Introduction to Control Systems

by Dr Mihai Ciobotaru
Senior Lecturer in Electrical Engineering
School of Engineering, Macquarie University, Sydney

Introduction

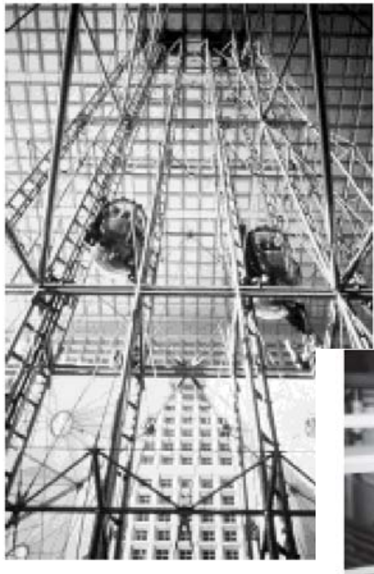
- Control system applications
- How you can benefit from studying control systems
- The basic features and configurations of control systems
- Analysis and design objectives
- The design process

Introduction

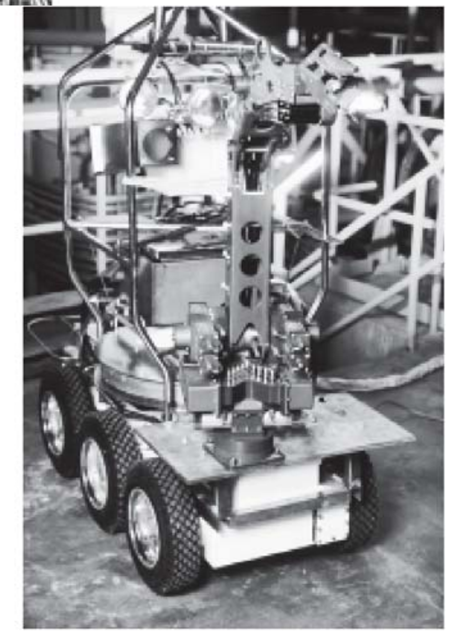
- Control systems are everywhere!
  - ***They can be engineered/man made systems.***
  - ***They can be naturally occurring – e.g., biological control systems: pancreas to regulate your blood sugar level, movement of eyes to keep object in view, etc.***
- Regulation is an important part of any natural and artificial complex system – accomplished by a control system.

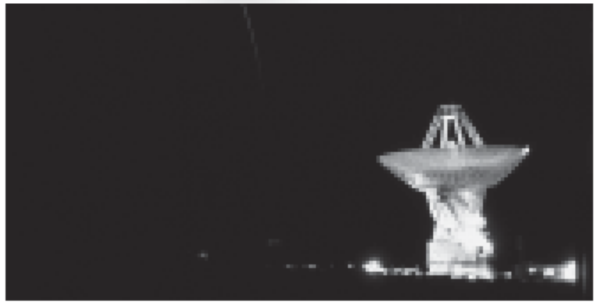
Introduction

(a)



(b)





Introduction

- a control system provides an output or response for a given input or stimulus

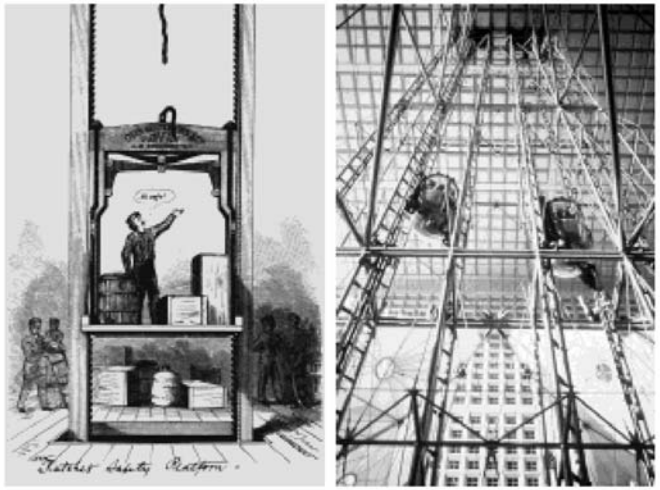
Simplified description of a control system

