Control Systems 1

EE4302

Chapter 1

An Introduction

Textbook: Control System Engineering, Norman S. Nise, 6th edition, Wiley

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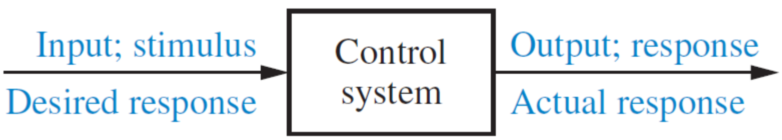
What is a Control System?

A Control System consists of subsystems and processes (or plants) assembled to control the outputs of a process.



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Typical Examples

- Central Temperature Control
- Fluid Level maintenance systems
- Battery Voltage Control
- Human has numerous control systems built in it.

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Control System another view

- A Control System is an arrangement of physical components connected/related in such a manner as to command, direct or regulate itself or another system.

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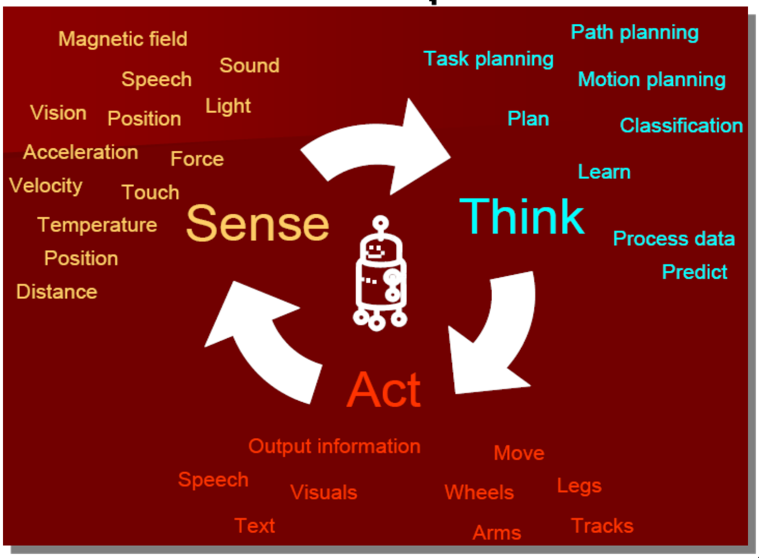
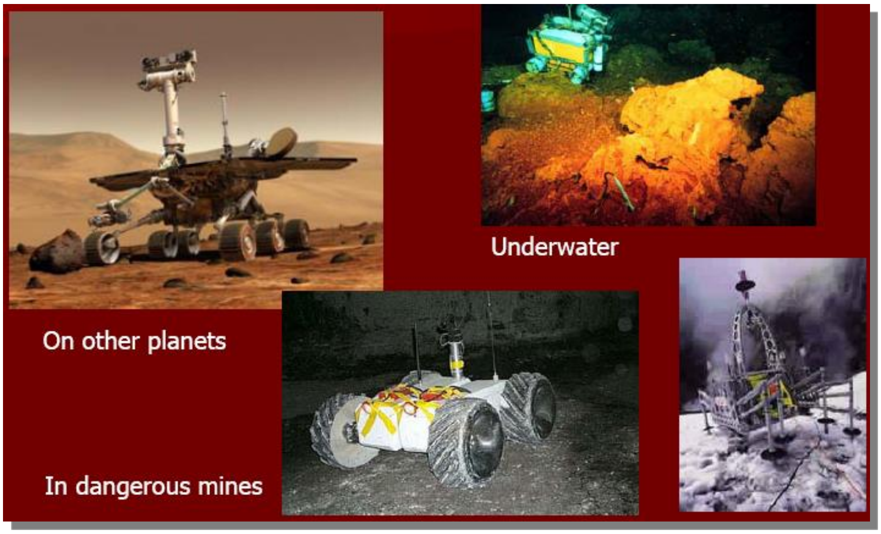
Human like Control

How….. Control Systems in Robotics Perspective



Autonomous planning and Exploration



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Industry

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……….Everywhere

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Control systems are divided into two classes:

a) If the aim is to maintain a physical variable at some fixed value when there are disturbances, this is a *regulator.*

Example: speed-control system on the ac generators of power utility companies.

b) The second class is the *servomechanism.* This is a control system in which a physical variable is required to follow (track) some desired time function.

Example: an automatic aircraft landing system, or a robot arm designed to follow a required path in space.

