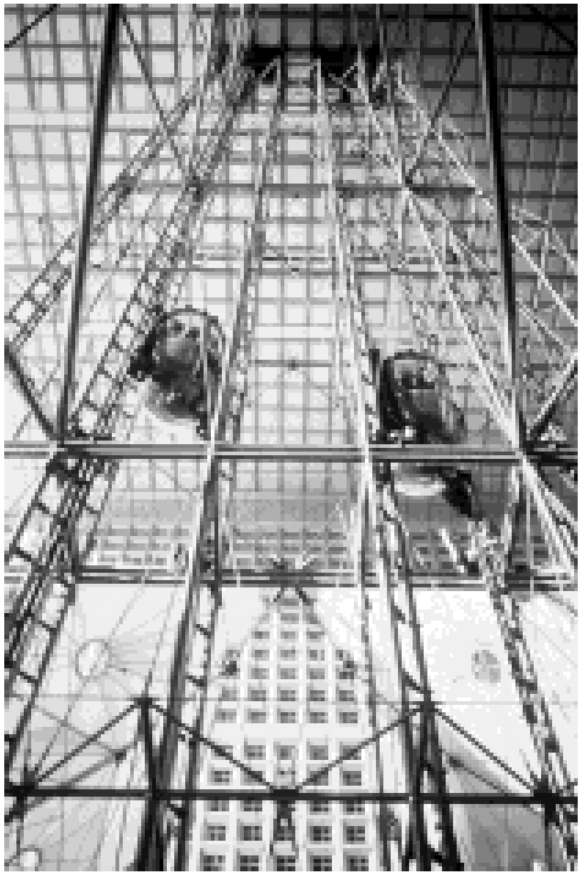
Figure 1.1
Simplified description of a control system

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*)

Figure 1.3
Rover was built to work in contaminated areas at Three Mile Island in Middleton, PA, where a nuclear accident occurred in 1979. The remote controlled robot's long arm can be seen at the front of the vehicle.

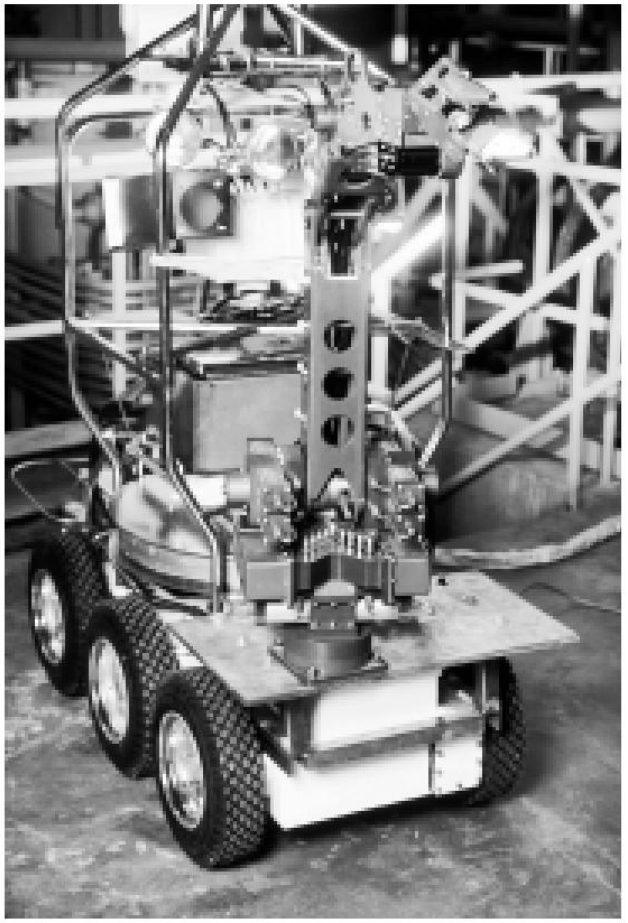
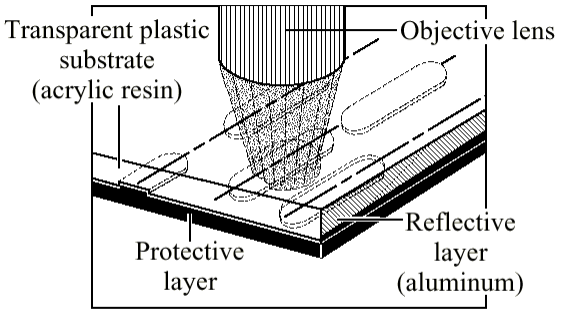


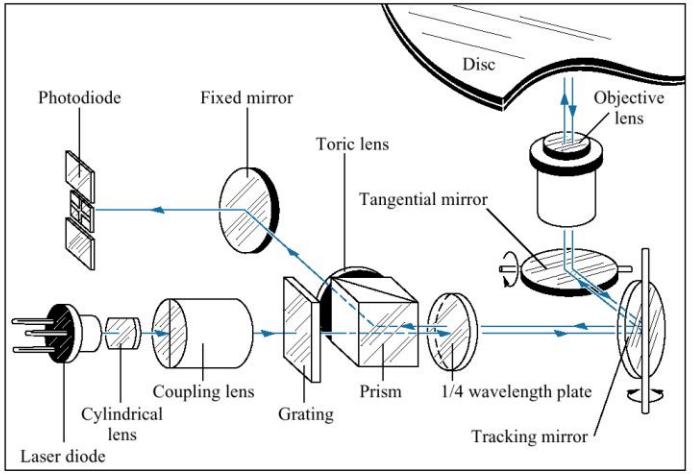
Figure 1.4

a. Video laser disc player;
b. objective lens reading pits on a laser disc;
c. optical path for playback showing tracking mirror rotated by a control system to keep the laser beam positioned on the pits.

