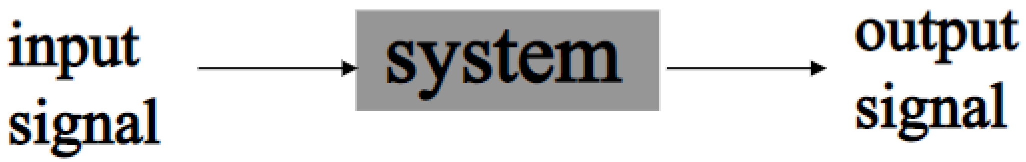
Systems and its Classification

Department of Electronics & Communication Engg.
University Institute of Engineering & Technology,
C S J M University , Kanpur

What is System ?

Systems process input signals to produce output signals

A system is combination of elements that manipulates one or more signals to accomplish a function and produces some output.



Introduction to Systems

- Systems are used to process signals to allow modification or extraction of additional information from the signal.
- A system may consist of physical components (hardware realization) or an algorithm (operator) that computes the output signal from the input signal.
- A physical system consists of inter-connected components which are characterized by their input-output relationships.

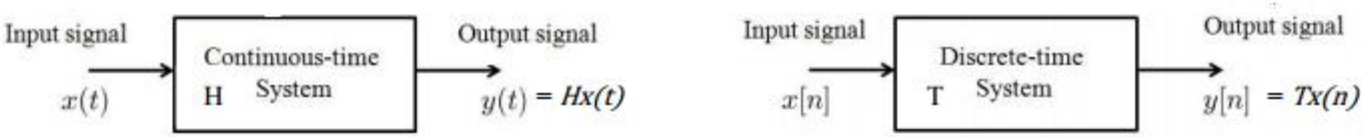


Figure : Continuous-time and discrete-time systems: Here H & T are operators.

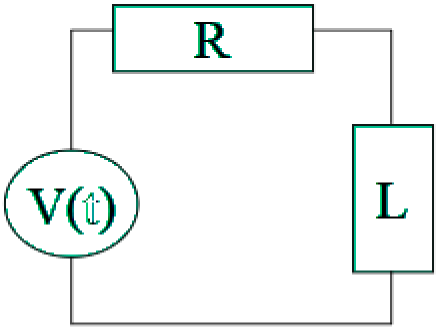
Example - System

Consider an RL series circuit

Using a first order equation:

$$V_L(t) = L\frac{di(t)}{dt}$$

$$V(t) = V_R + V_L(t) = i(t)\cdot R + L\frac{di(t)}{dt}$$



Mathematical Expression of continuous Time Systems

Most continuous time systems represent via **differential equations** .

e.g. RC circuit

$$\frac{dv_c(t)}{dt} + \frac{1}{RC} v_c(t) = \frac{1}{RC} v_s(t)$$

- Order of the Continuous System is the highest power of the derivative associated with the output in the differential equation
- For example the order of the system shown is 1.

$$m\frac{dv(t)}{dt} + \rho v(t) = f(t)$$

Mathematical Expression for Discrete time Systems

Most discrete time systems represent via **difference equations** e.g. bank account,

$$y[n] = 1.01y[n-1] + x[n]$$

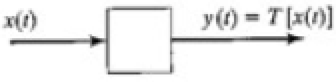
Order of the **Discrete Time System** is the highest number in the difference equation by which the output is delayed

For example the order of the system shown is 1.

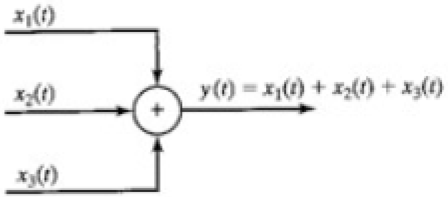
$$y[n] = 1.01y[n-1] + x[n]$$

Interconnected Systems

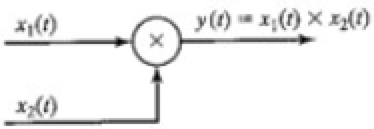
Serial (cascaded)
Parallel
Feedback



(a)



(b)



(c)