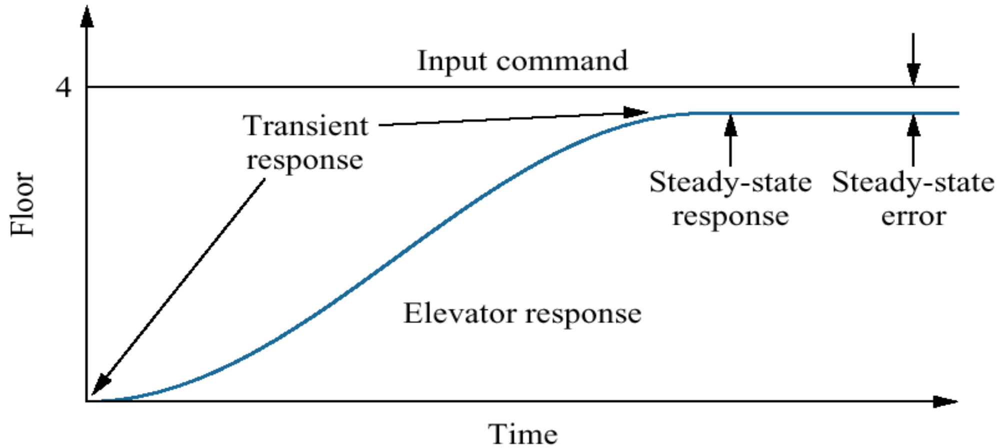
Introduction

Advantages of Control Systems

1. Power amplification (a radar antenna)
2. Remote control (robots)
3. Convenience of input form (temperature control)
4. Compensation for disturbances

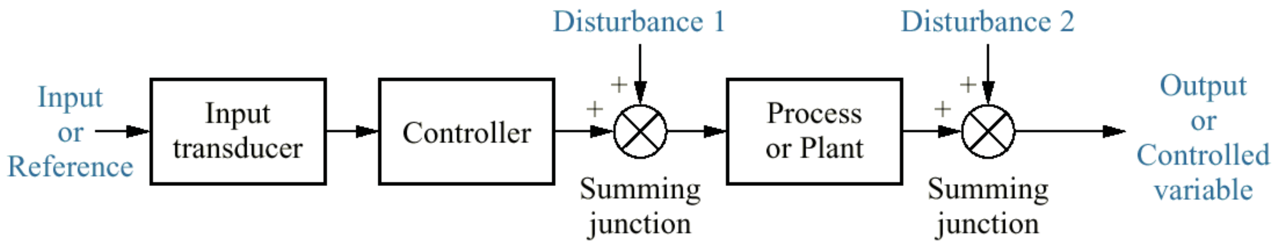
Response Characteristics and System Configurations



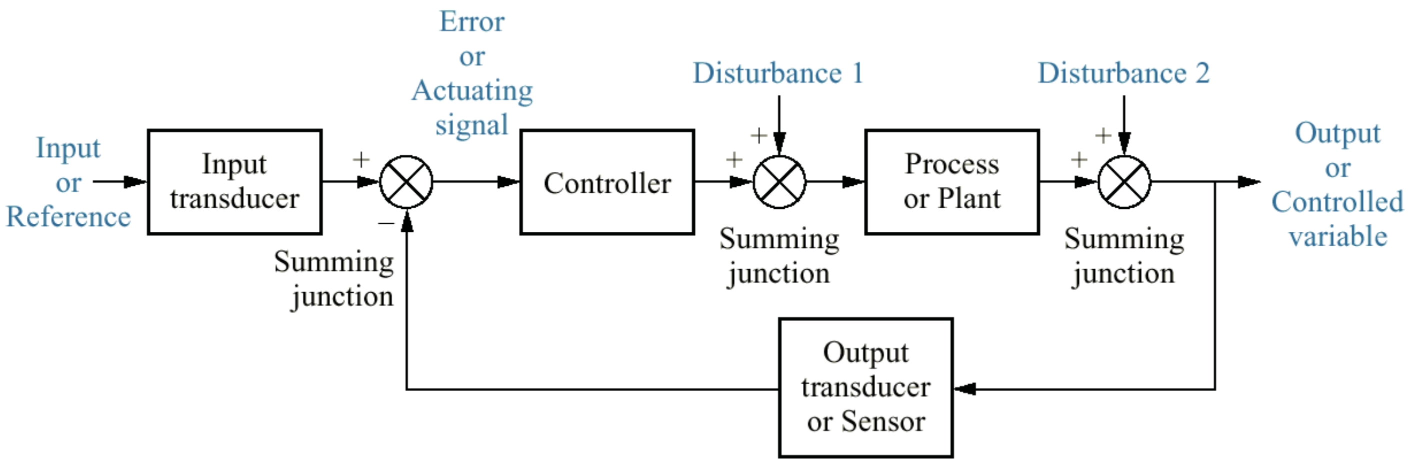


Two major configurations of control systems:

- **open loop -** does not correct for disturbances and is commanded by the input (eg toaster)



- **closed loop** - compensates for disturbances by measuring the output response, feeding that measurement back through a feedback path, and comparing that response to the input at the summing junction.

