ELEC 312
Systems I

Introduction

(Derived from Notes by Dr. Robert Barsanti)

(Images from Nise, 7^{th} Edition)

Required Reading: Chapter 1,
Control Systems Engineering

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Introduction to Control Systems

Control systems are an integral part of modern society. Numerous applications are all around us, such as automatic milling machines, self-guided vehicles, and assembly plant robots. The human body also has many automatic control systems as well, such as regulation of heart rate, blood sugar, and body temperature.

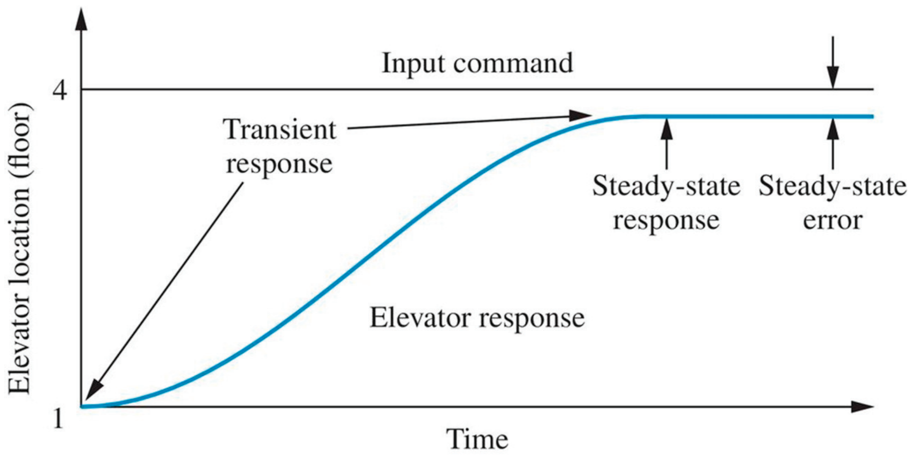
Control systems consist of subsystems, which contain plants (physical objects to be controlled) and processes assembled for the purpose of controlling the output of processes (operations) . For example, a furnace produces heat as the result of fuel flow. In this process, subsystems (fuel valves and fuel valve actuators) are used to regulate the temperature of a room by controlling the heat output of a furnace. Other subsystems such as thermostats (sensors) measure parameters of interest, like room temperature.

In its simplest form, however, a control system elicits an output or response for a given input or stimulus.

We build control systems for four main reasons: power amplification, remote control, compensate for disturbances, and convenience of input form.

- **Power amplification** - Example: moving a large tracking antenna
- **Remote control** - Example: robotic arm in radioactive environment
- **Disturbances** - Example: cruise control in automobiles
- **Changing input form** - Example: Position of thermostat to temperature

Input vs. Output



In many control systems, the input represents the desired response, and the output represents the actual system response.

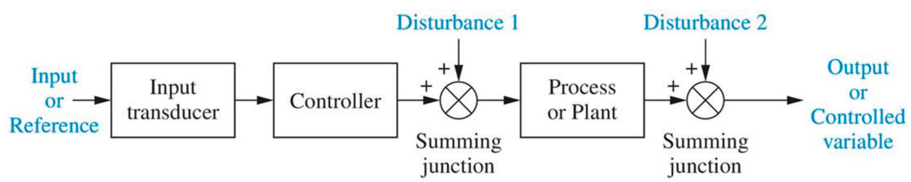
The above depicts the gradual rise of the elevator as it rises from the first (1st) floor to the fourth (4th) floor–this is the **transient response**.

After the transient, the elevator approaches its **steady-state** response, which is its approximation to the desired response.

The accuracy of the elevators final position relative to the desired position is the **steady-state error**.

Open-Loop vs. Closed-Loop Systems

Open Loop:

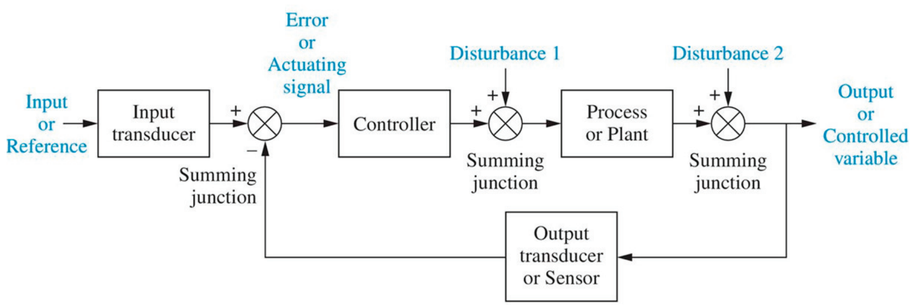


The distinguishing characteristic of an open-loop system is that it **cannot compensate for any disturbances** that add to the controller input signal.

Examples: toaster, washing machine

Open-Loop vs. Closed-Loop Systems

Closed Loop:



Some function of the system's output signal is used to control the overall system response.

