1

Introduction to Control Systems

In this lecture, we lead you through a study of the basics of control system. After completing the chapter, you should be able to

- Describe a general process for designing a control system.
- Understand the purpose of control engineering
- Examine examples of control systems
- Understand the principles of modern control engineering.
- Realize few design examples.

Textbook

1. Richard C. Dorf and Robert H. Bishop, Modern Control Systems, Prentice Hall, 2001.

1.1 INTRODUCTION

Control engineering is based on the foundations of feedback theory and linear system analysis, and it generates the concepts of network theory and communication theory. Accordingly, control engineering is not limited to any engineering discipline but is applicable to aeronautical, chemical, mechanical, environmental, civil, and electrical engineering.

A **control system** is an interconnection of components forming a system configuration that will provide a desired system response. The basis for analysis of a system is the foundation provided by linear system, which assumes a cause-effect relationship for the components of a system. A component or process to be controlled can be represented by a block as shown in Figure 1.

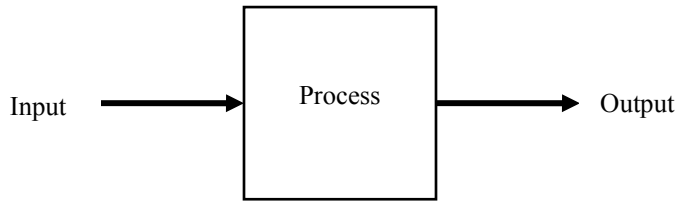


Figure 1 Process under control

An open-loop control system utilizes a controller or control actuator to obtain the desired response as shown in Figure 2. The open-loop control system utilizes an actuating device to control the process directly without using device. An example of an open-loop control system is an electric toaster.

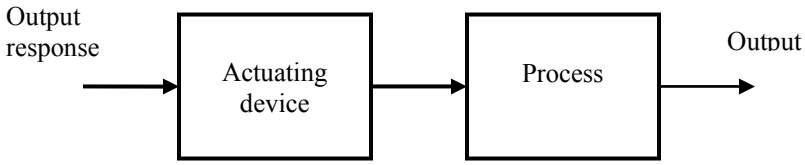


Figure 2 Open-loop control system (no feedback)

A **closed-loop control system** (Figure 3) utilizes an additional measure of the actual output to compare the actual output with the desired output response. The measure of the output is called the **feedback signal**. A feedback control system is a control system that tends to maintain a relationship of one system variable to another by comparing functions of these variables and using the difference as a means of control. As the system is becoming more complex, the interrelationship of many controlled variables may be considered in the control scheme. An example of closed-loop control system is a person steering an automobile by looking at the auto's location on the road and making the appropriate adjustments.

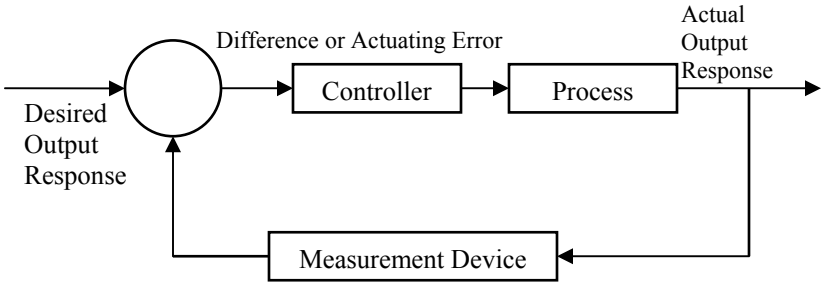


Figure 3 Closed-loop feedback system.

1.2 TEMPERATURE CONTROL SYSTEMS

Figure 4 shows a diagram of temperature control of an electric furnace. The temperature in the electric furnace is measured by a thermometer, which is an analog device. The analog temperature is converted to a digital temperature by an A/D converter. The digital temperature is fed to a controller through an interface. This digital temperature is compared with the programmed input temperature, and if there is any error, the controller sends out a signal to the heater, through an interface, amplifier, and relay, to bring the furnace temperature to a desired value.

