CAS 704
Embedded, Real-Time Software Systems

Slides 1: Introduction to Control Systems

Dr. Ryan Leduc

Department of Computing and Software
McMaster University

Material based on lecture notes of Mark Lawford and text *Control Systems Engineering* by N. Nise.

What is an Embedded System

- Pretty much any computing systems other than a desktop/server type computer.
- Often contained inside a larger device, and typically designed to perform a single function.
- Tends to be tightly constrained in terms of cost, size, and power consumption.
- Often requires real-time processing and must react to its environment.

What is an Embedded System - II

- Three main themes:

  1. Physical Control of a system.

  2. Real-time programming.

  3. Safe implementation of computer control systems.

What is a Control System?

- In its simplest form a control system provides an output (response) for a given input (stimulus)

Figure 1.1: Simplified description of a control system

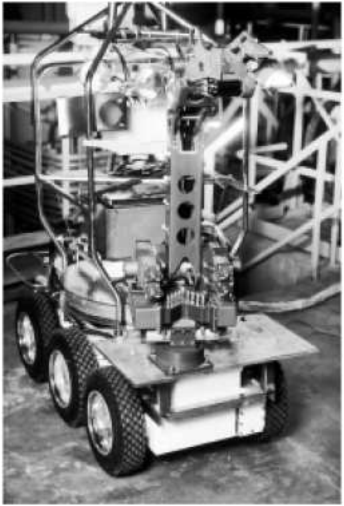
Why do We Need Control Systems?

- Power amplification (e.g. power steering)
- Remote control (e.g. Telerobotic surgery, bomb disposal robot, etc.)
- Convenience of input (e.g. Convert thermostat slider position to room temperature)
- Compensation for disturbances
- Improve system speed, accuracy, repeatability, performance, etc., etc.

Example Control Systems I

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 robots long arm can be seen at the front of the vehicle.



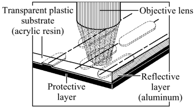
Example Control Systems II

Figure 1.4

(a) Video laser disc player.

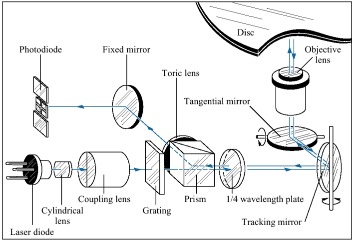
(a)

(b) Objective lens reading pits on a laser disc.



(b)

(c) Optical path for playback showing tracking mirror rotated by a control system to keep the laser beam positioned on the pits.



(c)

Example Control Systems III

Figure 1.7

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

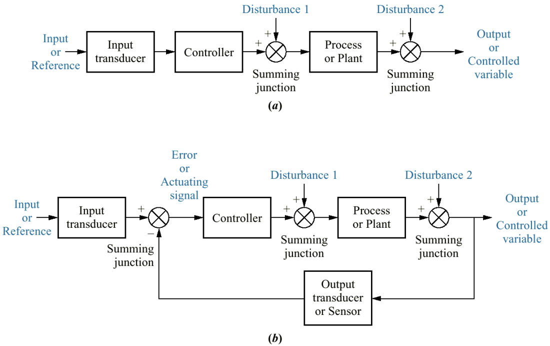
System Configurations

Figure 1.6

Block diagrams of control systems:

(a) Open-loop system.

(b) Closed-loop system.



