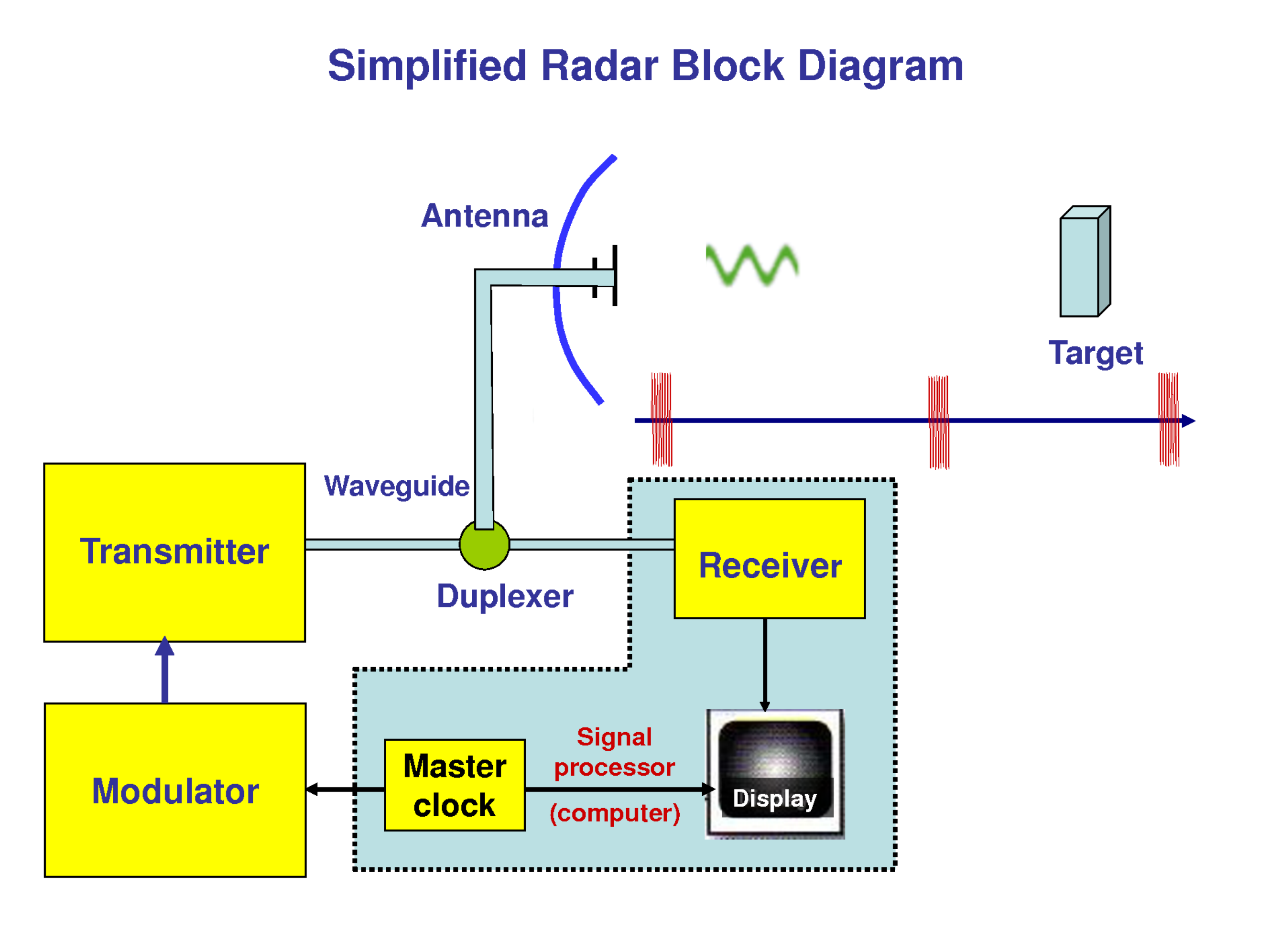
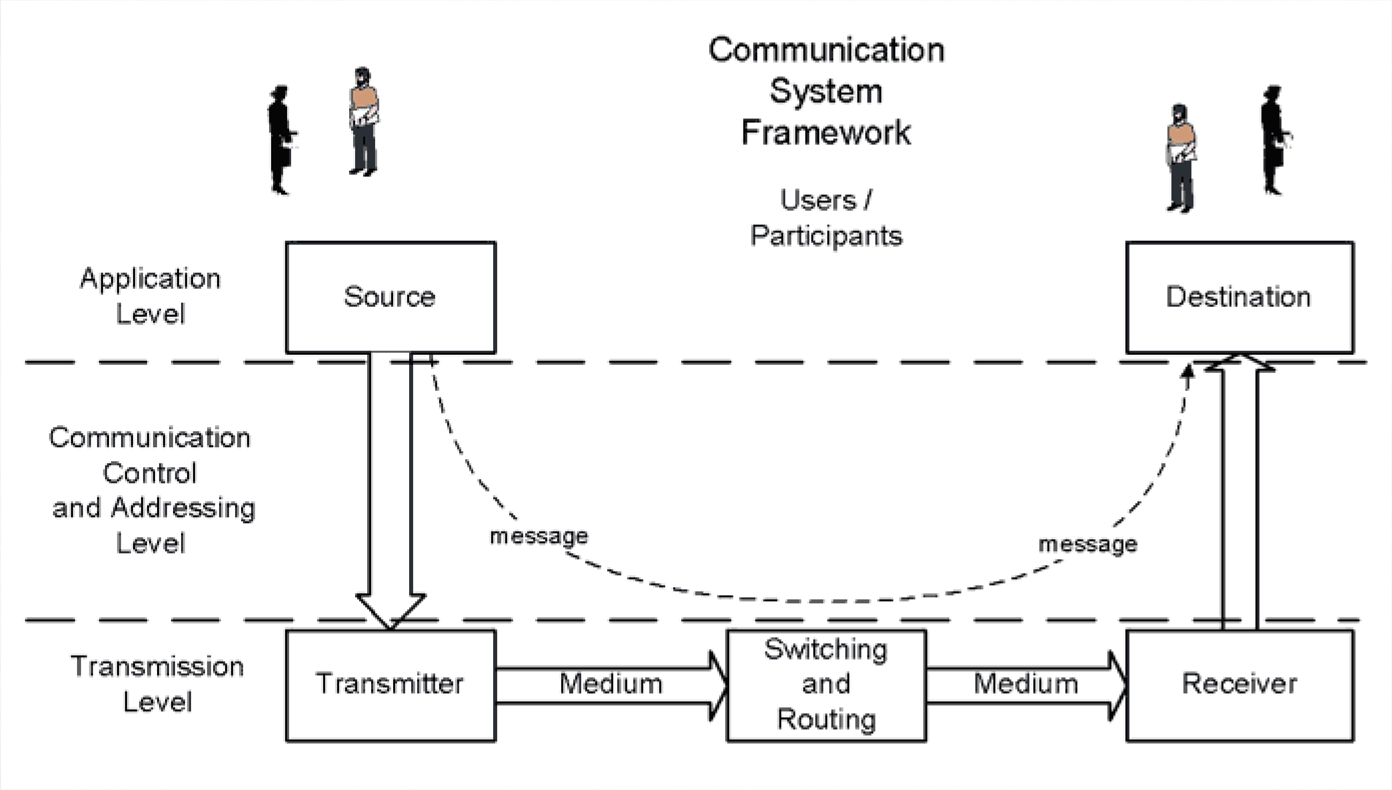
SYSTEMS

