<u>Control System Definition</u>

A control system consist of subsytems and processes (or plants) assembled for the purpose of *controlling the outputs of the process.*

For example, a furnace produces heat as a result of the flow of the fuel. In this process, the flow of the fuel is the ***<u>input</u>***, and heat to be controlled is the ***<u>output</u>***

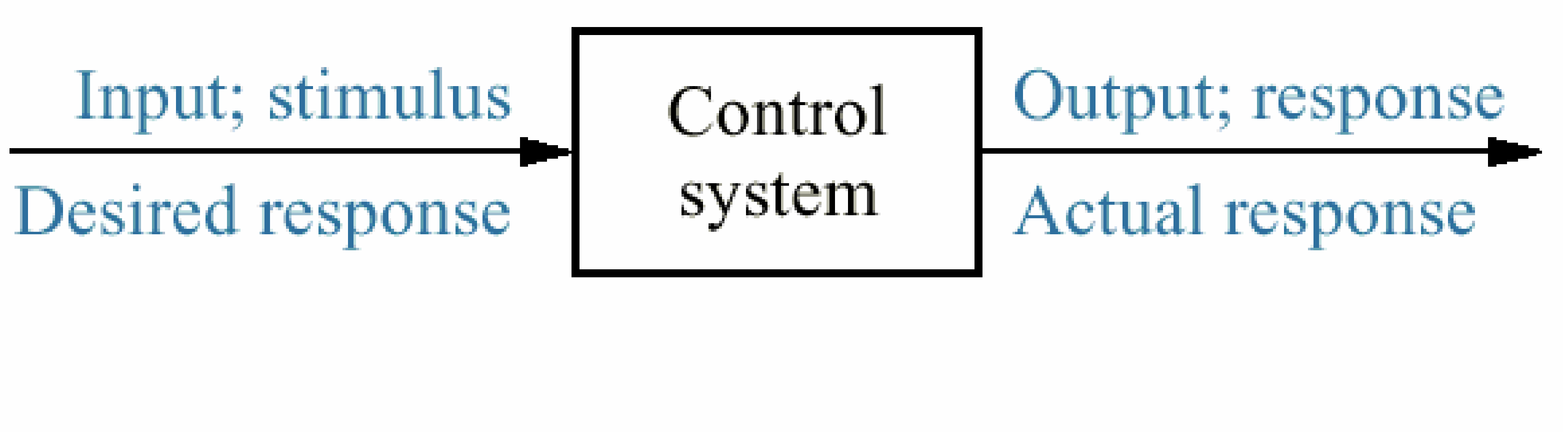


Figure 1.1
Simplified description of a control system

Advantages of the Control Sytems

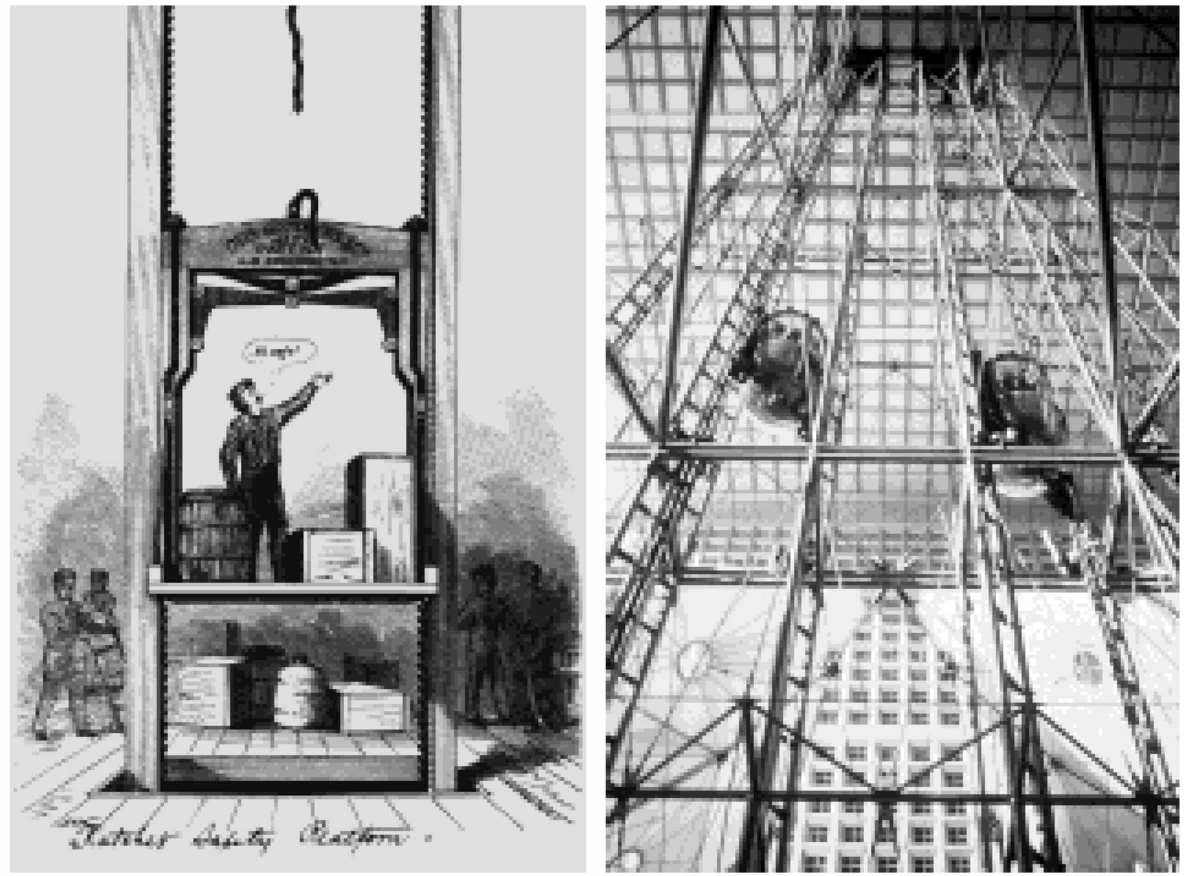
We build control systems for four primary reasons