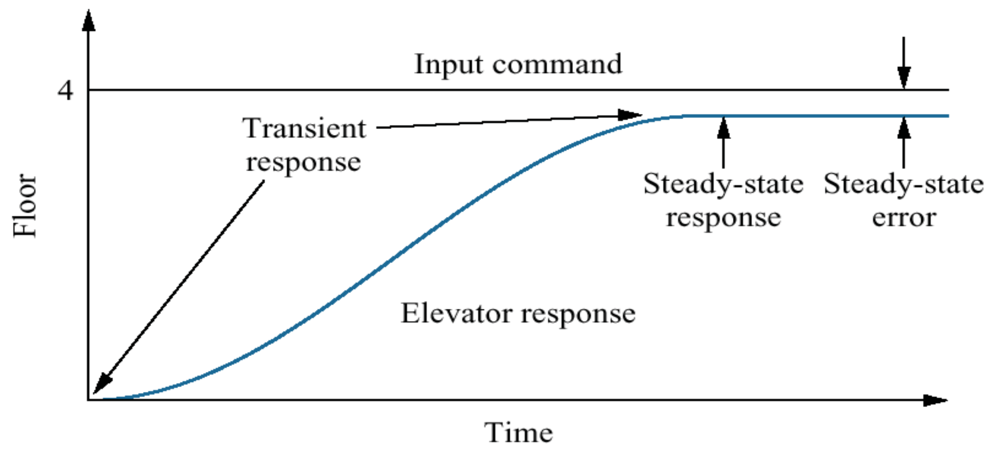


Analysis and Design Objectives

- **Control system** responds to an input by undergoing a transient response before reaching a steady-state response

There are several major **objectives of systems analysis and design**:

1. producing the desired **transient response**
2. reducing **steady-state error**
3. achieving **stability**
4. achieving **robust design**



Stability

$$\boxed{\text{Total response} = \text{Natural response} + \text{Forced response}}$$

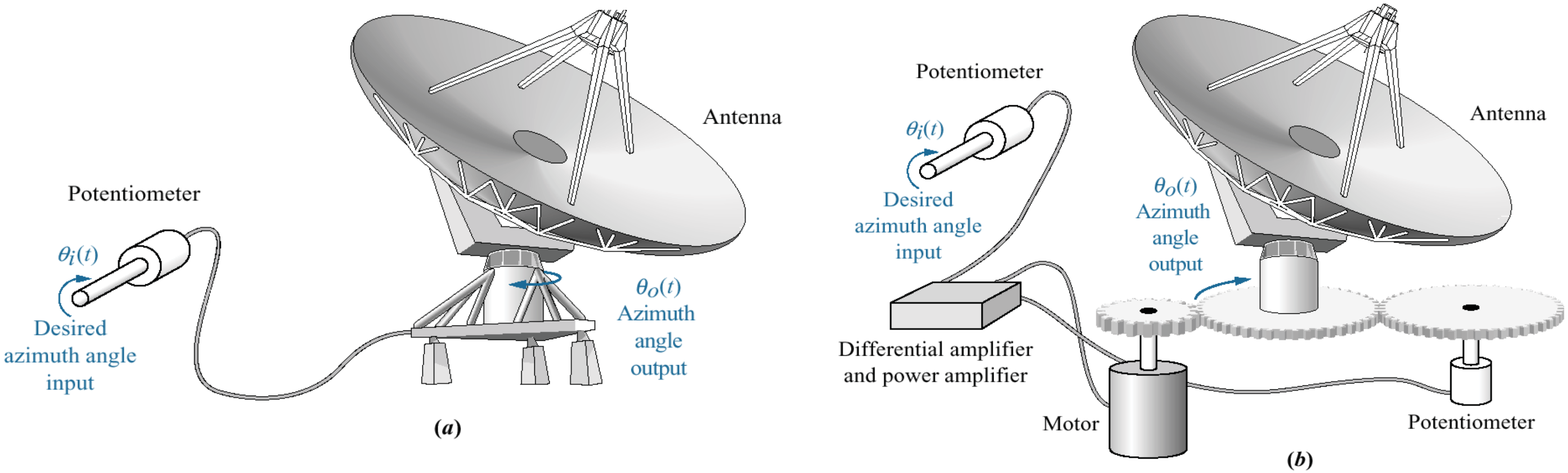
- **Natural response** is dependent only **on the system**, not the input
- **Forced response** is dependent **on the input**.

In a control system, the **natural response must either**:

(1) eventually **approach zero**, thus leaving only the forced response, or (2) **oscillate**.

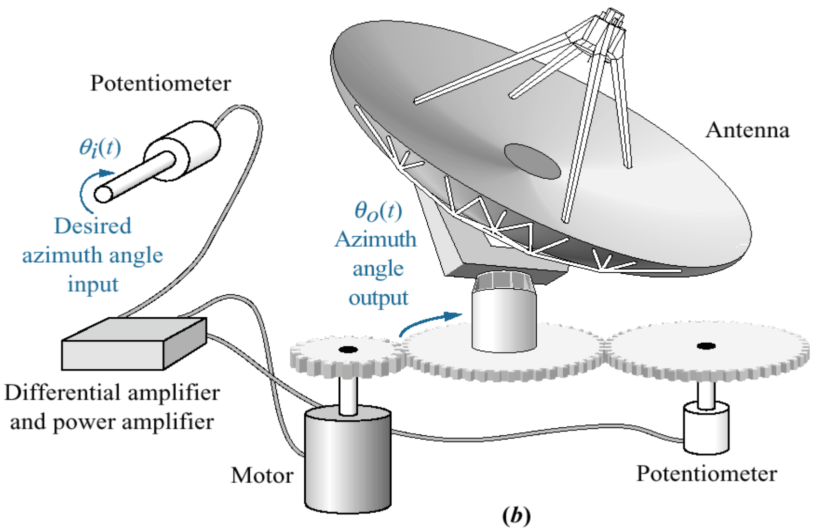
Antenna Azimuth: An Introduction to Position Control Systems

