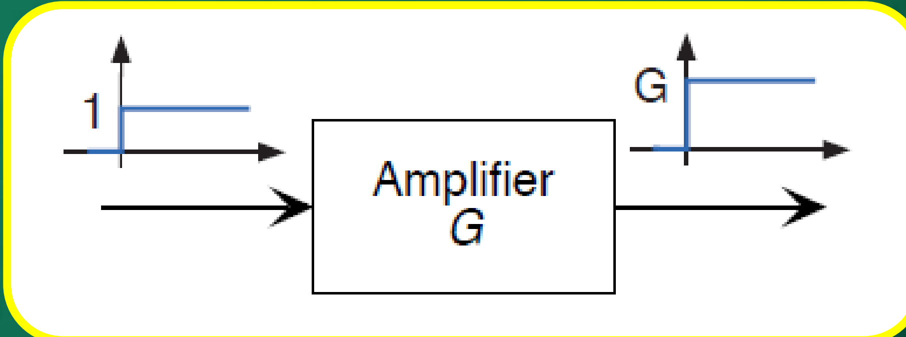


Simple Systems

- **Gain** $y(t) = Gx(t)$

$G > 1$	amplifier
$G < 1$	attenuator
$G < 0$	inverter



Simple Systems

- Time Delay

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$$y(t) = x(t - \tau)$$

Simple Systems

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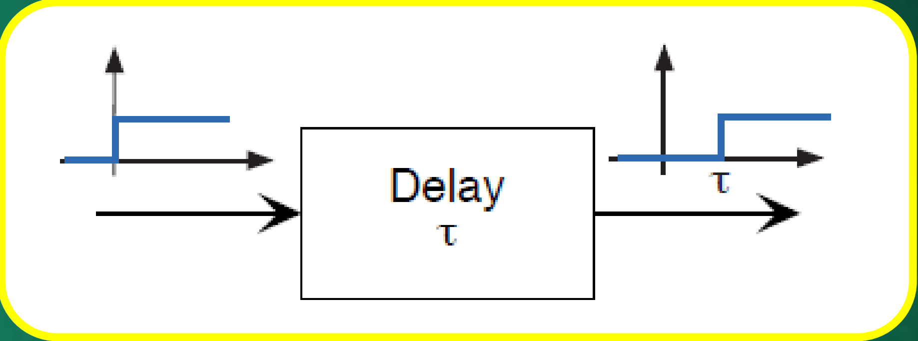
$$y(t) = x(t-\tau)$$



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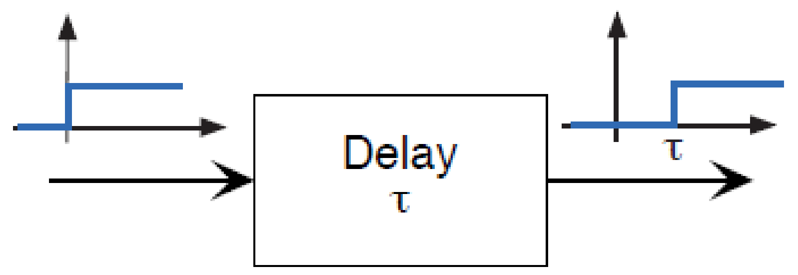

$\tau > 0$ time delay

$\tau < 0$ time advance

Simple Systems

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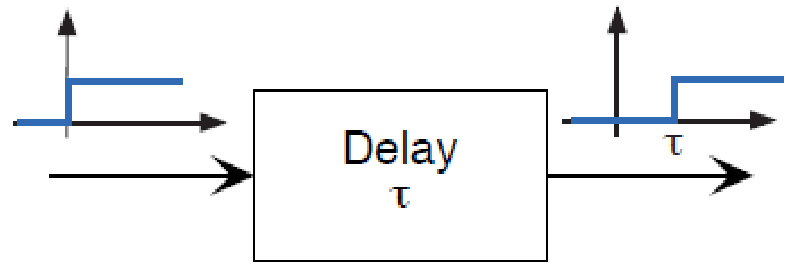
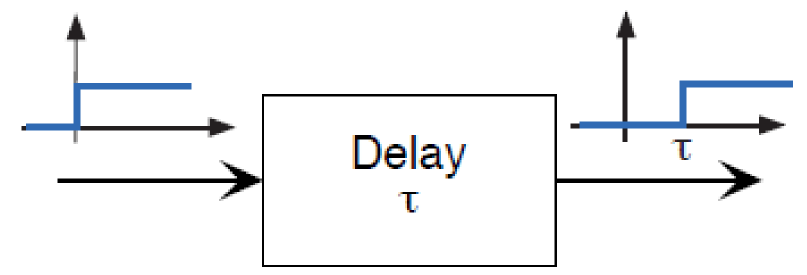


