Syllabus

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- Subject : 제어시스템공학1 (Control System Engineering 1)
- Textbook : Feedback Control of Dynamic Systems, 8th Edition, by G. F. Franklin et al.

(Summary)

본 과목에서는 제어 시스템의 기본개념을 습득하고, 제어 시스템의 해석 및 설계 방법을 학습한다.

(1) 전달함수와 신호흐름선도와 함께 물리 시스템의 수학적 모델링을 배운다.
(2) 시스템의 안정도에 대한 기초적인 개념과 아울러 간단한 안정도 판별법을 소개한다.
(3) 시간영역 해석에서 1차 및 2차 시스템에 대하여 공부한다.
(4) 제어 시스템의 매개변수의 변화에 따라 특성 근의 위치의 변화를 나타내는 근궤적법에 관하여 학습한다.

제어시스템의 기초가 되는 되먹임 제어(Feedback Control)의 원리를 배우고 실제 프랜트에 적용하기 위해 시스템을 설계하고 해석하는 과정을 체계적으로 공부한다.

(Schedule)

- (1st week) 1장 Overview
- (2,3,4th weeks) 2장 Dynamic Models
- (5,6,7th weeks) 3장 Dynamic Response
- (8th week) 중간고사, Midterm Exam
- (9,10,11th weeks) 4장 Analysis of Feedback
- (12th week) 모터 제어 실습
- (13,14,15th weeks) 5장 Root Locus
- (16th week) 기말고사, Final Exam

(Grade)

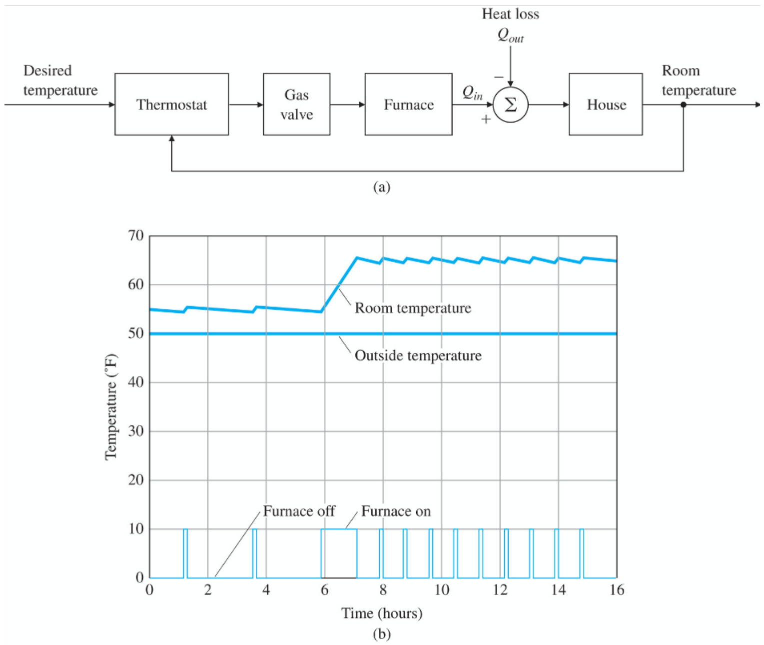
Final Exam(40%) + Midterm Exam(40%) + Experiment(10%) + HW(5%) + Attendance(5%) = 100%

제 1 장

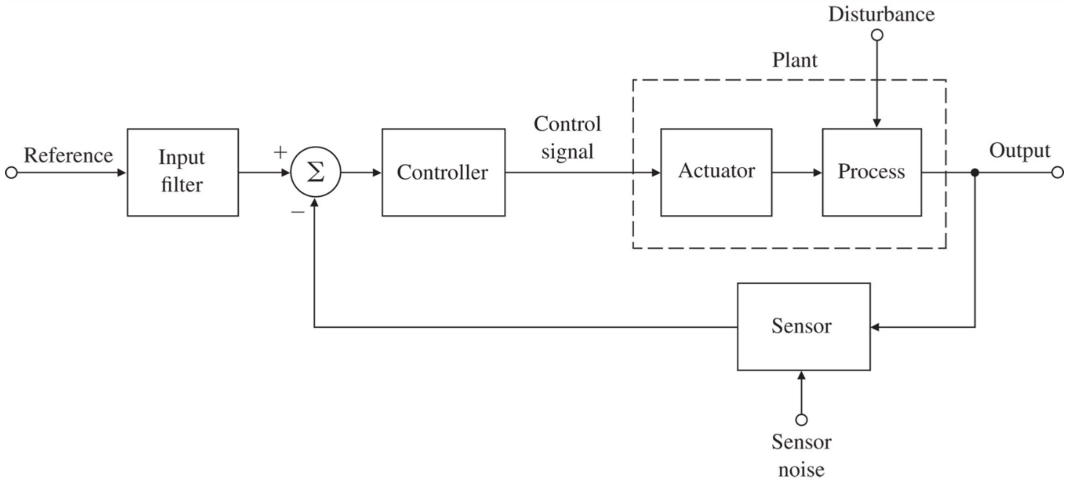
An Overview and Brief History of Feedback Control