EXAMPLES OF SYSTEMS



COMM. SYSTEM



Communication
System
Framework
Users /
Participants
Application
Level
Source
Destination
Communication
Control
and Addressing
Level
message
message
Transmission
Level
Transmitter
Medium
Switching
and
Routing
Medium
Receiver

MOTOR

Electrical
Energy

Mechanical
Energy

GENERATOR

Fuel

Electrical
Energy

JET ENGINE

Air

Propulsion

AUDIO SYSTEM

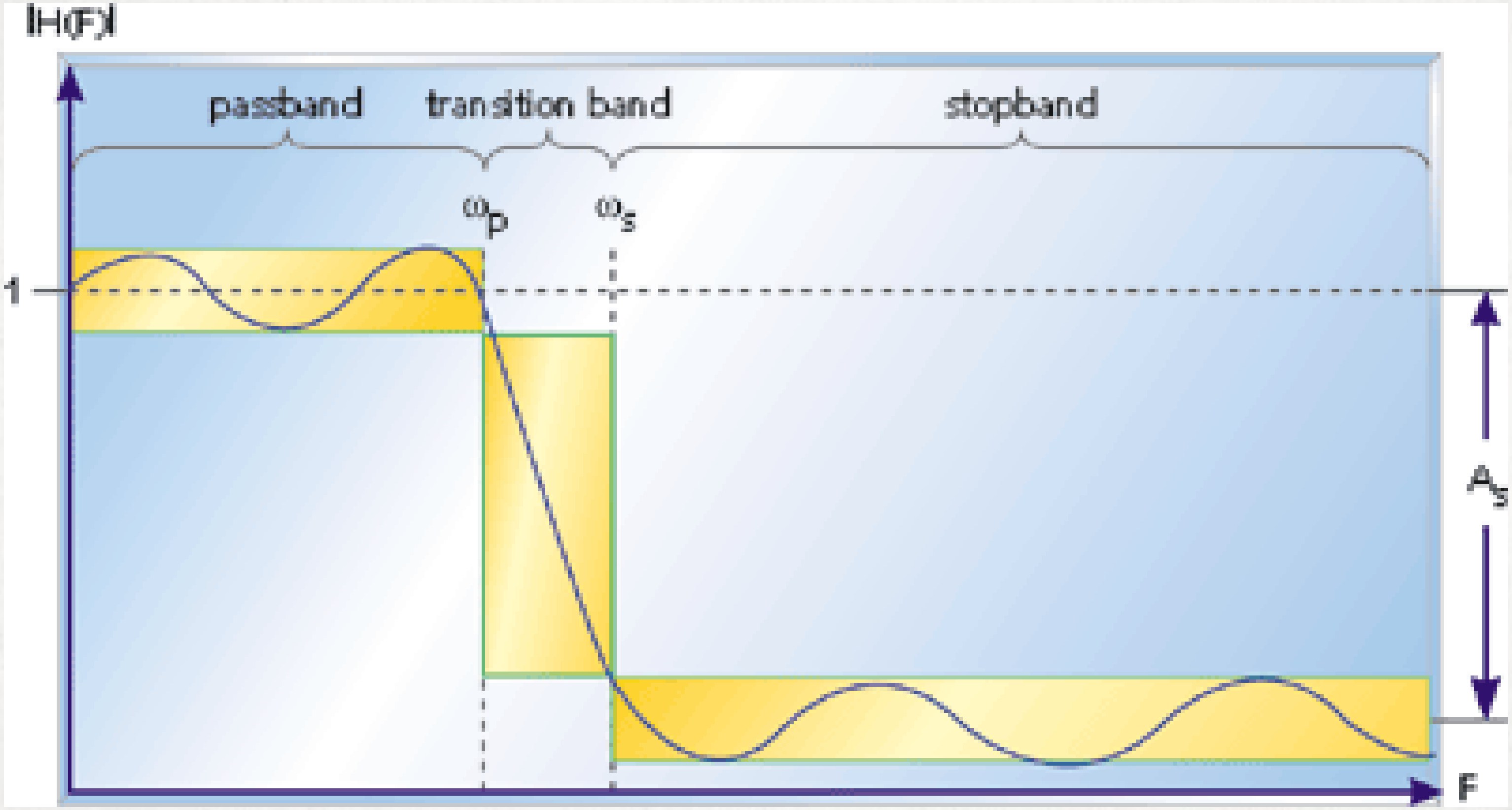
NOISE CANCELLING MICROPHONE

Acoustic Energy

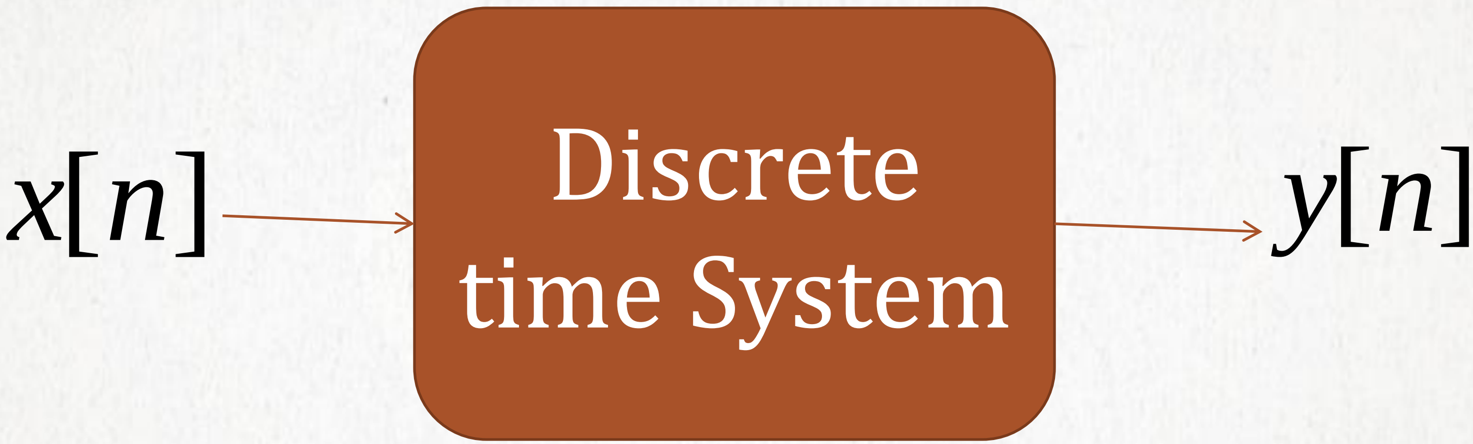
Electrical Energy

ANALOG FILTER

DIGITAL FILTER



DISCRETE SYSTEMS



A SYSTEM & DIFFERENCE EQUATION

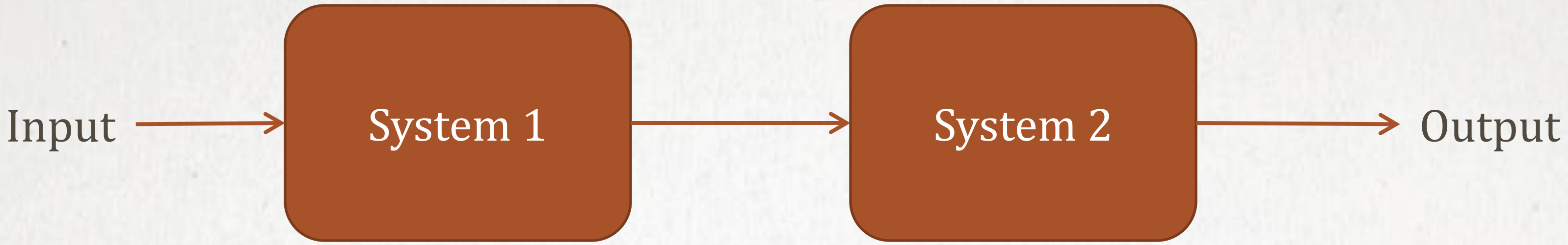
$$x(n) \longrightarrow \boxed{\text{System}} \longrightarrow y(n)$$