- Time Reversal

Simple Systems

❑ Time Delay

$$y(t) = x(t-\tau)$$



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❑ Time Reversal

$$y(t) = x(-t)$$

Simple Systems

❑ Time Delay

$$y(t) = x(t-\tau)$$

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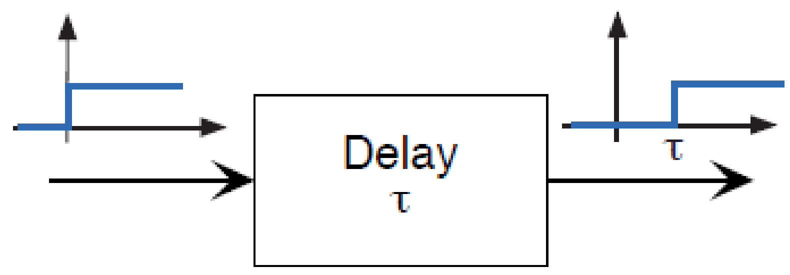

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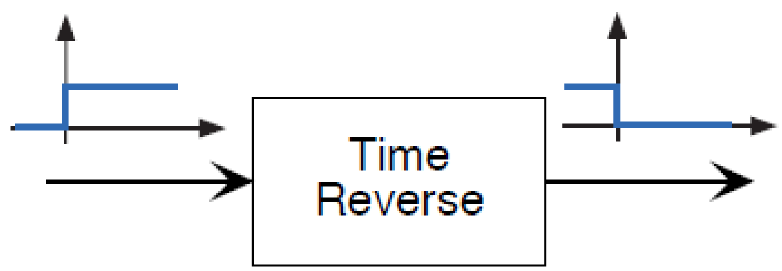

System Structures

- Cascade

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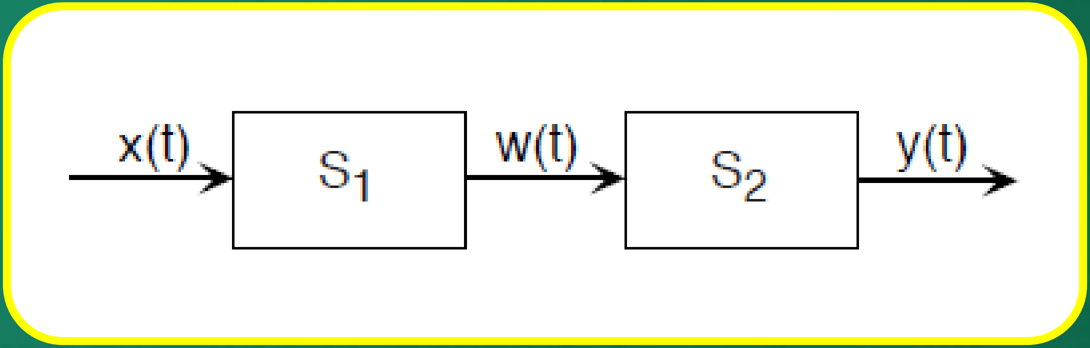
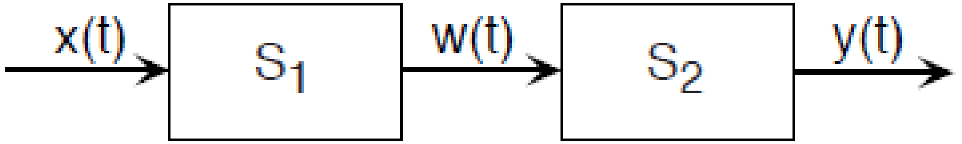