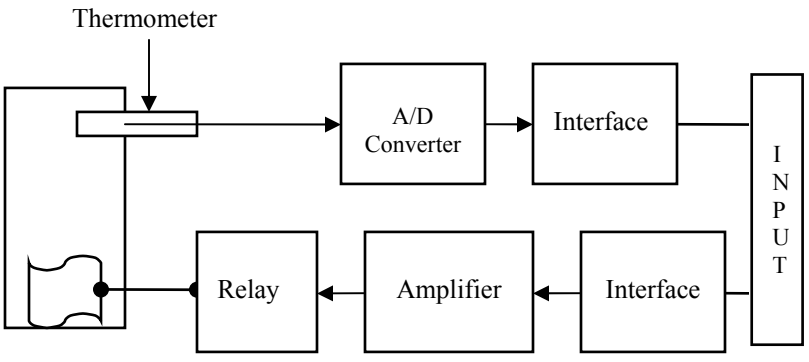
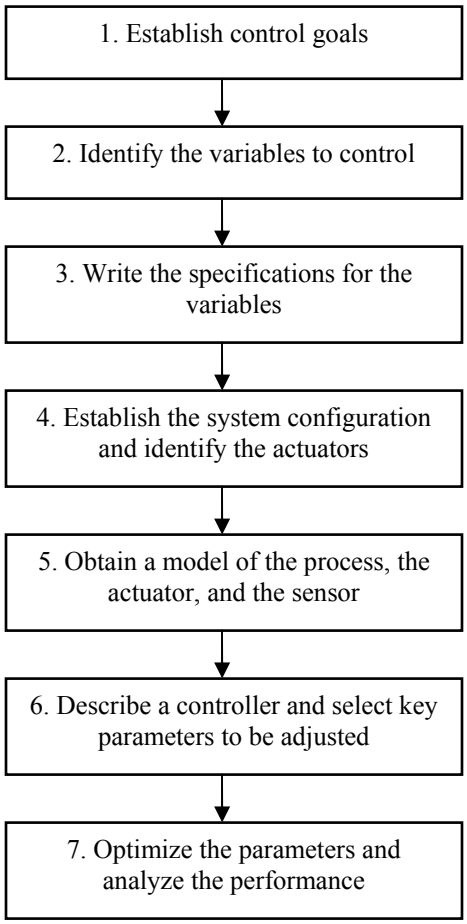


Figure 4 Temperature control system.

1.3 CONTROL SYSTEM DESIGN

The following table shows the control system design process.



- Variables to control are the quantities or conditions that are measured and controlled.
- Process is a natural, progressively continuing operation marked by a series of gradual changes that succeed one another in a relatively fixed way and lead toward certain result or end.
- A system is a combination of components that act together and perform a certain objective.

1.4 DESIGN EXAMPLE: TURNABLE SPEED CONTROL

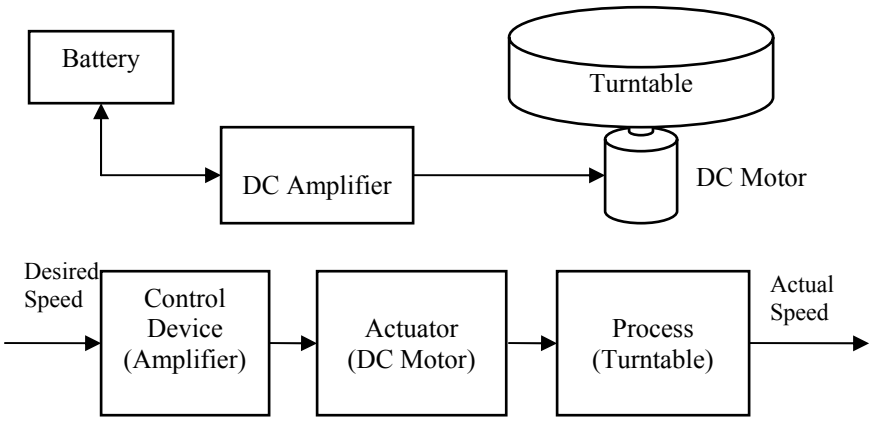


Figure 5 Open-loop control of speed of a turntable and a block diagram model.

