Control Systems Engineering Chapter 1: Introduction

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Introduction to Control System

- **What is Control System ?**

  A control system consists of *subsystems and processes (or plants) assembled for the* purpose of obtaining a desired *output with desired performance, given a specified input.*

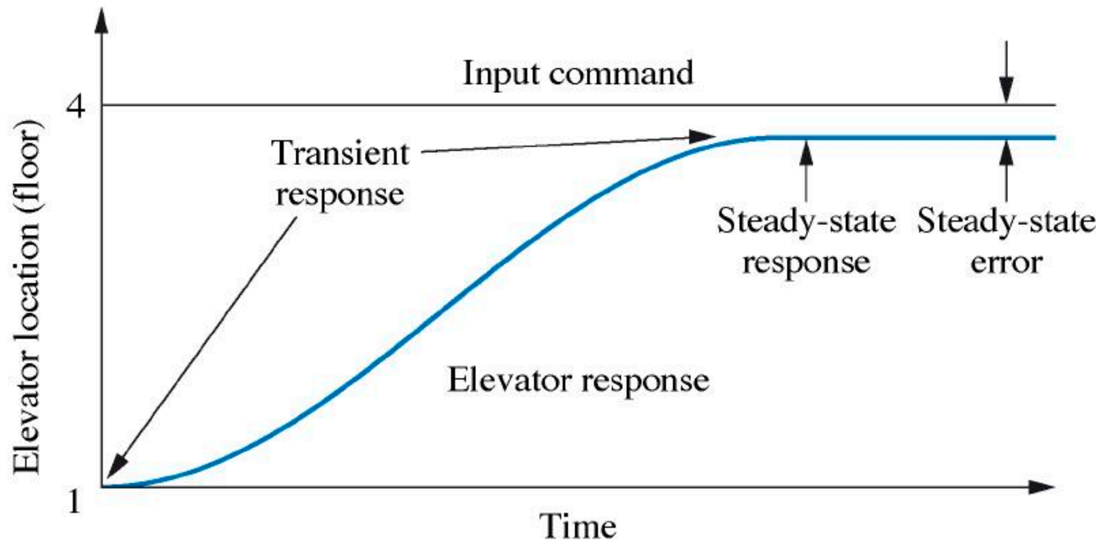
Introduction to Control System

- **Example of a control system: Elevator**

When the fourth-floor button is pressed on the first floor, the elevator rises to the fourth floor with a speed and floor-leveling accuracy designed for passenger comfort.

Introduction to Control System

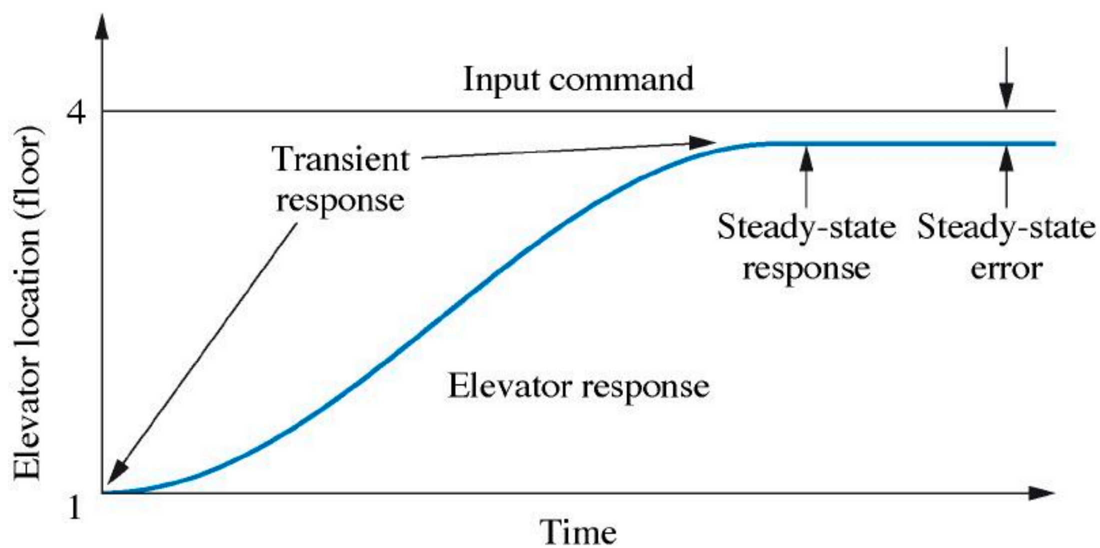
- **Example of a control system: Elevator**



Introduction to Control System

- **Example of a control system: Elevator**

Two major measures of performance:
(1) the transient response
(2) the steady-state error.



Introduction to Control System

- **Advantages of Control Systems**

We build control systems for four primary reasons:

1. Power amplification
2. Remote control
3. Convenience of input form
4. Compensation for disturbances

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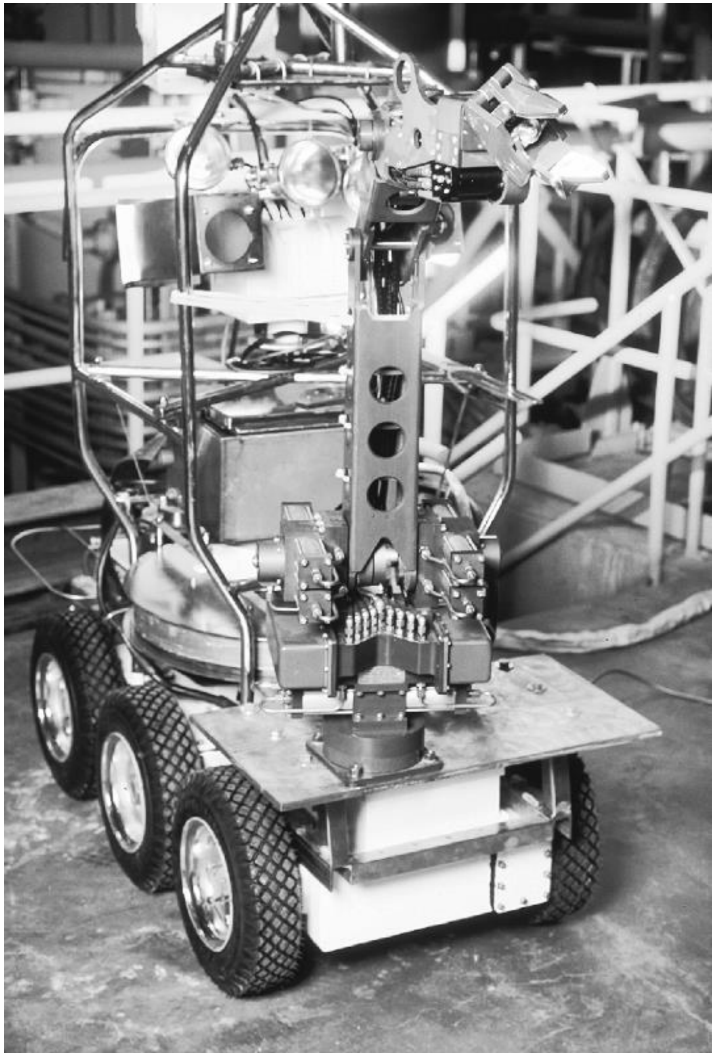
- **Advantages of Control Systems**



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Introduction to Control System

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1. Power amplification
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3. Convenience of input form
4. Compensation for disturbances

Introduction to Control System

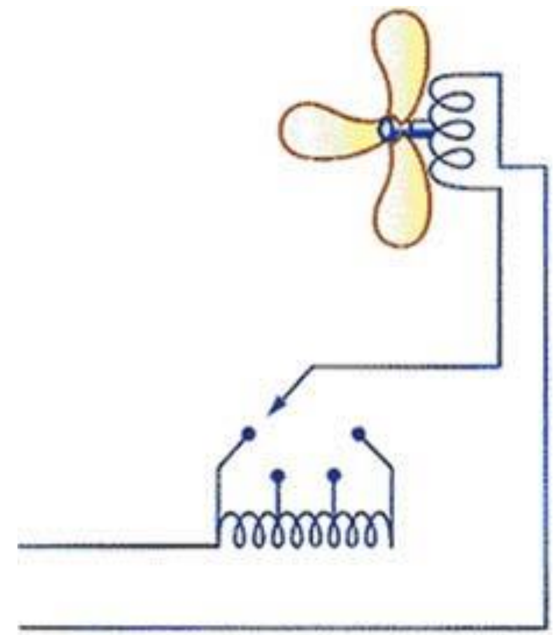
- **System Configurations**

We discuss two major configurations of control systems: **open loop** and **closed loop**.

We can consider these configurations to be the internal architecture of the total system shown in Figure 1.1.

Introduction to Control System

- Open Loop System



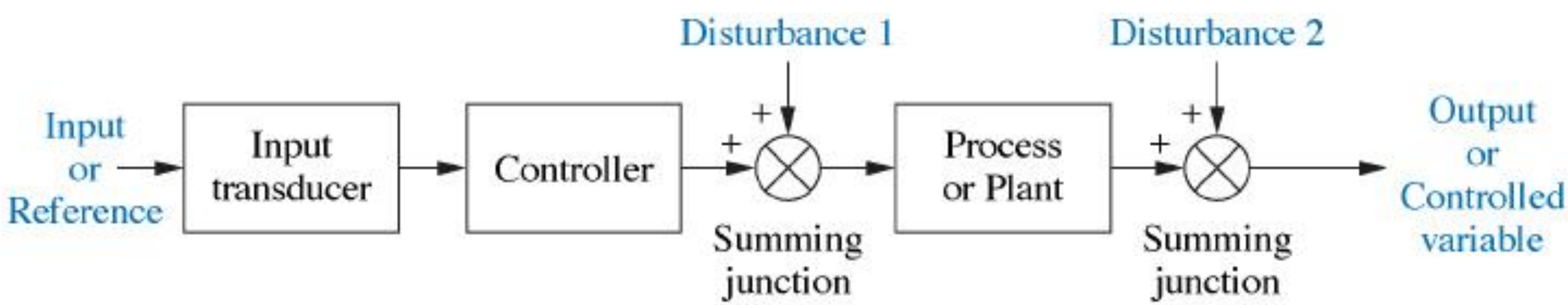
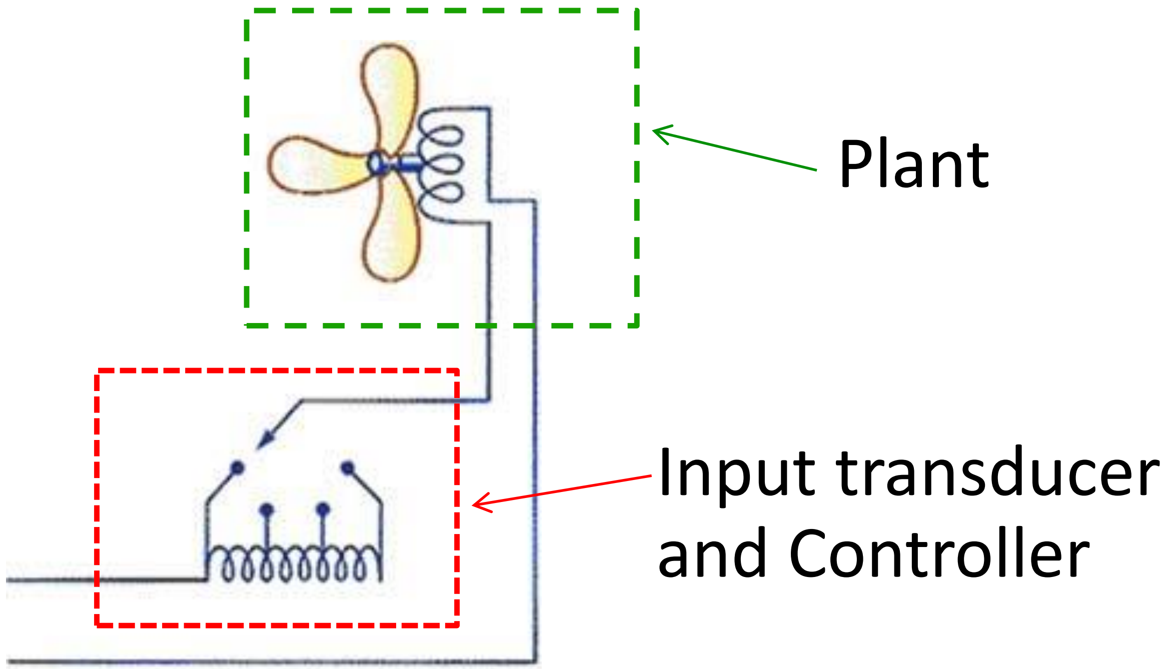


Figure 1.6 (a)

Introduction to Control System

- Open Loop System



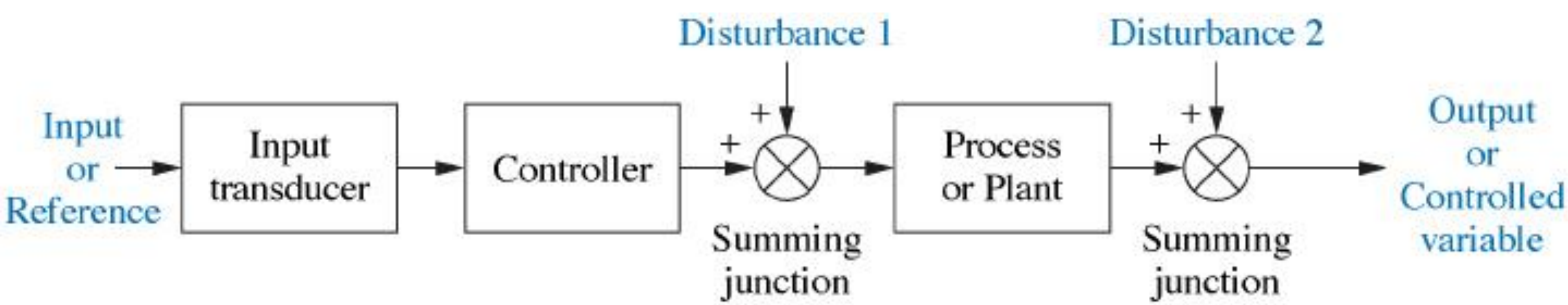
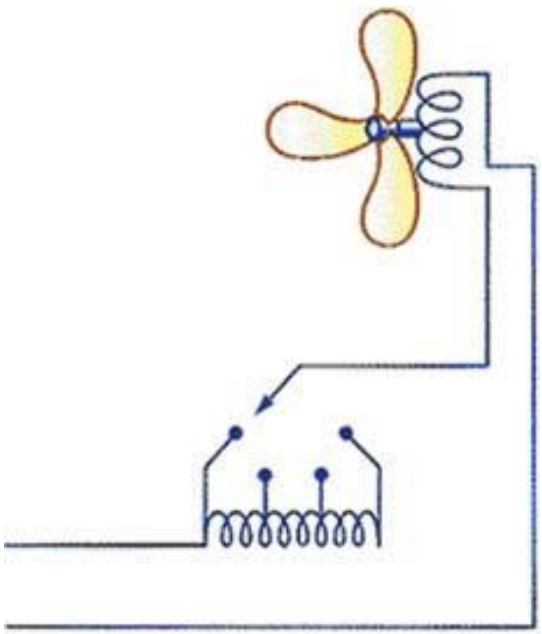


Figure 1.6 (a)

Introduction to Control System

- Open Loop System



The distinguishing characteristic of an open-loop system is that it cannot compensate for any disturbances that add to the controller's driving signal