Force

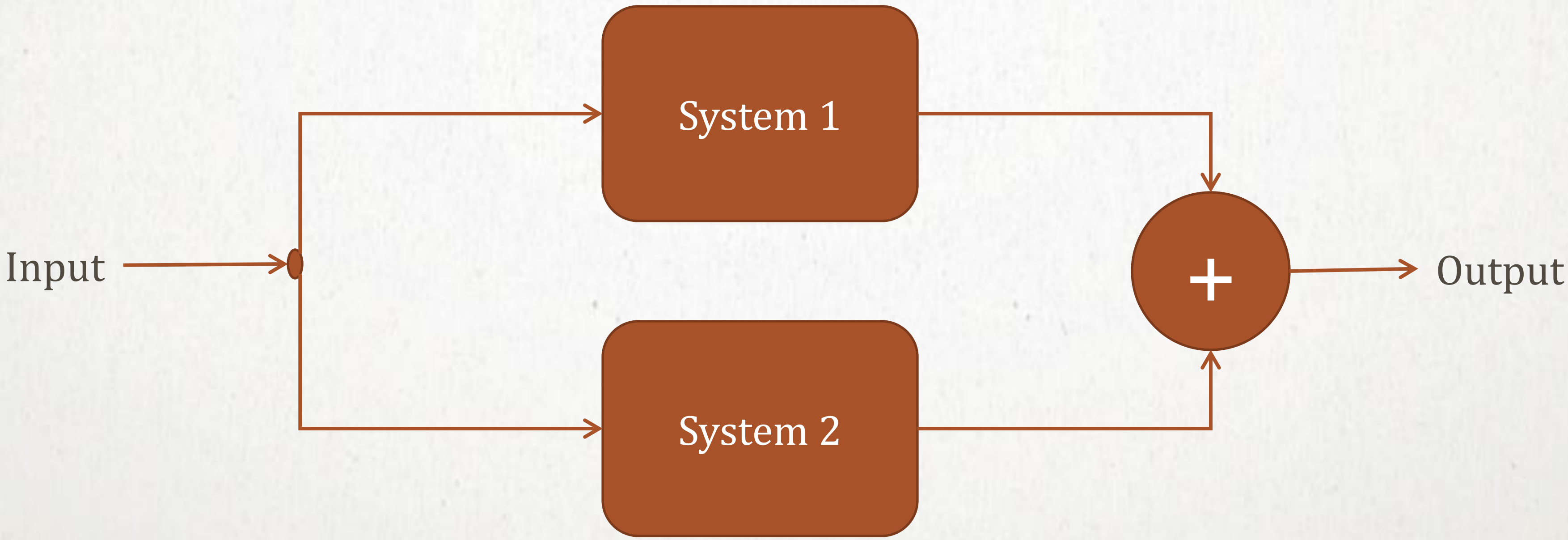
Velocity

$$y(n) = ay(n-1) + bx(n)$$

INTERCONNECTIONS OF SYSTEMS

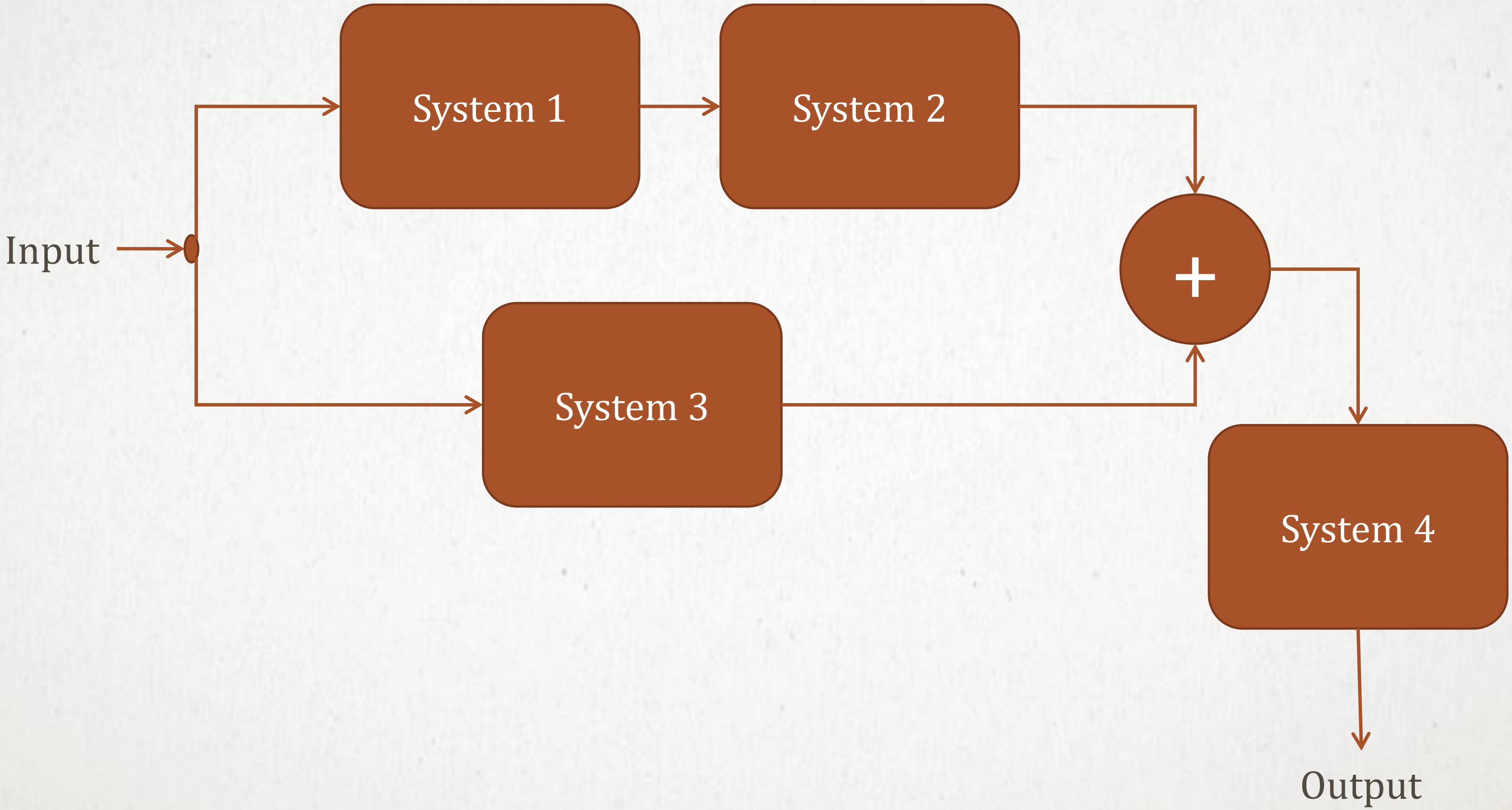


SERIES

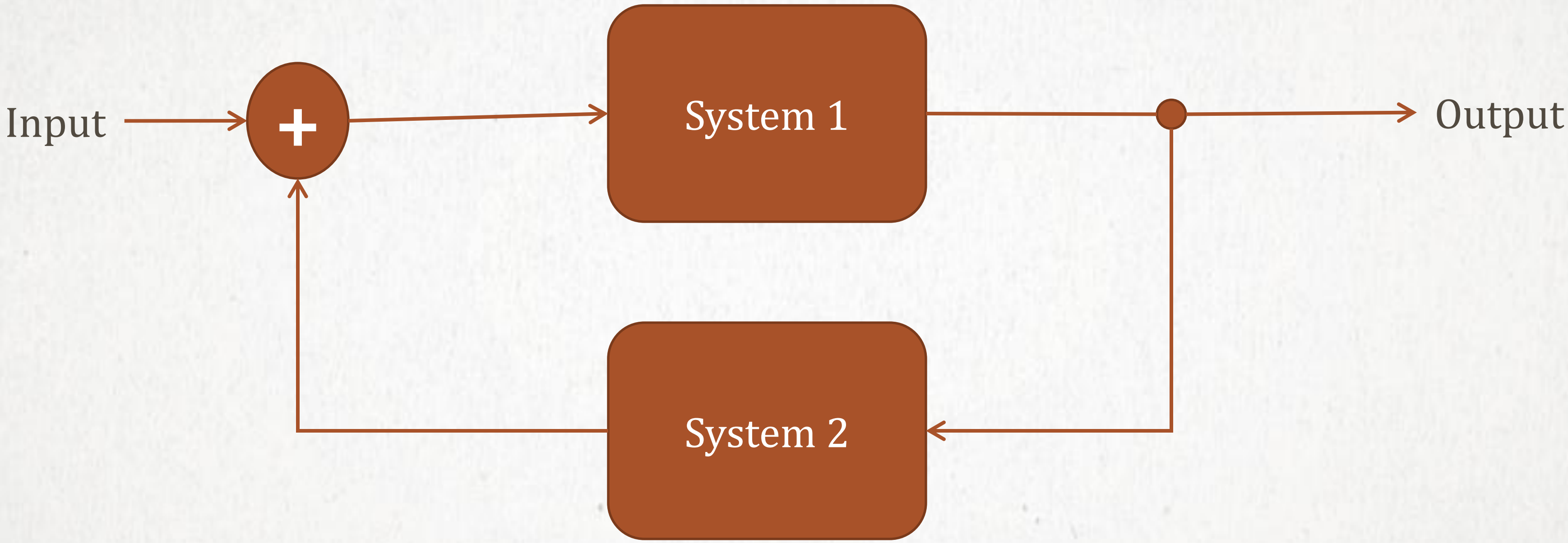


PARALLEL

SERIES-PARALLEL INTERCONNECTION OF SYSTEMS

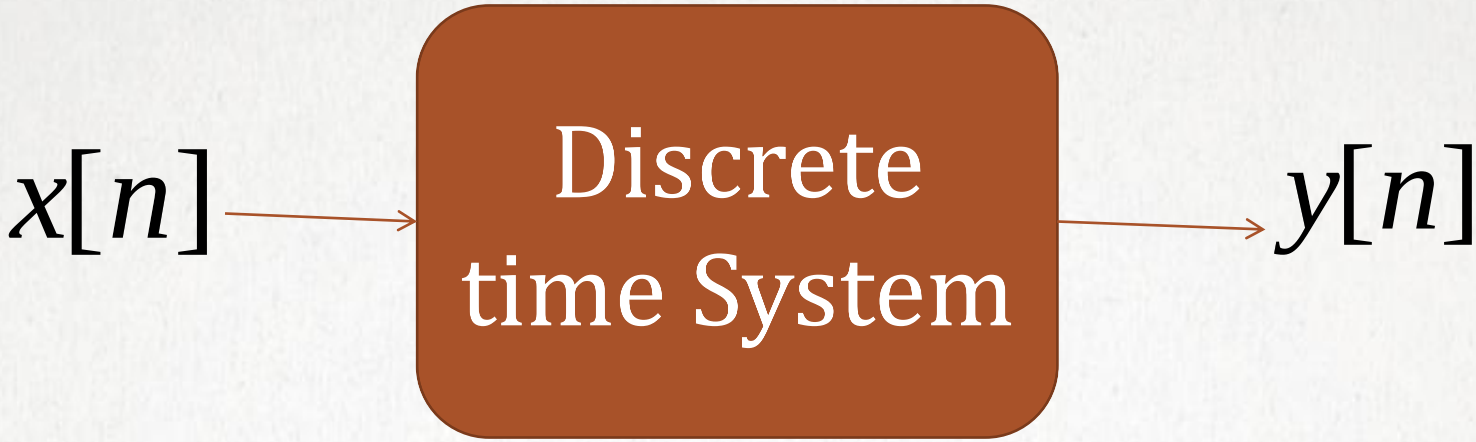