System Structures

- Cascade



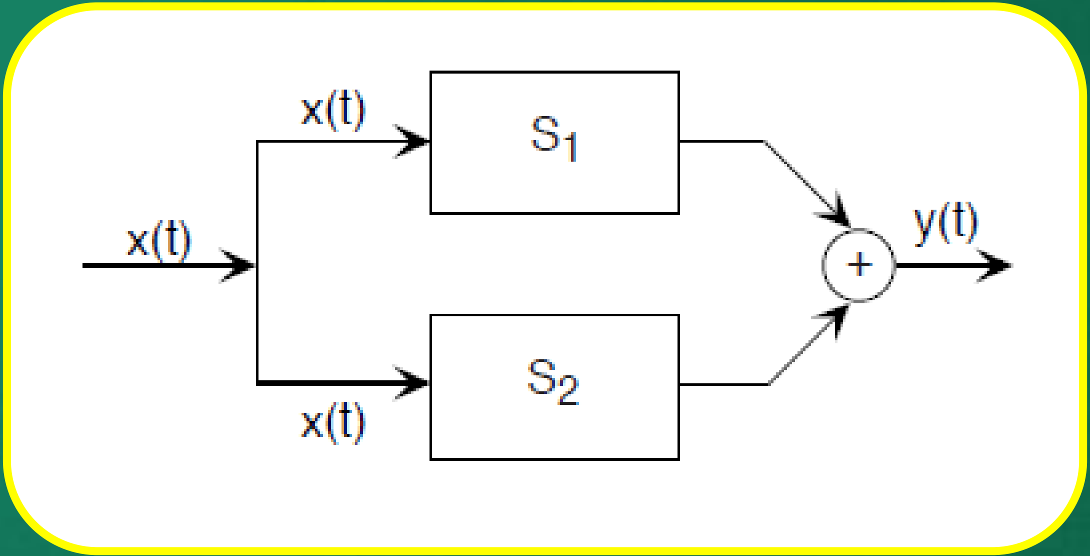
$$y(t) = S_2[w(t)] = S_2\big[S_1[x(t)]\big]$$