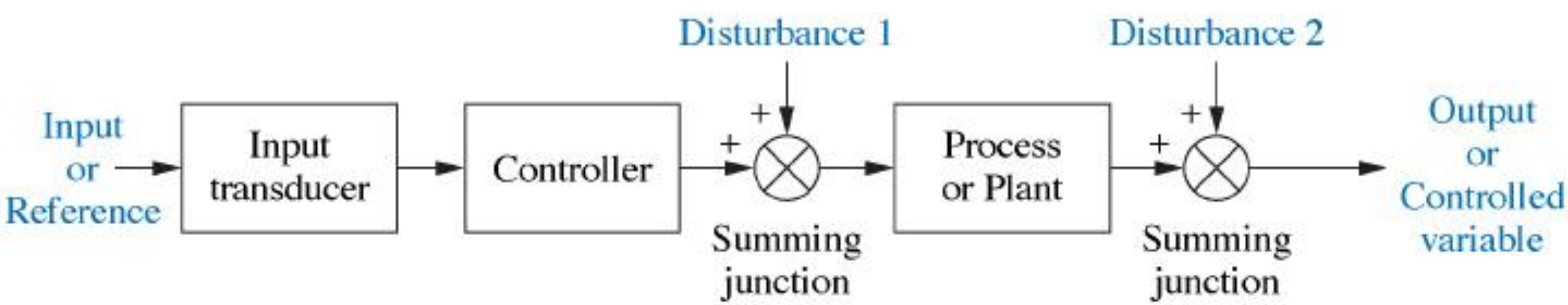


Figure 1.6 (a)

Introduction to Control System

- Open Loop System

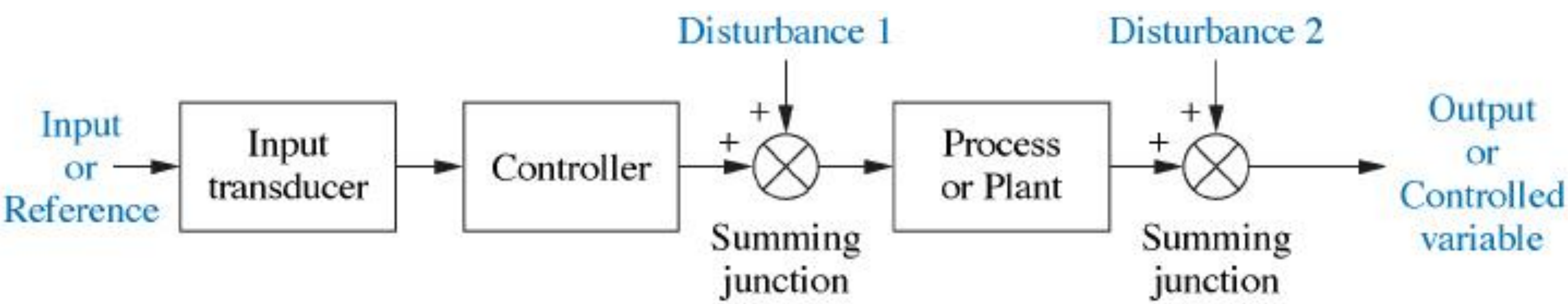
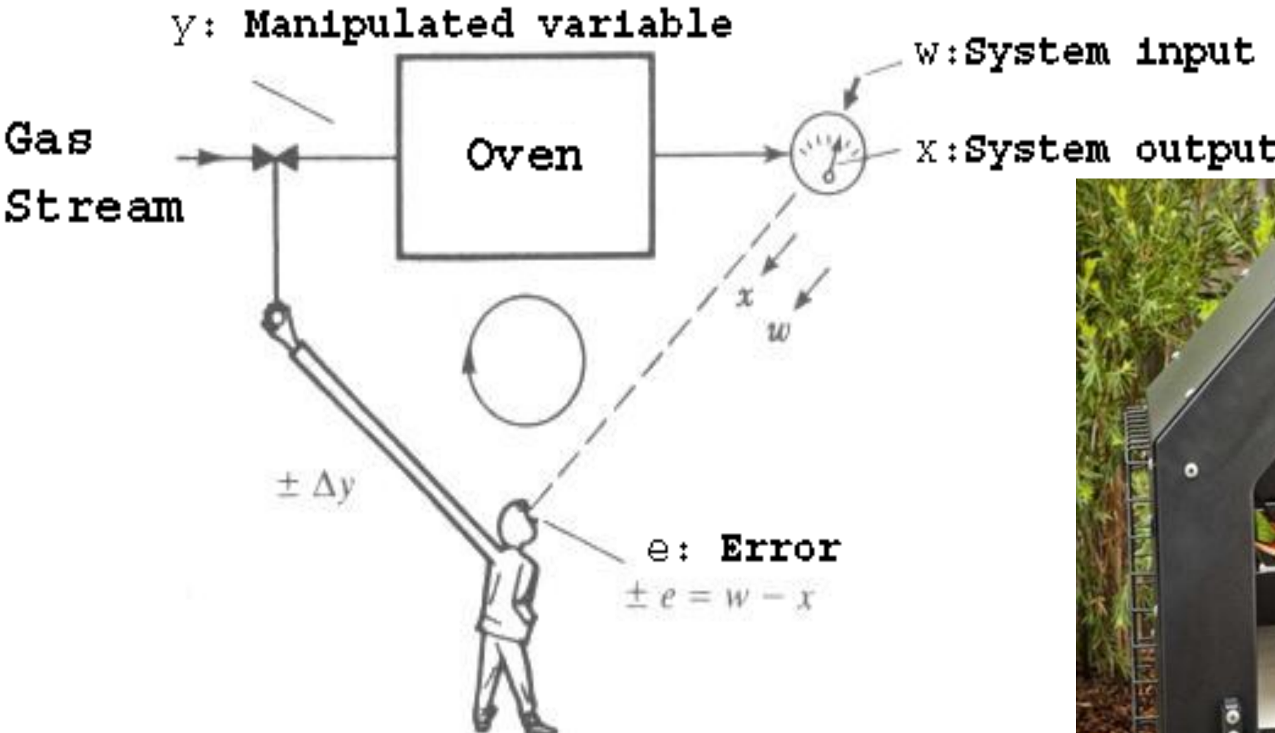


Figure 1.6 (a)

Introduction to Control System

- Open loop System



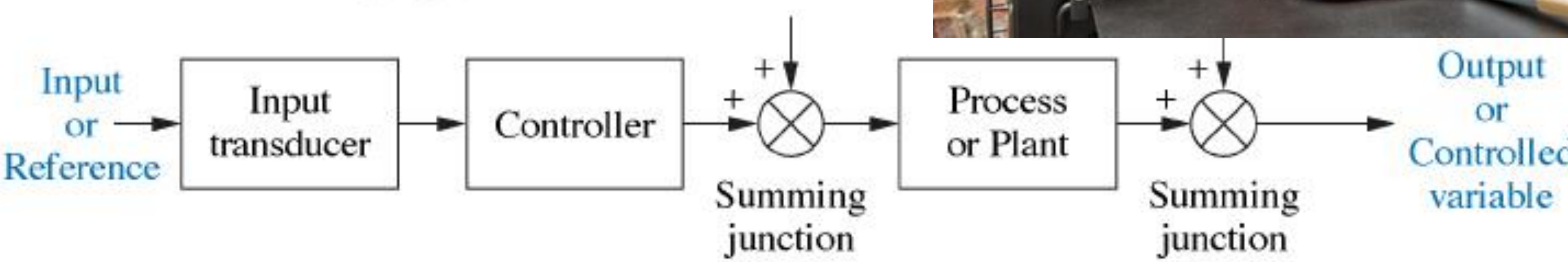
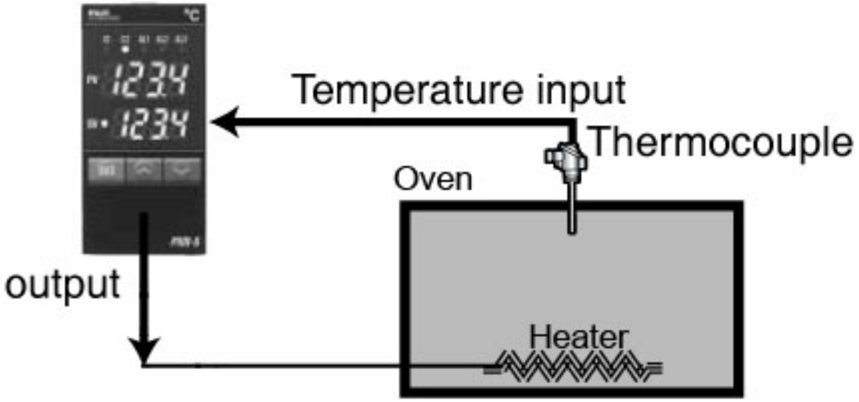


Figure 1.6 (a)

Introduction to Control System

- Closed Loop System



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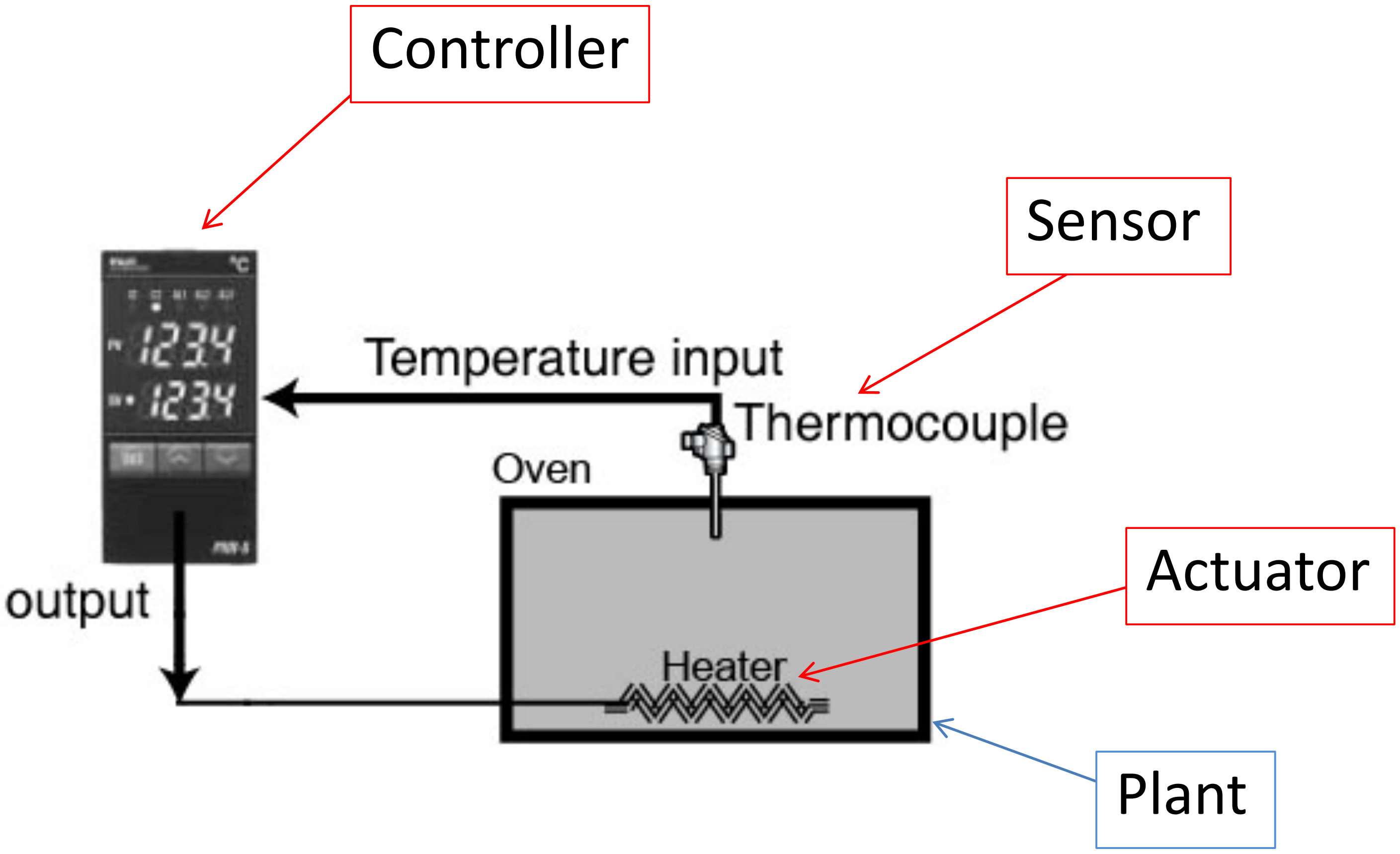
- Closed Loop System (Feedback control)



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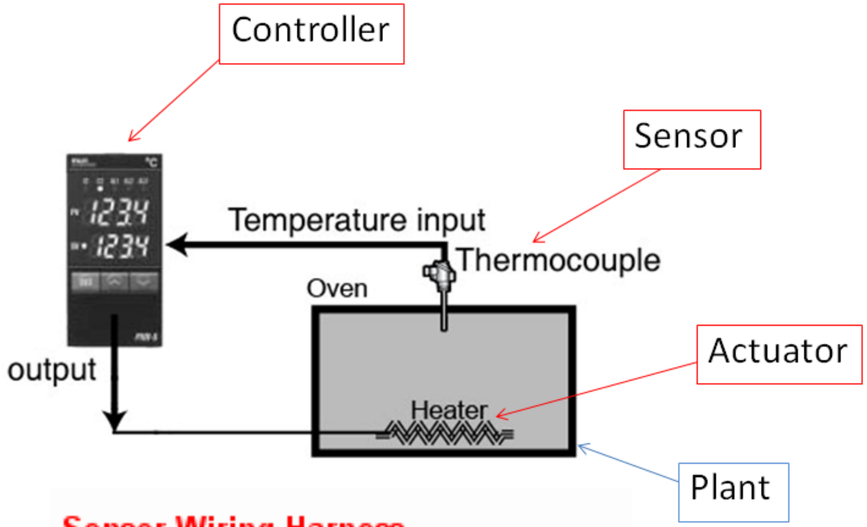
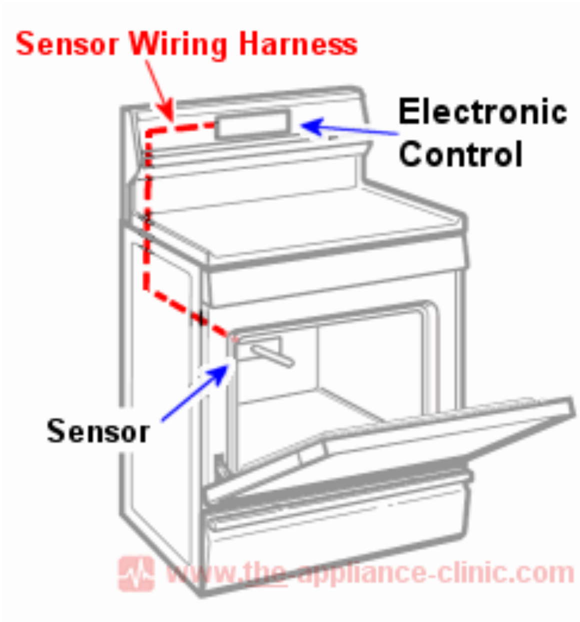
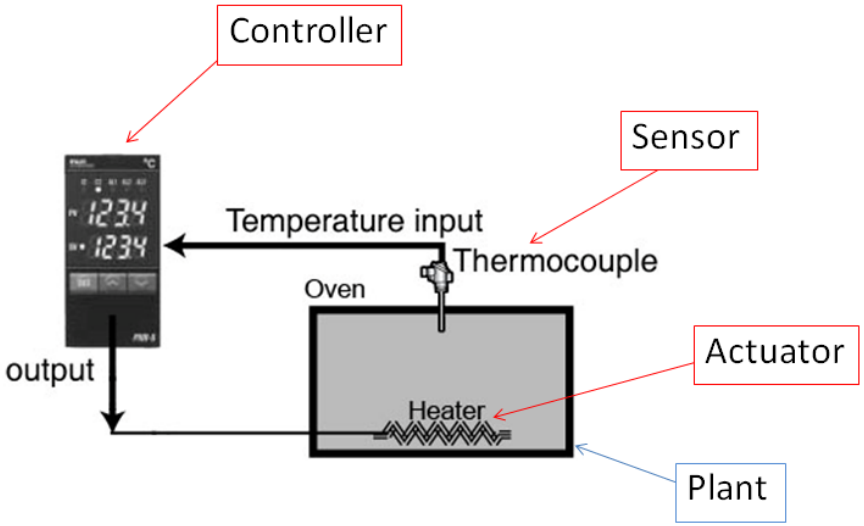
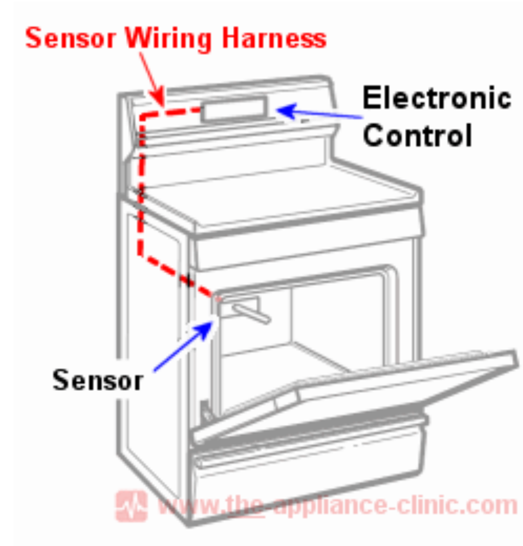