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

Figure 1.2
Elevators

a. Early elevators were controlled by hand ropes or an elevator operator. Here, a rope is cut to demonstrate the safety brake, an innovation in early elevators;
b. Modern Duo-lift elevators make their way up the Grande Arche in Paris, driven by one motor, with each car counterbalancing the other. Today, elevators are fully automatic, using control systems to regulate position and velocity.

Photos courtesy of United Technologies Otis Elevator.



(*a*) (*b*)

The Control System Engineer

The control engineer can be found at the top level of large projects. Many engineers are engaged in only one area, such as circuit design or software development. However, as a control system engineer, you may find yourself working in a broad arena. For example, mechanical engineering, electrical engineering, computer engineering, mathematics and physics.

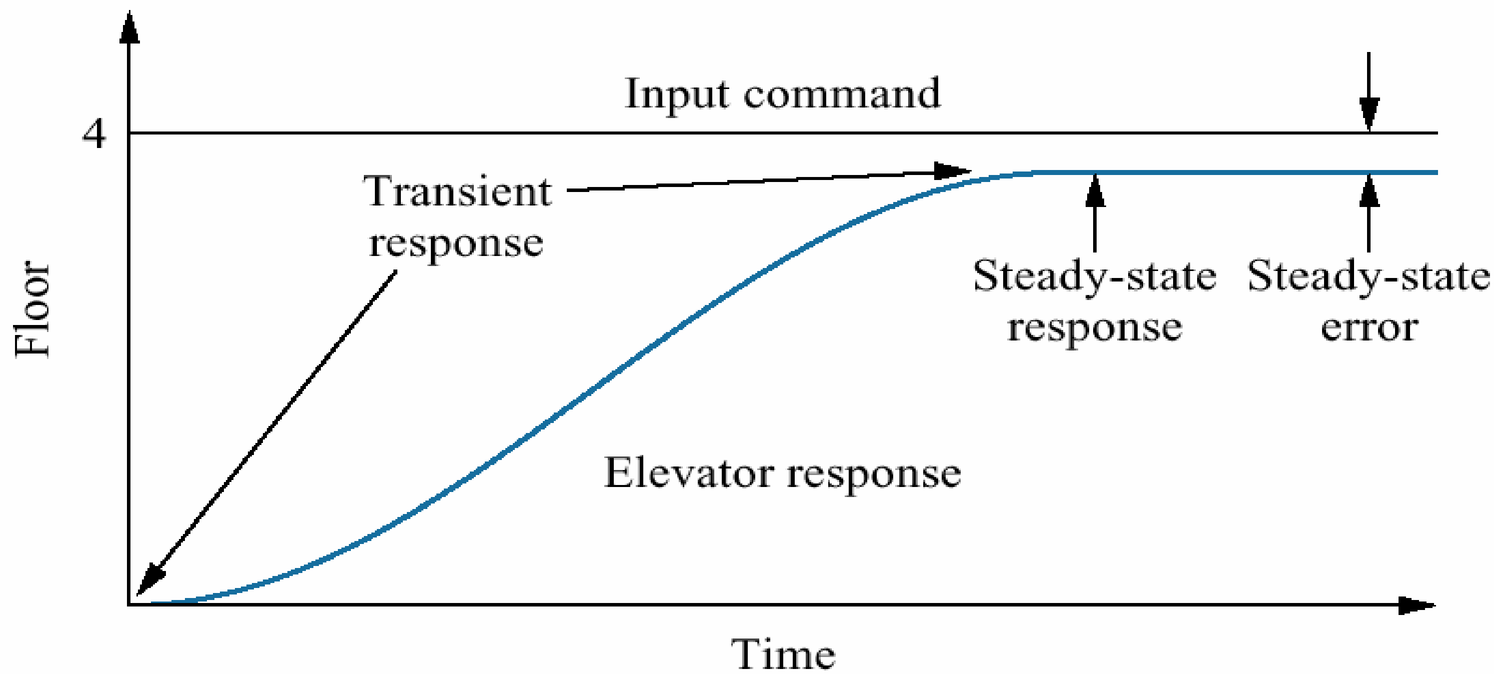
Response Characteristics and System Configurations