Advantages vs. Disadvantages of Feedback

Some **ADVANTAGES** of feedback:

1. Response less sensitive to external disturbances
2. Responses less sensitive to parameter variations
3. Automatic tracking of reference signals
4. Improved transient and steady-state responses
5. Can sometimes utilize otherwise unstable plants

Advantages vs. Disadvantages of Feedback

Some **DISADVANTAGES** of feedback:

1. Potential to introduce instability or oscillations into a system
2. Added cost of sensors, transducers, and controllers
3. Trade-off between response time and noise rejection

Control Systems Engineering Objectives

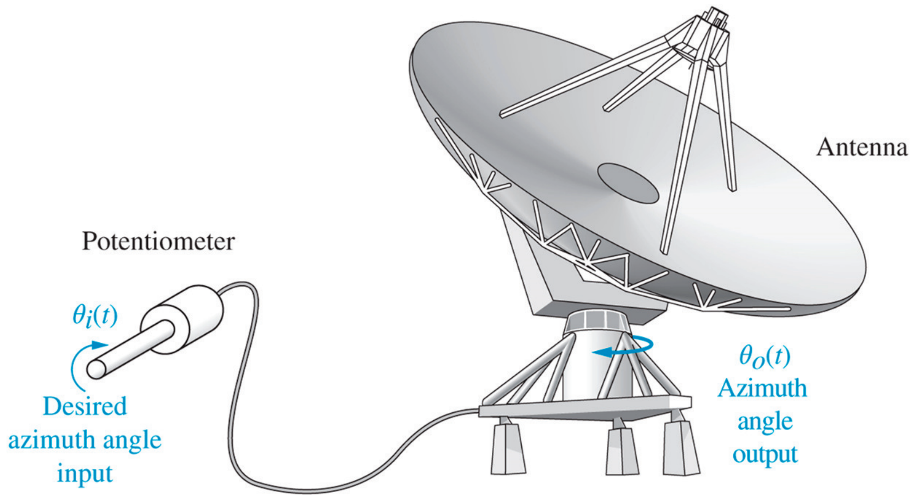
Three major objectives of systems analysis and design:

1. Producing the desired **transient response**
2. Reducing **steady-state** errors
3. Achieving **stability** (which for now means that the transient response of the system eventually decays to zero)

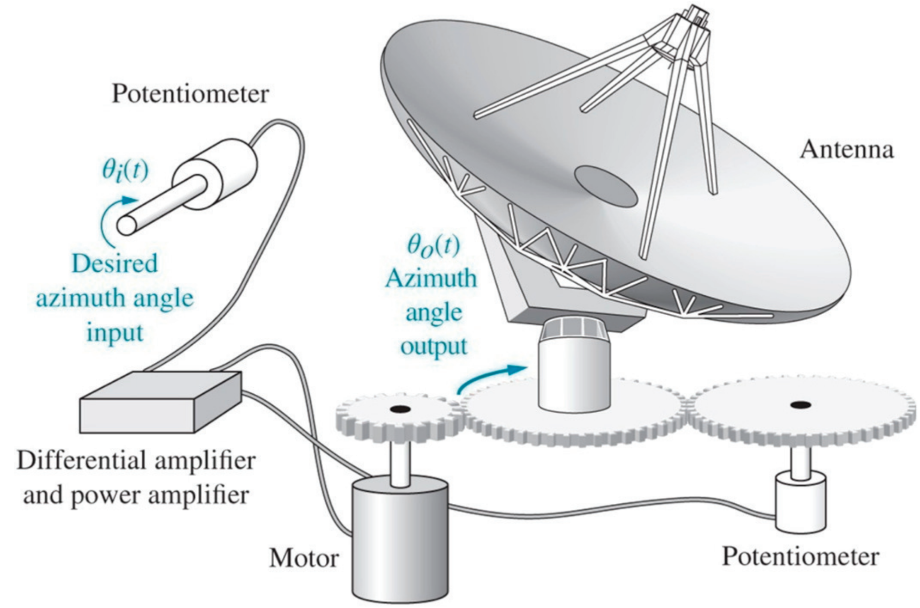
Of course, there are numerous other objectives, such as cost, power requirements, robustness,...