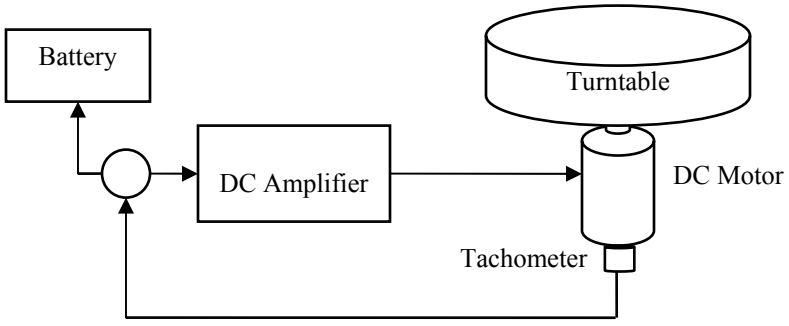


Figure 6 Closed-loop control of the speed of a turntable.

1.5 DESIGN EXAMPLE: DISK DRIVE READ SYSTEM

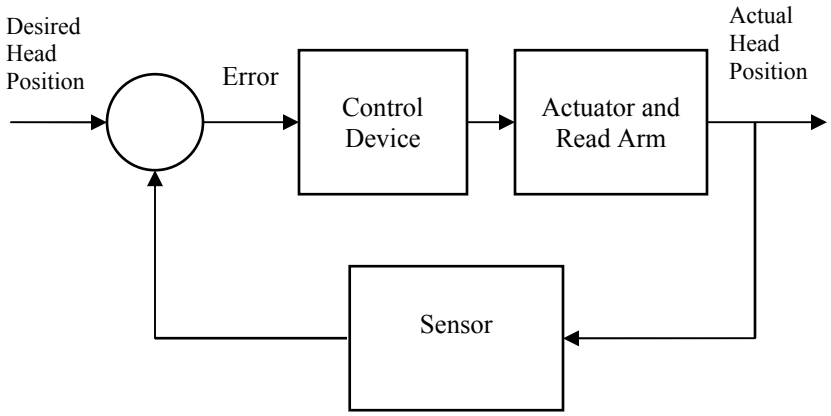


Figure 7 Closed-loop control system for disk drive.

A hard disk uses round, flat disks called *platters*, coated on both sides with a special *media* material designed to store information in the form of magnetic patterns. The platters are mounted by cutting a hole in the center and stacking them onto a *spindle*. The platters rotate at high speed, driven by a special *spindle motor* connected to the spindle. Special electromagnetic read/write devices called *heads* are mounted onto *sliders* and used to either record information onto the disk or read information from it. The sliders are mounted onto *arms*, all of which are mechanically connected into a single assembly and positioned over the surface of the disk by a device called an *actuator*. A *logic board* controls the activity of the other components and communicates with the rest of the computer. For details see Figure 8 and Figure 9.