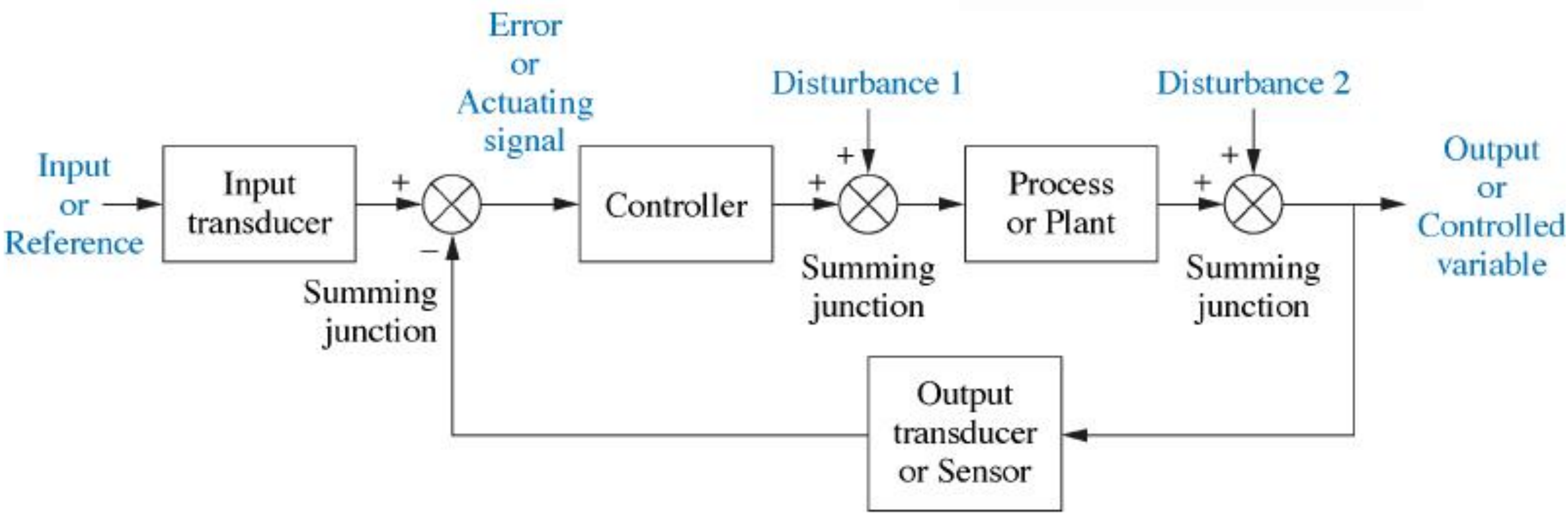


Introduction to Control System

- Closed Loop System (Feedback control)

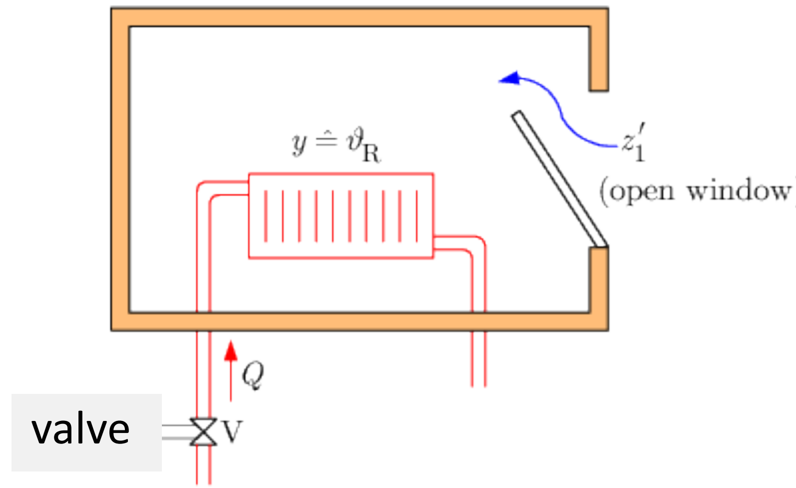


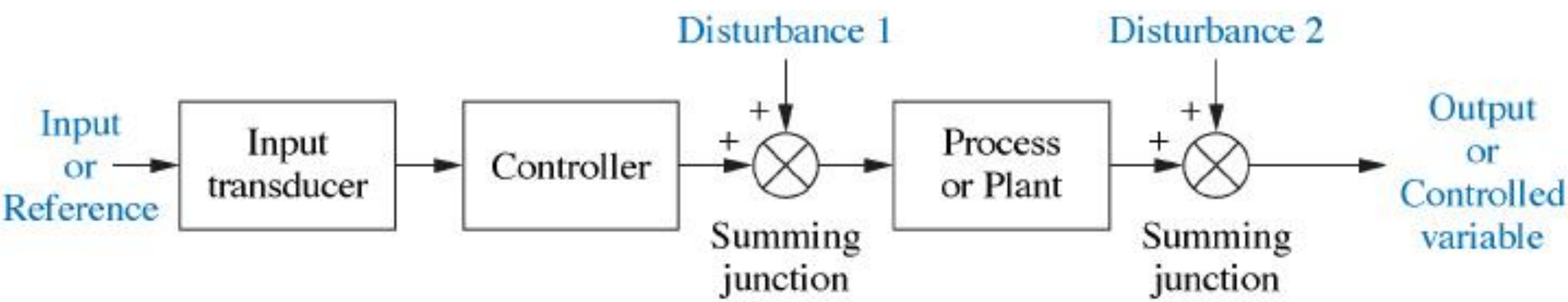




Introduction to Control System

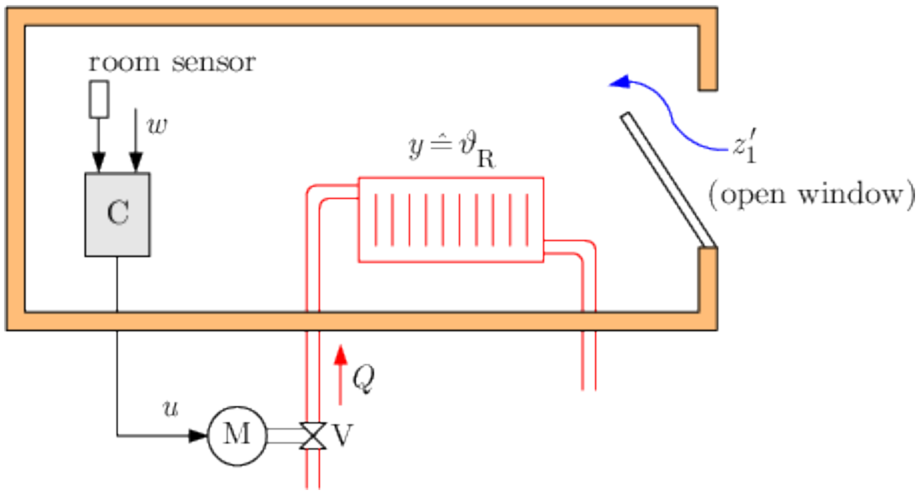
- Open Loop System

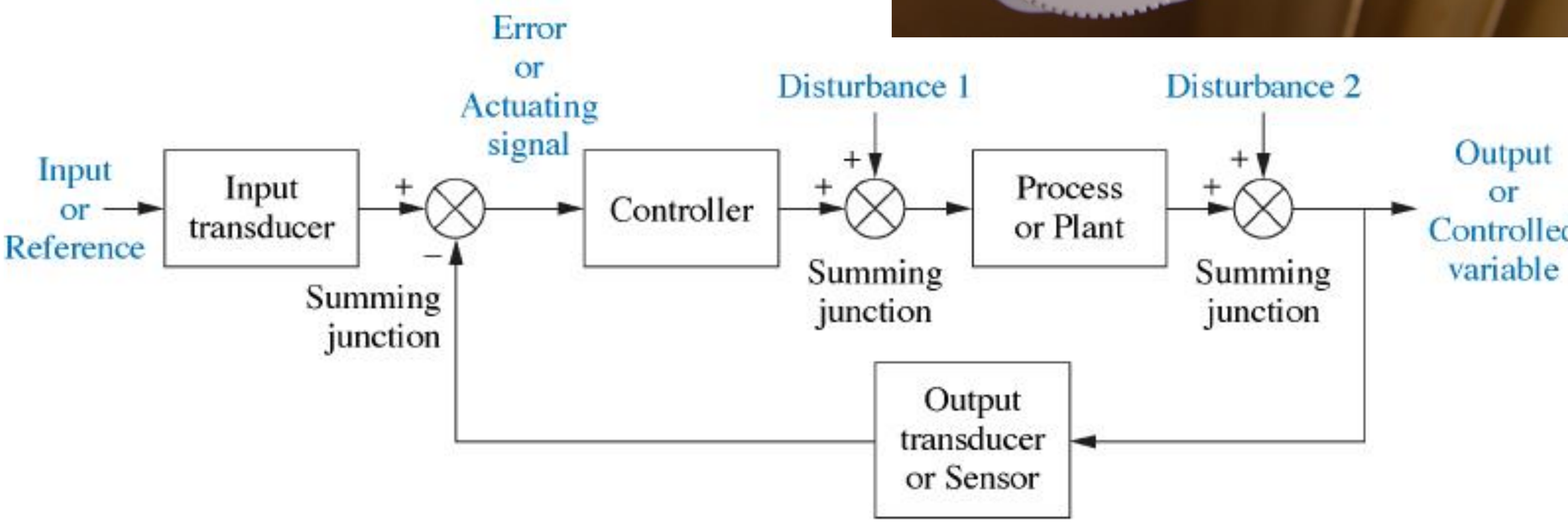




Introduction to Control System

- Closed Loop System (Feedback control)



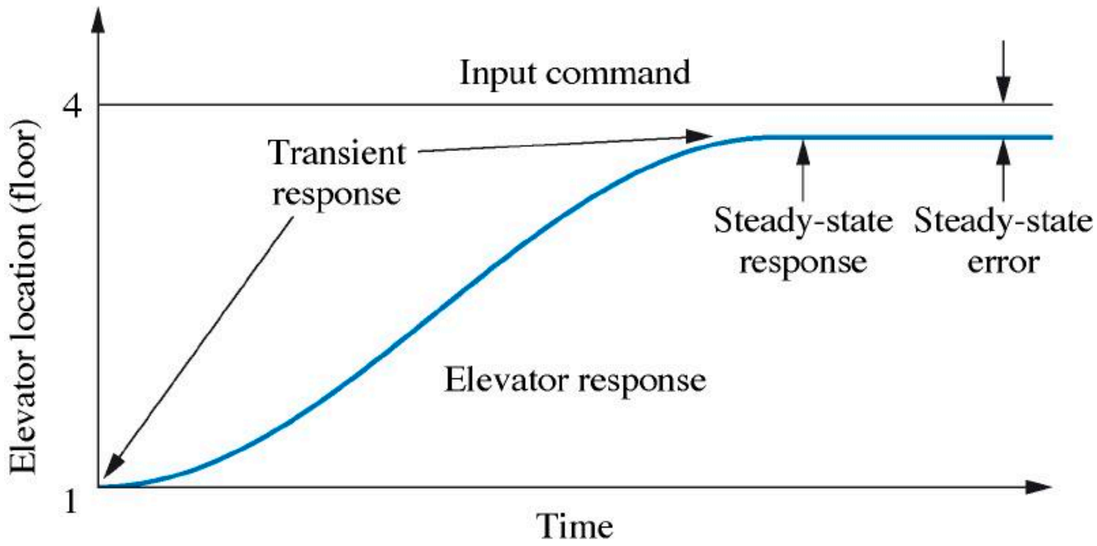


Introduction to Control System

- Control System

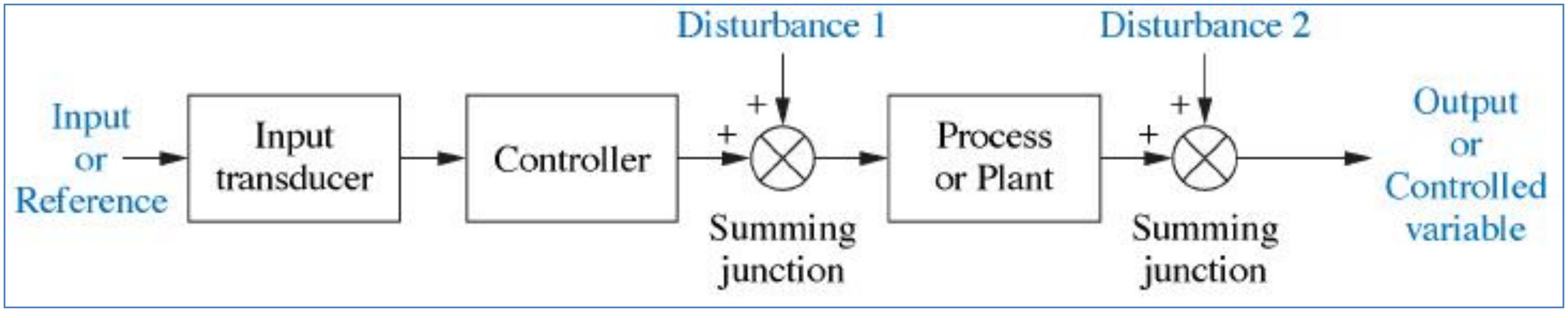
Summary

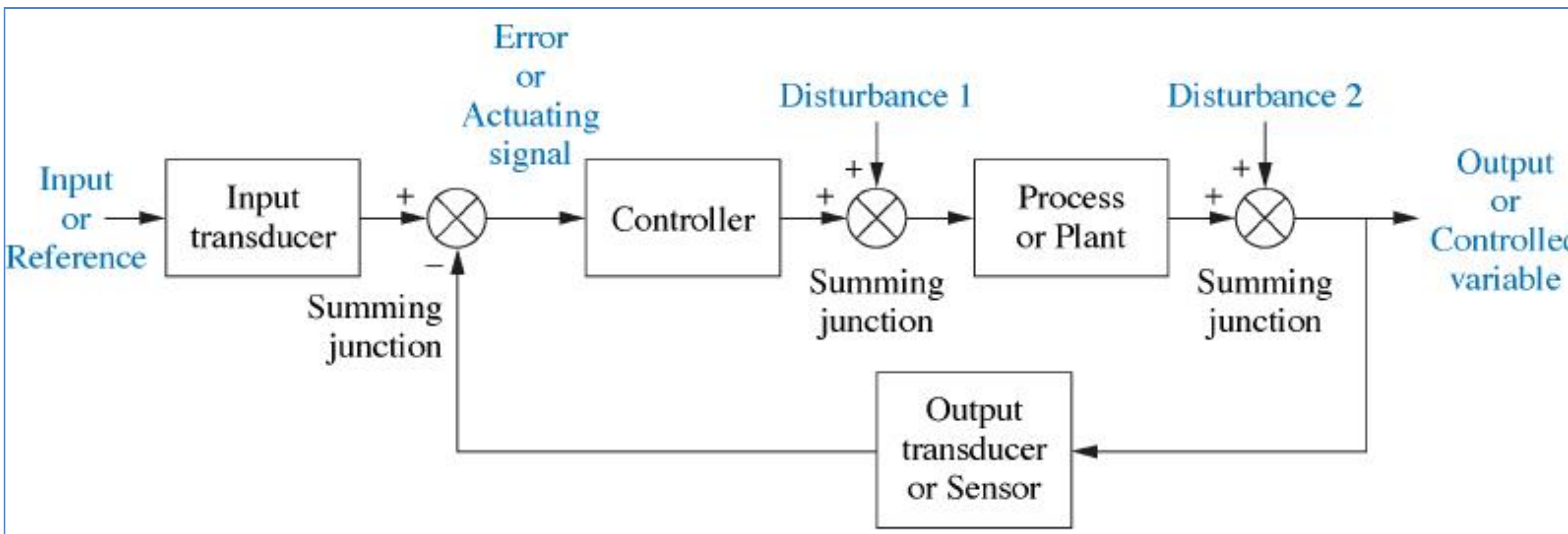
- A control system consists of *subsystems and plants assembled for the* purpose of obtaining a desired *output with desired performance, given a specified input*



Summary

- There are two major configurations of control systems: open loop and closed loop.