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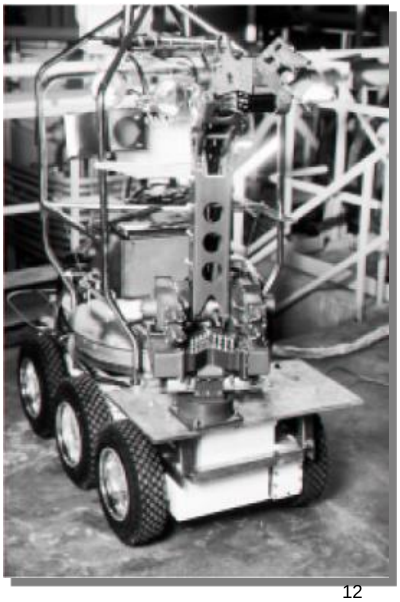
Advantages of a Control System

- **Power amplification**
  - Radar antenna positioned by the low-power rotation of a knob at the input, requires a large amount of power for its output rotation. Control system will produce the needed power amplification/power gain.

Advantages of a Control System

- **Remote control**

  Rover was built to work in contaminated areas at Three Mile Island where a nuclear accident occurred in 1979.



Advantages of a Control System

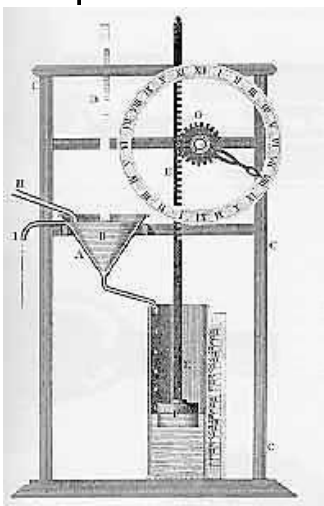
- **Convenience of input form**
  - In a temperature control system, the input is the position on a thermostat and the output is the heat. Thus a convenient position input yields a desired thermal output.

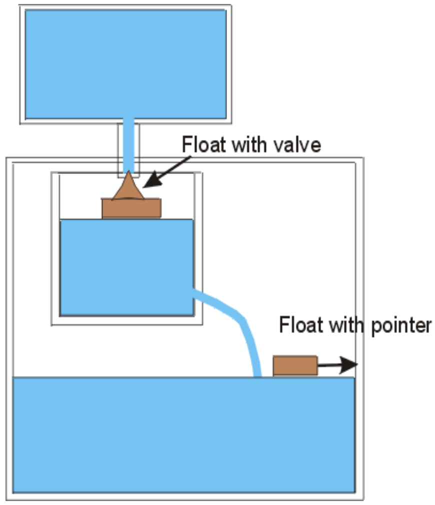
Advantages of a Control System

- **Compensation for disturbances**
  - In an antenna system that points in a commanded direction, wind can force the antenna to deviate from commanded direction. The system should detect the disturbance and act accordingly.

Classical Control Systems

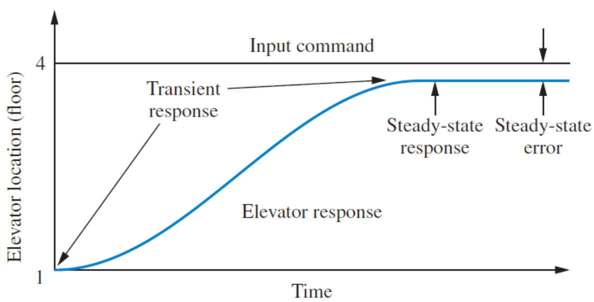
- Liquid Level Control





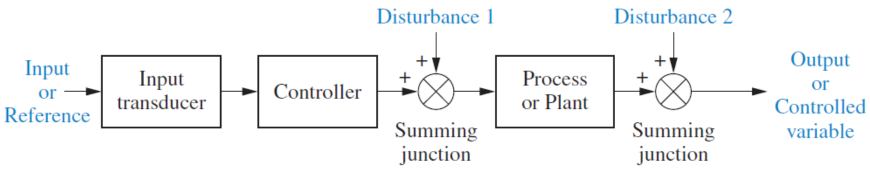
Response Characteristics

- Consider a control system for an elevator.
  – The input is a step function instructing the elevator to go to a higher floor (4).
  – The output is a transient response plus a steady-state response and has a steady-state error.



Open-Loop Systems

- An open-loop system cannot compensate for any disturbances that add to the controller's driving signal or to the process output.



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Closed-Loop (Feedback Control)

- A closed-loop system can compensate for disturbances by measuring the output, comparing it to the desired output, and driving the difference toward zero.