FEEDBACK SYSTEM



BASIC SYSTEM PROPERTIES

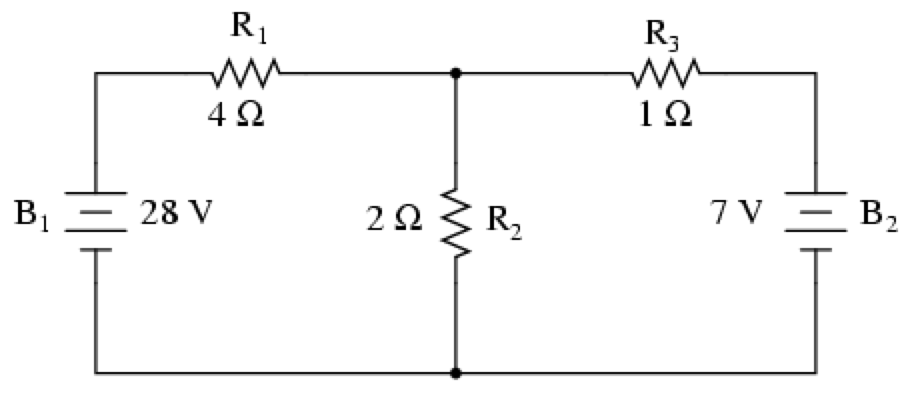
SYSTEMS WITH AND WITHOUT MEMORY



$$y[n] = f\,(x[n])$$

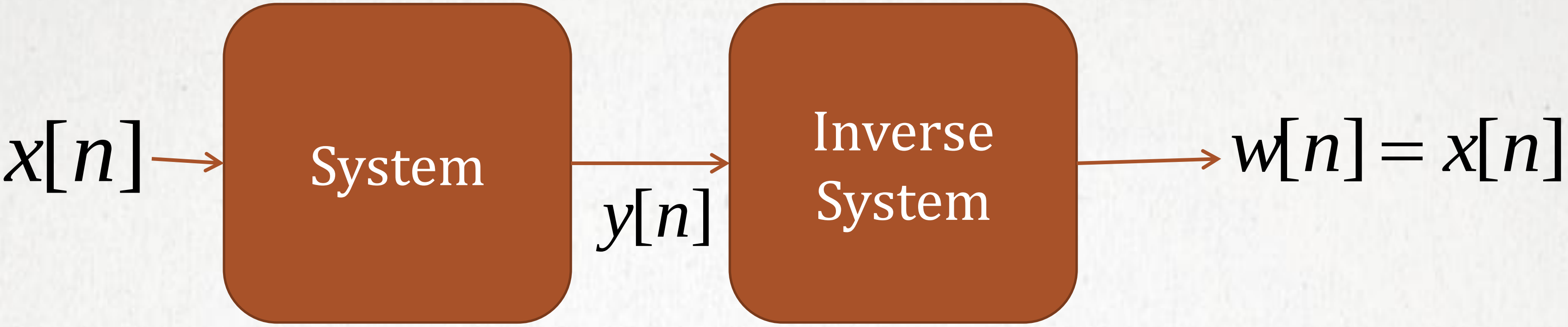
Current output only depends on current input and is independent of all previous inputs