(a)



(b)



(c)

(c) Pioneer Electronics, Inc.

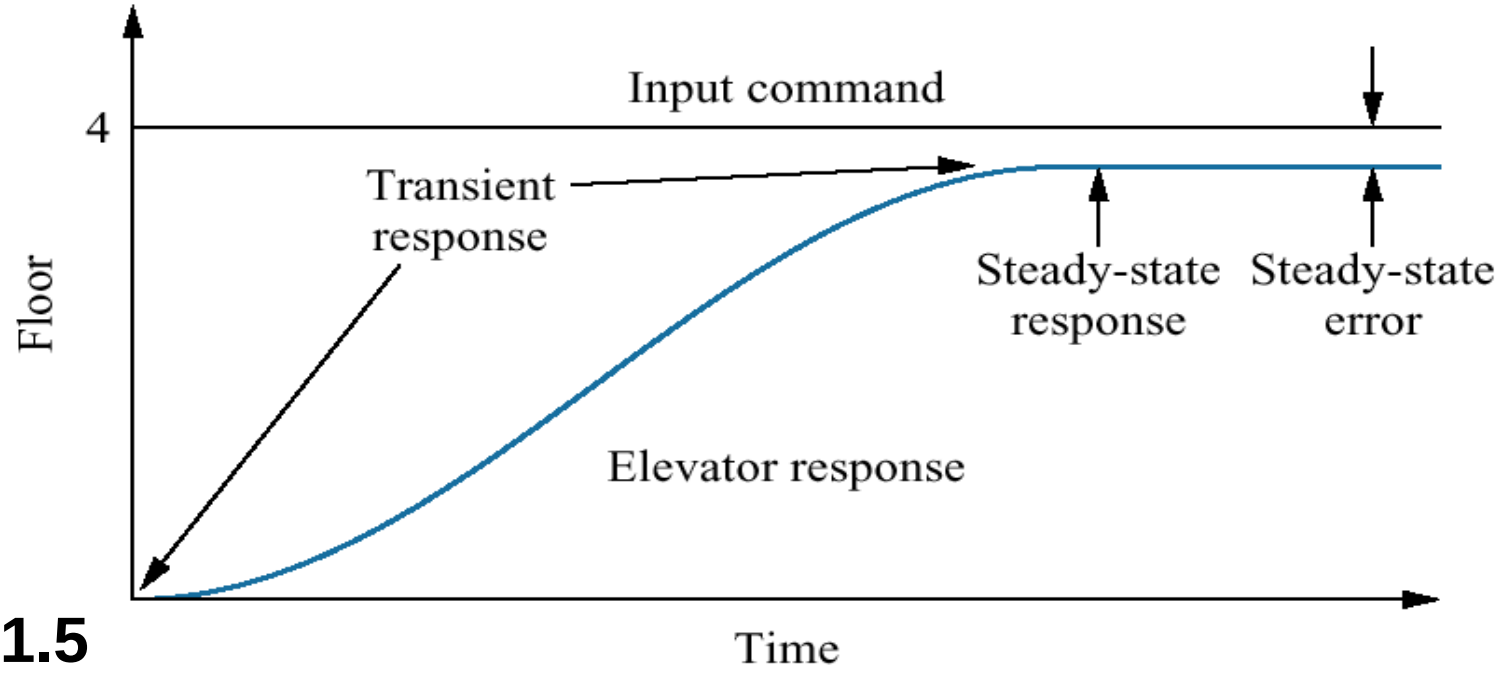


Figure1.5
Elevator input and output

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

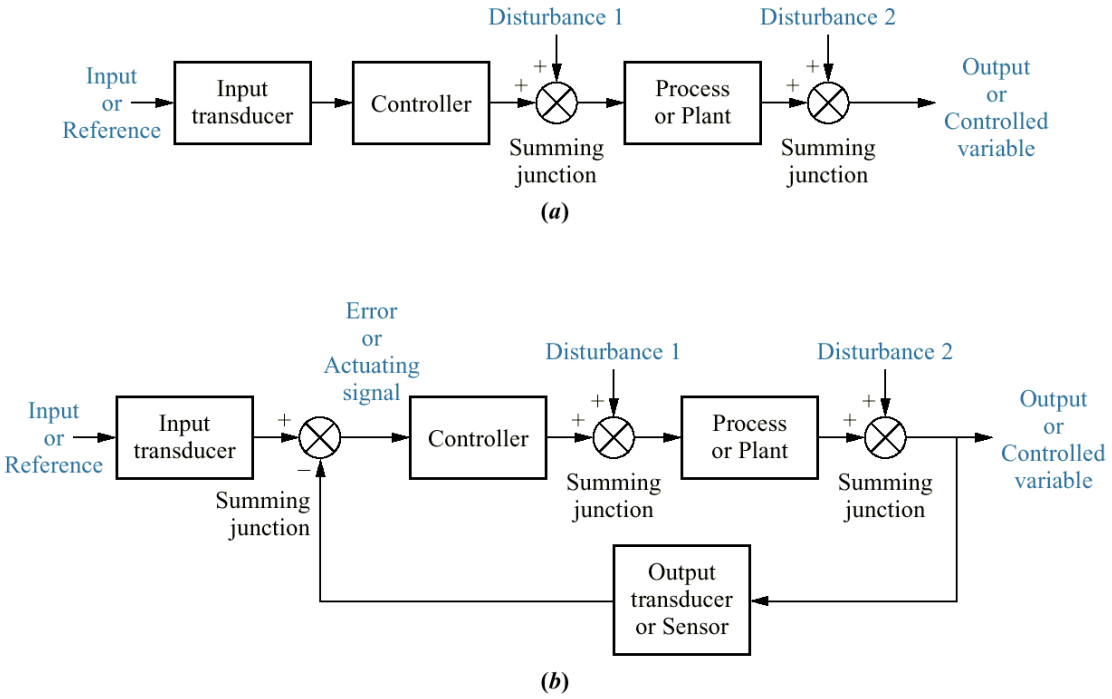


Figure 1.7
Computer hard disk drive, showing disks and read/write head

Courtesy of Quantum Corp.