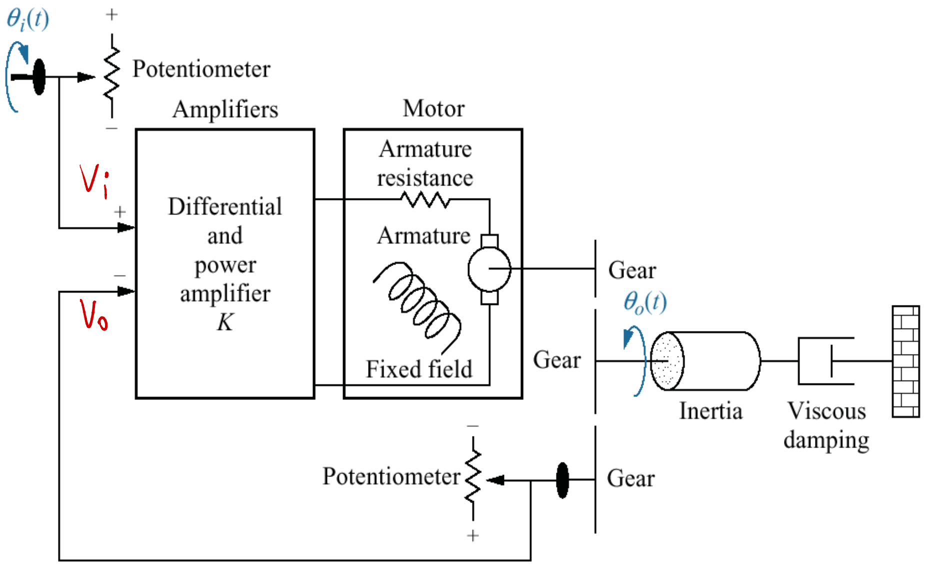
- converts a position input command to a position output response