MEMORY-LESS OR STATIC SYSTEMS



DYNAMIC SYSTEMS

INVERTIBILITY AND INVERSE SYSTEMS



Invertible systems: If distinct inputs lead to distinct outputs

If an inverse system exists: The output of this system produces the original input

INVERTIBLE SYSTEM EXAMPLE

Accumulator

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

$$y[n] = \sum_{k=-\infty}^{n} x[k]$$

First difference system

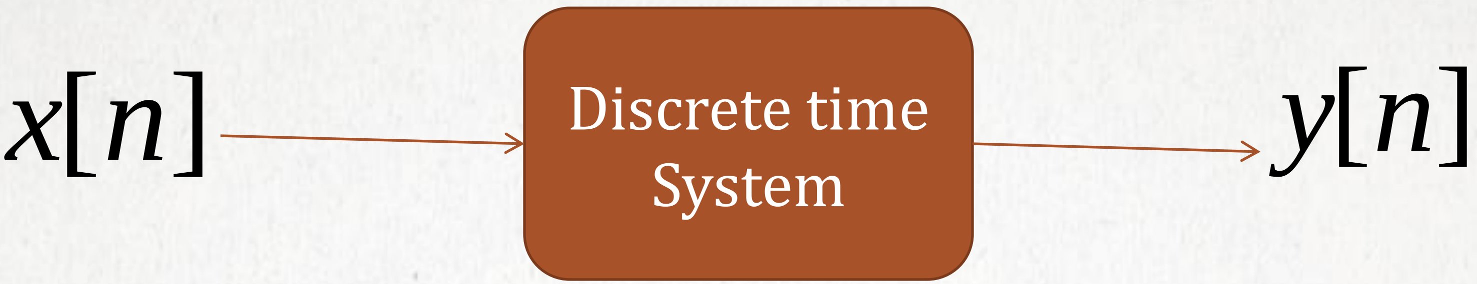
$$w[n] = y[n] - y[n-1]$$

Non-Invertible systems

$$y[n] = a$$

$$y[n] = x^2[n]$$

CAUSAL SYSTEM



$$y[n] = f\left(x[n], x[n-1], \ldots, x[m]\right)$$
$$m << n$$

Causal systems: The output at any time depends only on the values of the input at the present time and in the past.