As noted earlier, a control system provides an output or response for a given input or stimulus. The input represents a desired response, the output is actual response. Let's study on the elevator response.

One can see the difference between input command and elevator response. Some factors make the output different from the input. Note that the response curve changes instantaneously at some region.

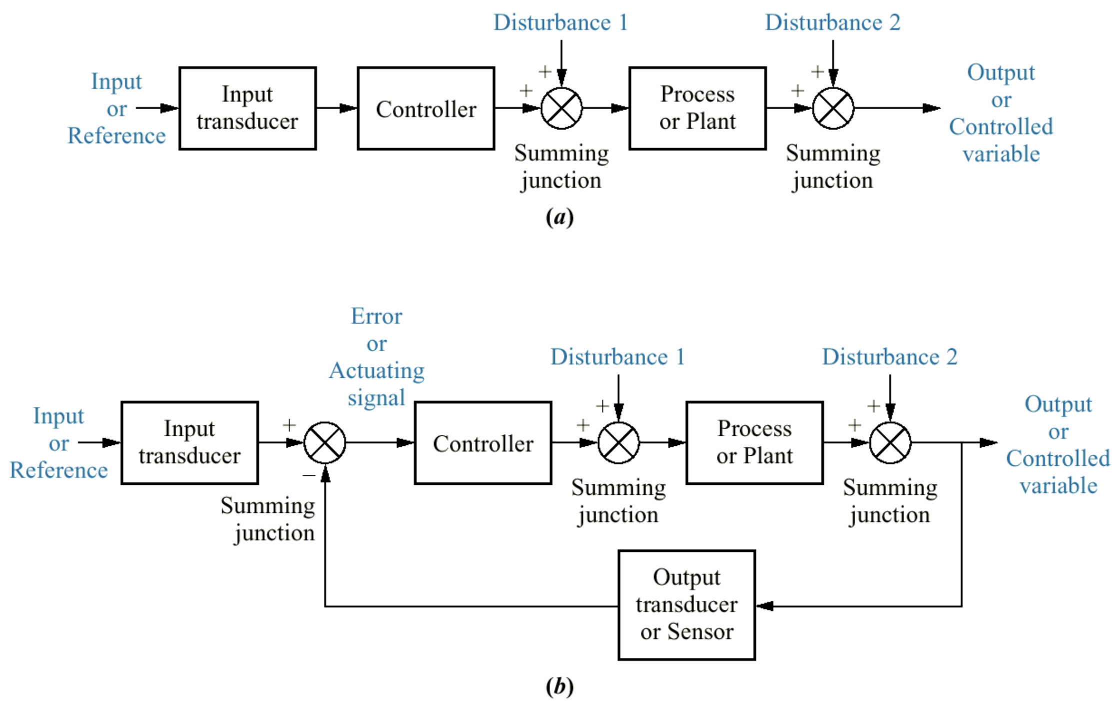
This response region is called "Transient Response".

After the transient response, system approaches its "Steady-State Response".