System Structures

- Parallel

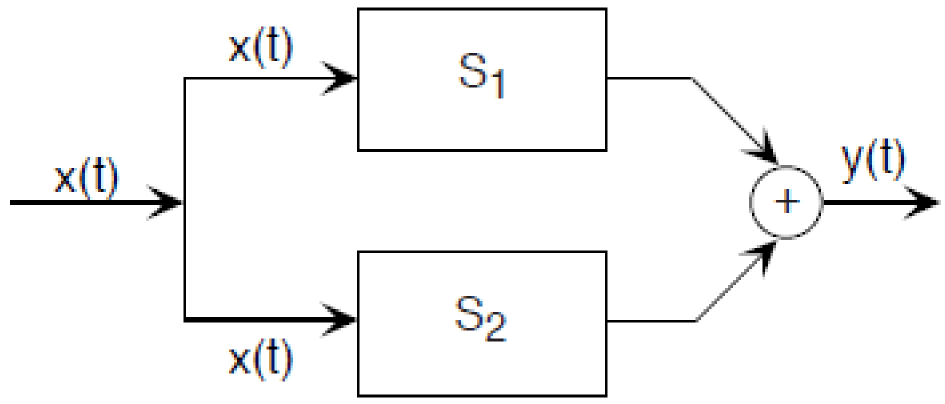
System Structures

- Parallel



System Structures

- Parallel



$$y(t) = S_1[x(t)] + S_2[x(t)]$$

System Structures

- Feedback

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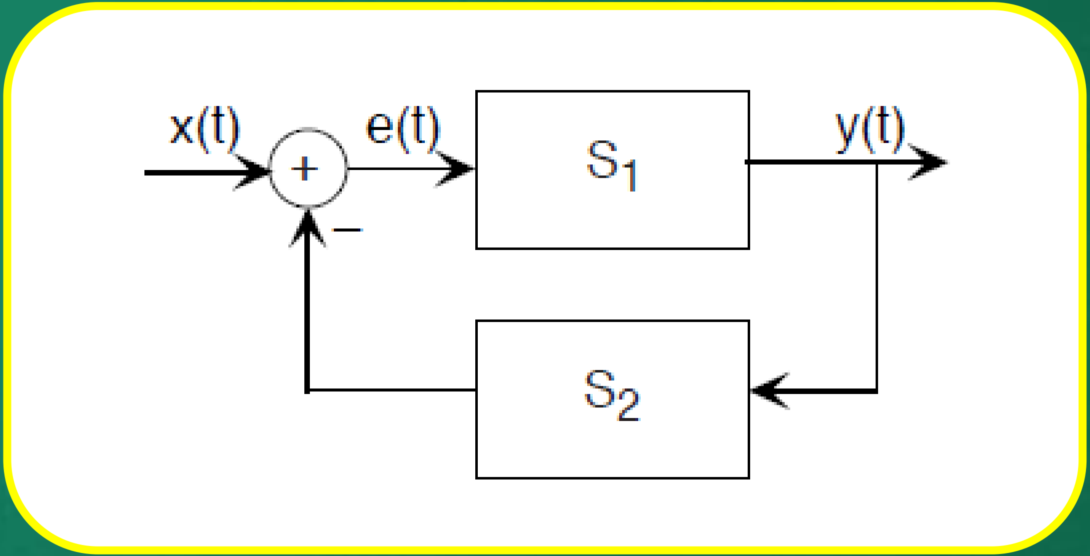