Figure 1.8
The search for extraterrestrial life is being carried out with radio antennas like the one pictured here. A radio antenna is an example of a system with position controls.

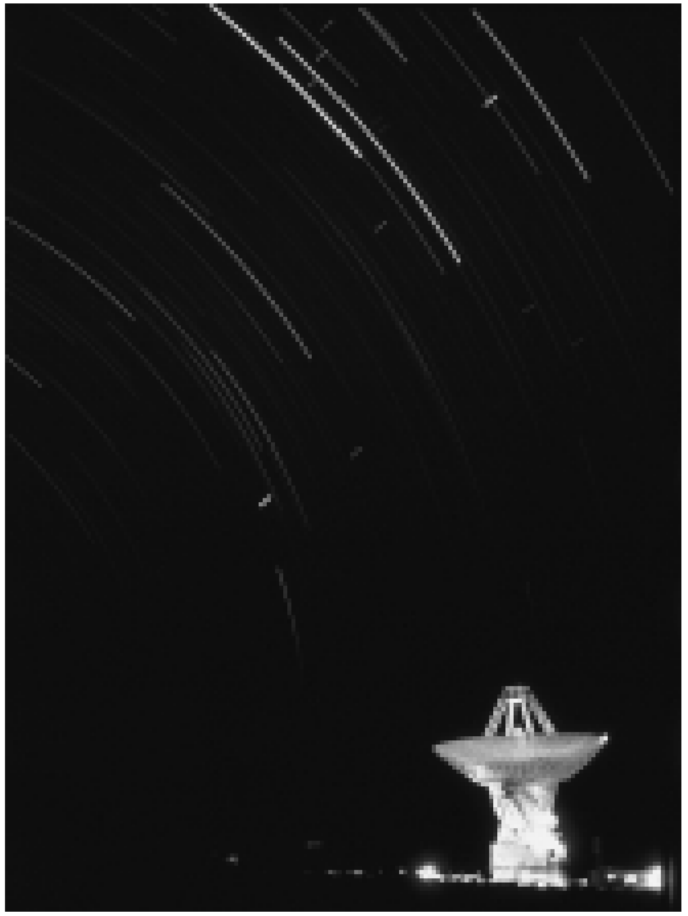
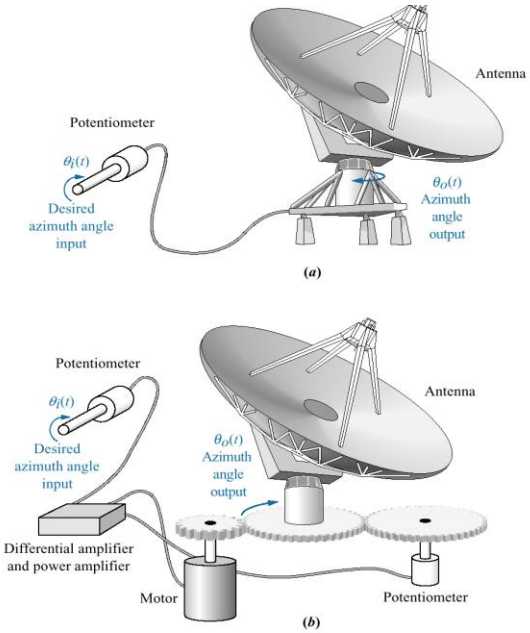
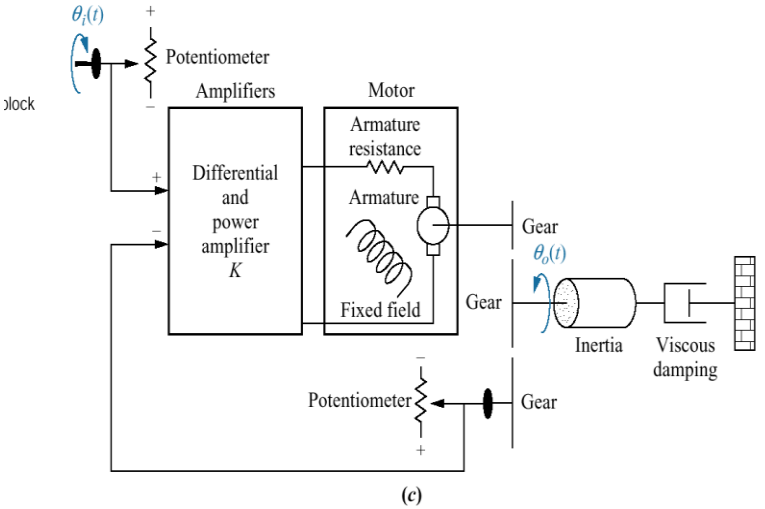


Figure 1.9
Antenna azimuth position control system:

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





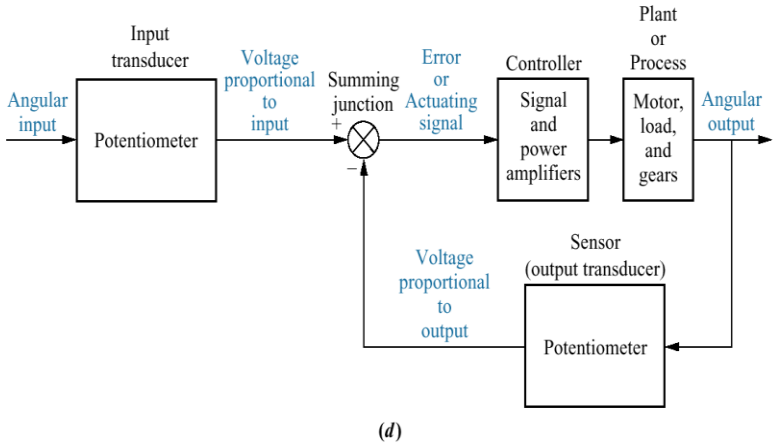
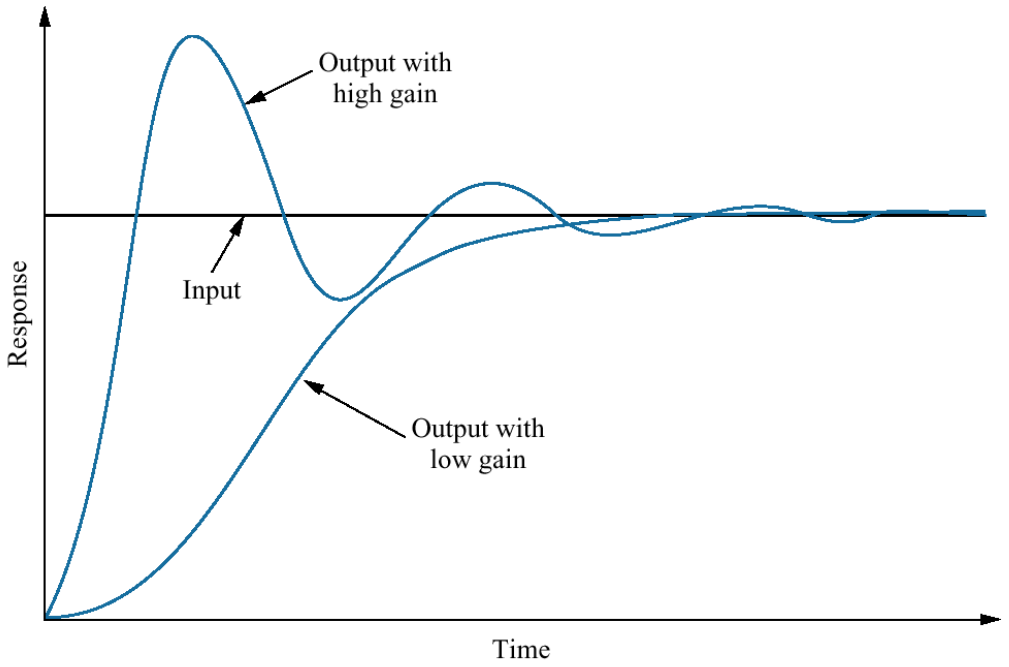


Figure 1.10
Response of a position control system showing effect of high and low controller gain on the output response



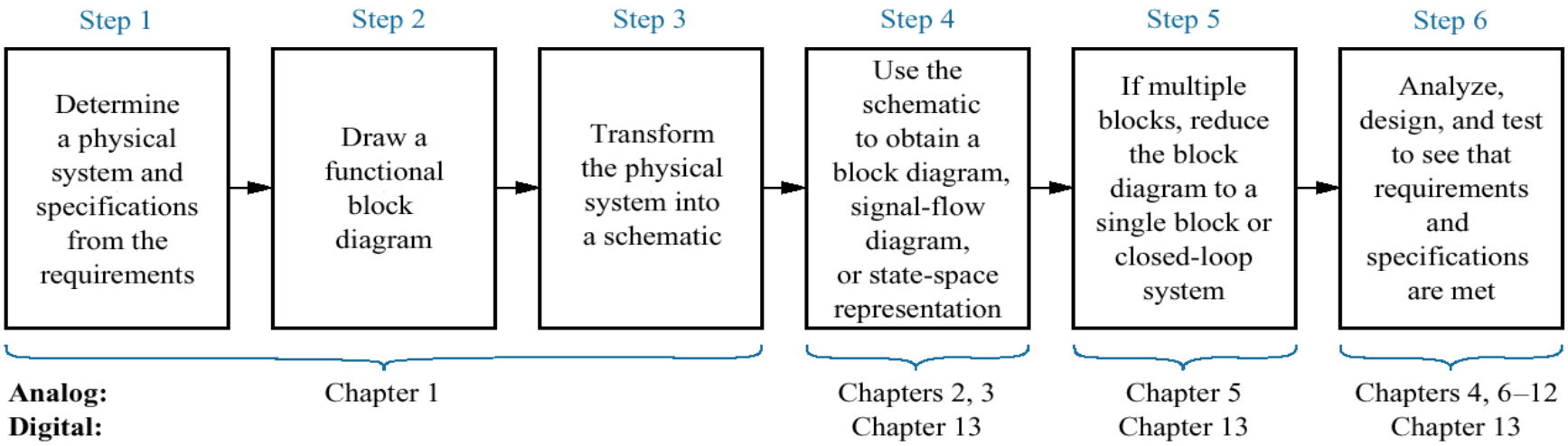
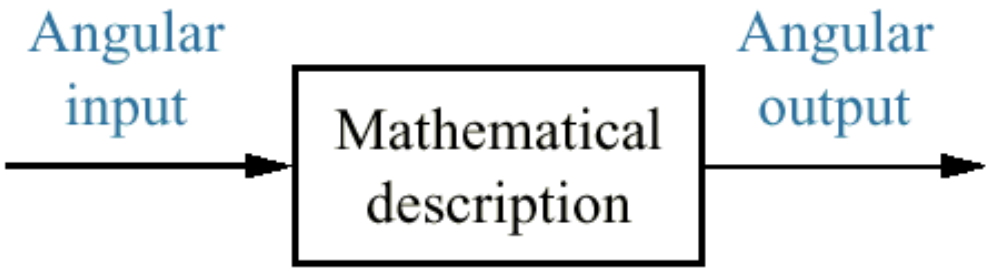