Transient and Steady State Response

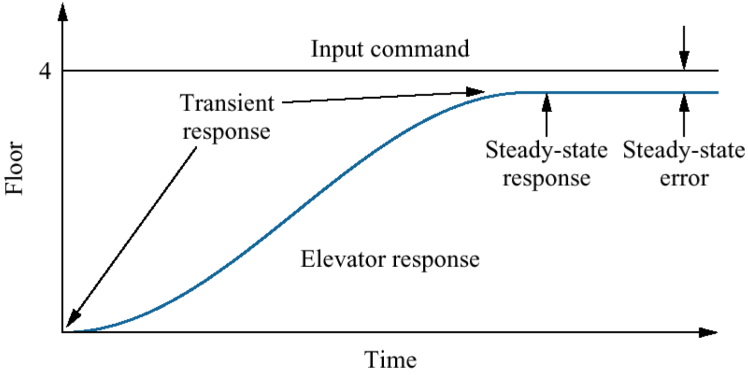


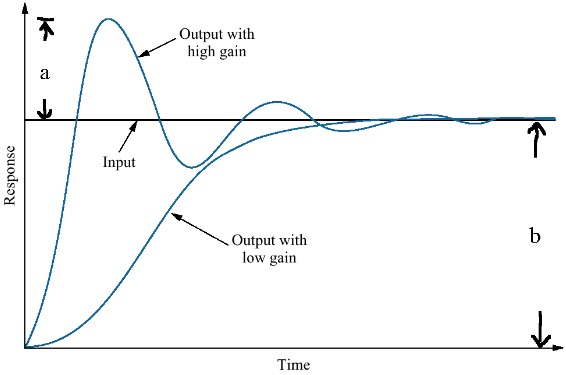
Figure 1.5: Elevator input and output

Transient Response Tradeoffs

Figure 1.10

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

Percent overshoot $= \frac{a}{b} \times 100\%$



Stability

$$\textit{Total response} = \textit{Natural response} + \textit{Forced Response}$$

- Natural Response (aka homogeneous solution): Evolution of system due to initial conditions.
- Forced Response (aka particular solution): Evolution of system due to input.
- Generally a system is stable if the natural response eventually goes to zero or at worst oscillates with some fixed amplitude.
- In an unstable system the natural response grows without bound, swamping the forced response and system is no longer controlled.

  ie a bounded input creates an unbounded output.
- In general, a control system must be stable to be useful.

Control Objectives

1. Stabilize the system.

2. Produce the desired transient response.

3. Decrease/eliminate steady state error.

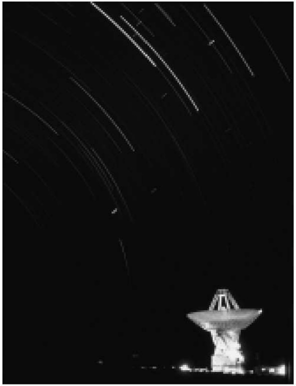
4. Make system robust to withstand disturbances and variations in parameters.

5. Achieve optimal performance.

Case study: Antenna Azimuth Position Control

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.



Azimuth Position Control System for Antenna

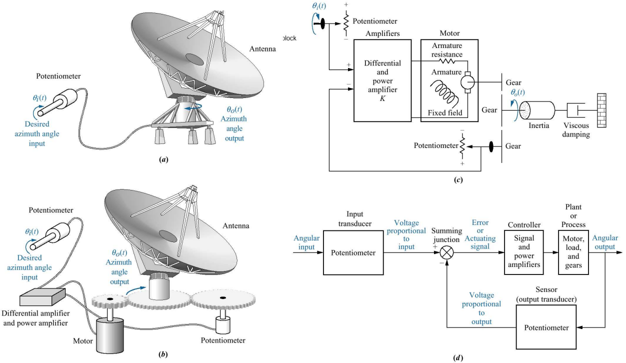
Figure 1.9

(a) System concept

(b) Detailed layout

(c) Schematic

(d) Functional block diagram



How do You Design a Control System?

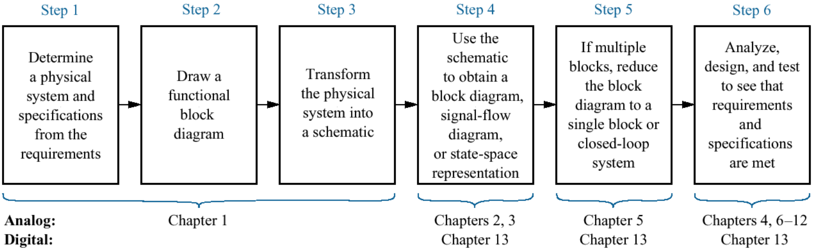


Figure 1.11: The control system design process

Test Waveforms

- Test signals used to verify design.
- Table 1.1 shows the standard test signals used.

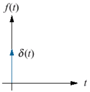
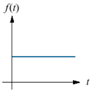
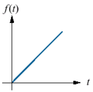
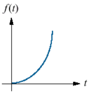
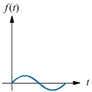
Input	Function	Description	Sketch	Use
Impulse	$\delta(t)$	$\delta(t) = \infty$ for $0- < t < 0+$ $= 0$ elsewhere $\int_{0-}^{0+} \delta(t)\,dt = 1$		Transient response Modeling
Step	$u(t)$	$u(t) = 1$ for $t > 0$ $= 0$ for $t < 0$		Transient response Steady-state error
Ramp	$tu(t)$	$tu(t) = t$ for $t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