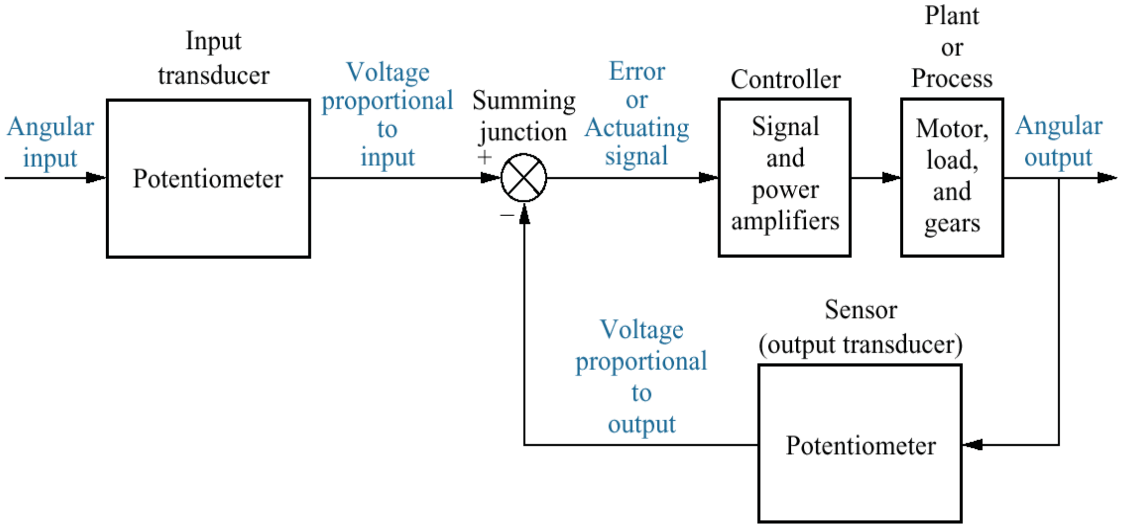


Antenna azimuth position control system

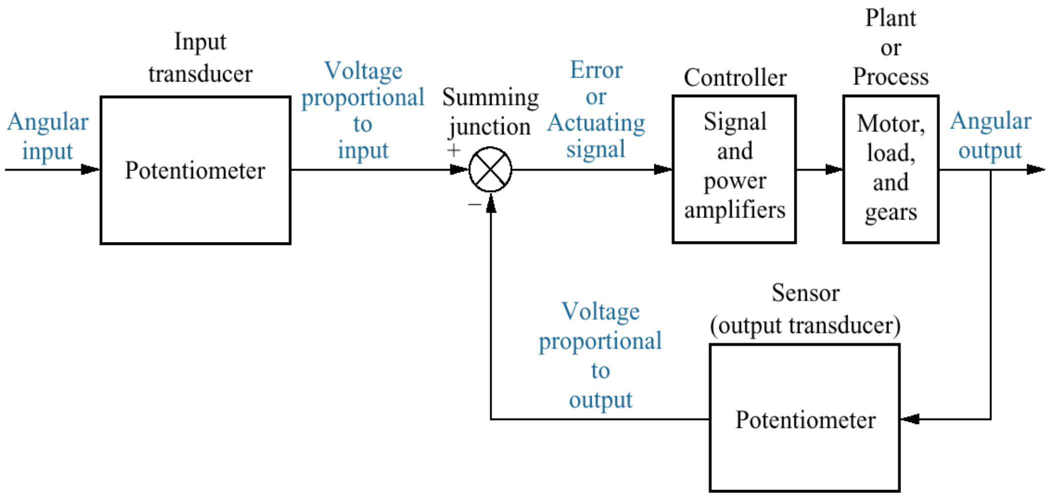
Antenna Azimuth

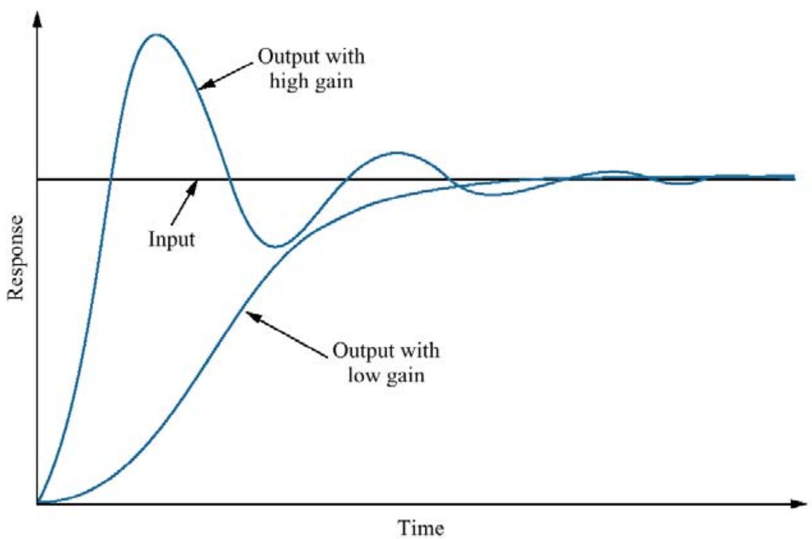






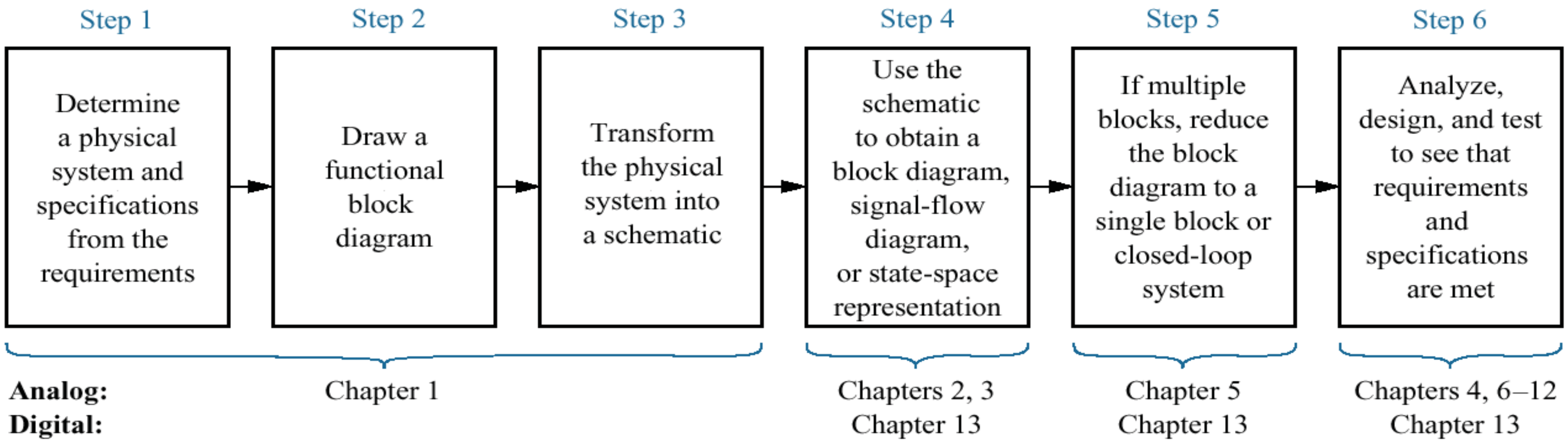
Antenna Azimuth





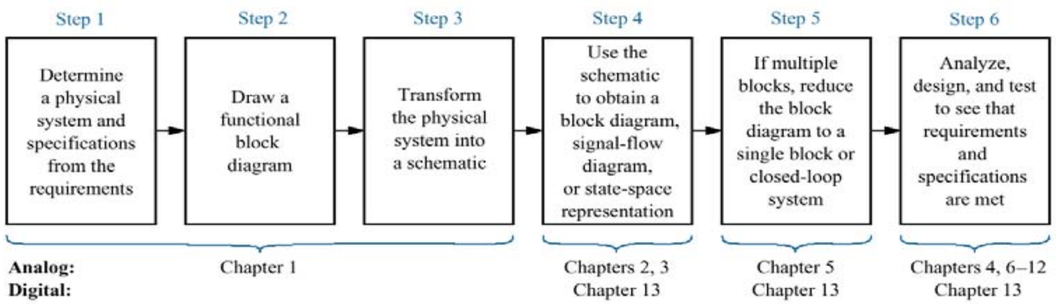
Response of a position control system showing effect of high and low controller gain on the output response