Feedback System

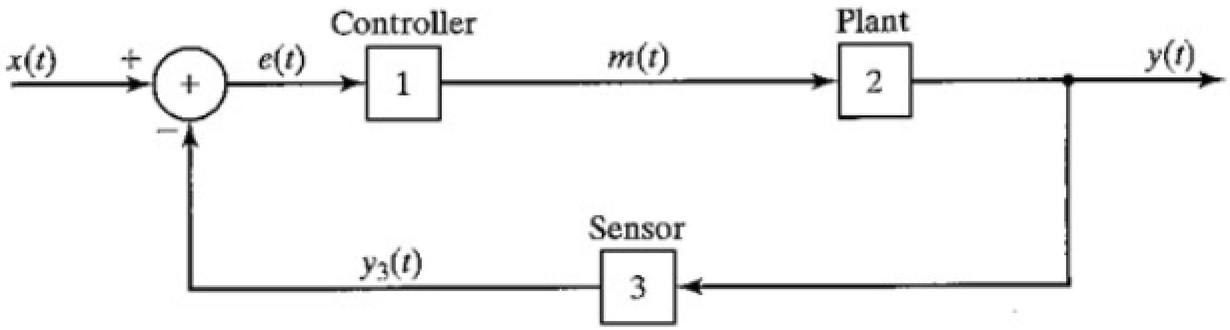
Used in automatic control

e(t)=x(t)-y3(t)= x(t)-T3[y(t)]=

y(t)= T2[m(t)]=T2(T1[e(t)])

→ y(t)=T2(T1[x(t)-y3(t)])= T2(T1([x(t)] - T3[y(t)])) =

=T2(T1([x(t)] –T3[y(t)]))



Types of Systems

- Linear & Non Linear
- Causal & Anticausal
- Time Variant &Time-invariant
- Stable & Unstable
- Static & Dynamic
- Invertible & Inverse Systems

Linear and Non Linear System

Linear system: A system is said to be linear if it satisfies two properties i.e., superposition & homogeneity.

Superposition: It states that the response of the system to a weighted sum of signals be equal to the corresponding weighted sum of responses (Outputs of the system to each of the individual input signal.

For an input $x(t) = x_1(t)$, the output $y(t) = y_1(t)$

and input $x(t) = x_2(t)$, the output $y(t) = y_2(t)$

then, the system is linear if & only if

$$T\,[a_1x_1(t) + a_2x_2(t)] = a_1\,T\,[x_1(t)] + a_2\,T\,[x_2(t)]$$

Homogeneity: If the input x(t) is scaled by a constant factor 'a', then the output y(t) is also scaled by exactly the same constant factor 'a'.

Causal & Anticausal System

Causal system : A system is said to be *causal* if the present value of the output signal depends only on the present and/or past values of the input signal.

Example: $y[n]=x[n]+1/2x[n-1]$

Causal & Anticausal System

Anticausal system : A system is said to be *anticausal* if the present value of the output signal depends only on the future values of the input signal.

Example: $y[n]=x[n+1]+1/2x[n-1]$

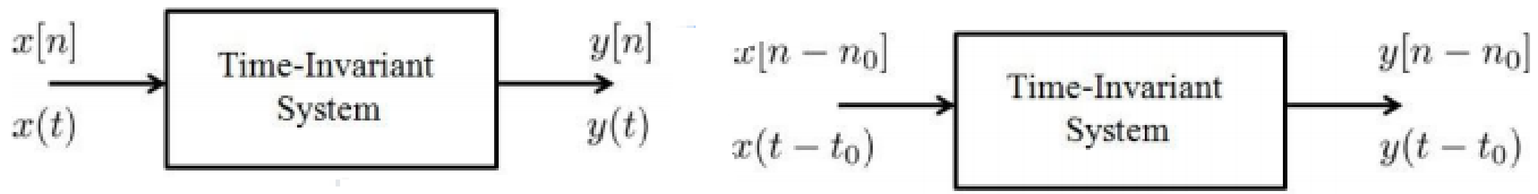
Time invariant and time variant system:

Time invariant: A system is time-invariant if a time-shift of the input signal results in the same time-shift of the output signal.