Elevator input and output

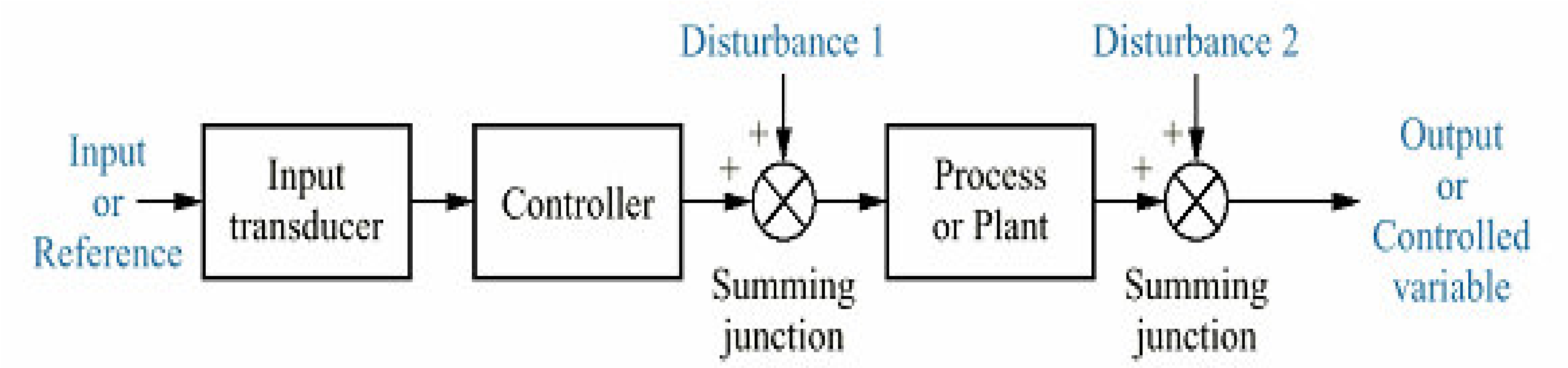
Figure 1.6
Block diagrams of control systems:
a. open-loop system;
b. closed-loop system



Block Diagrams of Control Systems

A.) Open Loop Systems

In the open loop case, desired input and actual output is **not** compared. It starts with an *input transducer* which converts the form of the input to that used by the *controller*. The controller drives a *plant*. The input is called reference, while the output can be called the *controlled variable.* Other signals, such as *disturbance*, are shown added to the controller output via *summing junction*.



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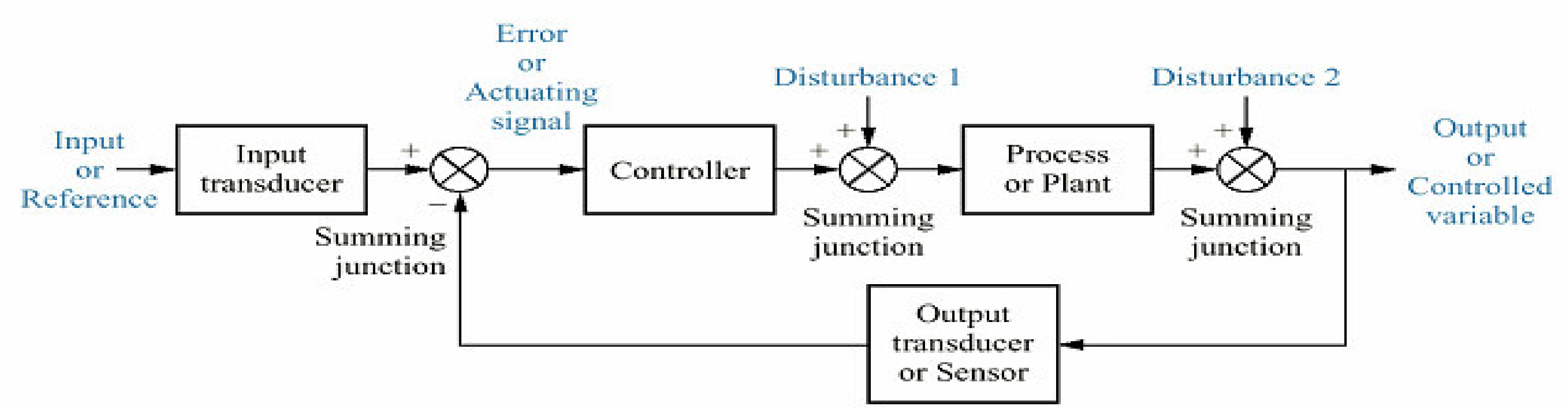
B. Closed Loop (Feedback Control) Systems

Open loop systems have some disadvantages in dealing with sensitivity and disturbance. In the closed loop case, there is an *output transducer*, or *sensor*, which measures the output response and converts it into the form used by the controller.