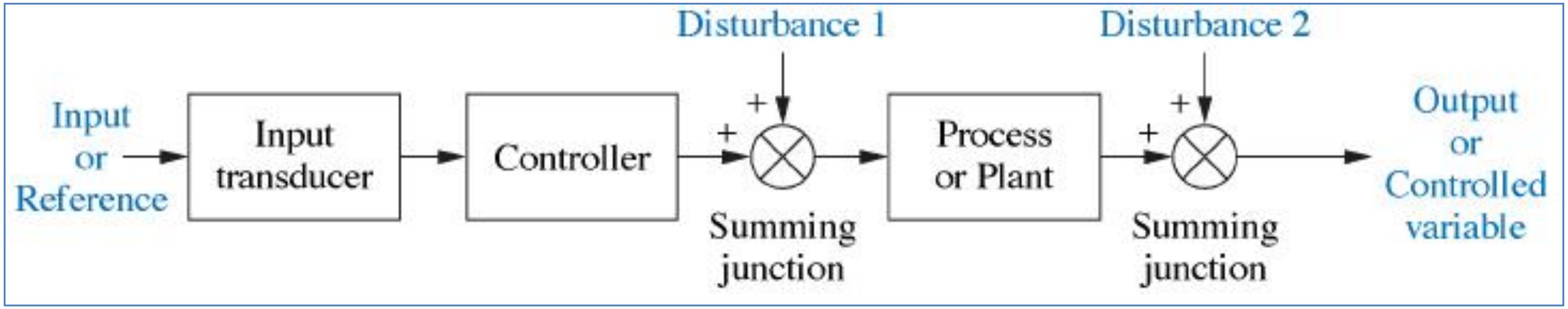


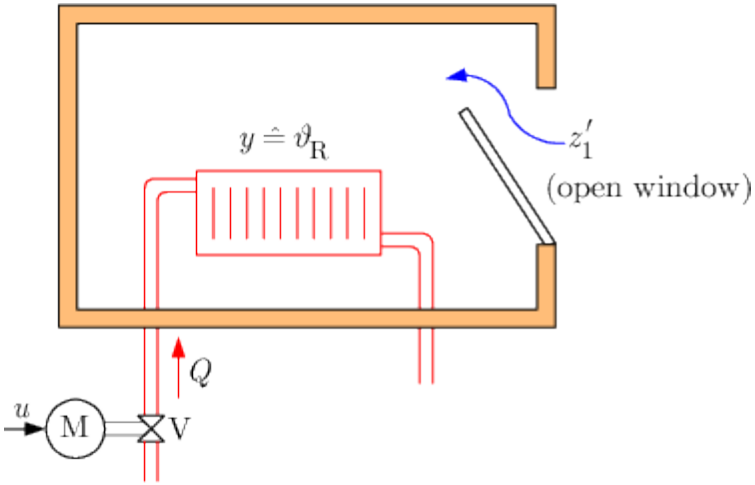


Summary

open-loop system

- The distinguishing characteristic of an open-loop system is that it cannot compensate for any disturbances that add to the controller's driving signal

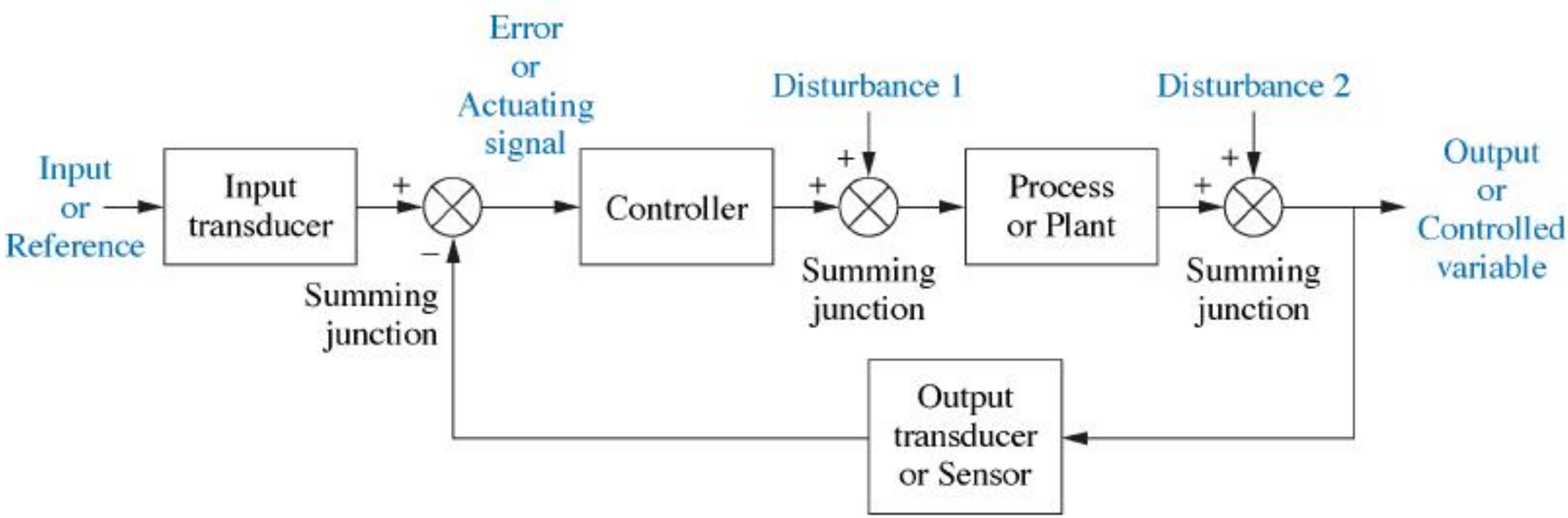


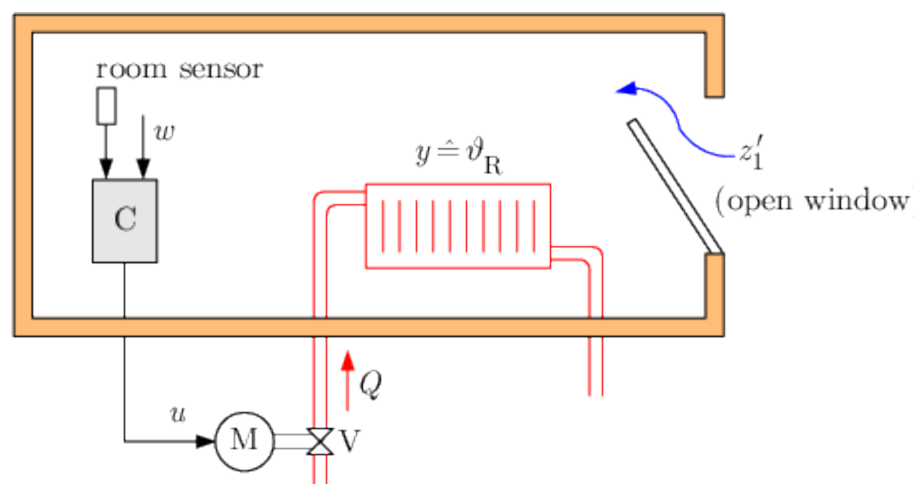


Summary

Closed loop system

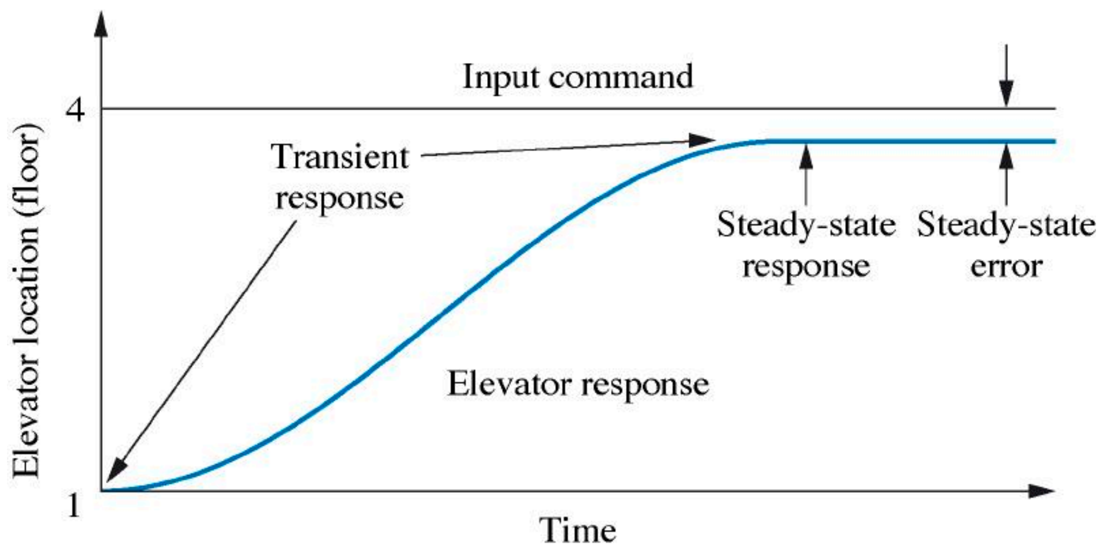
- The closed loop system is less sensitive to the disturbance.





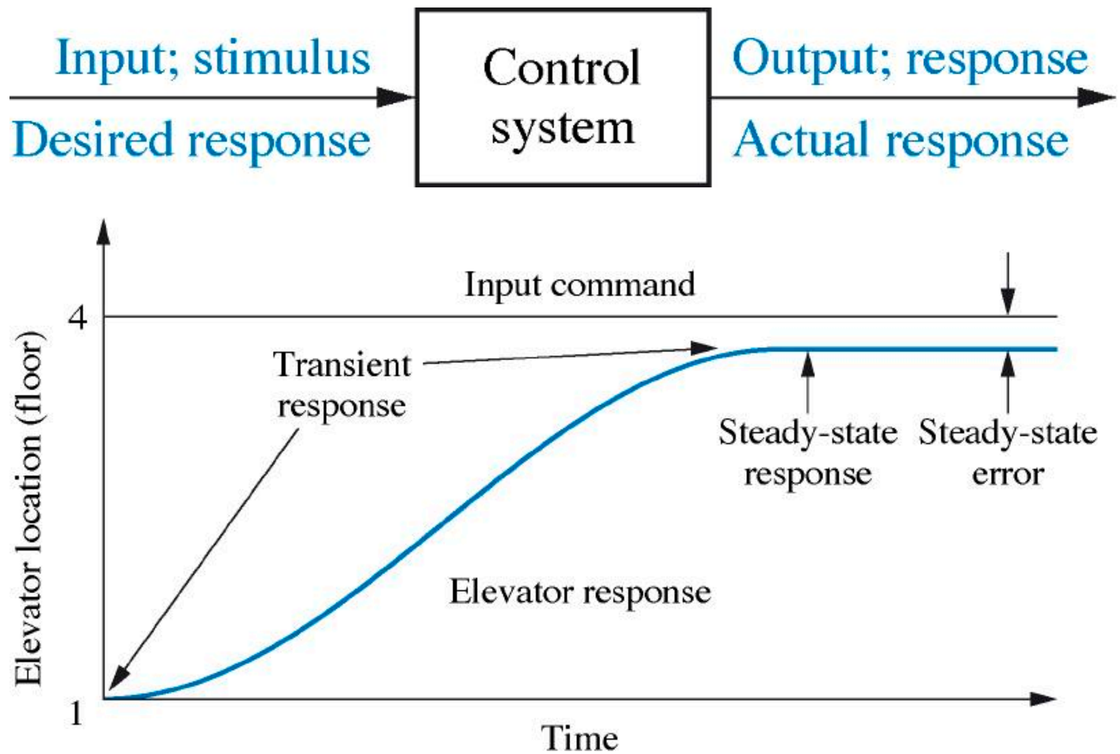
Analysis and Design Objectives

- *Analysis is the process by which a system's performance is determined. For* example, we evaluate its transient response and steady-state error to determine if they meet the desired specifications.



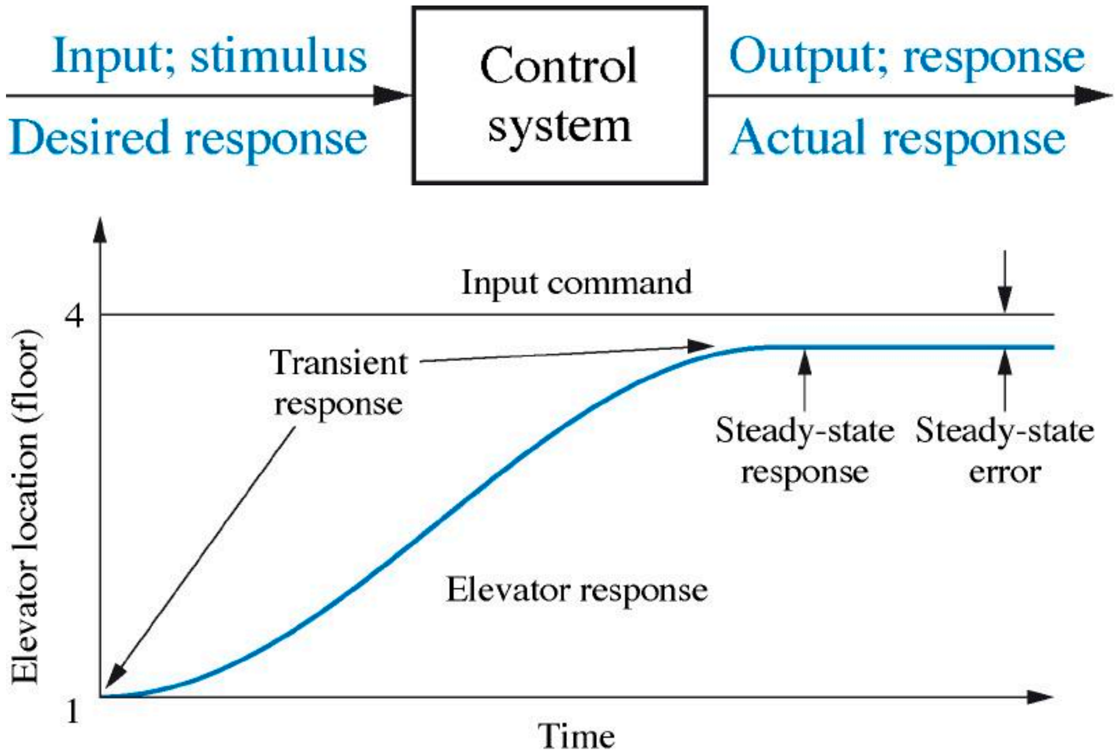
Analysis and Design Objectives

- *<u>Design is the process by which a system's</u>* <u>performance is created or changed.</u> For example, if a system's transient response and steady-state error are analyzed and found not to meet the specifications, then we change parameters or add additional components to meet the specifications.



