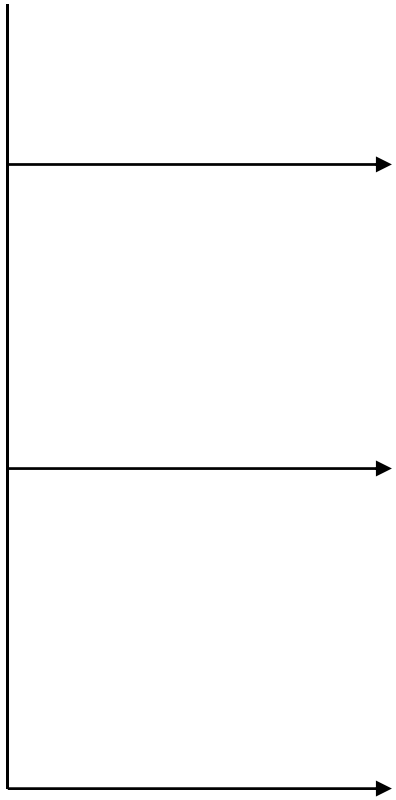
Introduction to Digital Control

Examples of control systems:



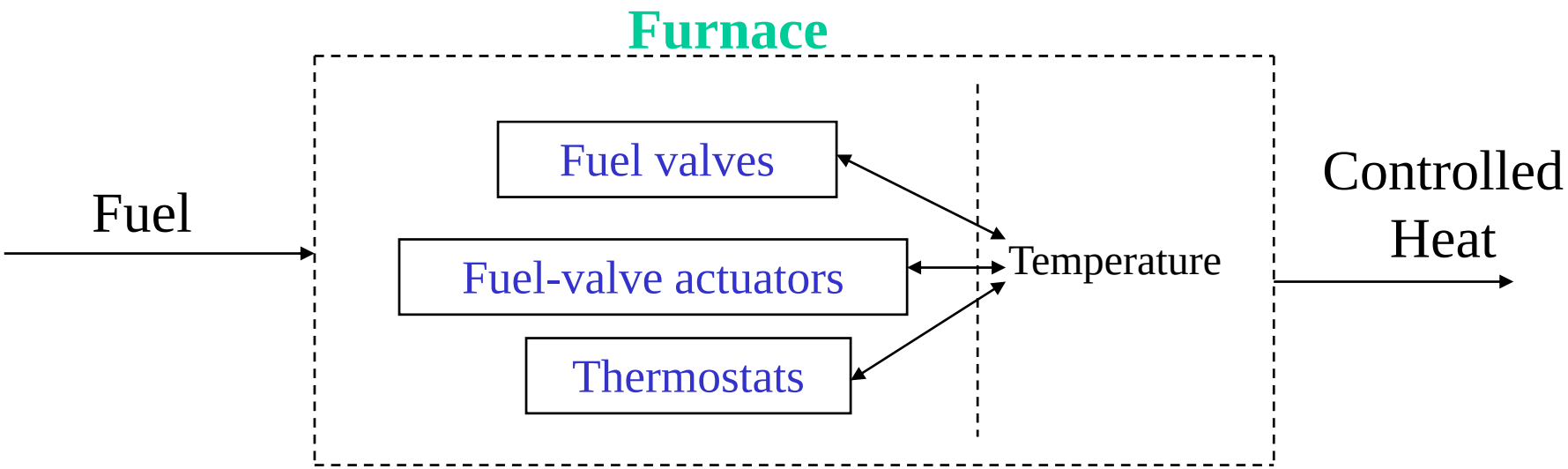
The rocket fires, and the space shuttle lifts off to earth orbit.

Our eyes follow a moving object to keep it in view; our hands grasp the object and place it properly at a fixed location.

Models showing automatic control of student performance.

Control System Definition

A control system consists of *subsystems* and *processes* (or *plants*) assembled for the purpose of controlling the outputs of the processes.