The Design Process



The control system design process

The Design Process (Antenna Azimuth)

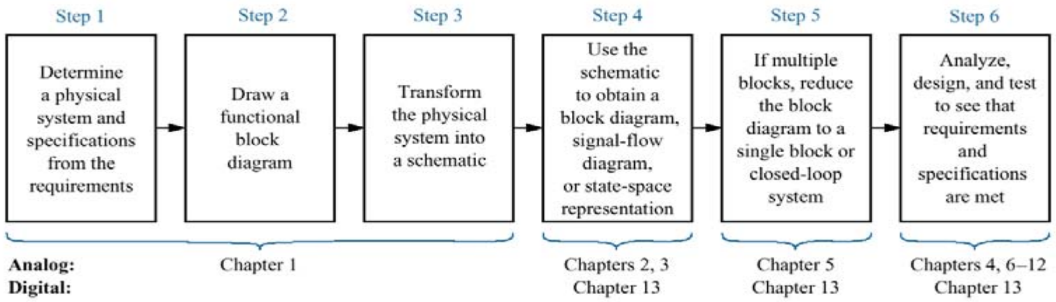


Step 1: Transform Requirements into a Physical System

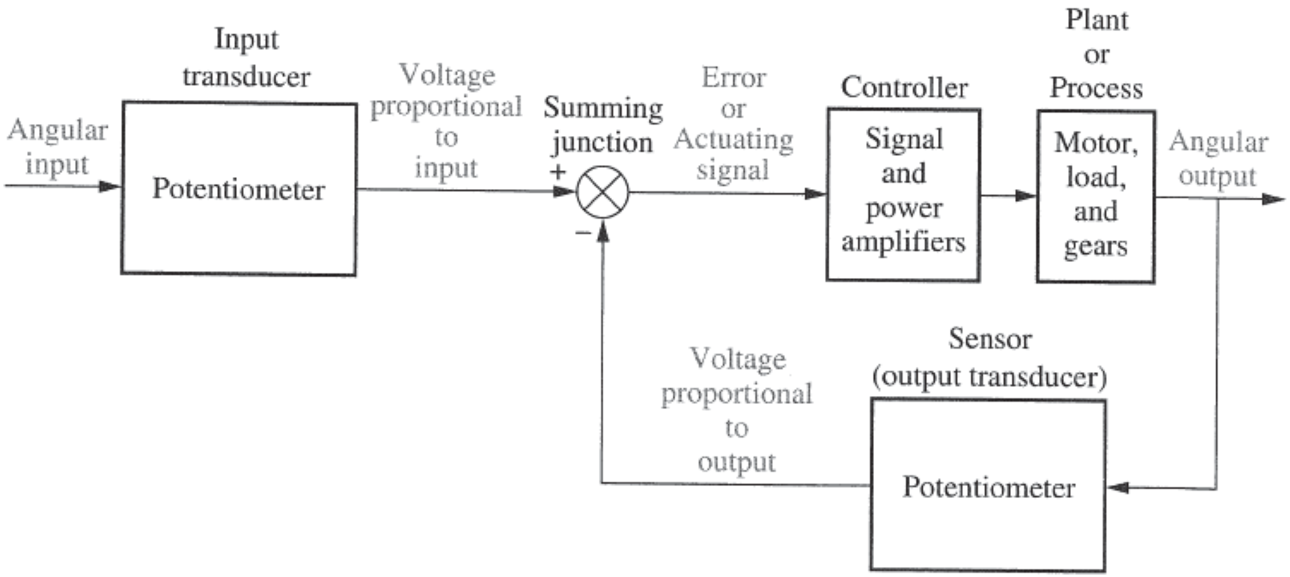
- **Requirements**: desire to position the antenna from a remote location; weight, dimensions of the system