System Structures

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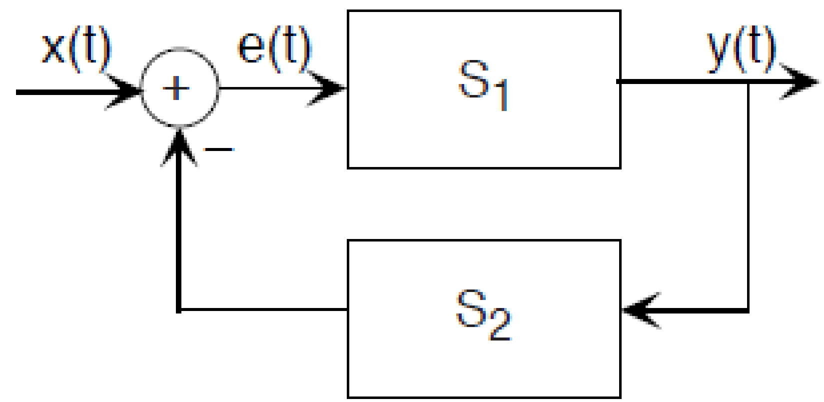
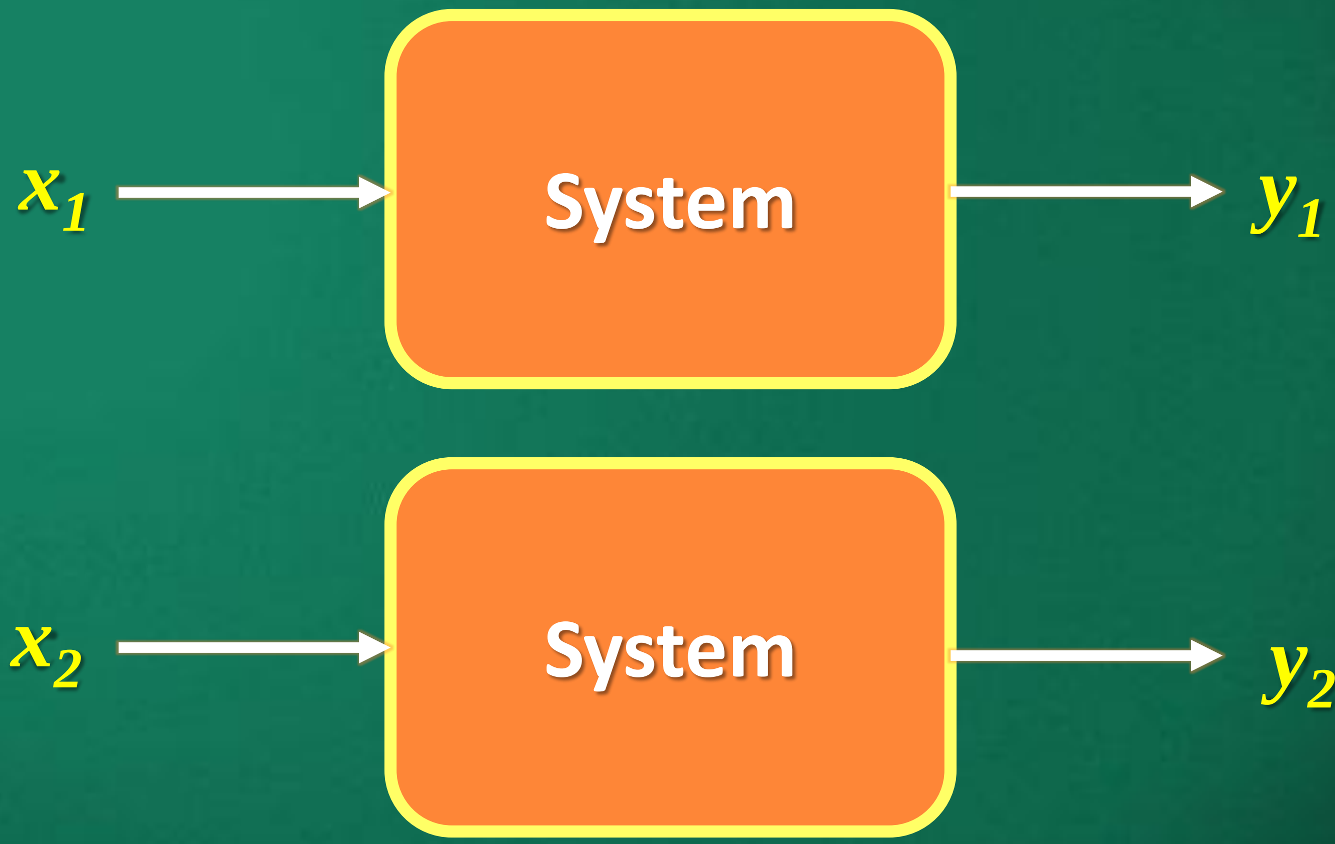
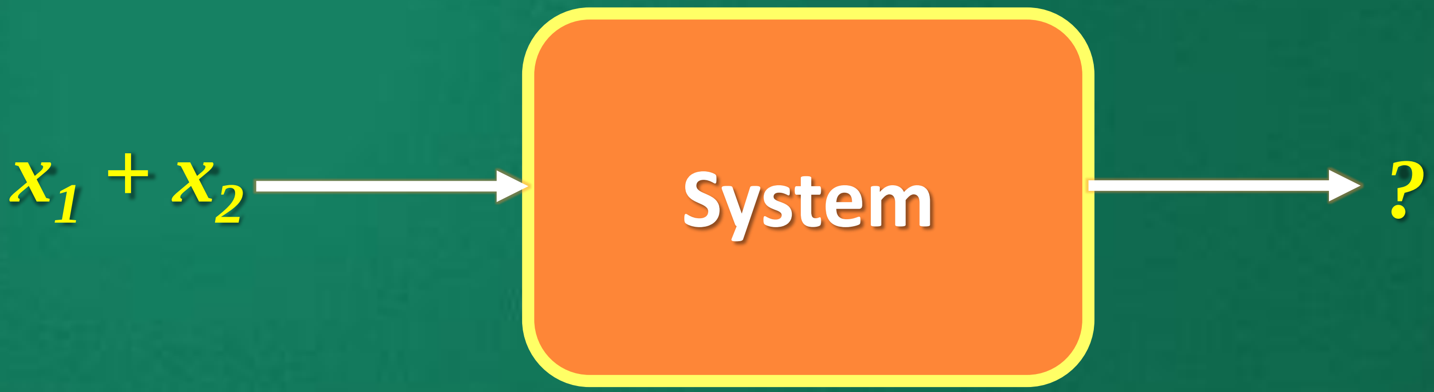


$$y(t) = S_1[e(t)]$$
$$e(t) = x(t) - S_2[y(t)]$$

Linear Systems



Linear Systems (Additivity)