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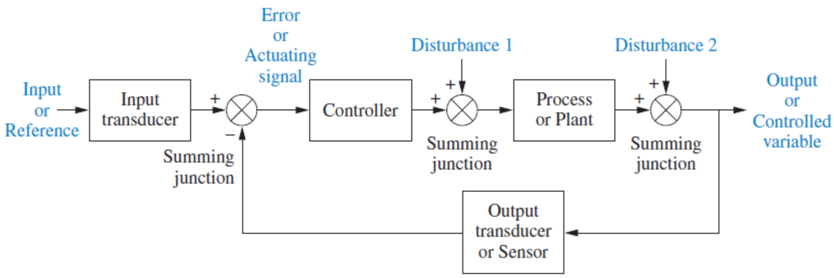
Closed-Loop (Feedback Control)



Closed-Loop (Feedback Control)

- Greater accuracy than open-loop systems
- Transient and steady-state responses can be controlled more easily
- More complex and expensive than open-loop systems
  - Requires monitoring the plant output

Analysis and Design Objectives

- Transient Response must meet certain criteria. Hard disk read write etc.
- Steady-State Response must meet certain criteria.
- The system must have Stability.
  - Total Response = Natural Response + Forced Response
    - Natural response describes the way the system dissipates or gain energy. It is dependent only on the system not the input
    - Forced response depends on the input.
    - Natural response must go to zero leaving only the forced response or oscillate

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Analysis and Design Objectives

- Other Considerations
  - Hardware limitations
  - Finances
  - Robust Design

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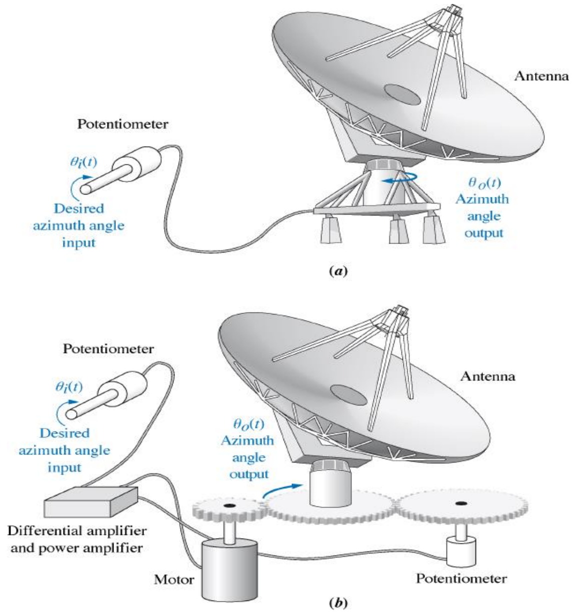
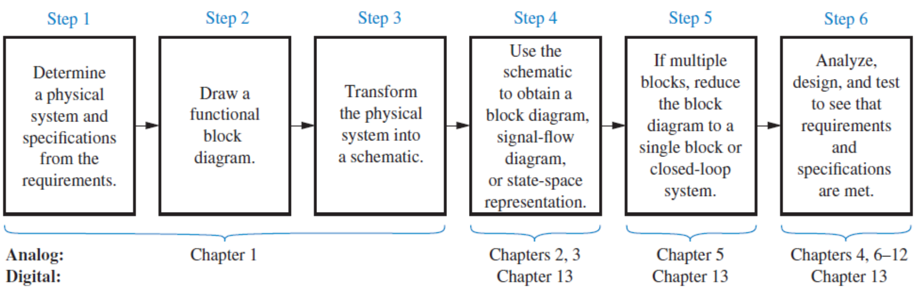
Antenna Azimuth Position Control

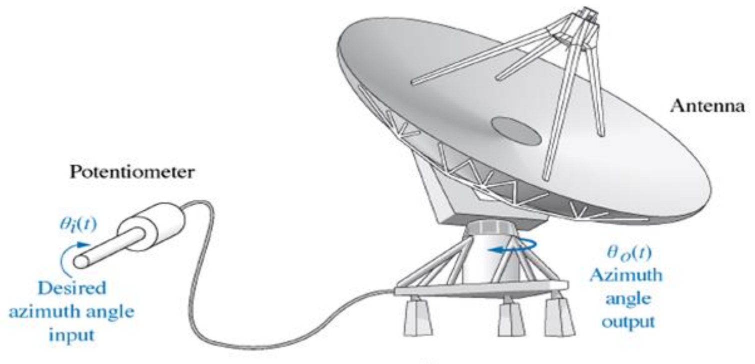


Design Stages for the Antenna



Step 1: Transform Requirements into a Physical System

We begin by transforming the requirements into a physical system. For example, in the antenna azimuth position control system, the requirements would state the desire to position the antenna from a remote location and describe such features as weight and physical dimensions. Using the requirements, design specifications, such as desired transient response and steady-state accuracy, are determined.