Computer Controlled Systems

In many modern systems, the controller (or compensator) is a digital computer. The advantage of using a computer is that many loops can be controlled or compansated by the same computer through time sharing. Furthermore, any adjustments of the compansator parameters required to yield a desired response can be made by changes in software rather than hardware.

Analysis and Design Objectives

Let's define our analysis and design objectives

1.) **Transient Response :** We analyze the system for its existing transient response. We then adjust parameters or design components to yield a desired transient response. (this is our first analysis and design objective)

2.) **Steady-State Response :** We are concerned about the accuracy of steady-state response. We analyze system's steady-state error, and then design corrective action to reduce steady-state error. (this is our second analysis and design objective)

3.) Stability : Discussion of transient response and steady state error is moot if the system does not have *stability*! For a linear sytem, we can write;

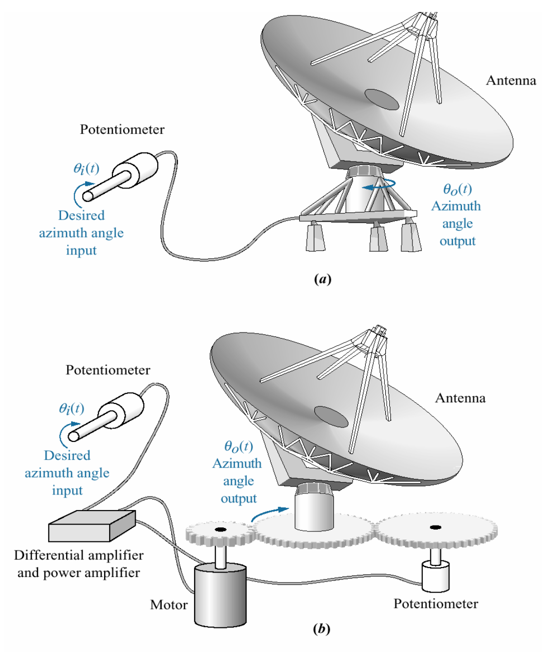
Total response = Natural response + Forced response

For a control systems to be useful, the natural response must eventually approach to zero, thus leaving only the forced response. If the natural response approaches to zero, we can say the system is "stable"

Figure 1.9

Antenna azimuth position control system:

a. system concept;
b. detailed layout;
c. schematic;
d. functional block diagram



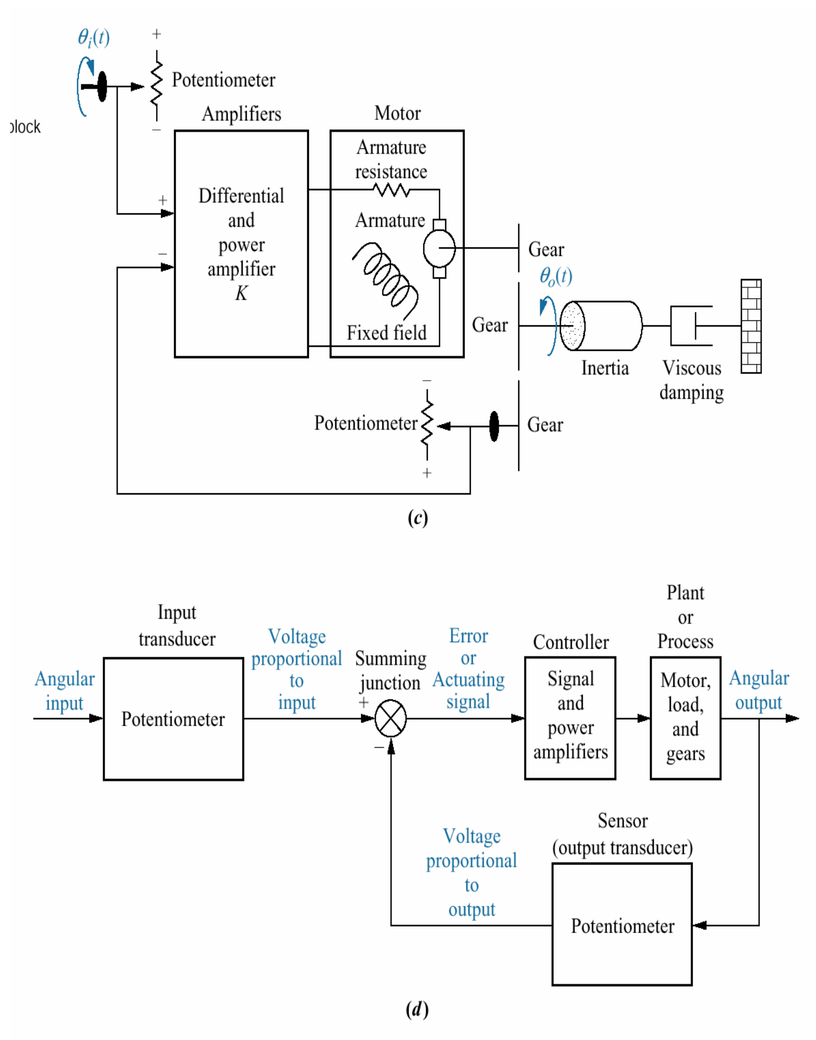
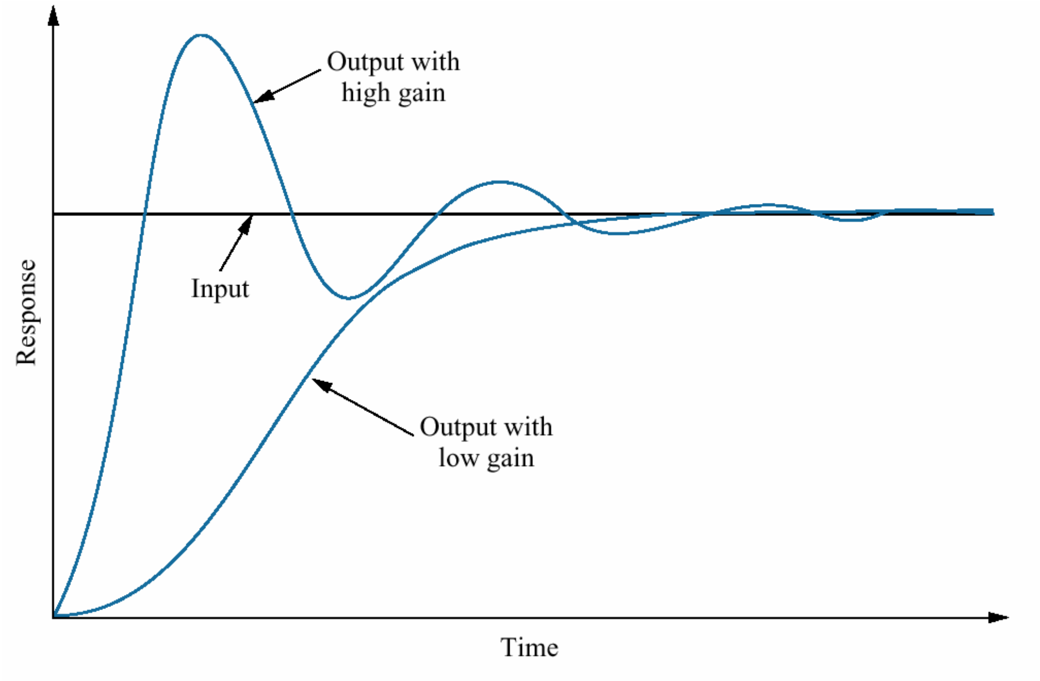


Figure 1.10
Response of a position control system showing effect of high and low controller gain on the output response



DESIGN PROCESS

Figure 1.11 shows the design process step by step

Step 1: Determine the specifications such as transient reponse, steady- state error.