That is, if $x(t) \to y(t)$,

then the system is time-invariant if

$$x(t - t_0) \to y(t - t_0), \text{ for any } t_0 .$$



Time variant: A system is time-variant if its input –output characteristic changes with time.

Example

The system $y[n] = nx[n]$ is time-variant.

Stable & Unstable System

A system is said to be *bounded-input bounded-output stable* (BIBO stable) iff every bounded input results in a bounded output.

i.e.

$$\forall t \quad |x(t)| \leq M_x < \infty \rightarrow \forall t \quad |y(t)| \leq M_y < \infty$$

Example:
1. y(t) = x (t-3) is a stable system.
2. y(t) = t x(t) is an unstable system.
3. $y[n] = e^{x[n]}$ is a stable system.

Example: The system represented by

$y(t) = A\,x(t)$ is unstable ; $A > 1$

Reason: let us assume $x(t) = u(t)$, then at every instant $u(t)$ will keep on multiplying with A and hence it will not be bonded.

Static & Dynamic Systems

- A static system is memoryless system
- It has no storage devices
- its output signal depends on present values of the input signal

For example $i(t) = {}^{1}\!/_{R}\, v(t)$

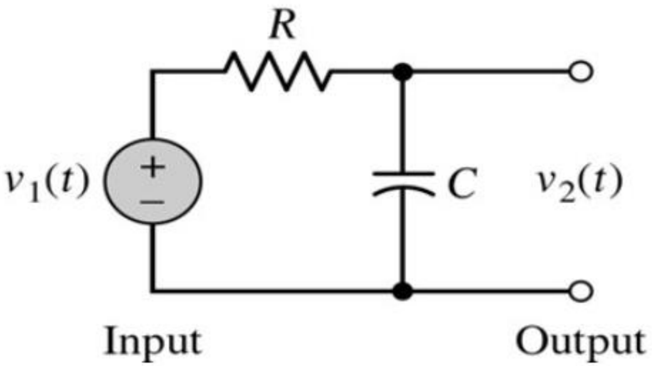
Static & Dynamic Systems

- A dynamic system possesses memory
- It has the storage devices
- A system is said to possess *memory* if its output signal depends on past values and future values of the input signal

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

$$y[n] = x[n] + x[n-1]$$

Example – given System is Stable or Dynamic



Answer:

The system shown above is RC circuit

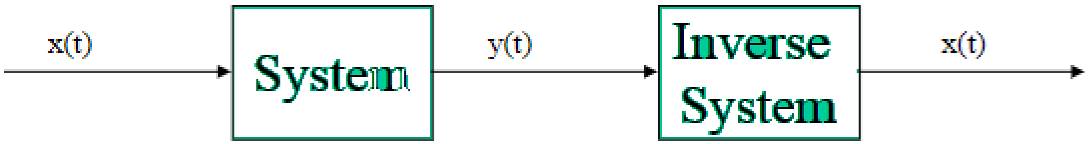
R is memoryless

C is memory device as it stores charge because of which voltage across it can't change immediately

Hence given system is dynamic or memory system

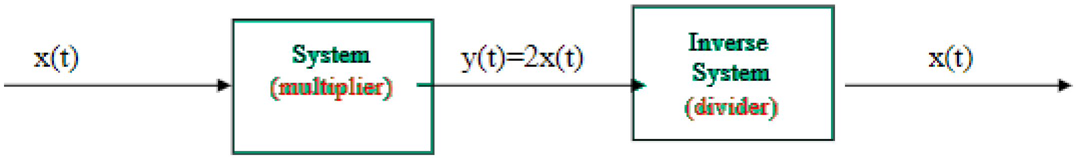
Invertible & Non-invertible Systems

If a system is invertible it has an Inverse System



Example: y(t)=2x(t)

- System is invertible→ must have inverse, that is:
- For any x(t) we get a distinct output y(t)
- Thus, the system must have an Inverse
  - x(t)=1/2 y(t)=z(t)



Thank You!