- **Design specifications**: desired transient response, steady-state accuracy

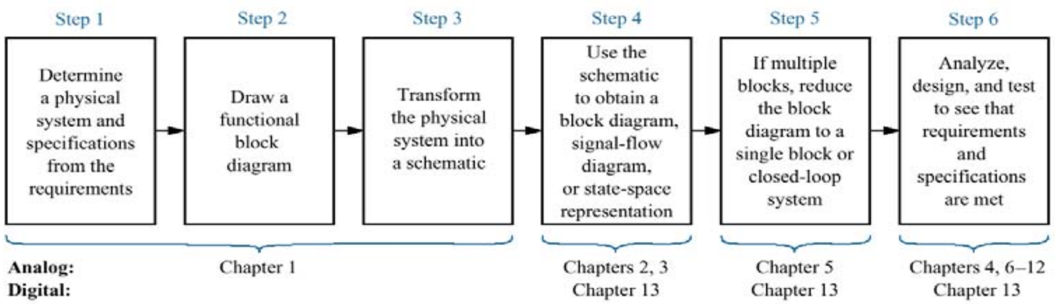
The Design Process (Antenna Azimuth)



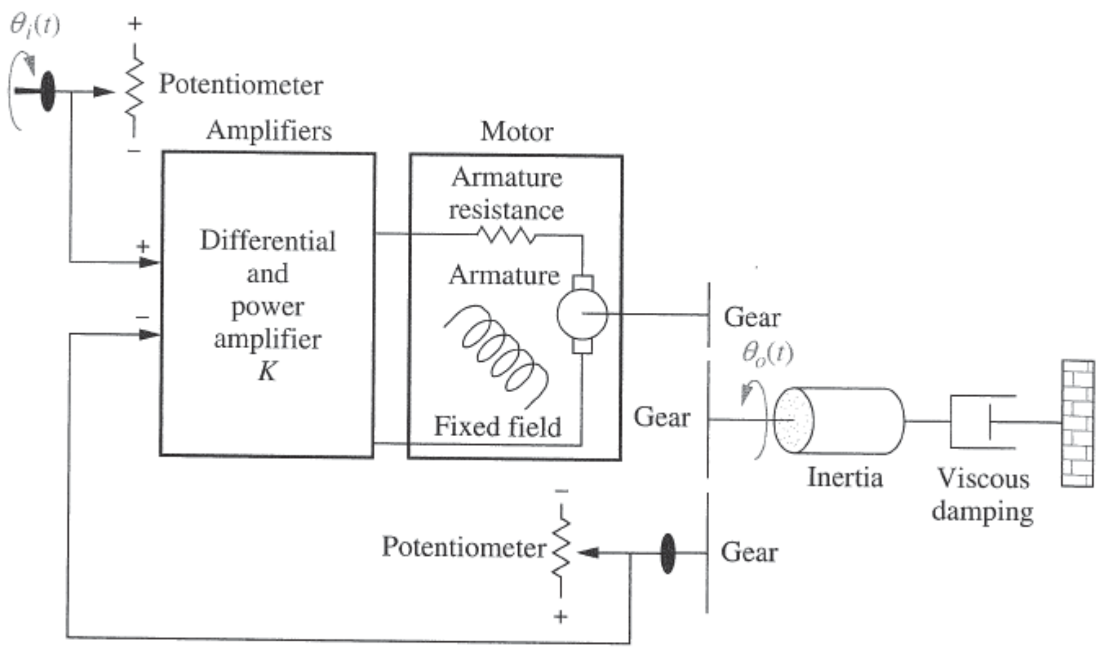
Step 2: Draw a Functional Block Diagram



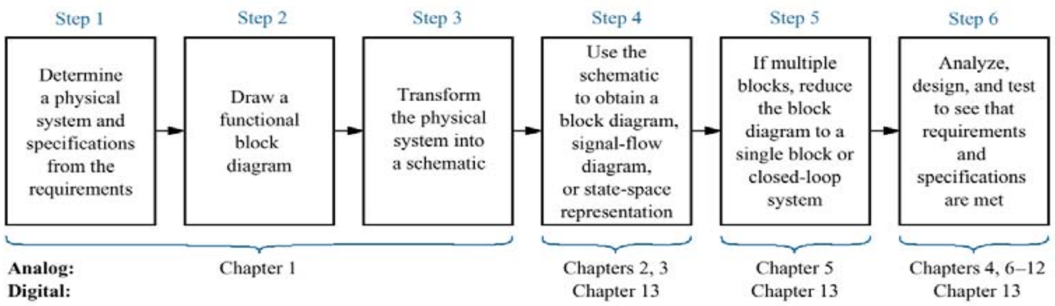
The Design Process (Antenna Azimuth)



Step 3: Create a Schematic



The Design Process (Antenna Azimuth)