Figure 1.11
The control system design process

Figure 1.12
Equivalent block diagram for the antenna azimuth position control system



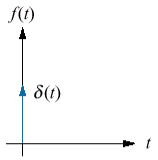
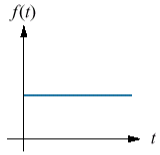
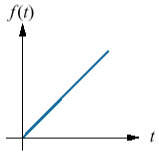
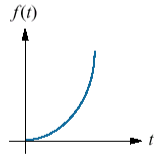
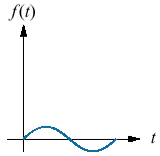
Input	Function	Description	Sketch	Use
Impulse	$\delta(t)$	$\delta(t) = \infty$ for $0- < t < 0+$ $= 0$ elsewhere $\int_{0-}^{0+} \delta(t)\,dt = 1$		Transient response Modeling
Step	$u(t)$	$u(t) = 1$ for $t > 0$ $= 0$ for $t < 0$		Transient response Steady-state error
Ramp	$tu(t)$	$tu(t) = t$ for $t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

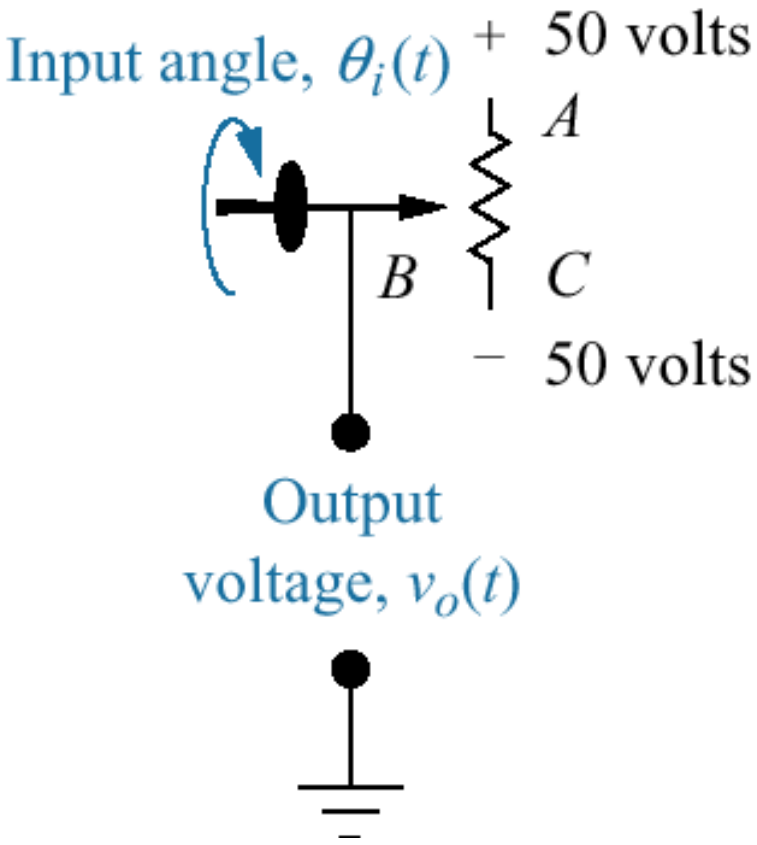


Figure P1.1
Potentiometer

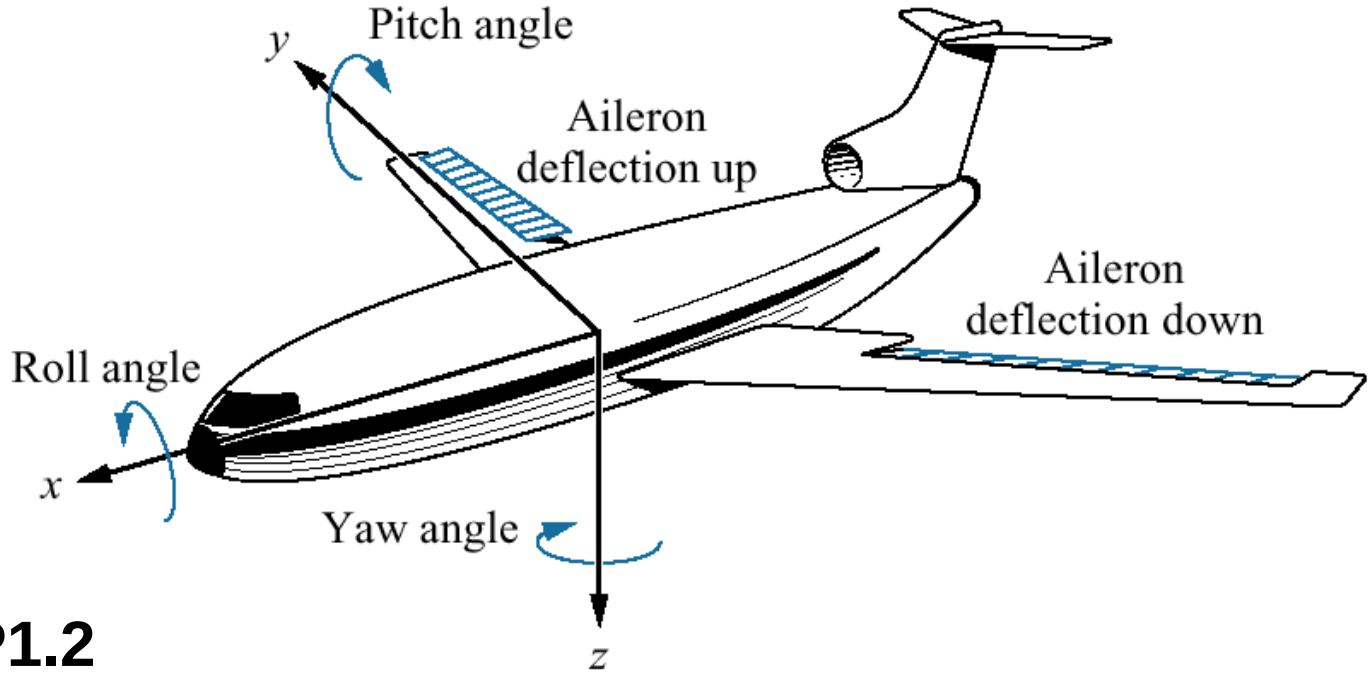


Figure P1.2
Aircraft attitude defined

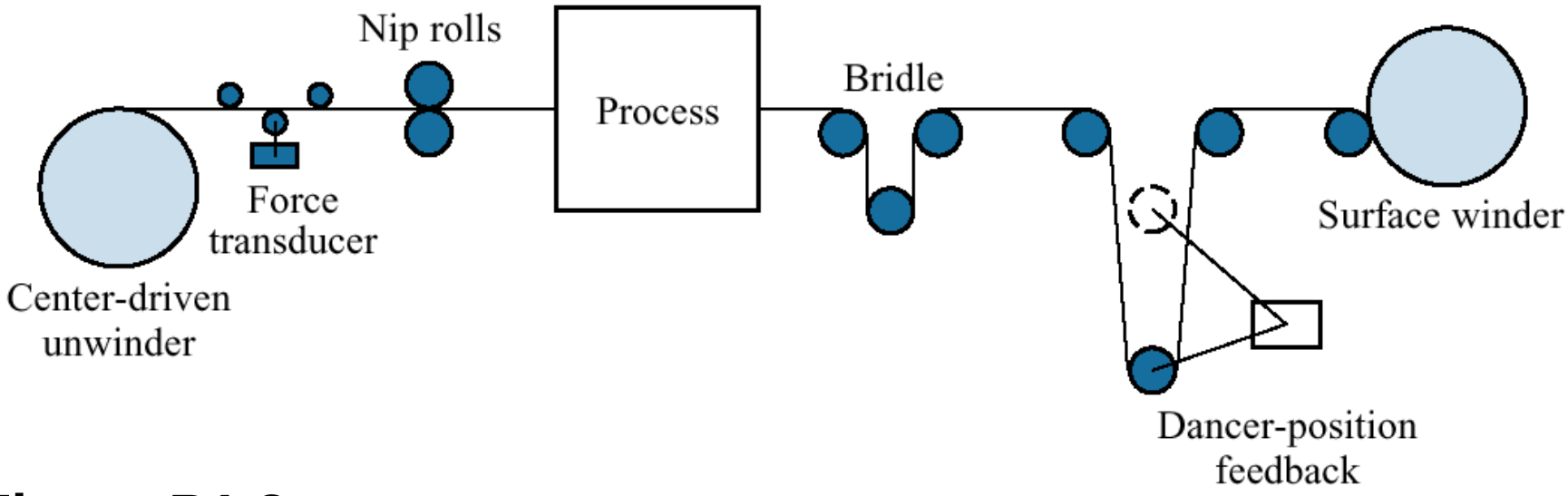
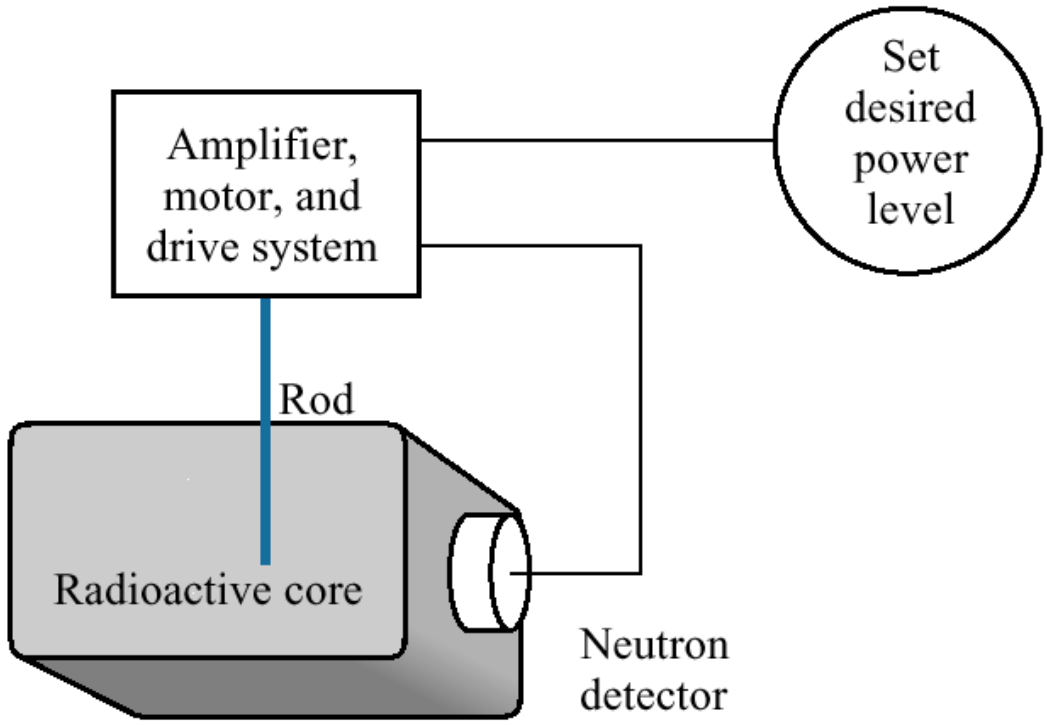