Step 2 : Draw a functional block diagram and show interconnections of components

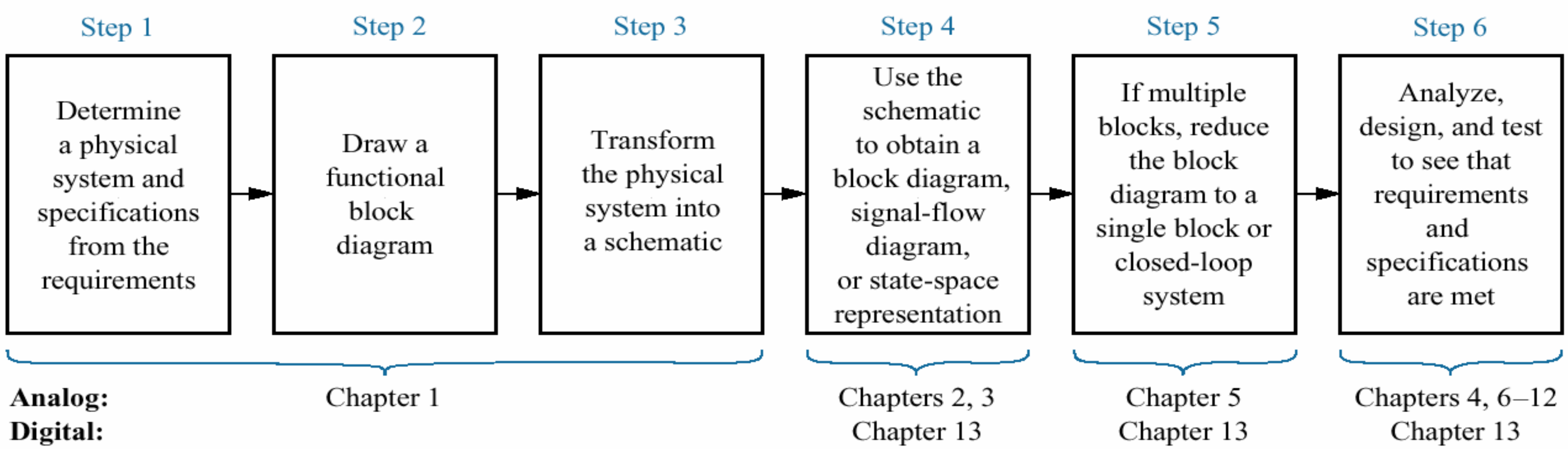
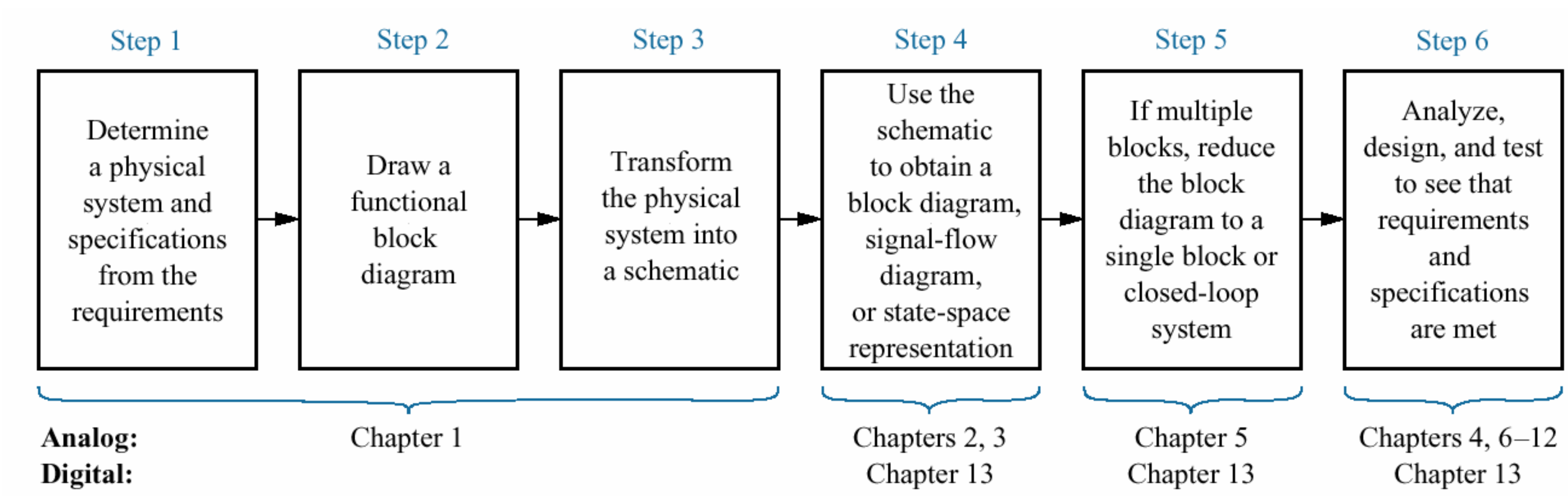


Figure 1.11
The control system design process

Step 3 : Create a schematic and transform physical system to a schematic diagram

Step 4 : Develop a mathematical model. Once schematic is drawn, designer uses physical laws, such as Kirchoff's laws for electrical network

Step 5 : Reduce the block diagram using some reduction techniques to avoid unnecessary calculations