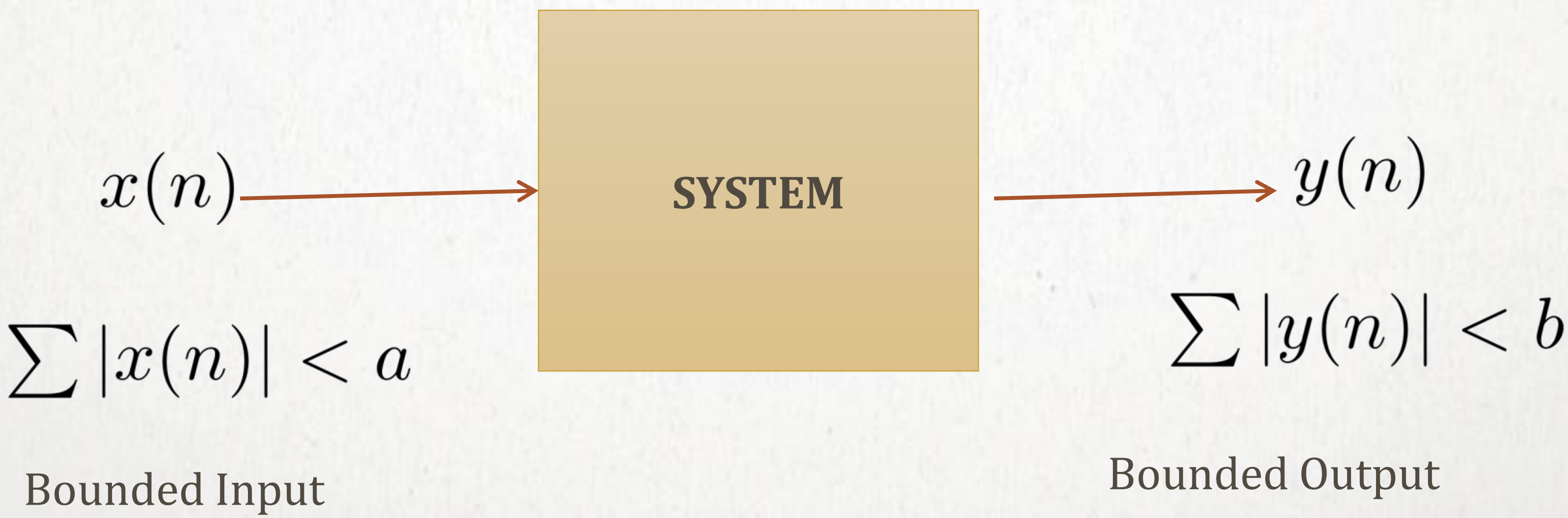
$$y[n] = x[n] - x[n-1]$$

CAR ENGINE: A CAUSAL SYSTEM

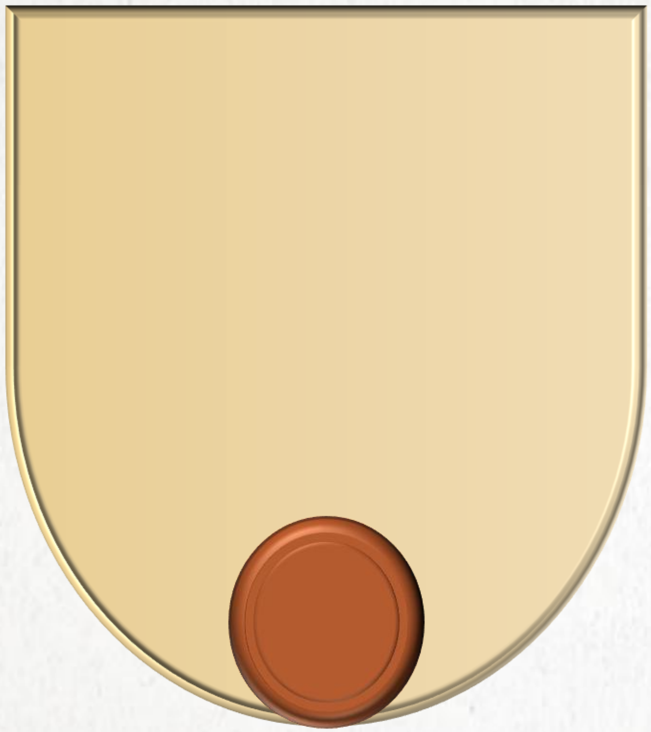
STABLE SYSTEMS

DEFINITION

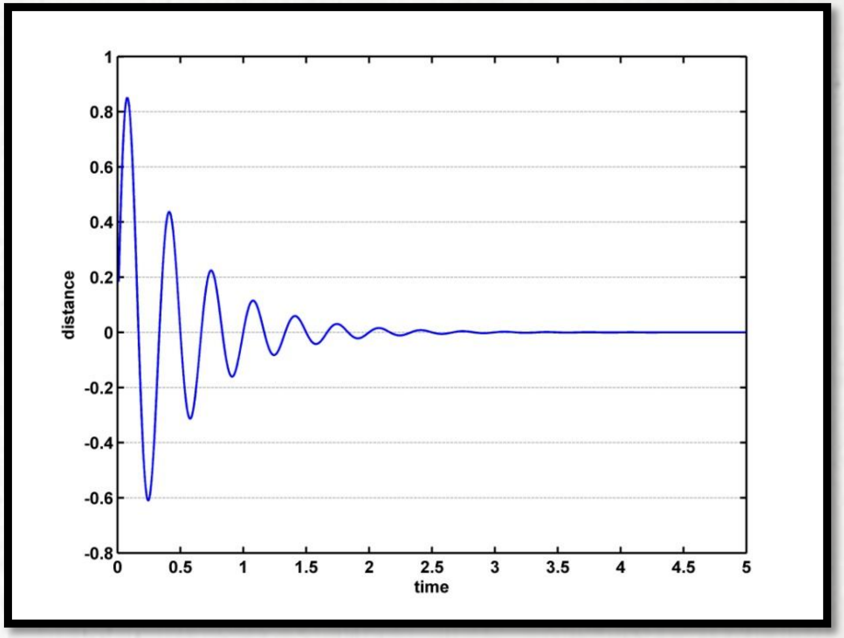
- Intuitive definition
  - A system in which small inputs lead to outputs that do not diverge
- Bounded input bounded output stability
  - If the input to a linear system is finite then the corresponding output is also finite.