Analysis and Design Objectives

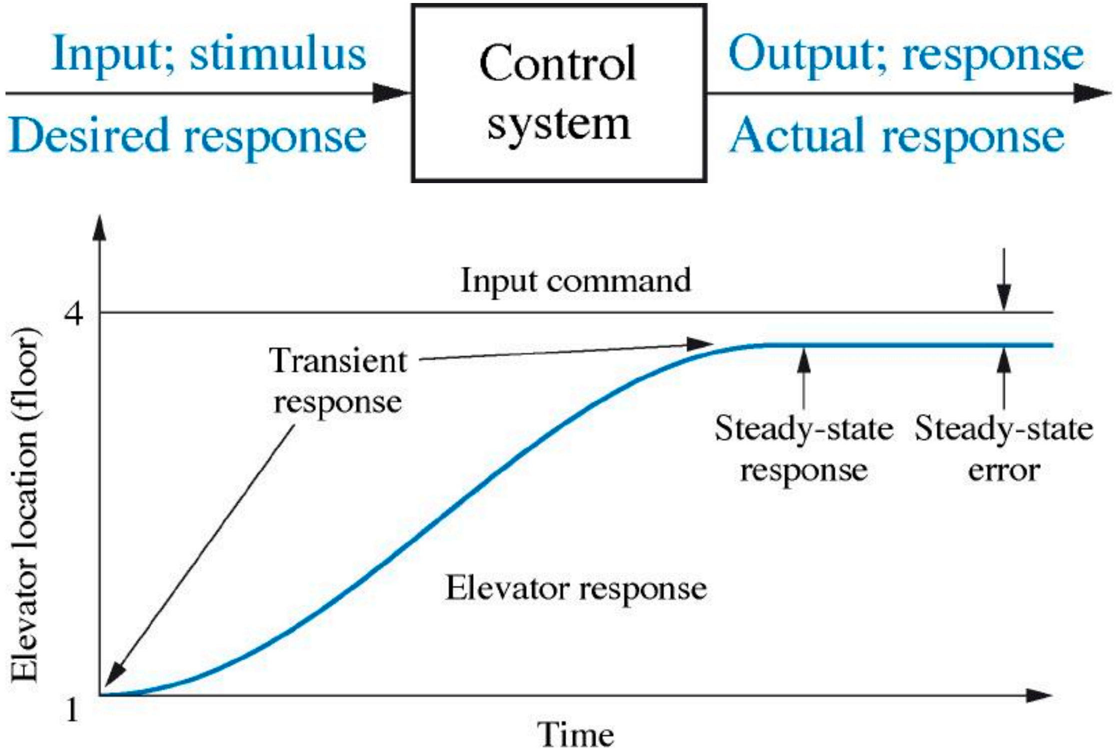
- The **major objectives** of systems analysis and design:
  1. Producing desired transient response
  2. Reducing steady-state error
  3. Achieving <u>stability</u>



Analysis and Design Objectives

Stability

- Control system is a dynamic system.
- Total response = Natural response + Forced response



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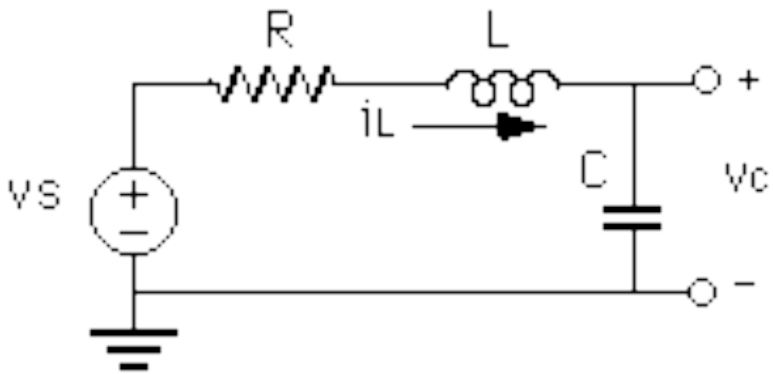

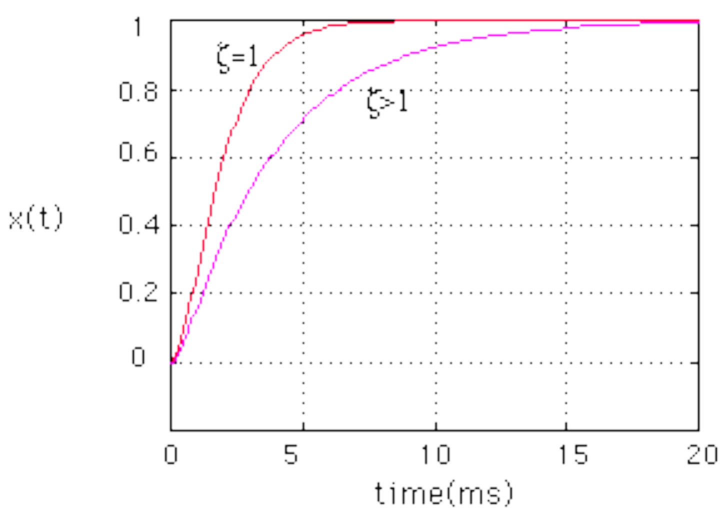

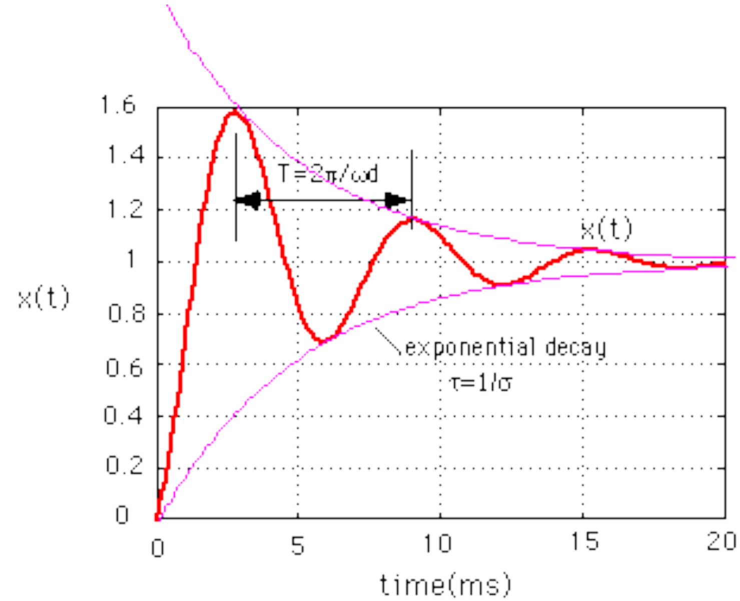

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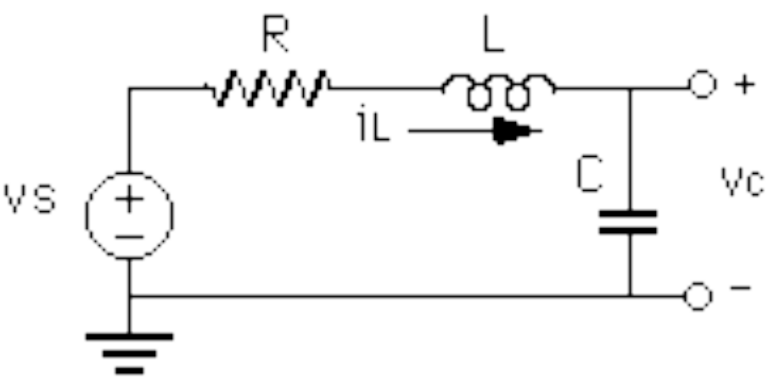
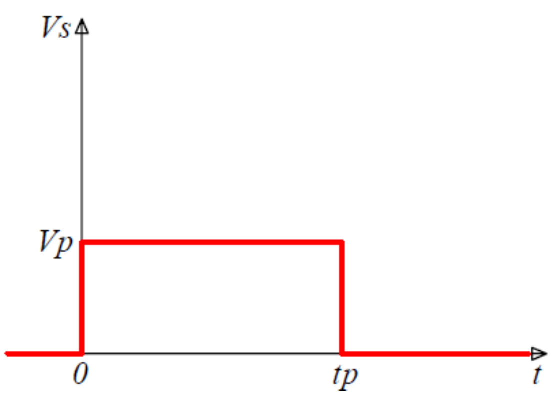
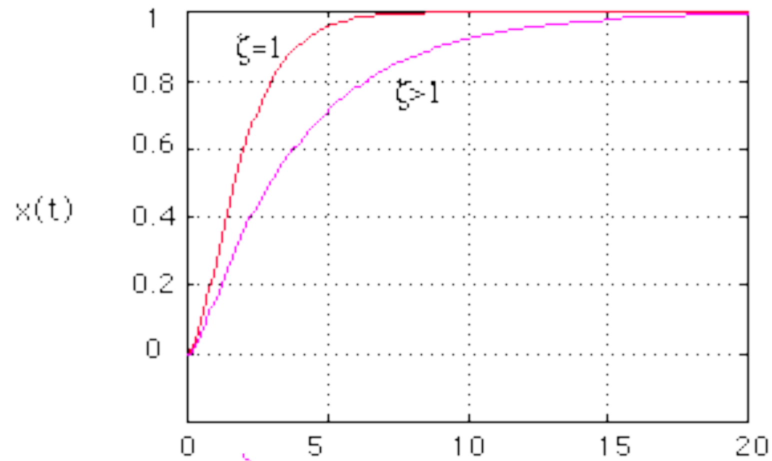
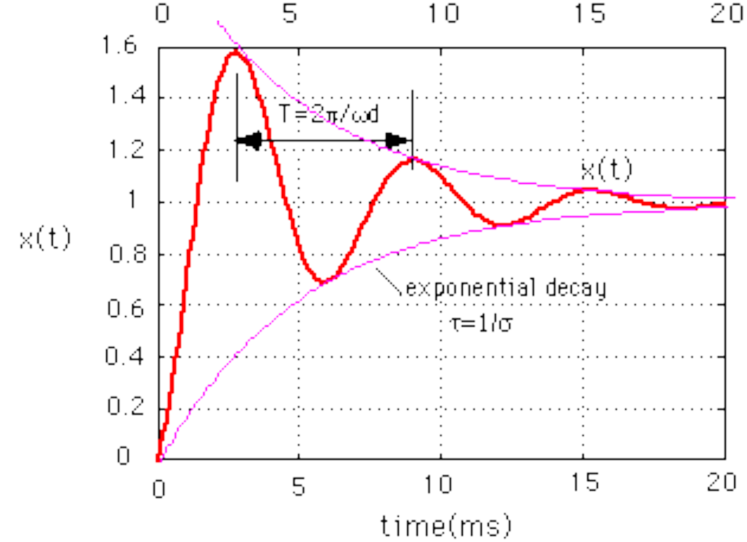




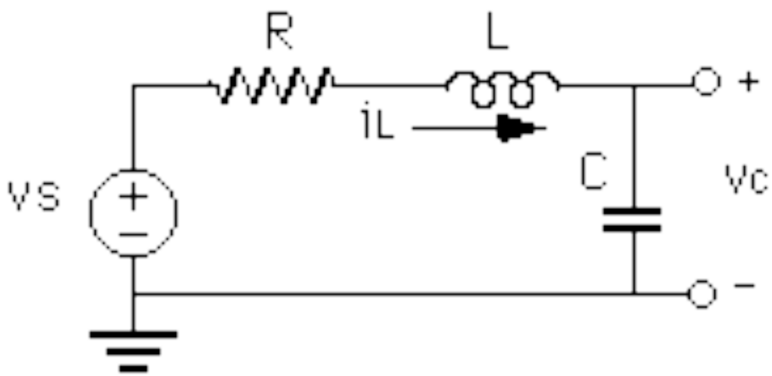


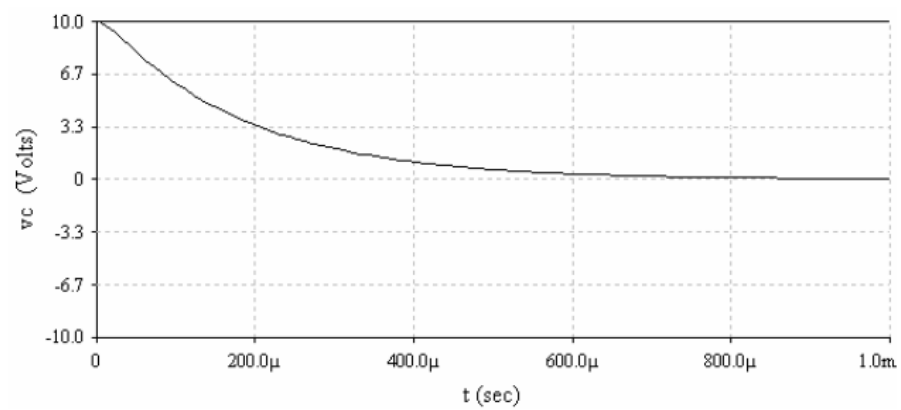


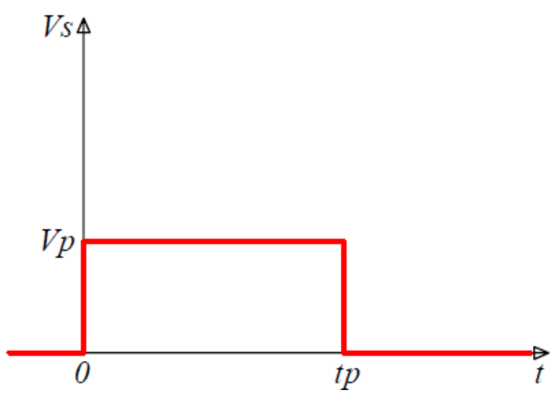
Analysis and Design Objectives

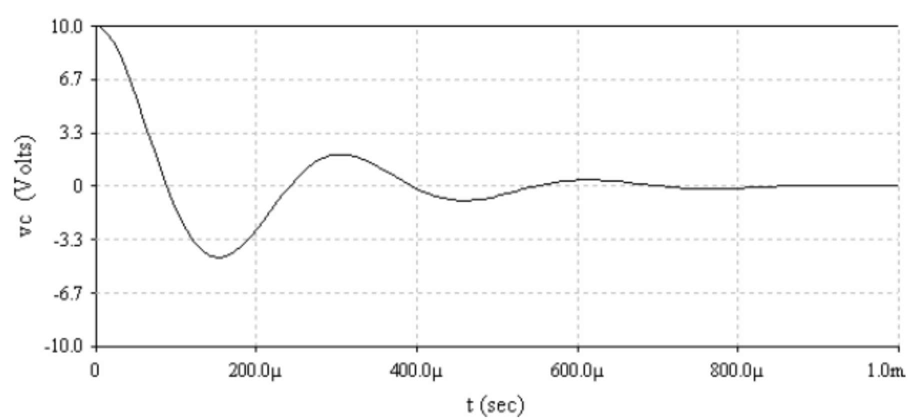
Stability

- **Total response** = Natural response + Forced response
- The **nature response** is dependent only on the system, not the input.