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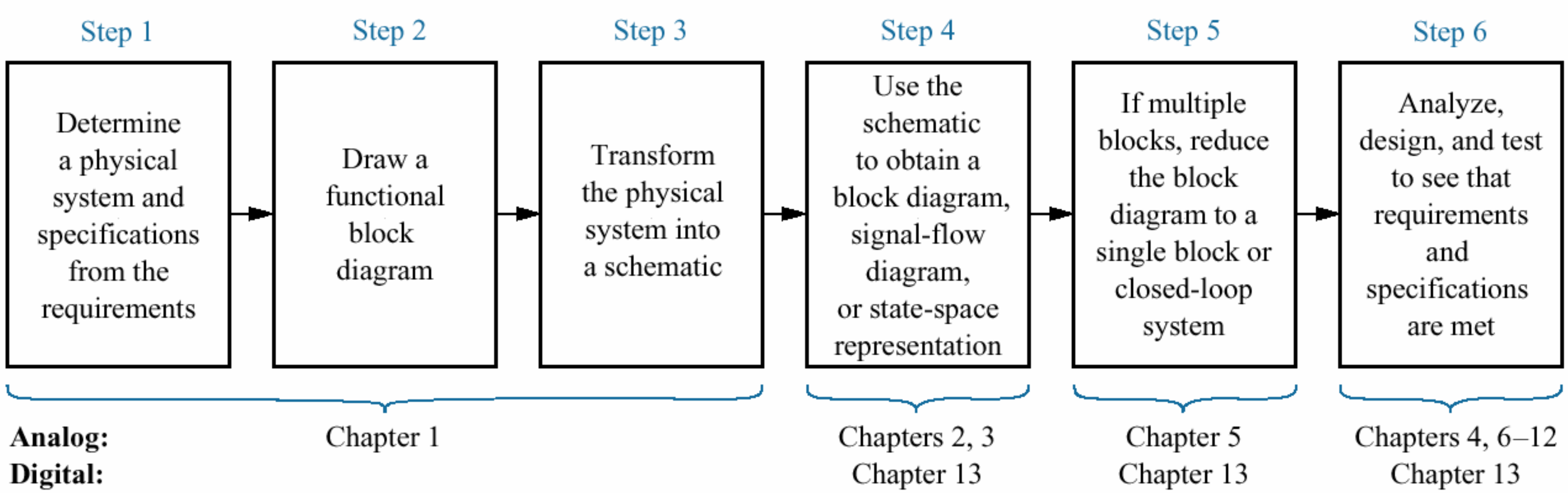
Step 6 : Analyze and design the system. Engineer analyzes the system to see if the response specifications and performance requirements can be met simple adjustments of system parameters. If specification can not be met, the designer then designs additional hardware in order to effect a desired performance. The enginner usually selects standart test inputs to analyze the system performance. These inputs are shown in Table 1.1



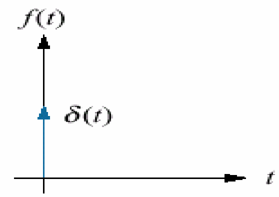
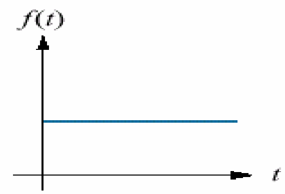
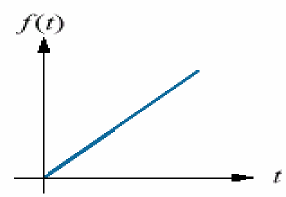
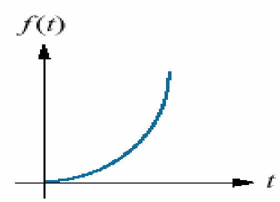
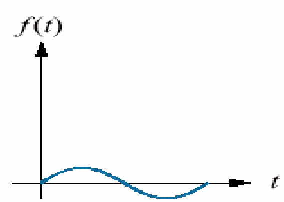
Input	Function	Description	Sketch	Use
Impulse	$\delta(t)$	$\delta(t) = \infty$ for $0- < t < 0+$ $= 0$ elsewhere $\int_{0-}^{0+} \delta(t)\,dt = 1$		Transient response Modeling
Step	$u(t)$	$u(t) = 1$ for $t > 0$ $= 0$ for $t < 0$		Transient response Steady-state error
Ramp	$tu(t)$	$tu(t) = t$ for $t \geq 0$ $= 0$ 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

Table 1.1

Test waveforms used in control systems

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COMPUTER AIDED DESIGN

We will use MATLAB and Control System toolbox. Included are

1.) Simulink

2.) LTI Viewer

3.) SISO Design Tool

4.) Symbolic Math Toolbox

p.s. Students are advised to review lecture notes related Laplace transform, transfer function and MATLAB for next week