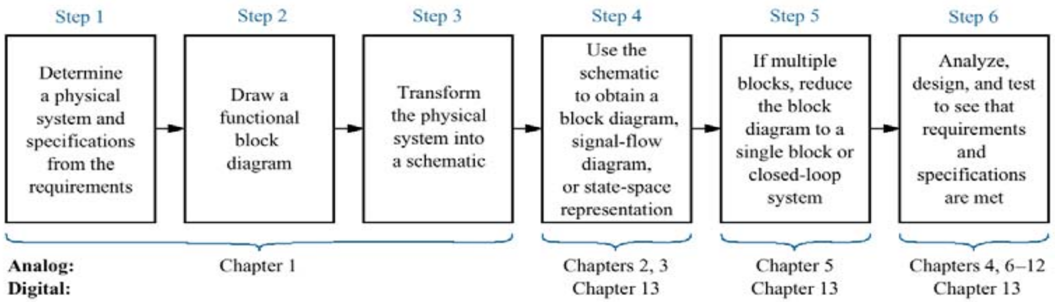
Step 4: Develop a Mathematical Model (Block Diagram)

- Use physical laws, such as **Kirchhoff's laws** for electrical networks and **Newton's law** for mechanical systems

- Mathematical models can be described using

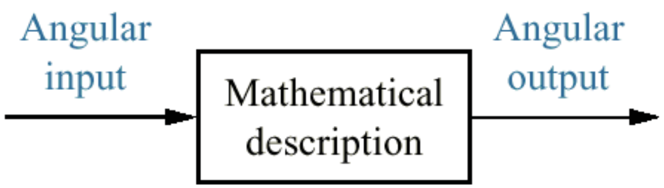
  1. **Differential equations**
  2. **Laplace transform**
  3. **State-space representation**

The Design Process (Antenna Azimuth)



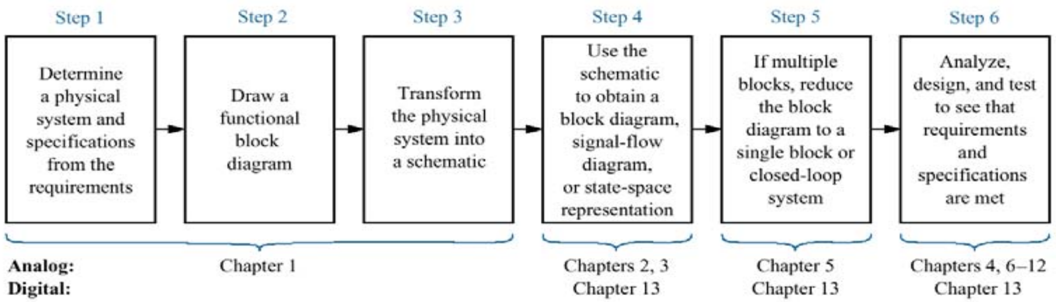
Step 5: Reduce the Block Diagram

- In order **to evaluate** the system response we **reduce** the large system's block diagram **to a single block** with a mathematical description that represents the system from its input to its output



Equivalent block diagram for the antenna azimuth position control system

The Design Process (Antenna Azimuth)



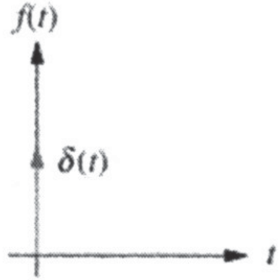
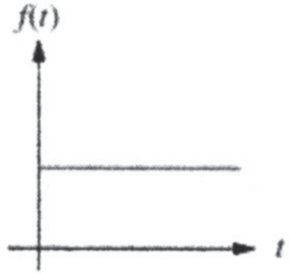
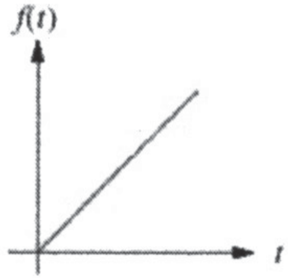
Step 6: Analyze and Design

- analyze the system to see if the **response specifications and performance requirements can be met** by simple adjustments of system parameters

- if specifications cannot be met, the designer designs additional hardware in order to **achieve a desired performance**

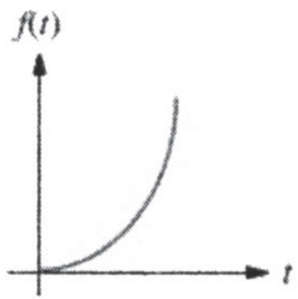
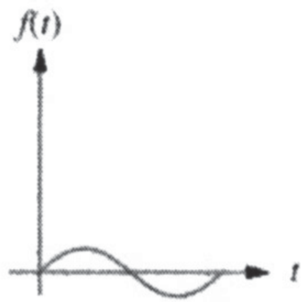
Step 6: Analyze and Design

Test waveforms used in control systems

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	$tu(t)$	$t \cdot u(t)$ $\quad t<0$ $\quad : t \cdot u(t) = 0$ $tu(t) = t$ for $t \geq 0$ $= 0$ elsewhere		Steady-state error

Step 6: Analyze and Design

Test waveforms used in control systems

Input	Function	Description	Sketch	Use
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