Antenna Azimuth Position Control System

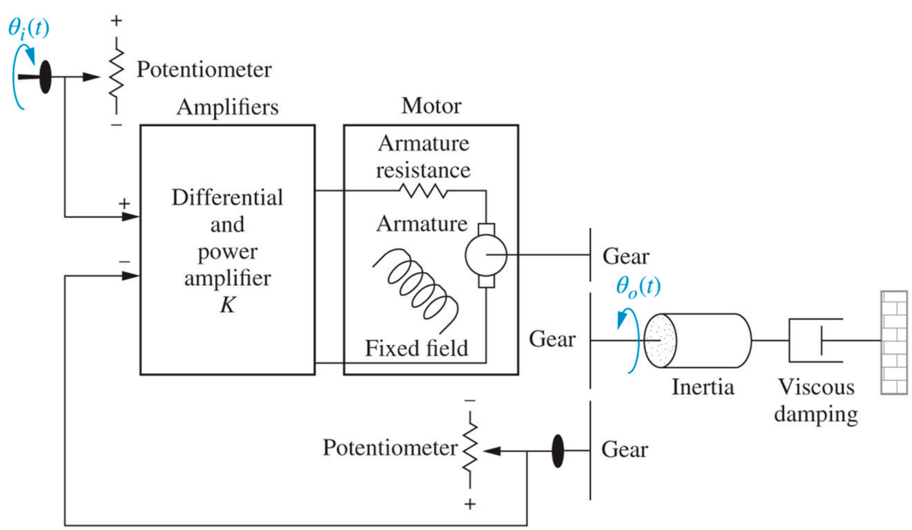
Consider a Position-Control System:



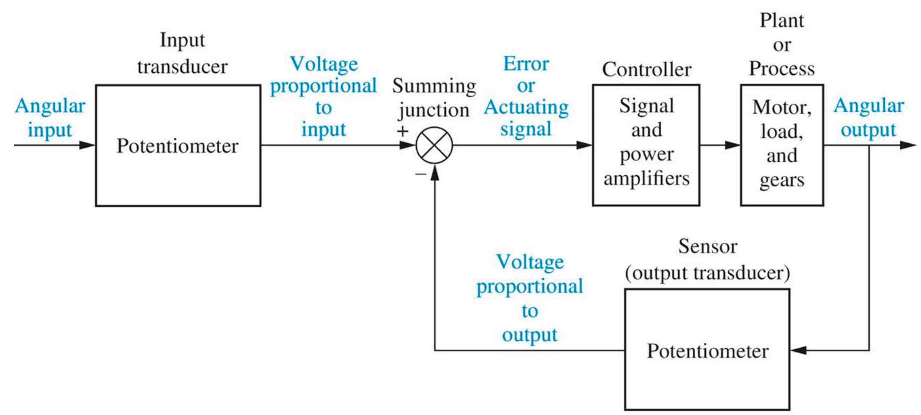
Antenna Azimuth Position Control System



Antenna Azimuth Position Control System



Antenna Azimuth Position Control System



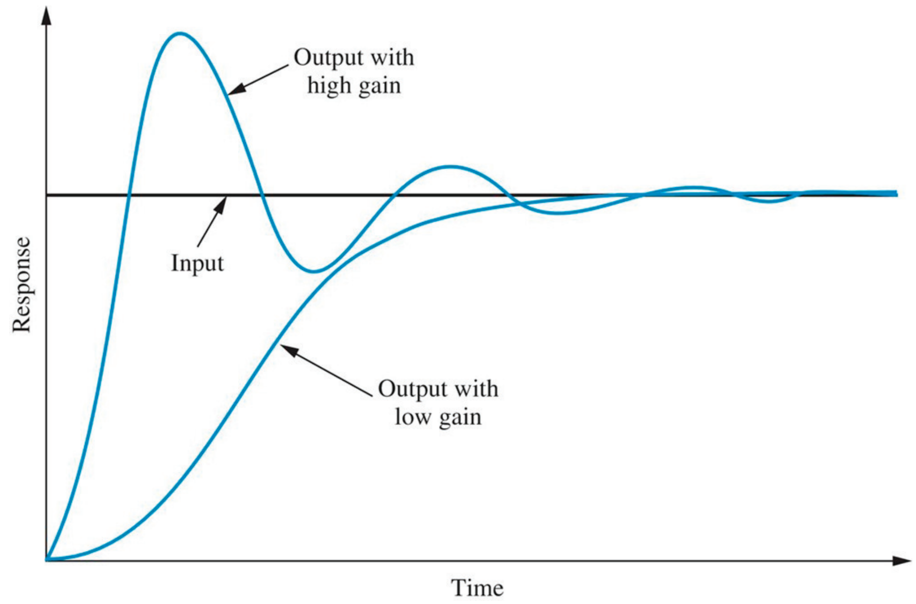
Antenna Azimuth Position Control System

The system normally operates to drive the error signal to zero. When input and output signals match, the error is zero, and the motor will not turn.

If we increase the gain of the amplifier, the motor will be driven harder for a given error signal–however, the motor will still stop when the output reaches the input. The difference will be that the motor will turn faster, and reach the final position sooner. However, due to inertia, it may overshoot the desired position.

Thus, the **transient response** is affected.

Antenna Azimuth Position Control System



Antenna Azimuth Position Control System

The **steady-state response** in this case was not affected, and is shown to have zero steady-state error. If the steady-state error was not zero, a more complex controller might be necessary.

Scope of Study

This course will explore the modeling, analysis, and design of linear time-invariant lumped-element control systems

Modeling – consists of using physical laws to describe the salient features of our system in mathematical terms

Analysis – consists of a series of techniques to determine properties and behavior of the system modeled

Design – consists of a series of techniques to alter or control the overall system behavior to conform to a set of requirements