1 A Simple Feedback System

1. Consider the household furnace controlled by a thermostat [Fig. 1.1]



2. Component block diagram of an elementary feedback control [Fig. 1.2]



Block diagram the method that is helpful for visualizing system structure and the flow of information in control systems

Actuator the device that can influence the controlled variable of the process

Plant the combination of process and actuator

Controller the component that actually computes the desired control signal

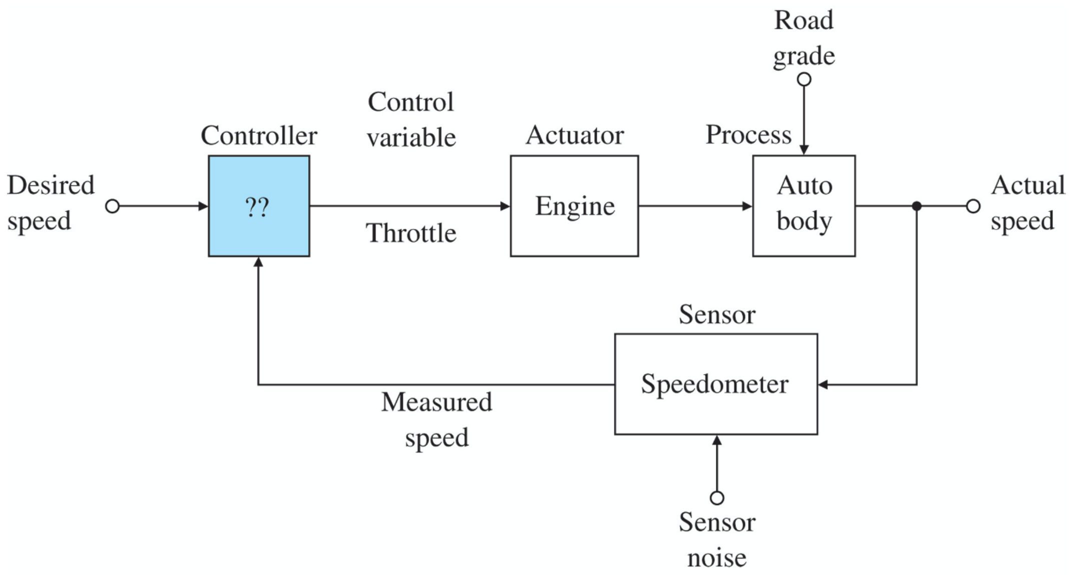
Input filter to convert the reference signal to electrical form for later manipulation by the controller

AI or machine learning A thermostat system that includes a motion detector can determine whether anybody is home nad learns from the patterns observed what the desired temperature profile should be. The process of learning the desired setpoint is an example of artificial intelligence (AI) or machine learning.

3. The goal of this course is (1) to present methods for analyzing feedback control systems, (2) to describe most important techniques, and (3) to study the specific advantages of feedback.

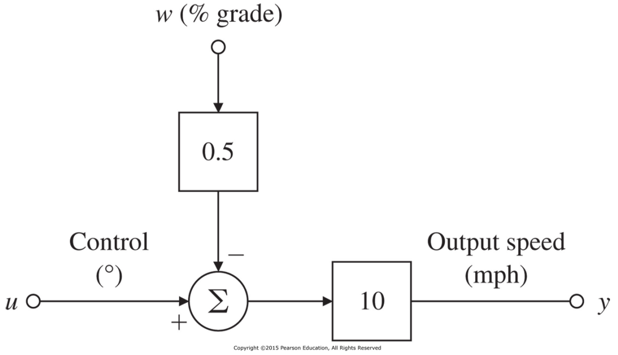
2 A First Analysis of Feedback

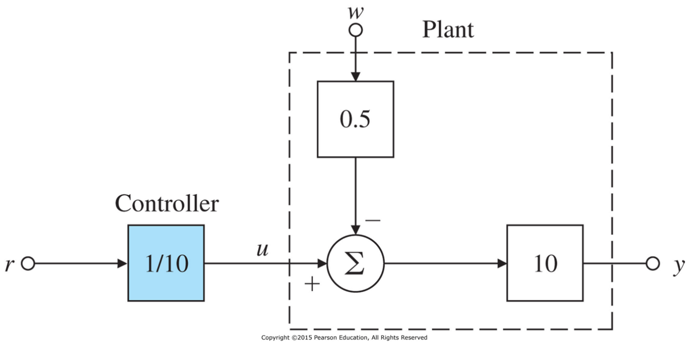
1. Consider the cruise control of an automobile [Fig. 1.3]