Advantages of Control Systems

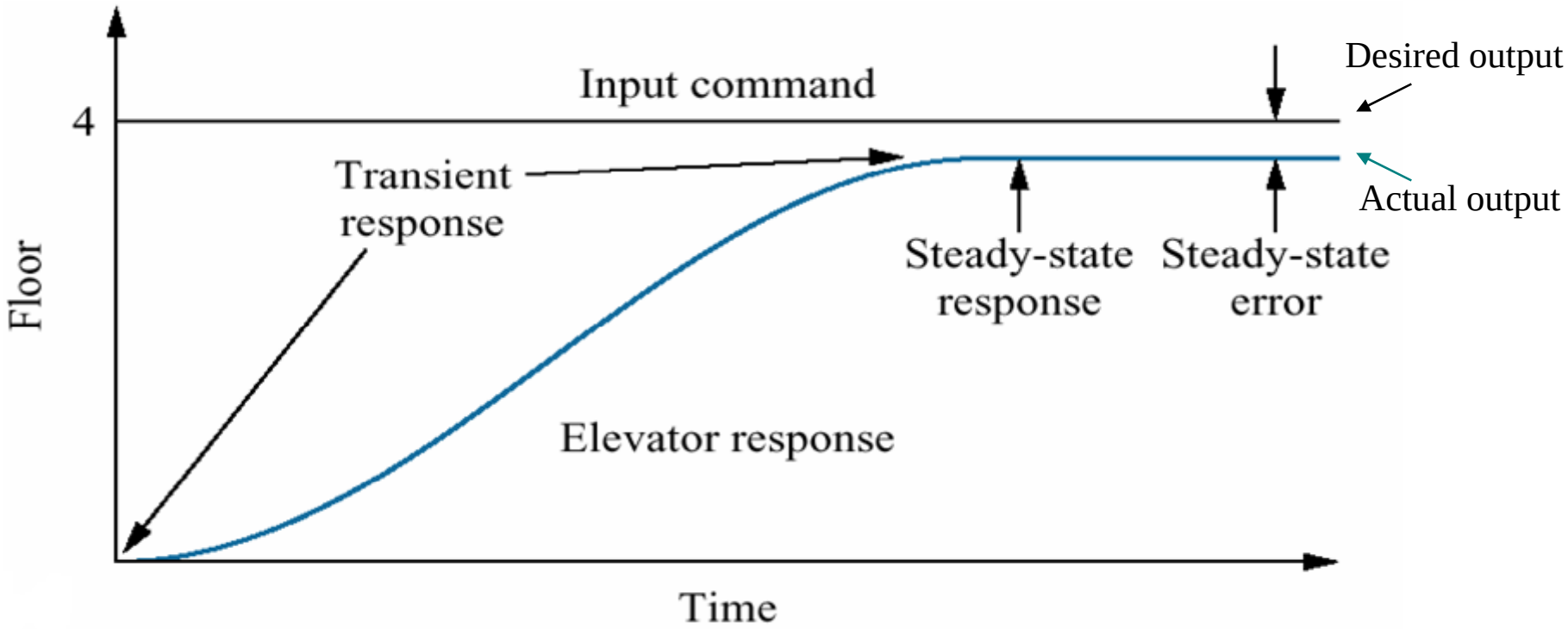
We build control systems for four primary reasons:

1. Power amplification → Low power input; high power output
2. Remote Control → Remote controlled robots
3. Convenience of input form → Temperature control system
4. Compensation for disturbances → Antenna system interrupted by wind or noise

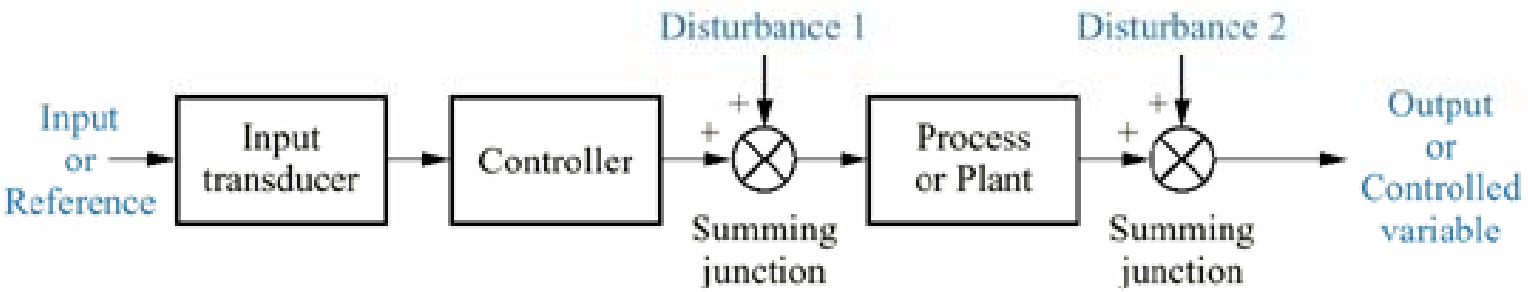
Find some applications of control systems!!

Response Characteristics

Elevator Input-Output:



Open Loop Systems



Example:

Plant → a furnace or air conditioning system.

Controller → a heating system (with fuel valves) and an electrical system (operates the valves).