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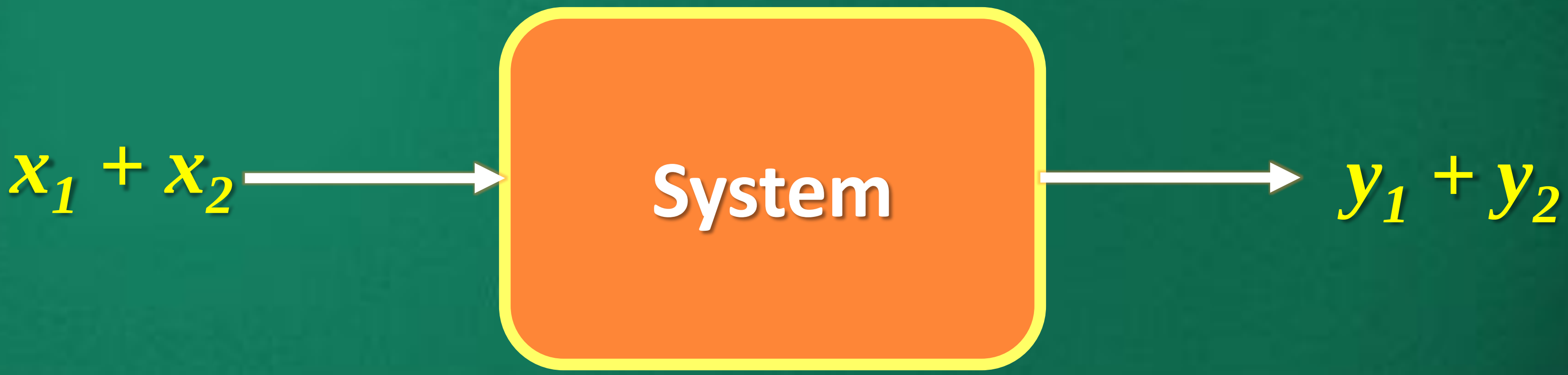


Linear Systems (Homogeneity)

Linear Systems (Homogeneity)

Linear Systems (Linearity Test)

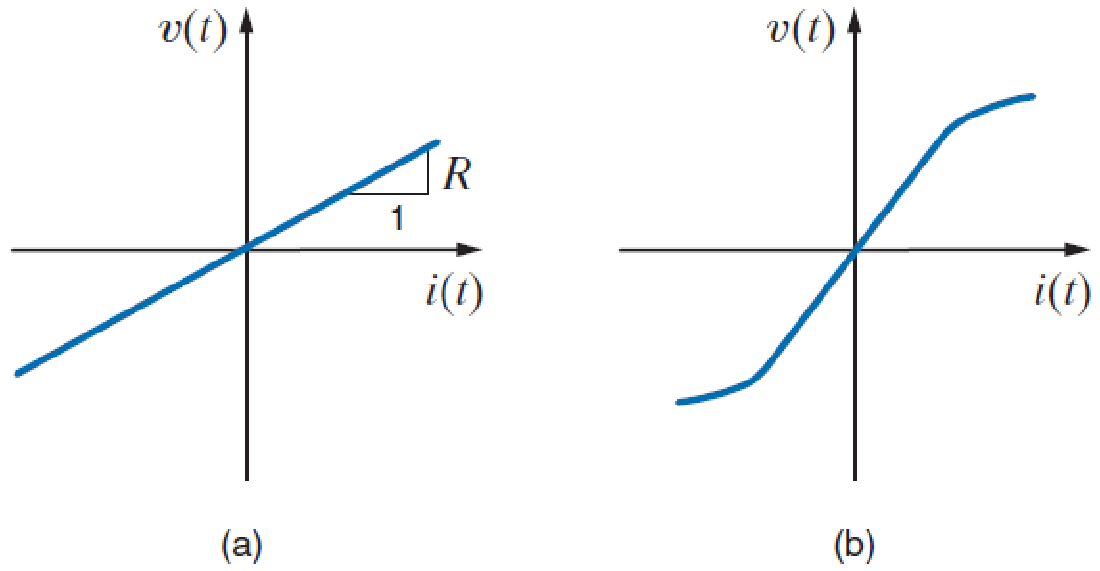
$$a(x_1) + b(x_2) \longrightarrow \boxed{\text{System}} \longrightarrow a(y_1) + b(y_2)$$

Linear systems

An system which satisfies (passes) both additivity and homogeneity properties is termed as a linear system, otherwise it is termed as a nonlinear system.