STABLE SYSTEM



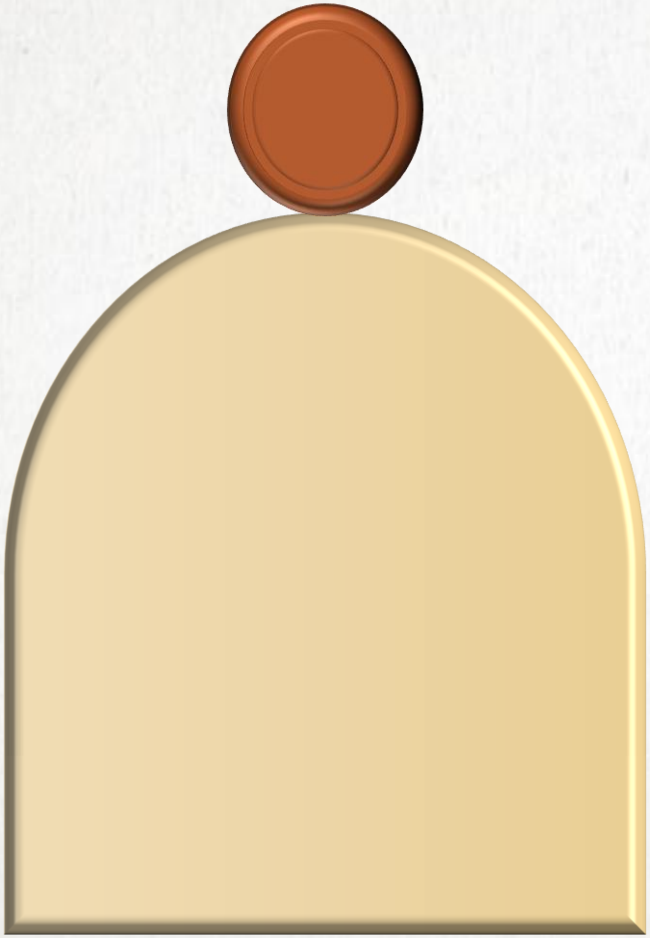
Wheel in a valley

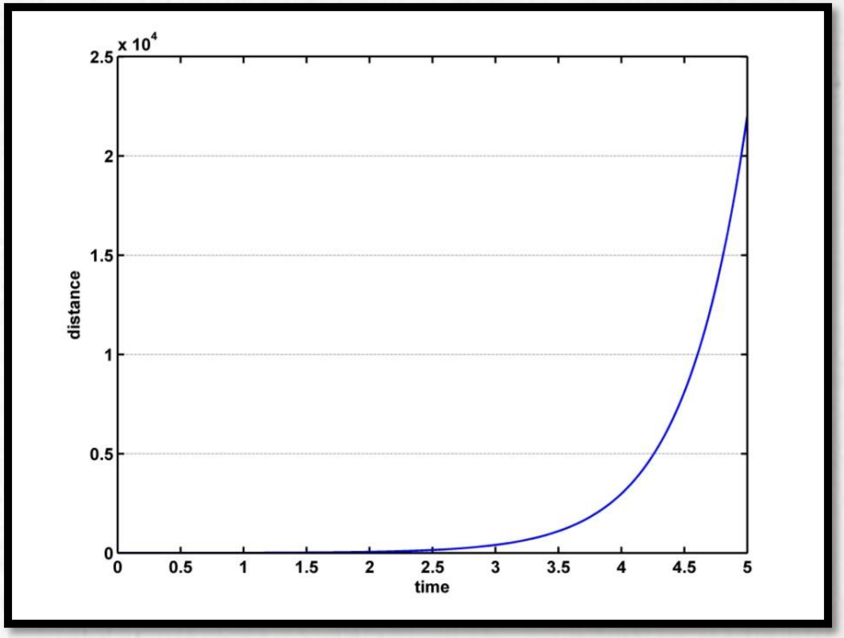


Damped Sinusoid

UNSTABLE SYSTEM

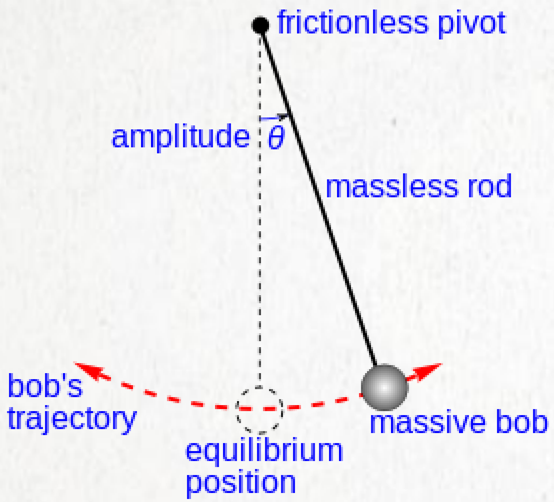
Wheel on a hill





Growing Exponential

EXAMPLES

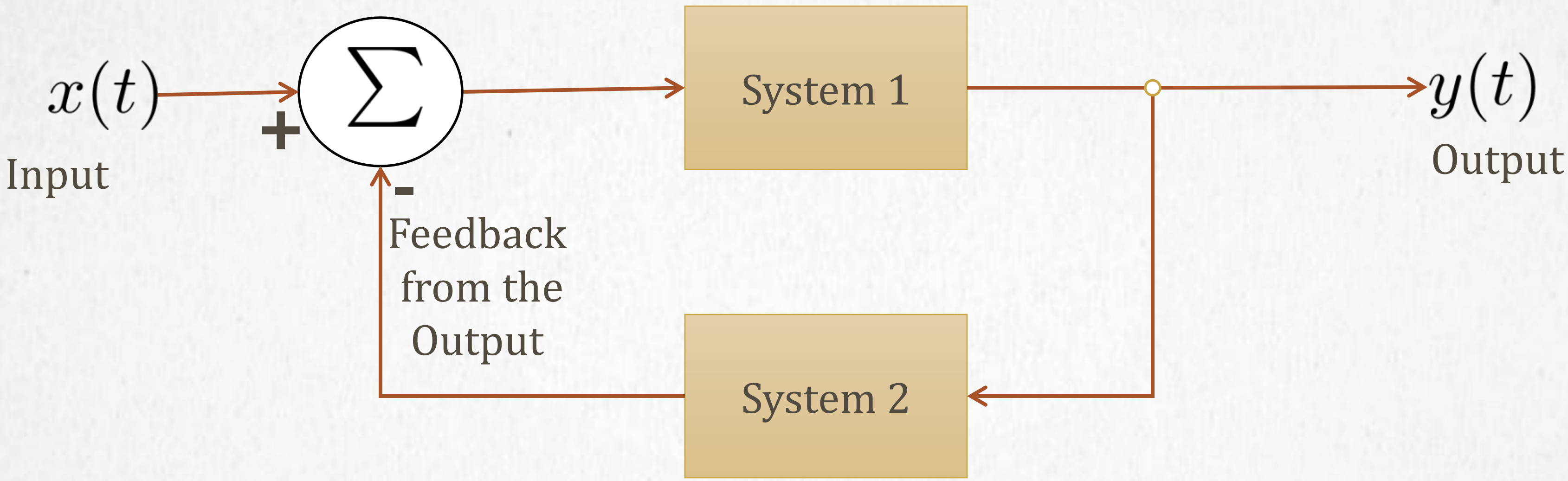


A stable system: A pendulum

An unstable system: Try to balance a football on your toes

TO ACHIEVE STABILITY

- Feedback to achieve stability



EXAMPLE OF FEEDBACK

Ronaldinho balancing a football on his head.

Ref: http://www.allfamouspeople.com/famous-sports/ronaldinho/photo-1.htm

TIME INVARIANCE

$$x[n] \longrightarrow \boxed{\text{Discrete time System}} \longrightarrow y[n]$$

$$y[n-n_0] = f(x[n-n_0])$$

Time Invariance

$$y[n] = f(n, x[n])$$

Time variance

A system is time invariant if the behavior and characteristics of the system are fixed over time

LINEARITY

$$x_1[n] \to y_1[n] \qquad\qquad x_2[n] \to y_2[n]$$

$$x_1[n] + x_2[n] \to y_1[n] + y_2[n]$$

