Control Systems

Introduction

• Recommended Text: Control Systems Engineering, Norman S. Nise, John Wiley and Sons, Inc., Chapter 1
Control System Definition

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

Advantages of a Control System

• Power amplification
• Remote control
  – Rover was built to work in contaminated areas at Three Mile Island where a nuclear accident occurred in 1979.
• Convenience of input form
• Compensation for disturbances
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.
- An open-loop system has no feedback path.
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.

Closed-Loop Systems

- 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
- Introduces the possibility of instability
- There is a trade-off between the simplicity and low cost of an open-loop system and the accuracy and higher cost of a closed-loop system.
Analysis and Design Objectives

- Transient Response must meet certain criteria.
- Steady-State Response must meet certain criteria.
- The system must have Stability.
- Other Considerations
  - Hardware limitations
  - Finances
  - Robust Design

Antenna Azimuth Position Control

System Concept

![Antenna Azimuth Position Control System Concept Diagram]
Antenna Azimuth System

Schematic

Antenna Azimuth System

Functional Block Diagram
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.
Three Models

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

1) Linear, time-invariant differential equation.
2) Transfer function written using the Laplace transform.
3) State-Space model: An \(n\)th order differential equation is represented as \(n\) simultaneous first-order differential equations in matrix form.

Antenna Azimuth Block Diagram

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

<table>
<thead>
<tr>
<th>Input</th>
<th>Function</th>
<th>Description</th>
<th>Sketch</th>
<th>Use</th>
</tr>
</thead>
</table>
| Impulse| $\delta(t)$ | $\delta(t) = 1$ for $0^- < t < 0^+$  
$= 0$ otherwise  
\[ \int_{0^-}^{0^+} \delta(t) \, dt = 1 \] | ![Sketch](image1.png) | Transient response  
Modeling |
| Step    | $u(t)$   | $u(t) = 1$ for $t > 0$  
$= 0$ for $t < 0$ | ![Sketch](image2.png) | Transient response  
Steady-state error |
| Ramp    | $r(t)$   | $r(t) = t$ for $t \geq 0$  
$= 0$ elsewhere | ![Sketch](image3.png) | 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 | ![Sketch](image4.png) | Steady-state error |
| Sinusoid| $\sin at$ | $\sin at$ | ![Sketch](image5.png) | Transient response  
Modeling  
Steady-state error |