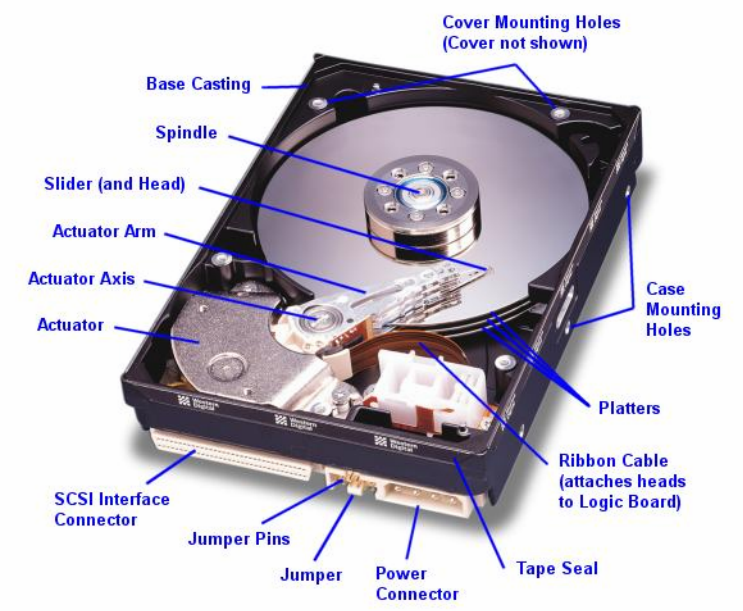


Figure 8 A hard disk.