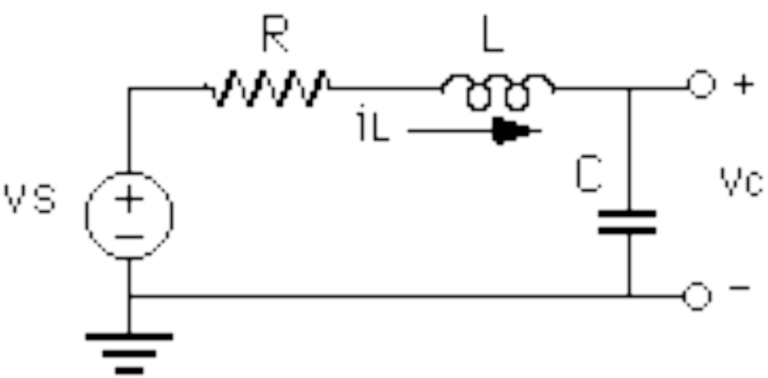


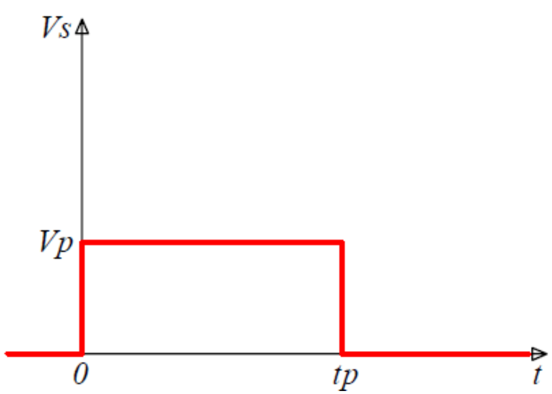


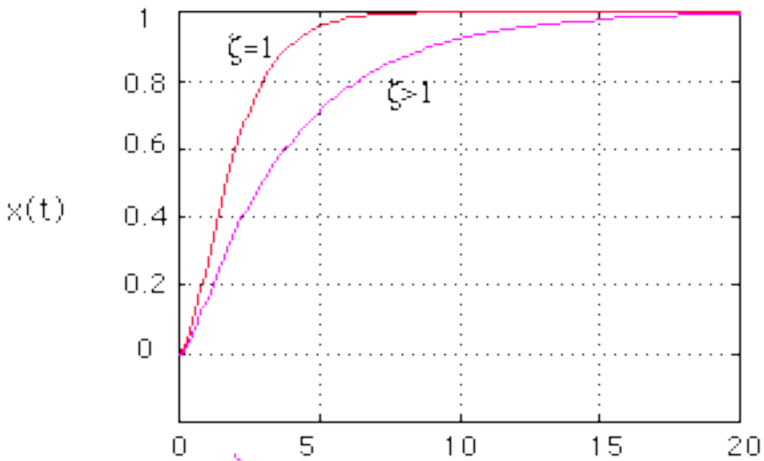
Analysis and Design Objectives

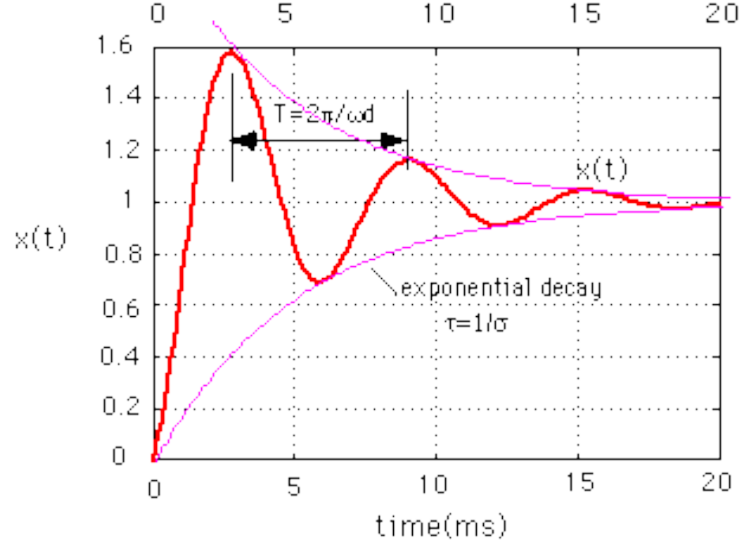
Stability

- If the natural response keeps increasing, the system is unstable.





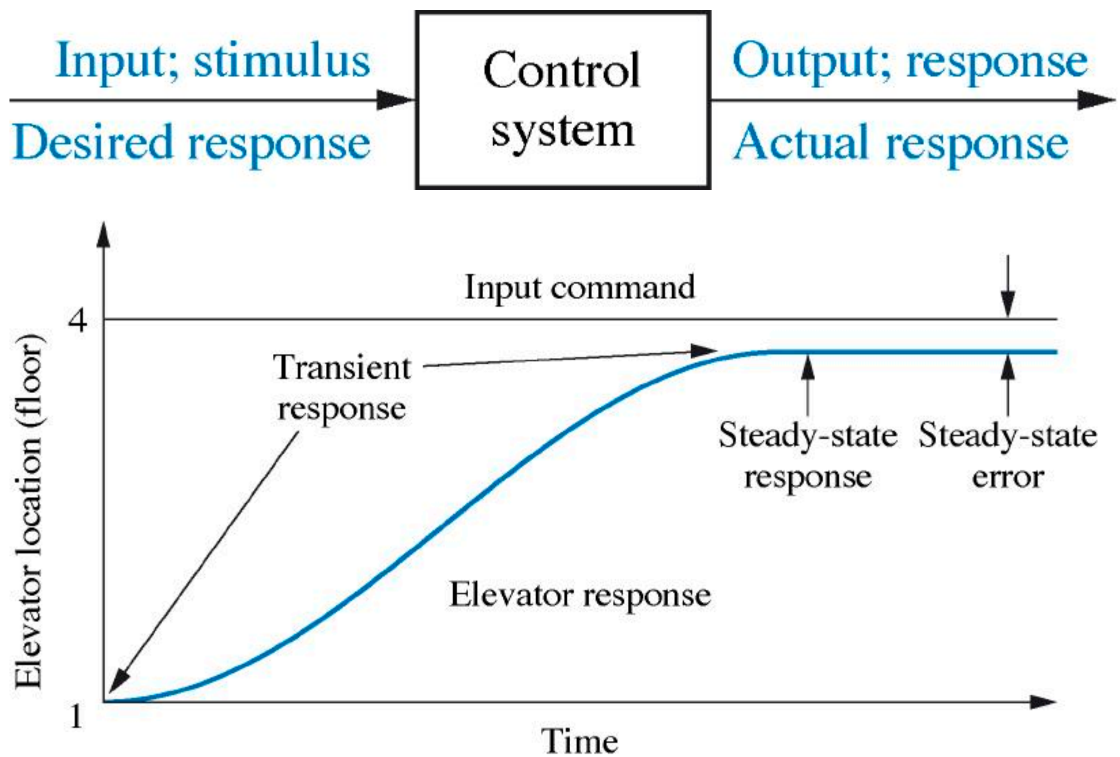




Analysis and Design Objectives

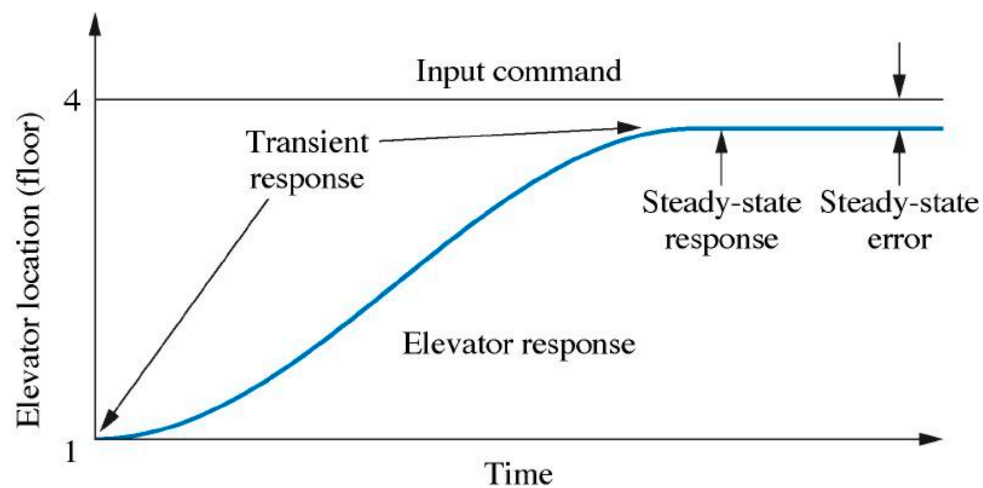
Stability

- For a control system to be useful, the natural response must eventually approach zero, thus leaving only the forced response, or oscillate. Hence the control systems must be designed to be stable.



Analysis and Design Objectives

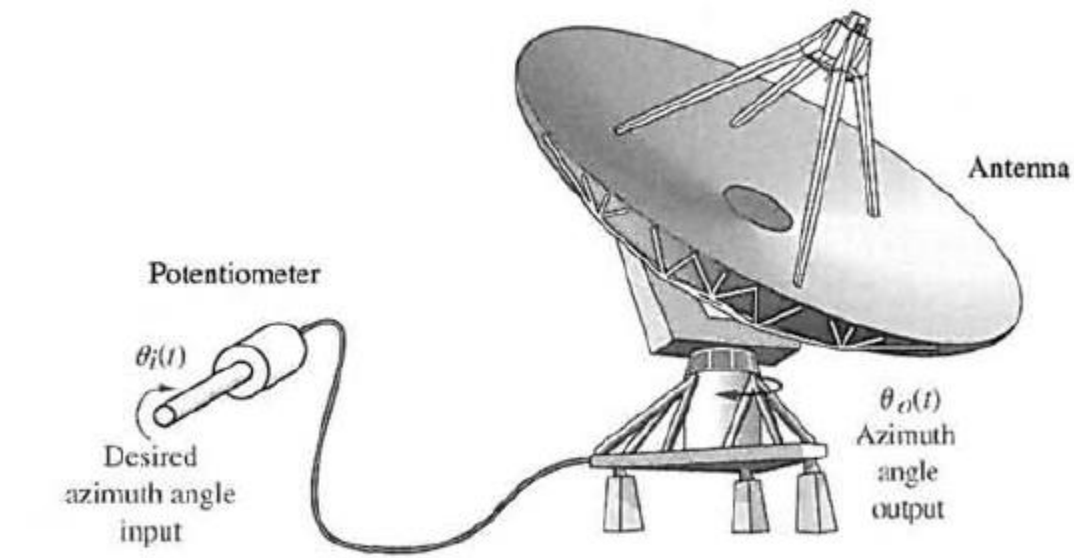
- The **major objectives** of systems analysis and design:
  1. Producing desired transient response
  2. Reducing steady-state error
  3. Achieving stability
- Other considerations:
  - Disturbance rejection
  - Robustness.



Case Study: Antenna Azimuth

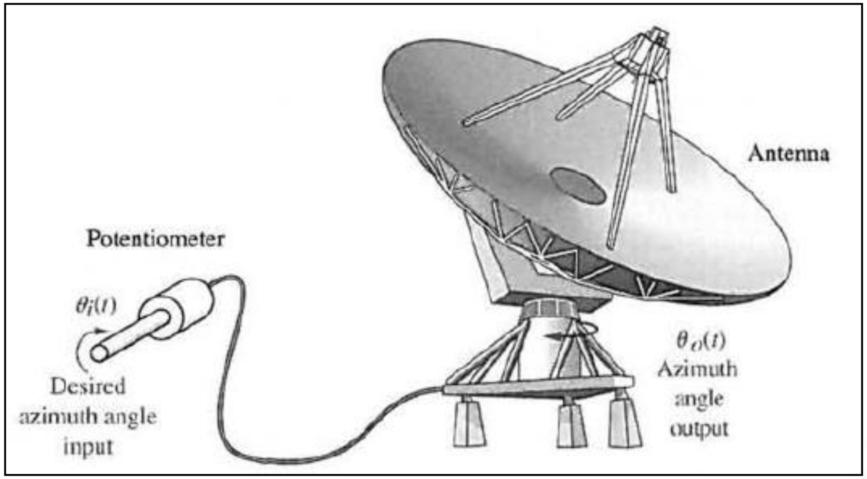
Antenna Azimuth: a position control system

- The radio telescope antennas in the figure is one example of <u>a system that uses *position control systems*</u>



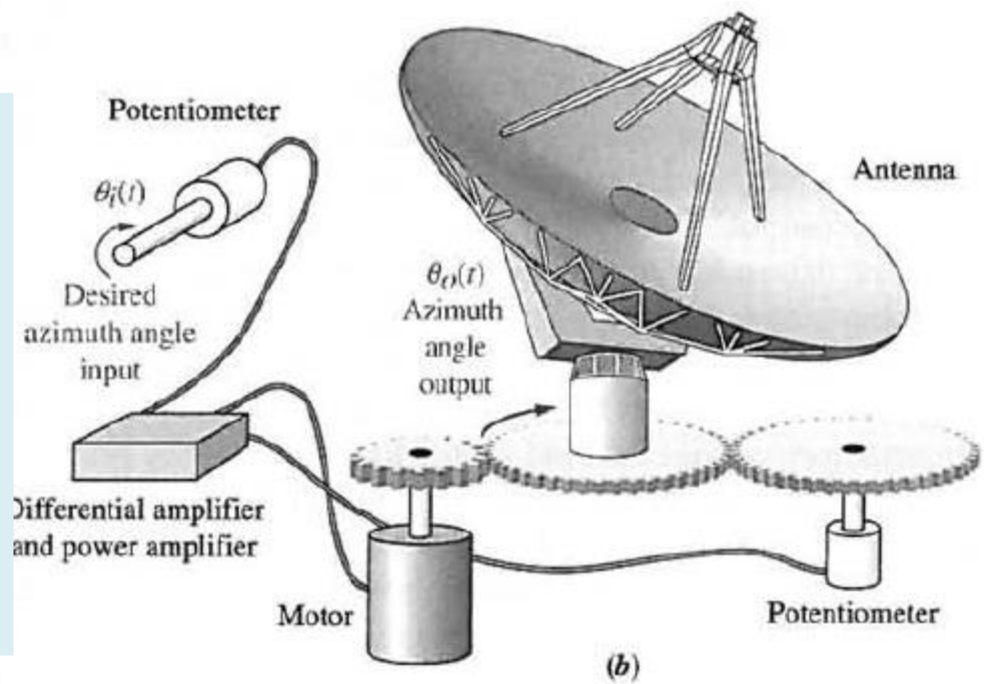
Case Study: Antenna Azimuth

Antenna Azimuth: a position control system



<u>System Concept</u>: The purpose of this system is to have the azimuth angle output of the antenna *follow the input angle of the potentiometer.*

<u>Detailed Layout</u>:
The potentiometer converts the angular displacement into a voltage. The output angular displacement is converted to a voltage by the potentiometer in the feedback path.



Case Study: Antenna Azimuth

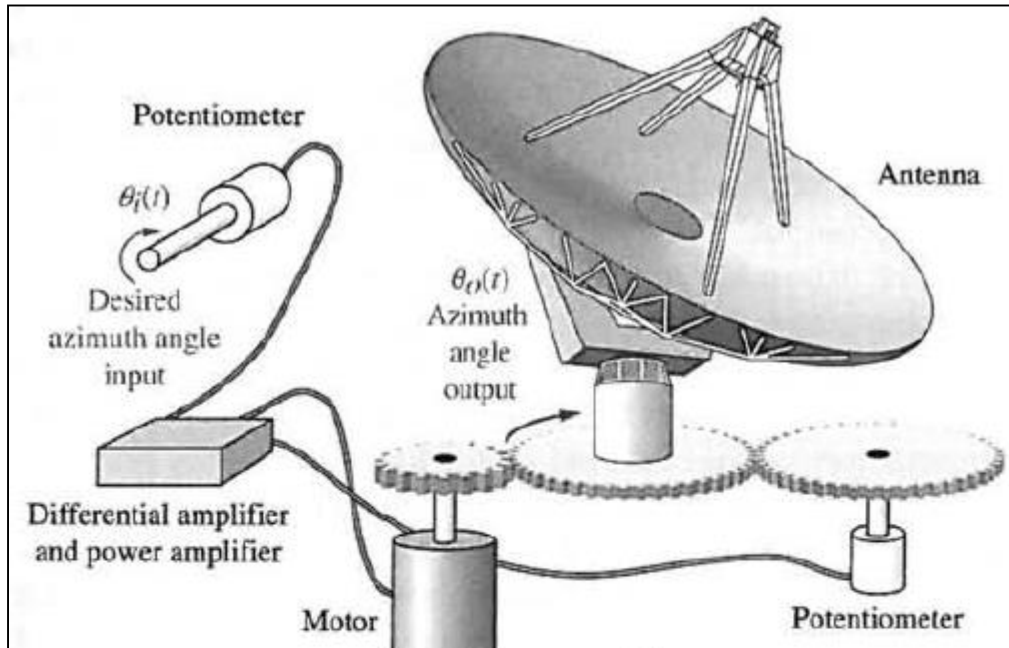
Antenna Azimuth: a position control system

<u>Detailed Layout</u>:

- The potentiometer converts the angular displacement into a voltage.
- The output angular displacement is converted to a voltage by the potentiometer in the feedback path.
- The signal and power amplifiers boost the difference between the input and output voltages.