Figure P1.3
Winder

Figure P1.4
Control of a nuclear reactor



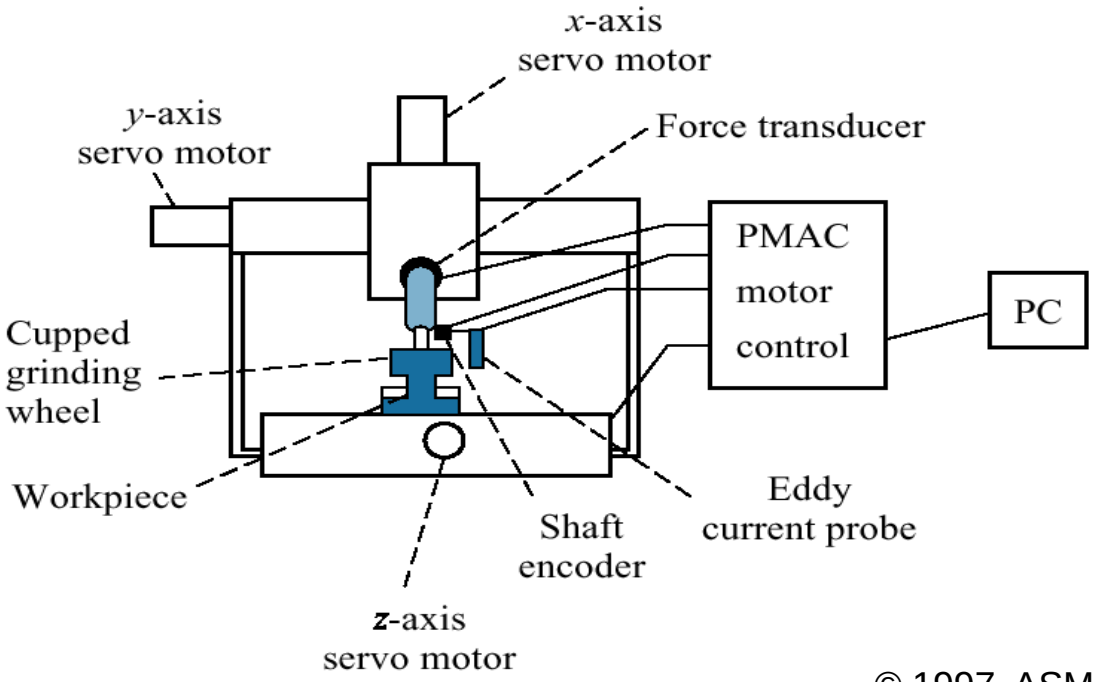


Figure P1.5
Grinder system

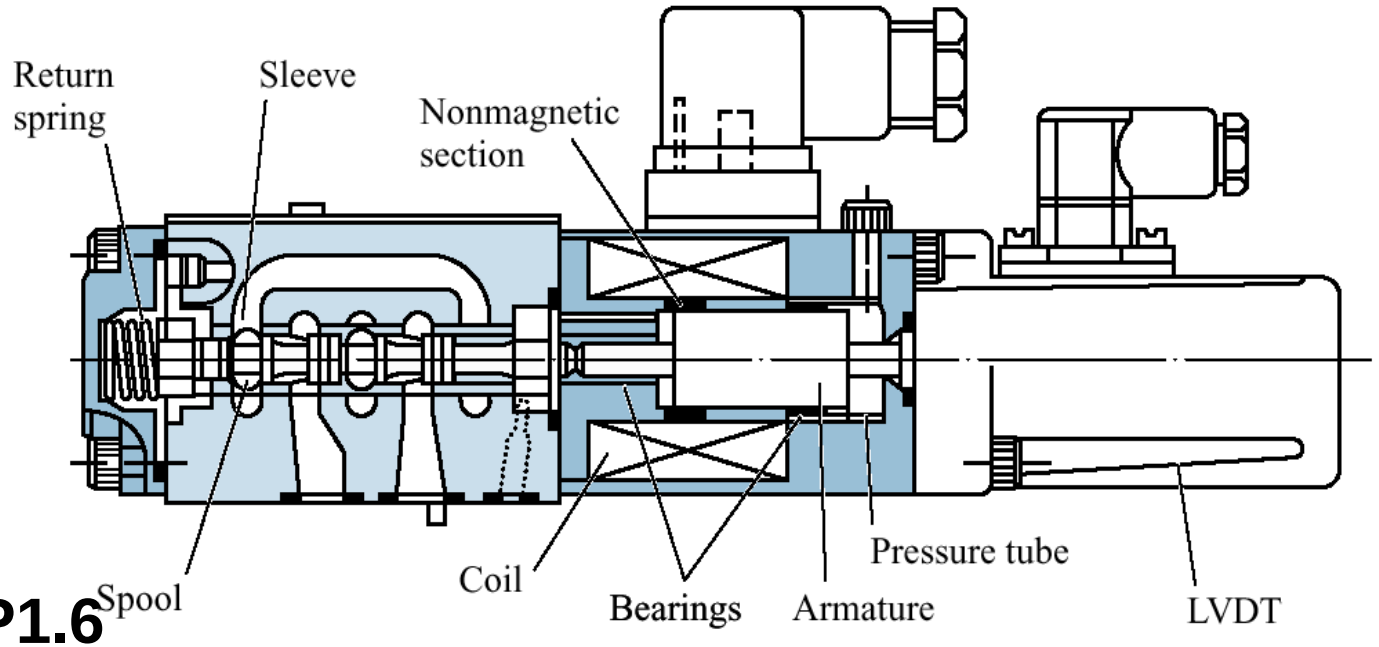


Figure P1.6
High-speed proportional solenoid valve