Characteristics:

Open loop systems cannot compensate for any disturbances that add to:

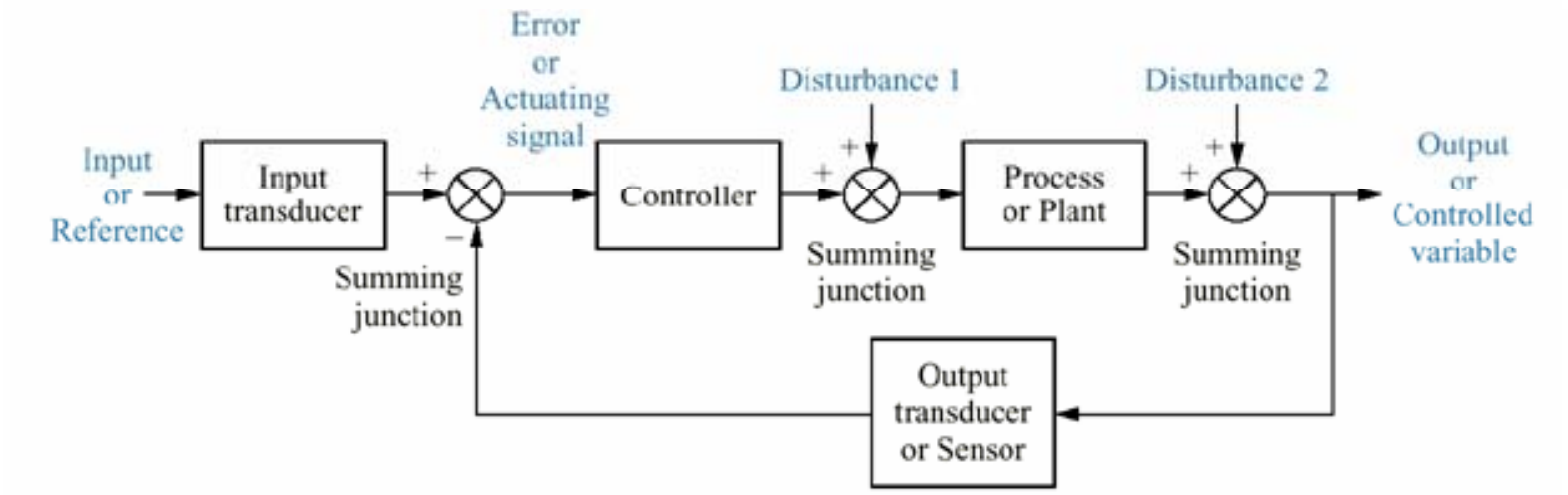
i) The controller's driving signal (disturbance 1 in Figure);

ii) The output (disturbance 2 in Figure).

Example:
Toaster

Simple and inexpensive

Closed Loop (Feedback Control) Systems



Output transducer / sensor measures the output response and converts it into the form used by the controller.

Example

Characteristics:

1. Can compensate disturbances, noise and changes in the environment
2. More complex and expensive than open-loop systems.

Analysis and Design Objectives

Controller: Digital Computer

Three major objectives:

1. Producing the desired transient response.
2. Reducing steady-state error.
3. Achieving stability.

Examples: Elevator:

A slow transient response makes passengers impatient;
an excessively rapid response makes them uncomfortable.

Must be level enough with the desired floor for passengers to exit.

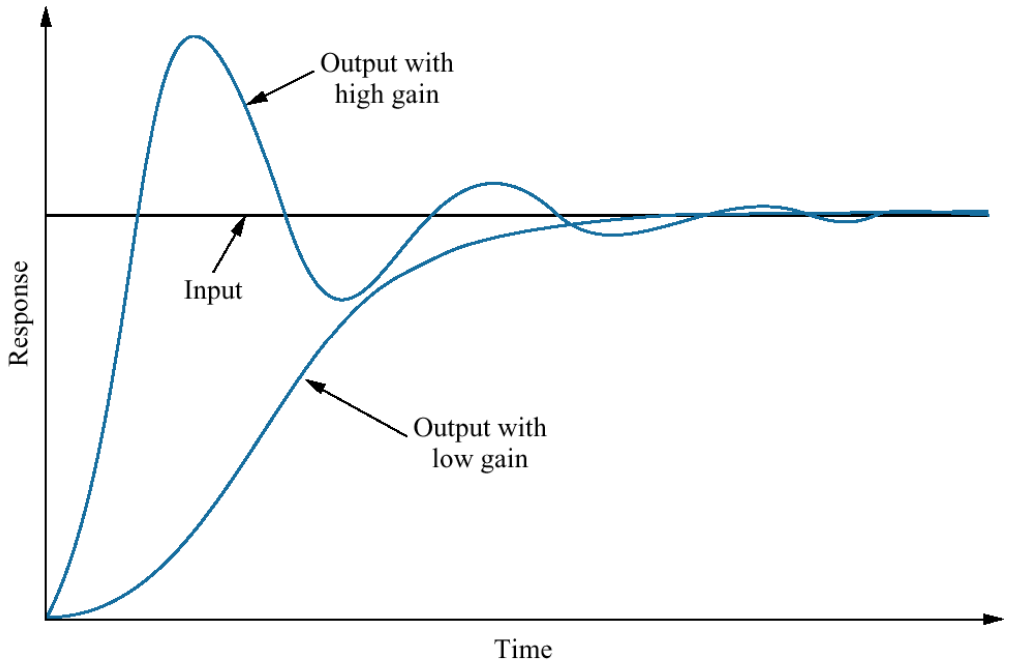
Natural force must be zero or oscillate; otherwise elevator may crash through the floor or exit through the ceiling.