-This amplified actuating signal drives the plant.

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



(b)

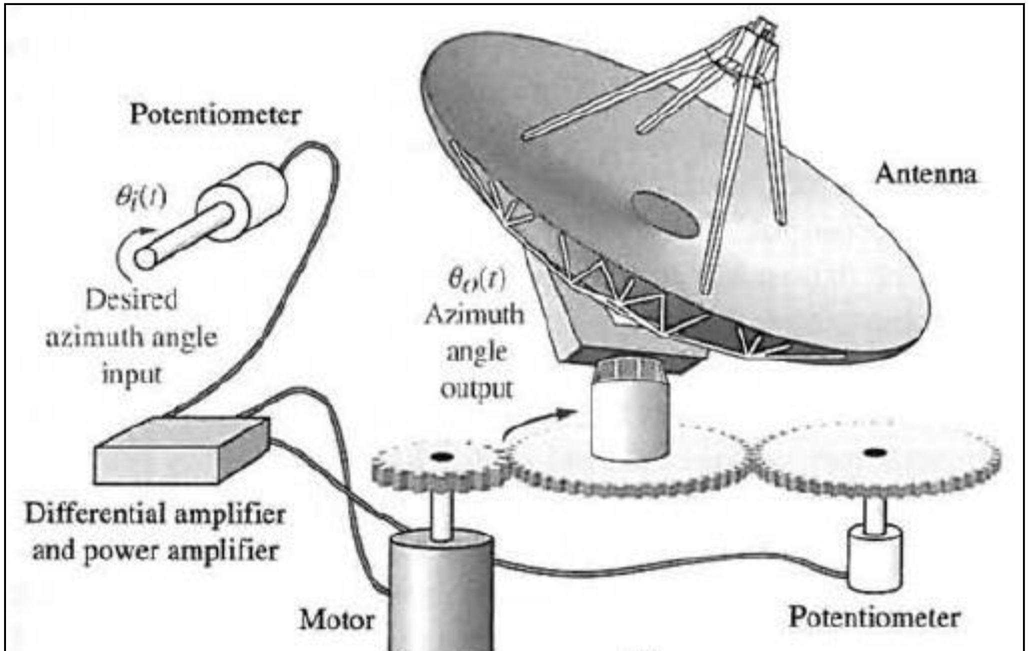
Case Study: Antenna Azimuth

Antenna Azimuth: a position control system

Detailed Layout:

Thus, the motor is driven only when the output and the input do not match. The greater the difference between the input and the output, the larger the motor input voltage, and the faster the motor will turn.

If we increase the gain of the signal amplifier, will there be an increase in the steady-state value of the output?



(*b*)

Case Study: Antenna Azimuth

Antenna Azimuth: a position control system

Detailed Layout:

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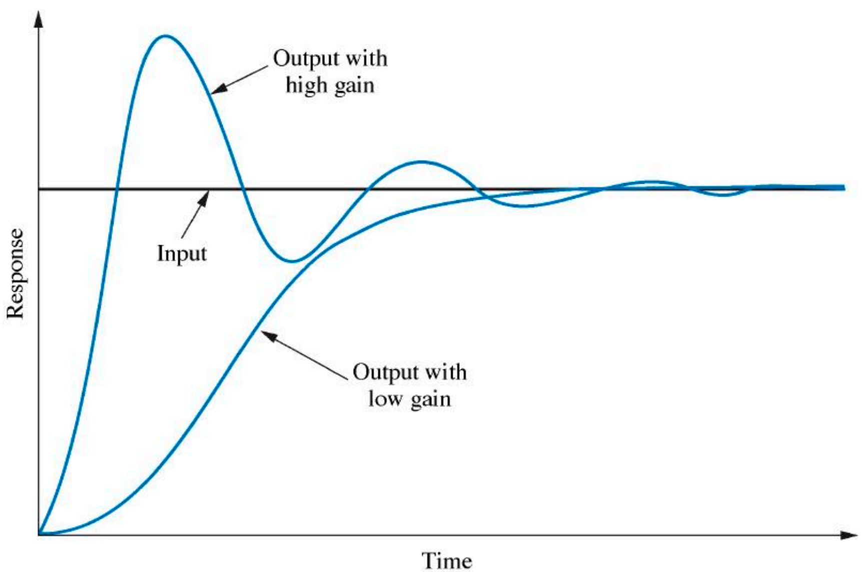
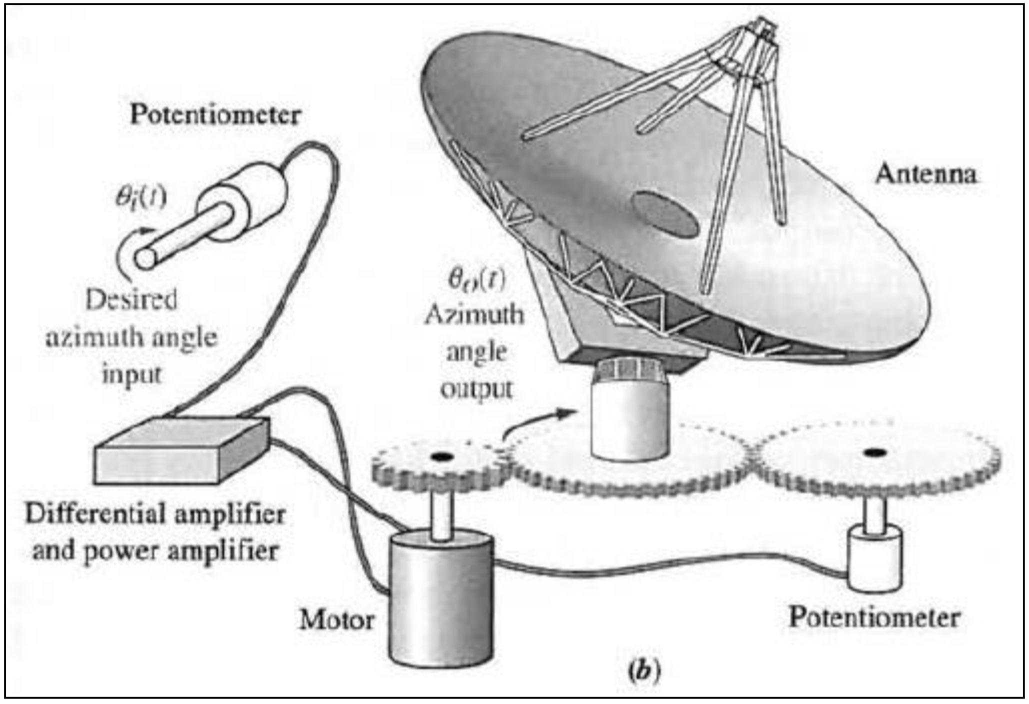




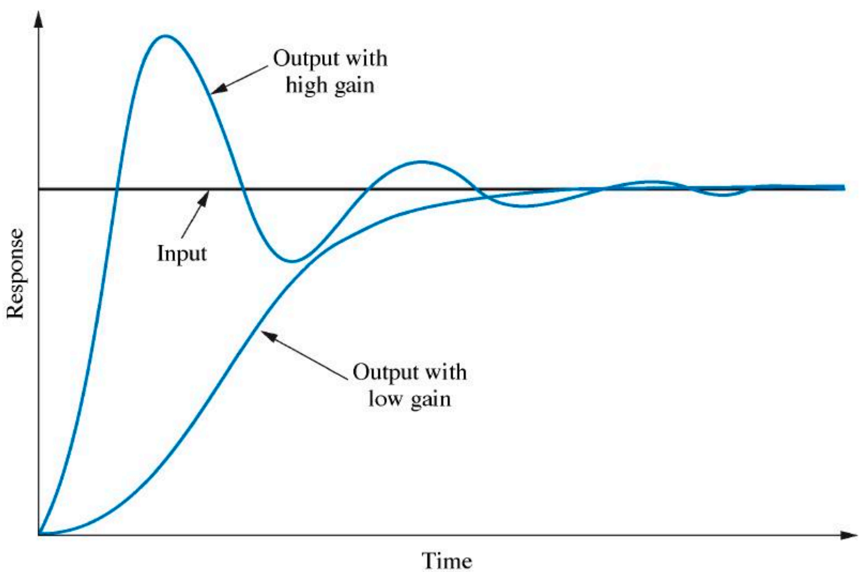
Case Study: Antenna Azimuth

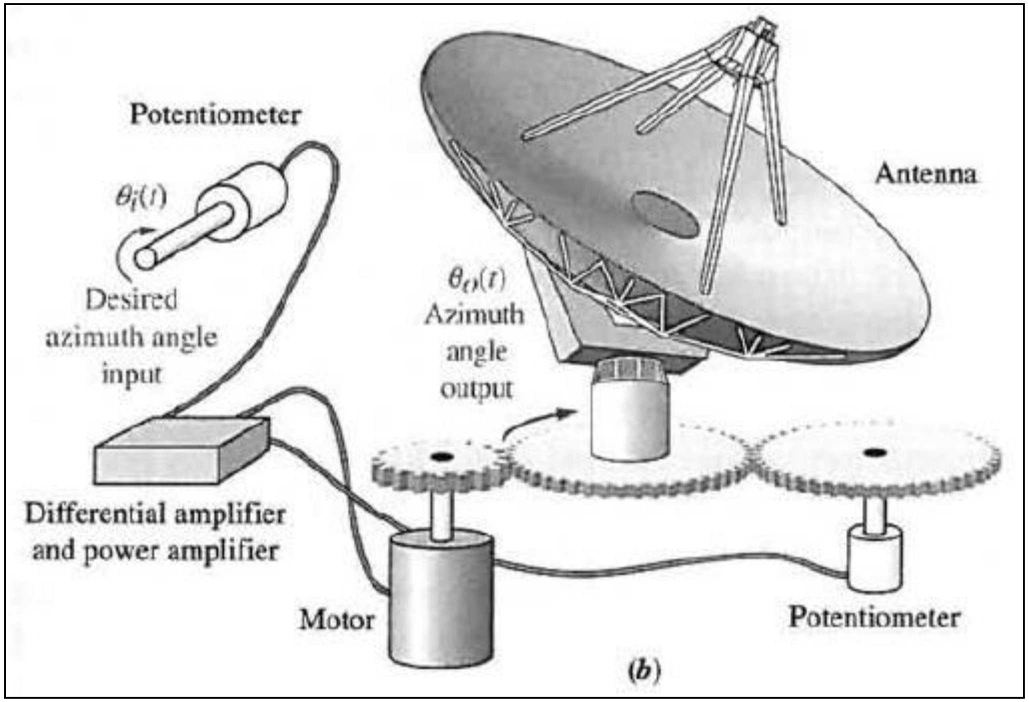
Antenna Azimuth: a position control system

Detailed Layout:

Steady-state error is the difference between the input and the output after the transients have effectively disappeared.

Typically, the steady-state error decreases with an increase in gain and increases with a decrease in gain.



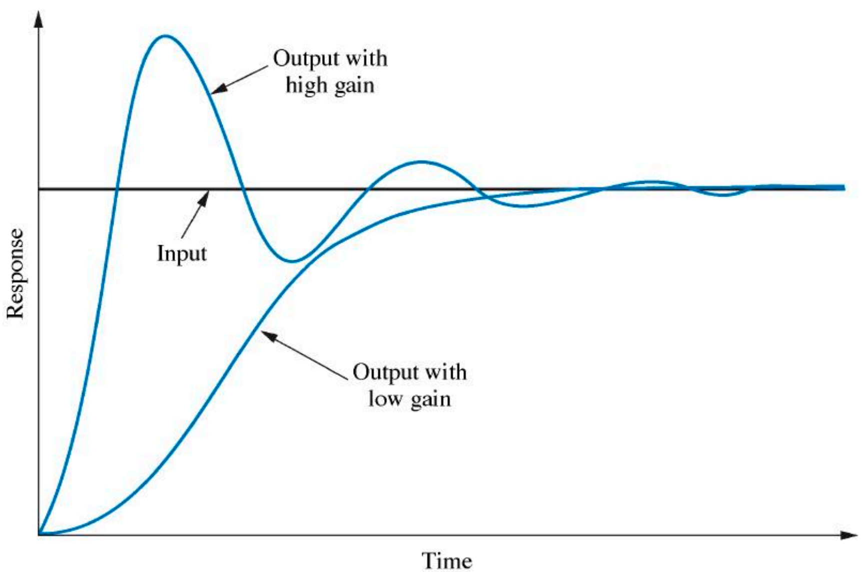


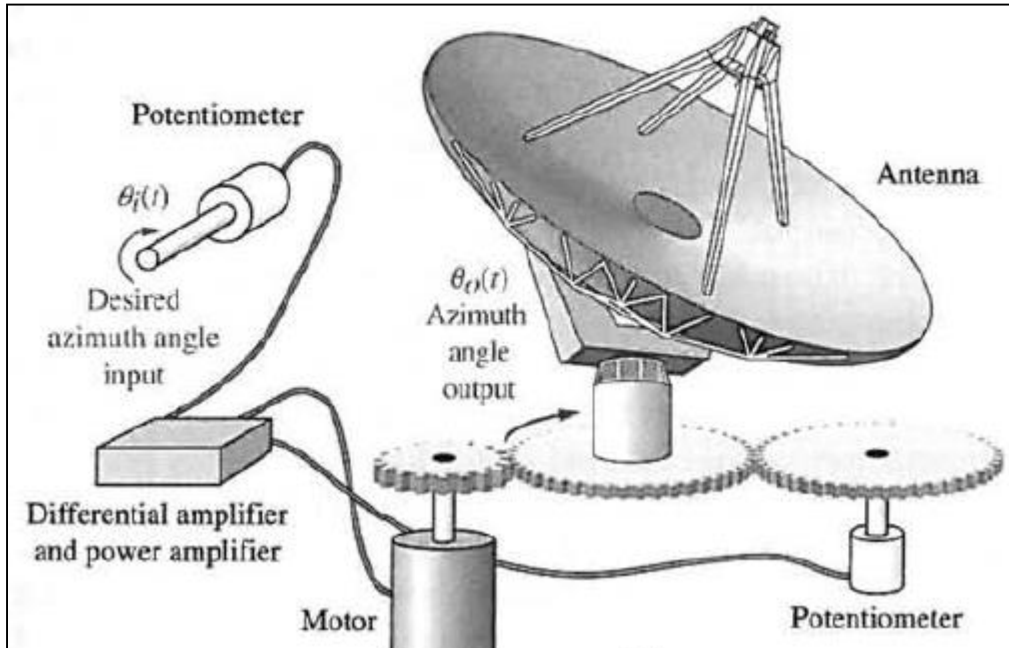
Case Study: Antenna Azimuth

Antenna Azimuth: a position control system

Detailed Layout:

Gain adjustments can affect performance and sometimes lead to trade-offs between the performance criteria.