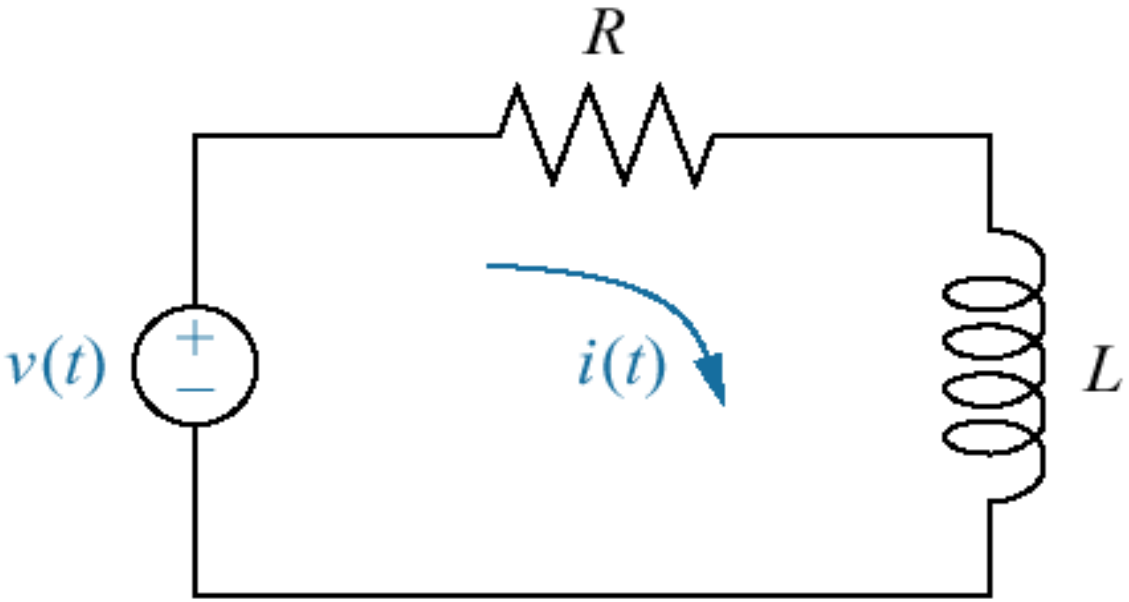


Figure P1.7
RL network

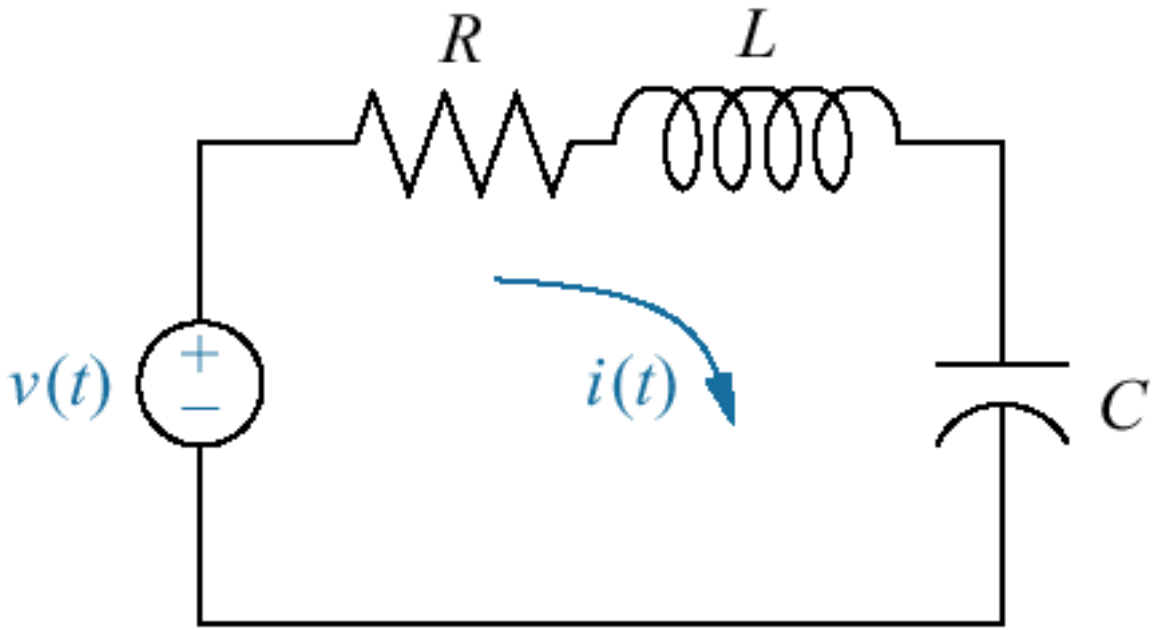


Figure P1.8
RLC network

Figure P1.9
High-speed rail system showing pantograph and catenary