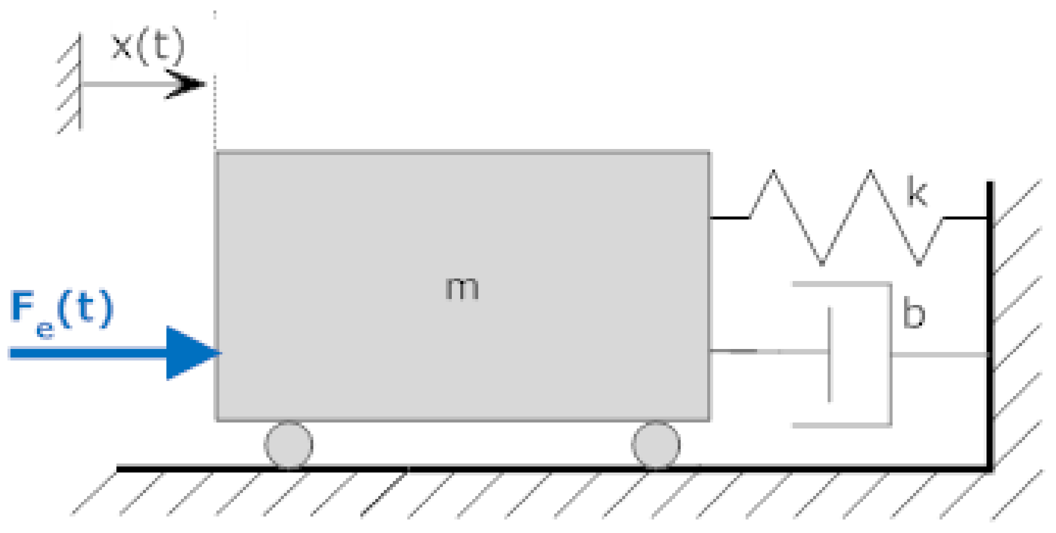
Examples: Resistive Circuit, Mass Spring Systems

Linear Resistor and Light Bulb



***v-i* characteristics**

Spring Mass Damper System



Spring Mass Damper System

Governing Equation

$$F_e = m\frac{d^2x}{dt} + b\frac{dx}{dt} + kx$$

Is the system linear?

Spring Mass Damper System

Input to the system is external force (Fe) and the output is the displacement (x)

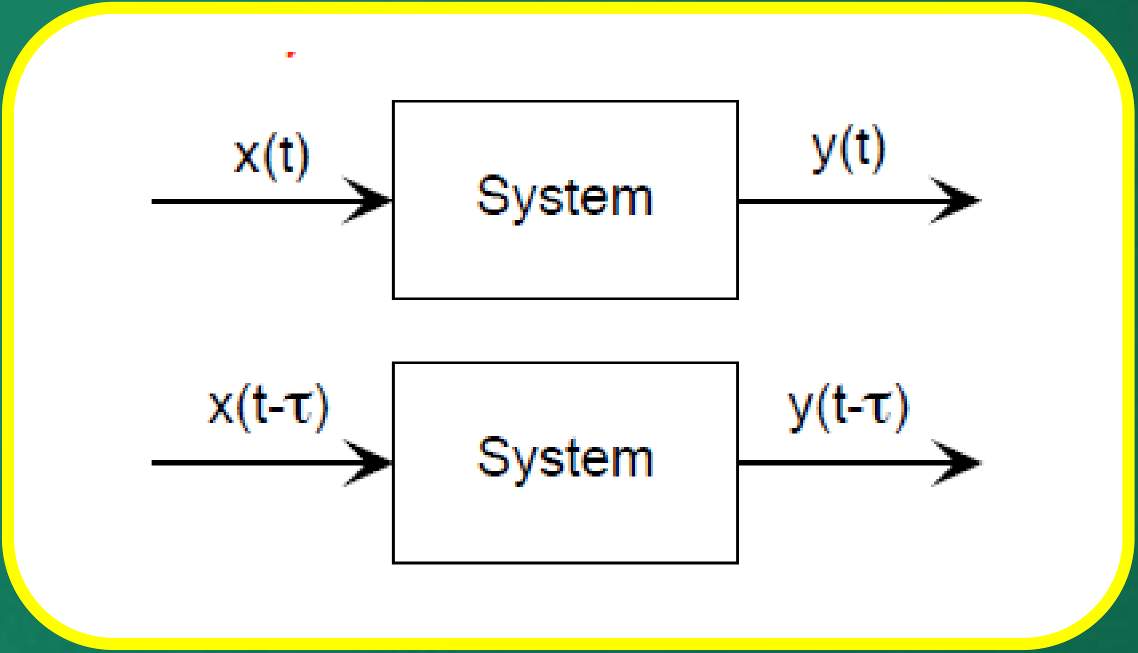
Apply linearity test to check.