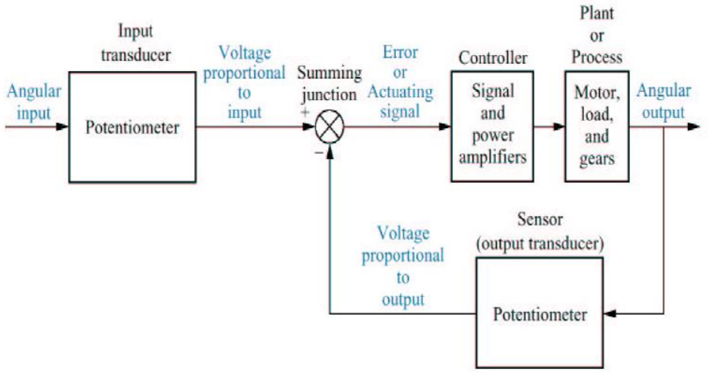


Step 2: Draw a Functional Block Diagram

The designer now translates a qualitative description of the system into a functional block diagram that describes the component parts of the system (that is, function and/or hardware) and shows their interconnection.

Antenna Azimuth System

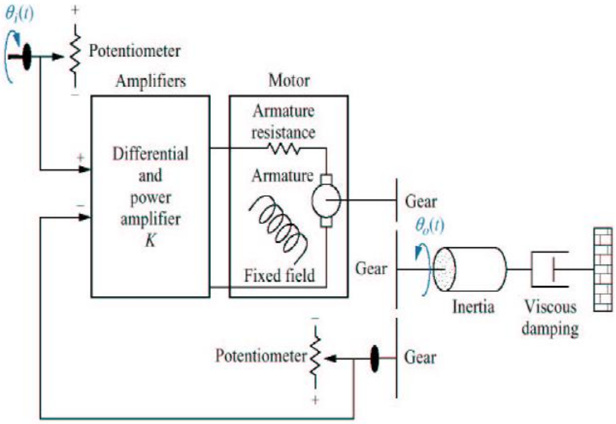
Functional Block Diagram



Step-3: Draw Schematic

Antenna Azimuth System

Schematic



Step-4: Mathematical Models

- Model the system mathematically using physical laws.
  - Kirchoff's Voltage Law - The sum of voltages around a closed path is zero.
  - Kirchoff's Current Law - The sum of currents flowing from a node is zero.
  - Newton's Laws - The sum of forces on a body is zero (considering mass times acceleration as a force).

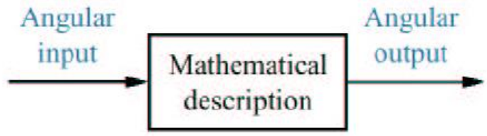
  The sum of moments on a body is zero.
- The model describes the relationship between the input and the output of the dynamic system.

$$\frac{d^m c(t)}{dt^m} + a_{n-1}\frac{d^{m-1}c(t)}{dt^{m-1}} + \cdots + a_0 c(t)$$
$$= b_m \frac{d^m r(t)}{dt^m} + b_{m-1}\frac{d^{m-1}r(t)}{dt^{m-1}} + \cdots + b_0 r(t)$$

1) Linear, time-invariant differential equation.
2) Transfer function written using the Laplace transform.

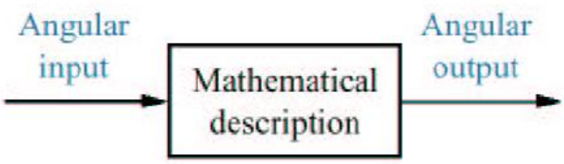
Step-5: Reduce the Block Diagram

Antenna Azimuth Block Diagram



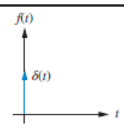
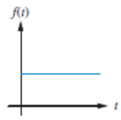
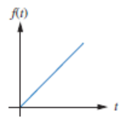
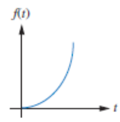
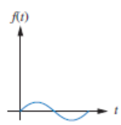
reduce this large system's block diagram to a single block with a mathematical description that represents the system from its input to its output

Step-6: Analyze and Design



- The input signal is the desired position of the antenna.
- Several common forms of input functions are used for test purposes

TABLE 1.1 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	$tu(t)$	$tu(t) = t$ 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

Why Control Systems?

- *Engineering involves the study of design and analysis of engineering systems.*
- *Engineering systems are physical systems which could be modeled mathematically (mathematical models).*
- *Many engineering or physical systems are control systems.*
  Examples are: central heating system, auto pilot, robots, automobiles, etc.
- *Software engineers often participate in the development of large softwares for control systems, e.g. software for the control of the space shuttle.*