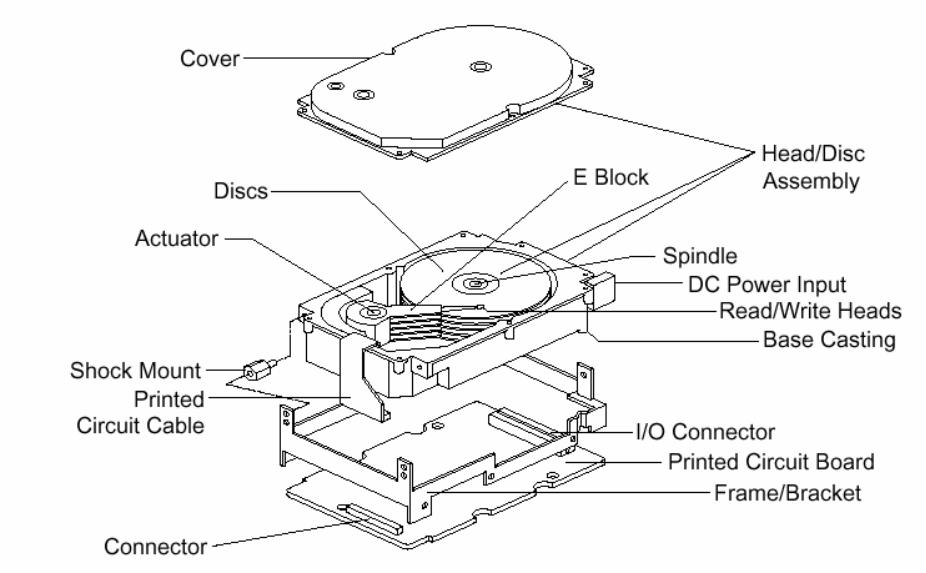


Figure 9 Components of a hard disk

1.6 FEEDBACK CONTROL OF AN ANTIAIRCRAFT GUN

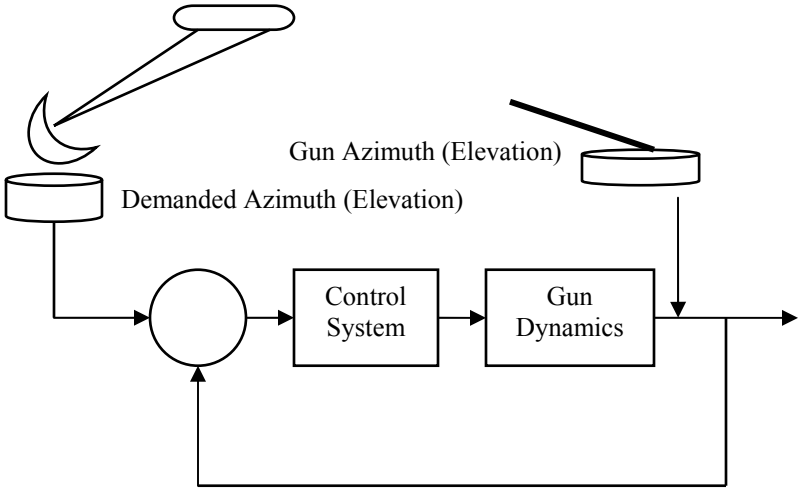
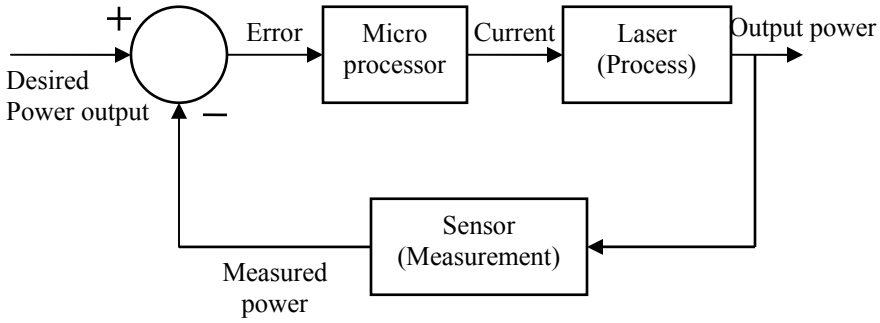


Figure 10 Feedback control of an antiaircraft system.

Exercises

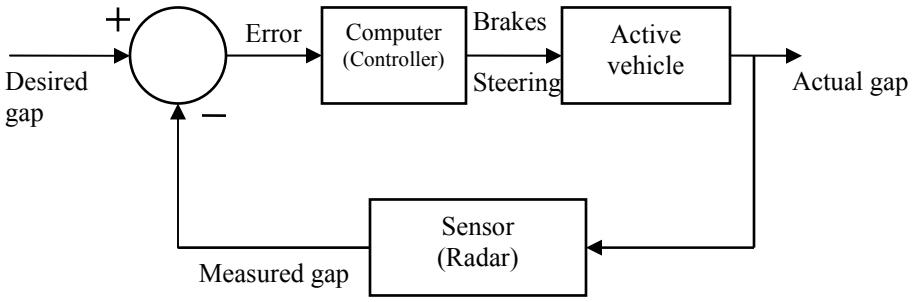
E1.1

A precise optical signal source can control the output power level to within 1%. A laser is controlled by an input current to yield the output power. A microprocessor controls the input current to the laser. The microprocessor compares the desired power level with a measured signal proportional to the laser power output obtained from a sensor. Draw the block diagram representing the closed-loop control system.



E1.6

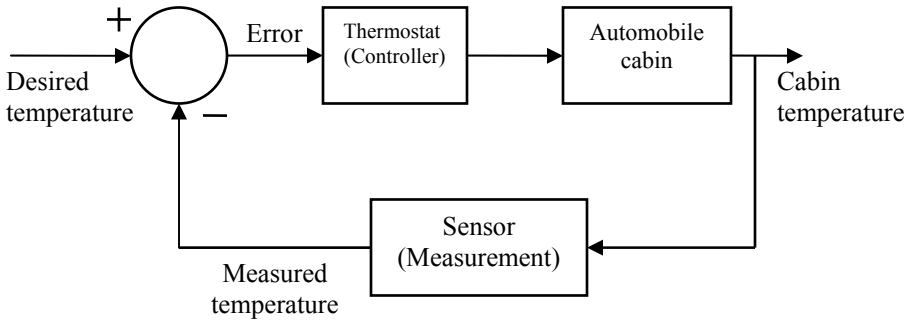
Automated highways may be prevalent in the next decade. Consider two automated highway lanes merging into a single lane, and describe a control system that ensures that the vehicle merge with a prescribed gap between two vehicles.