Response of Position Control System

High gain causes oscillation.

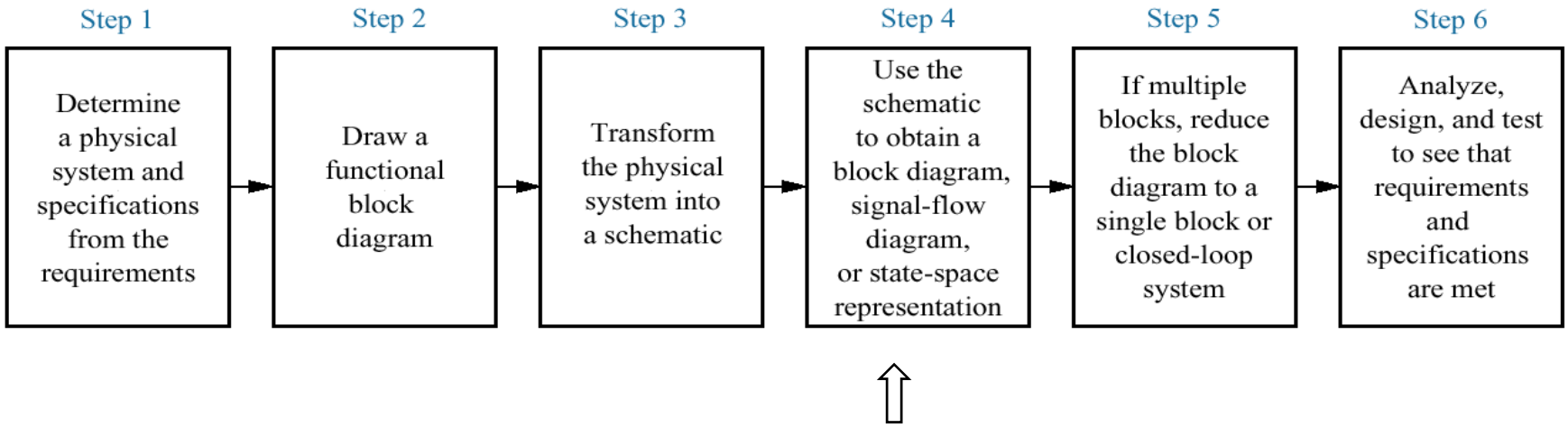
Zero error at steady state.

If not zero error, a controller is needed for gain adjustment to regulate transient response



Response of a position control system showing effect of high and low controller gain on the output response

The Design Process

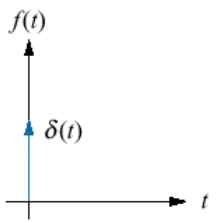
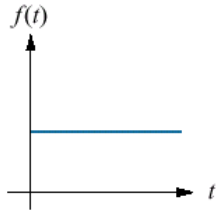
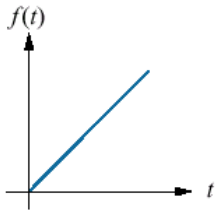
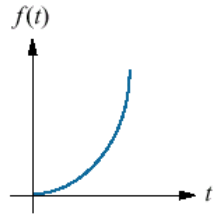
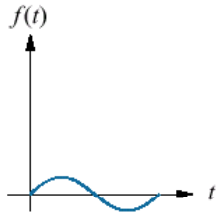


Mathematical Model

Kirchhoff's voltage / current law
Newton's law

Test Waveforms Used in Control Systems

If t < 0, function value = 0

Input	Function	Description	Sketch	Use
Impulse	$\delta(t)$	$\delta(t) = \infty$ for $0- < t < 0+$ $= 0$ elsewhere $\int_{0-}^{0+} \delta(t)\,dt = 1$		Transient response Modeling
Step	$u(t)$	$u(t) = 1$ for $t > 0$ $= 0$ for $t < 0$		Transient response Steady-state error
Ramp	$tu(t)$	$tu(t) = t$ for $t \geq 0$ $= 0$ elsewhere		Steady-state error
Parabola	$\frac{1}{2}t^2u(t)$	$\frac{1}{2}t^2u(t) = \frac{1}{2}t^2$ for $t \geq 0$ $= 0$ elsewhere		Steady-state error
Sinusoid	$\sin \omega t$			Transient response Modeling Steady-state error