Spring Mass Damper System

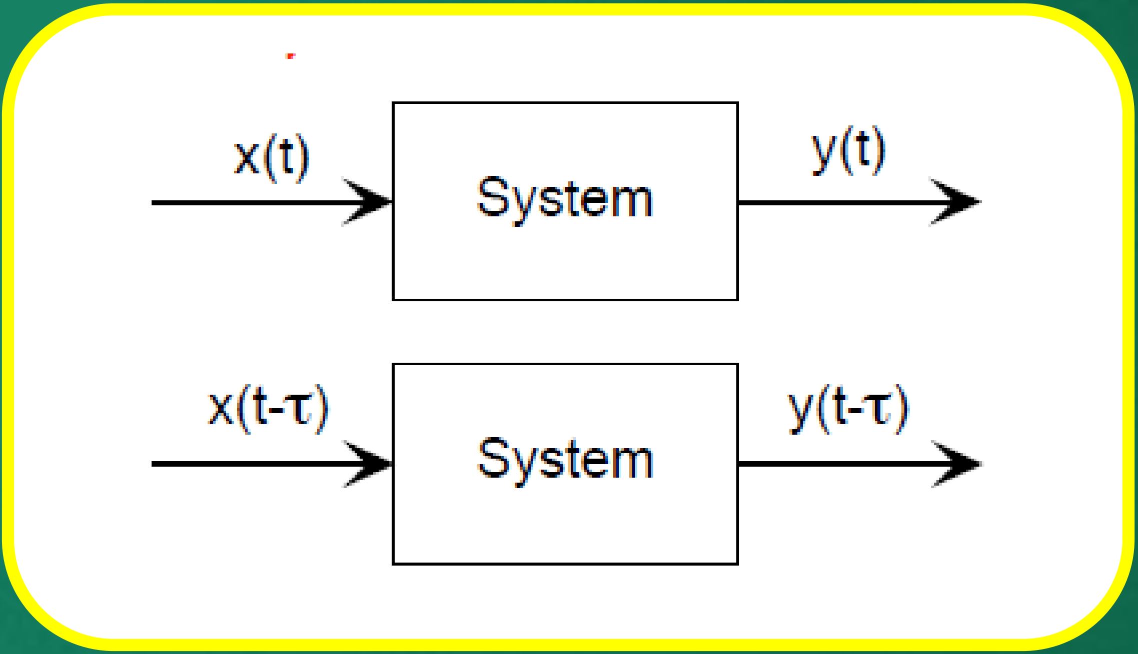
Input to the system is external force (Fe) and the output is the displacement (x)

Since both additivity and homogeneity are satisfied the system is **linear**.

Time Invariant Systems



Time Invariant Systems



Systems that does not change their behaviour with time are called **time invariant systems.**

Linear Time Invariant System

System which is linear as well as time invariant is called Linear Time Invariant System or an LTI System.

Linear Time Invariant System

System which is linear as well as time invariant is called Linear Time Invariant System or an LTI System.

Exercise: Check whether the systems are LTI

$$y(t) = G \cdot x(t)$$

$$y(t) = \frac{d\,x(t)}{dt}$$

$$y(t) = x^2(t)$$

$$y(t) = x(t) \cdot \cos 2\pi f_c t$$

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$y(t) = \dfrac{d\,x(t)}{dt}$	Linear Time Invariant
$y(t) = x^2(t)$	Nonlinear Time Invariant
$y(t) = x(t) \cdot \cos 2\pi f_c t$	

Linear Time Invariant System

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$y(t) = G \cdot x(t)$	Linear Time Invariant
$y(t) = \dfrac{d\,x(t)}{dt}$	Linear Time Invariant
$y(t) = x^2(t)$	Nonlinear Time Invariant
$y(t) = x(t) \cdot \cos 2\pi f_c t$	Linear Time Varying