A linear system in discrete time is a system that possesses the important property of superposition.

Main consequence of linearity

$$0 = 0 \cdot x[n] \to 0 \cdot y[n] = 0$$

Zero in Zero out property

LTI SYSTEMS

IMPORTANCE

Linear Time Invariant Systems

Systems that have the properties of linearity and time invariance are very important

Reasons: Many physical systems are LTI

LTI systems can be analyzed in great detail

AMENABLE TO ANALYSIS

- If the inputs to LTI can be represented as a linear combination of fundamental signals
- The output can be easily computed as a linear combination of responses to these basic signals.

Given $$x[n] = \sum_k a_k \phi_k[n]$$ $\phi_k[n] \rightarrow$ Basic Signals

Then $$y[n] = \sum_k a_k \psi_k[n]$$ $\psi_k[n]$ Responses to Basic Signals

EXAMPLES OF BASIC SIGNALS & DECOMPOSITIONS

Given $$x[n] = \sum_k a_k \delta_k[n]$$ $\delta_k[n] \rightarrow$ Unit Impulse

Impulse Response

Then $$y[n] = \sum_k a_k h_k[n]$$ $h_k[n]$

$$x[n] = \sum_k a_k \cos[k\omega_0 n]$$

$$x[n] = \sum_k a_k \exp[jk\omega_0 n]$$