Problems

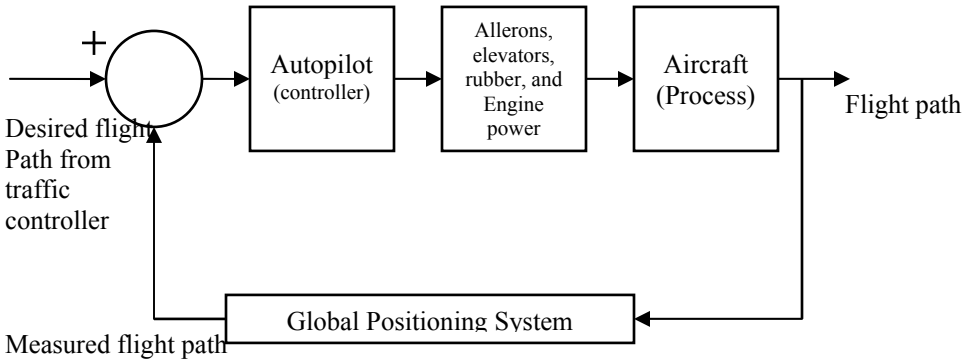
P1.1

Many luxury automobiles have thermostatically controlled air-conditioning systems for the comfort of the passengers. Sketch a block diagram of an air-conditioning system where the driver sets the desired interior temperature on a dashboard panel.



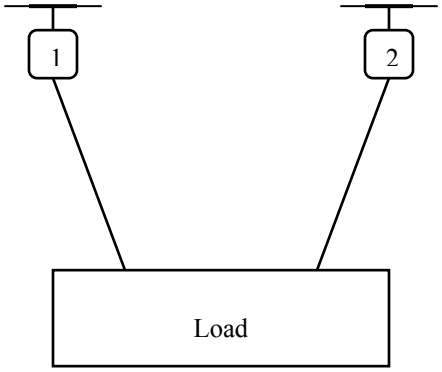
P1.10

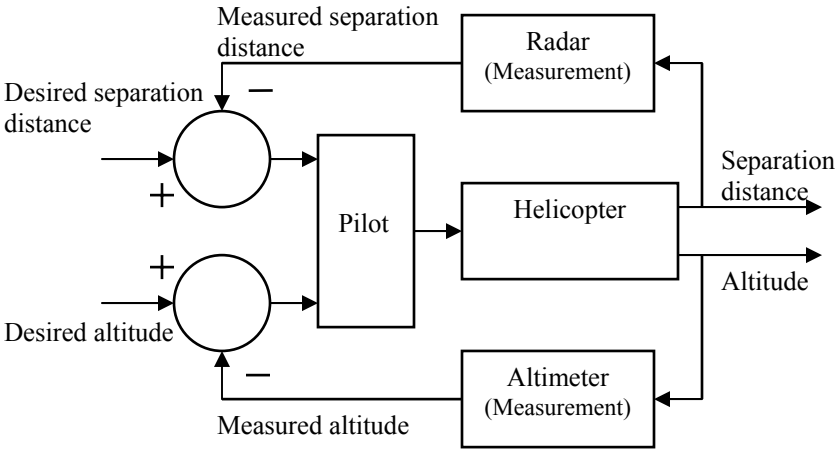
The role of air traffic control systems is increasing as airplane traffic increases at busy airports. Engineers are developing air traffic control systems and collision avoidance systems using the Global Positioning System (GPS) navigation satellites. GPS allows each aircraft to know its position in the airspace landing corridor very precisely. Sketch a block diagram depicting how an air traffic controller might utilize GPS for aircraft collision avoidance.



P1.21

The potential of employing two or more helicopters for transporting payloads that are too heavy for a single helicopter is a well-addressed issue in the civil and military rotorcraft design arenas. A case of a multilift arrangement wherein two helicopters jointly transport payloads has been named twin lift as shown in the following figure. Develop the block diagram describing the pilots' action, the position of each helicopter, and the position of the load.





Design Problems

DP1.2

Many cars are fitted with cruise control that, at the press of a button, automatically maintains a set speed. In this way, the driver can cruise at a speed limit or economic speed without continually checking the speedmeter. Design a feedback control in block diagram for a cruise control system.