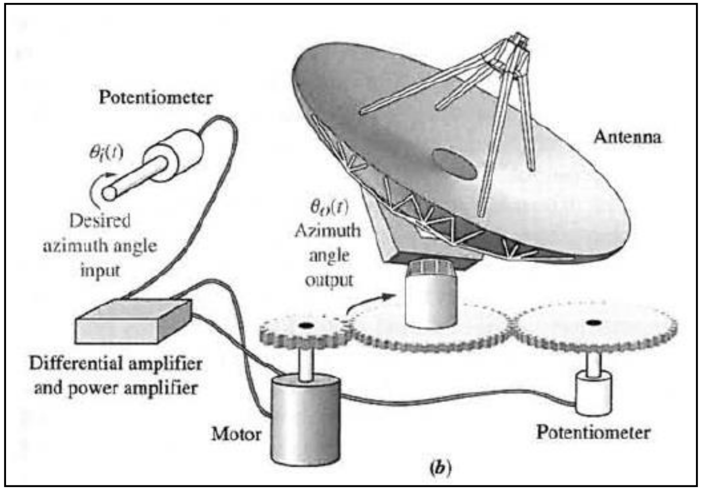




(b)

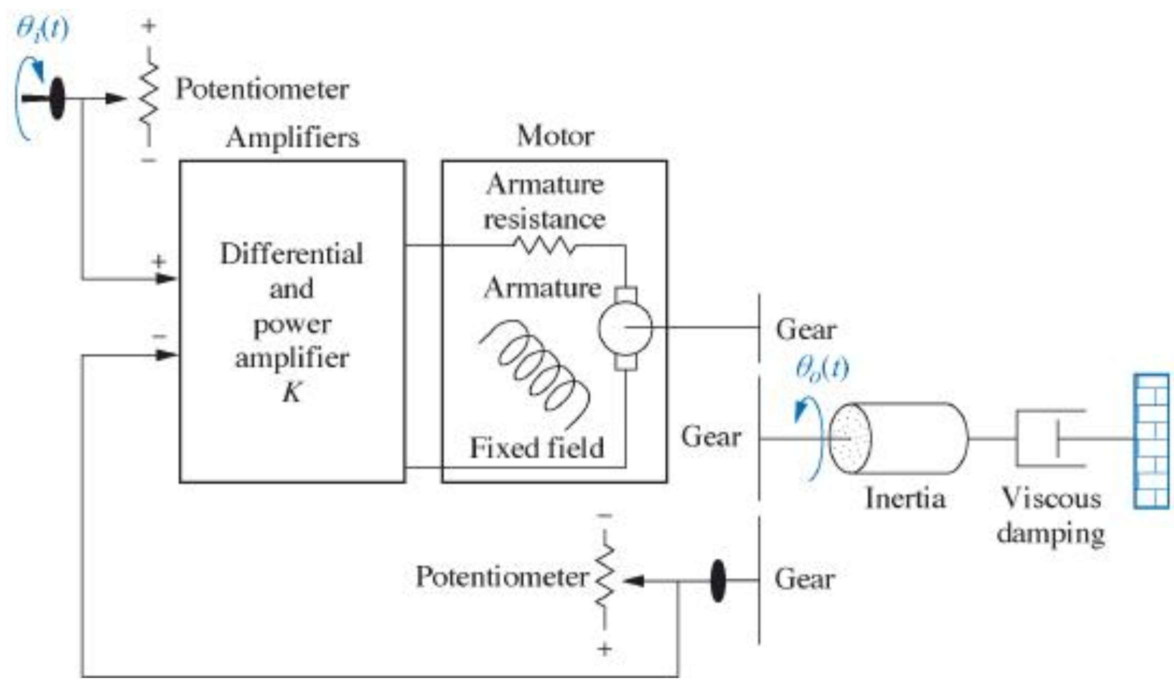
Case Study: Antenna Azimuth

Antenna Azimuth: a position control system



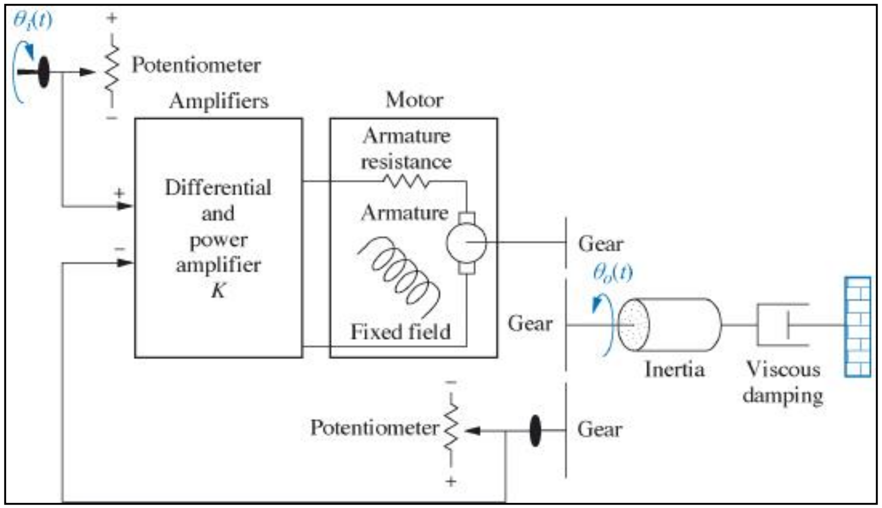
<u>Schematic</u>:

- Schematic is a better way to show the system than the detailed layout.
- However it is not convenience to draw the schematic.

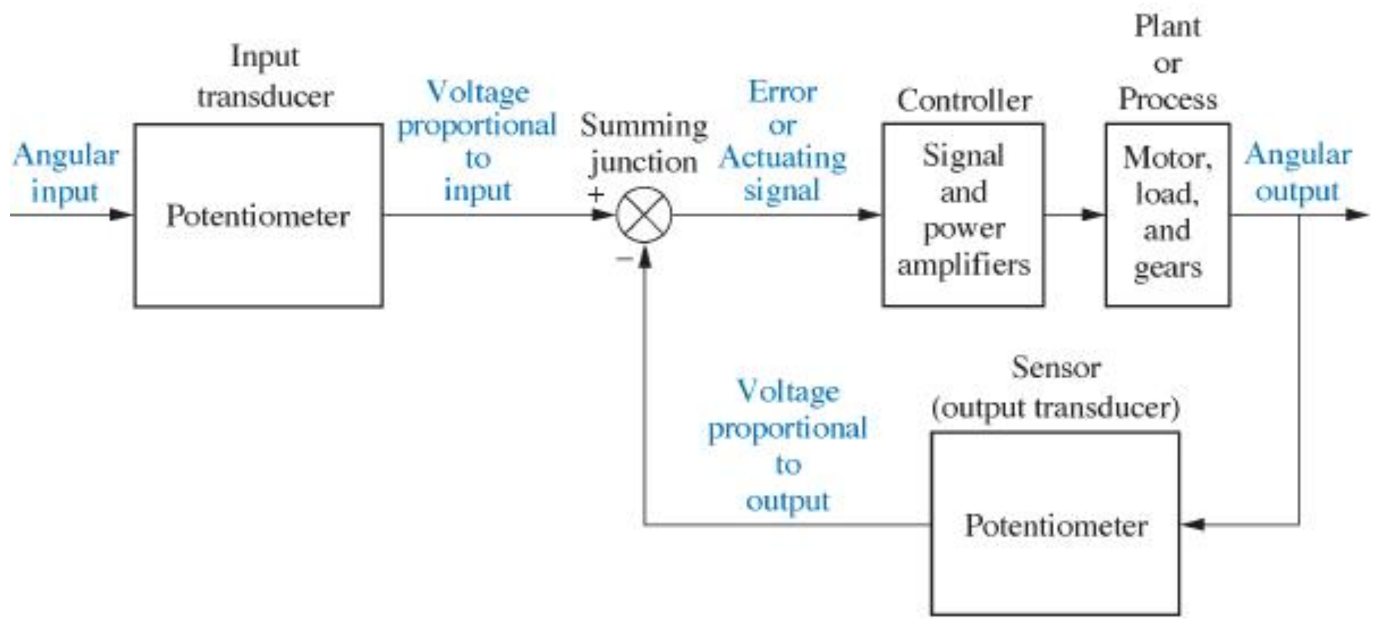


Case Study: Antenna Azimuth

Antenna Azimuth: a position control system



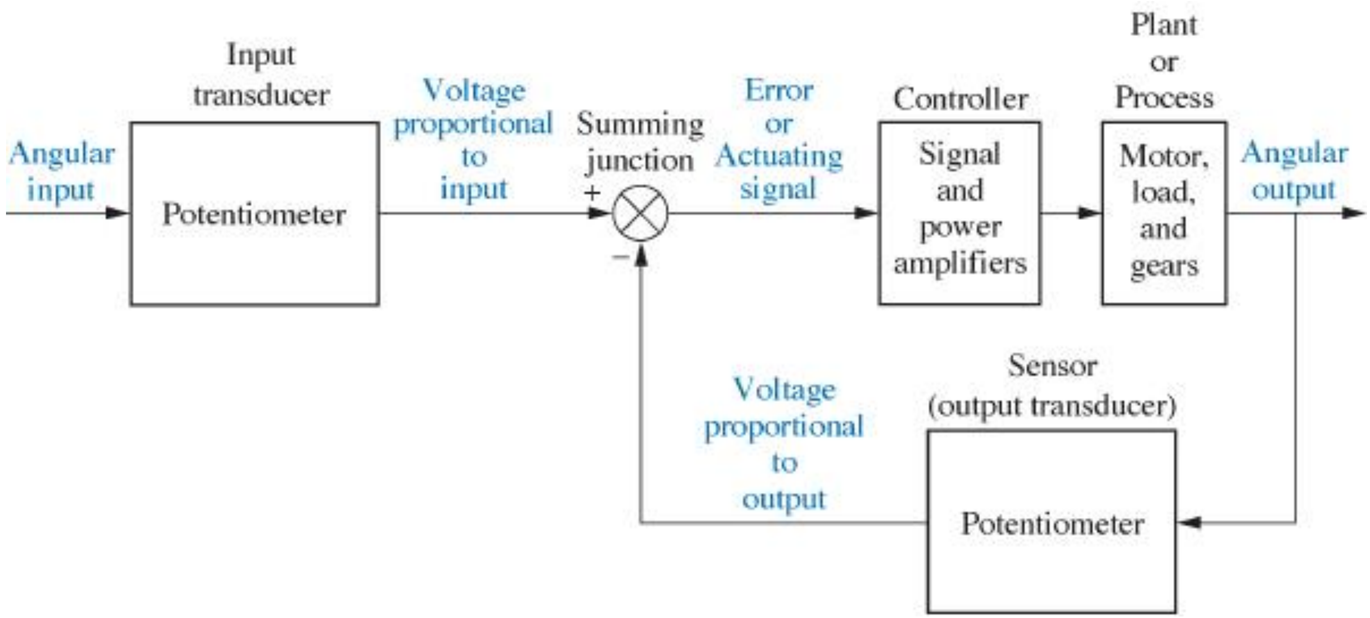
Block diagram:
- The diagram is suitable for system analysis and design.
- **In Control Engineering, the systems are shown by using block diagram.**



Analysis and Design Objectives

Antenna Azimuth: a position control system

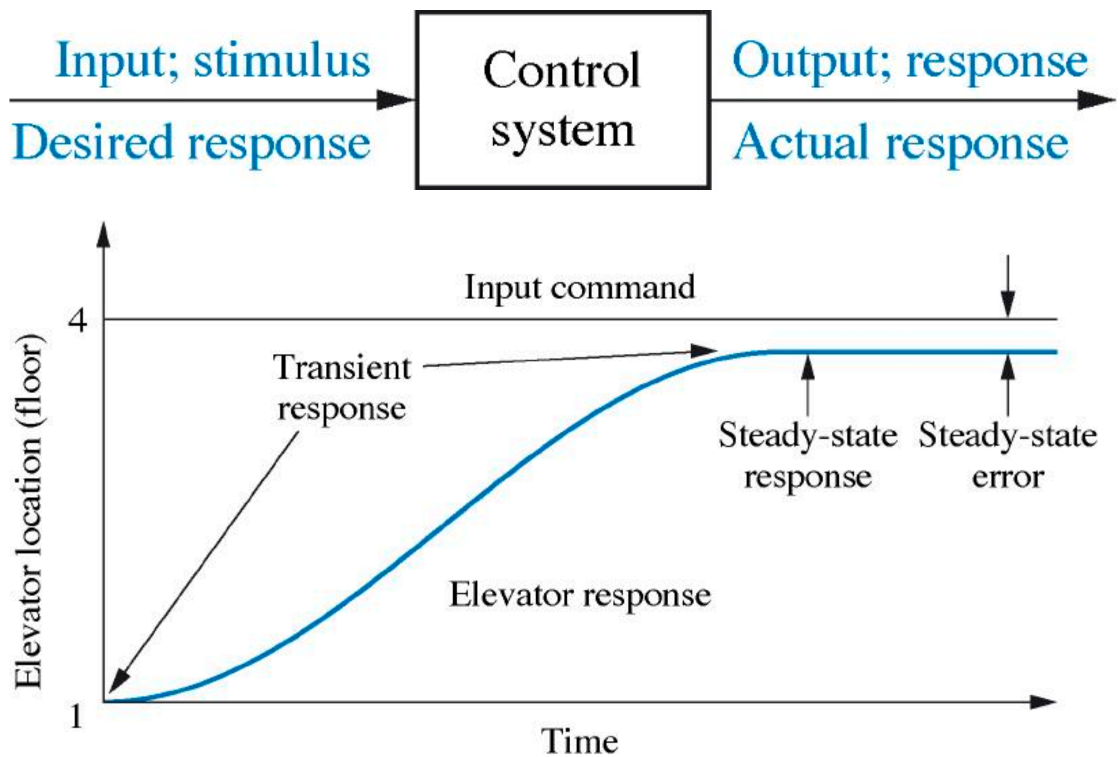
<u>Note</u>: Before analysis and design, the system must be displayed in block diagram. Then the mathematical model of each block has to be defined.



Analysis and Design Objectives

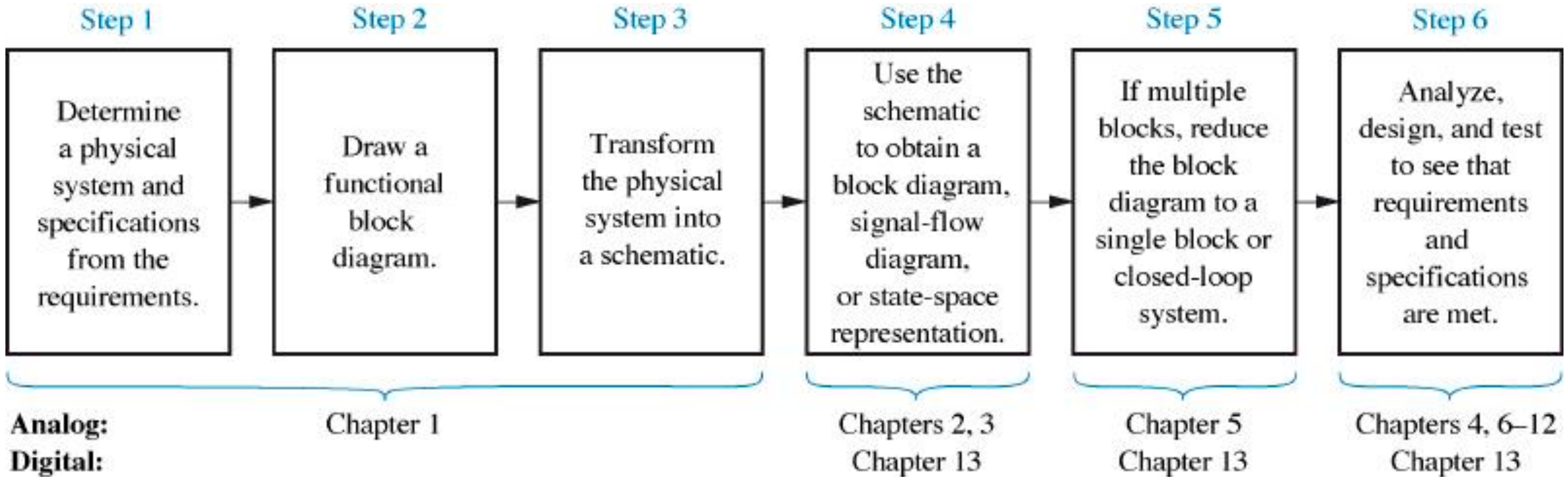
Summary:

- Our design objectives and the system's performance revolve around the transient response, the steady-state error, and stability.



Introduction

- **The Design Process**



Conclusion

- A control system has an *input, a process, and an output. Control systems can be open loop or closed loop.*

- Open-loop systems do not monitor or correct the output for disturbances.
- Closed-loop systems monitor the output and compare it to the input.

Conclusion

- Control systems analysis and design focuses on three primary objectives:

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

Conclusion

The design of a control system follows these steps:

1. Determine a physical system and specifications from requirements.
2. Represent the physical system as a schematic.
3. Use the schematic to obtain a mathematical model, such as a *transfer function*.
4. Reduce the block diagram.
5. Analyze and design the system to meet specified requirements and specifications that include stability, transient response, and steady-state performance.