For simplified speed model, we find that a 1° change in the throttle angle (u) causes a 10 mph change in speed (y) and also, while driving up and down hills, it is found that we measure a speed change of 5mph (y) when the grade changes by 1% (w)

2. Its mathematical model of the plant [Fig. 1.4] and open-loop control [Fig. 1.5]





Example of an open-loop control system, let us set $u = \frac{r}{10}$, then the open-loop output speed, y_{ol} is given by the equations:

$$y_{ol} = 10(u - 0.5w) = 10\left(\frac{r}{10} - 0.5w\right) = r - 5w$$

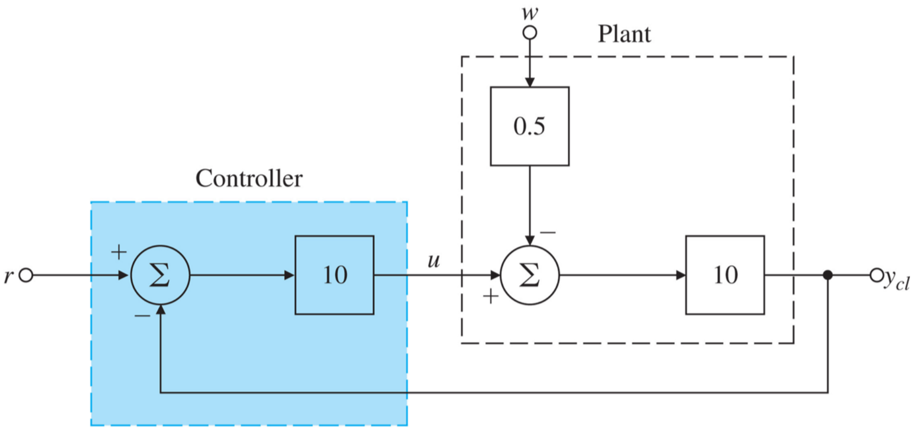
The error in output speed is

$$e_{ol} = r - y_{ol} = 5w$$

and the percent error is

$$\begin{aligned} \%error &= \frac{(output\ \ when\ \ w = 0) - (output\ \ when\ \ w \neq 0)}{(output\ \ when\ \ w = 0)} \times 100 \\ &= \frac{r - (r - 5w)}{r} \times 100 = \frac{5w}{r} \times 100 = 500\frac{w}{r} \end{aligned}$$

3. Example of feedback (or closed-loop) control scheme [Fig. 1.6]



let us set $u = 10(r - y)$, the closed-loop output speed is

$$\begin{aligned} y_{cl} &= 10(u - 0.5w) = 10\left(10(r - y_{cl}) - 0.5w\right) \\ &= \frac{100}{101} r - \frac{5}{101} w \end{aligned}$$

The error in output speed is

$$e_{cl} = r - y_{cl} = \frac{1}{101} r + \frac{5}{101} w$$

and the percent error is

$$\begin{aligned} \%error &= \frac{(output\ when\ w = 0) - (output\ when\ w \neq 0)}{(output\ when\ w = 0)} \times 100 \\ &= \frac{(\frac{100}{101} r) - (\frac{100}{101} r - \frac{5}{101} w)}{(\frac{100}{101} r)} \times 100 = 5 \frac{w}{r} \end{aligned}$$

4. Comparisons b/w open-loop control and closed-loop (feedback) control:

	open-loop	closed-loop
output speed	$y_{ol} = r - 5w$	$y_{cl} = \frac{100}{101}r - \frac{5}{101}w$
error	$e_{ol} = 5w$	$e_{cl} = \frac{1}{101}r + \frac{5}{101}w$
percent error	$500\frac{w}{r}$	$5\frac{w}{r}$

- Feedback has reduced the sensitivity of the speed error to grade by a factor of 101 when compared with open-loop system.
- There is now a small speed error on level ground b/c even when $w = 0$.
- Control Design Trade-off : the issues of how to get the gain as large as possible to reduce the errors w/o making the system become unstable.

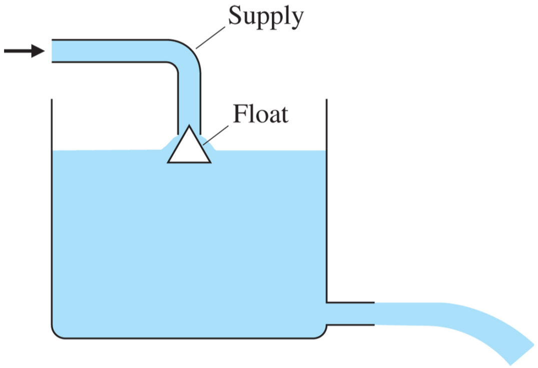
3 Feedback System Fundamentals

To achieve good control, there are typical goals:

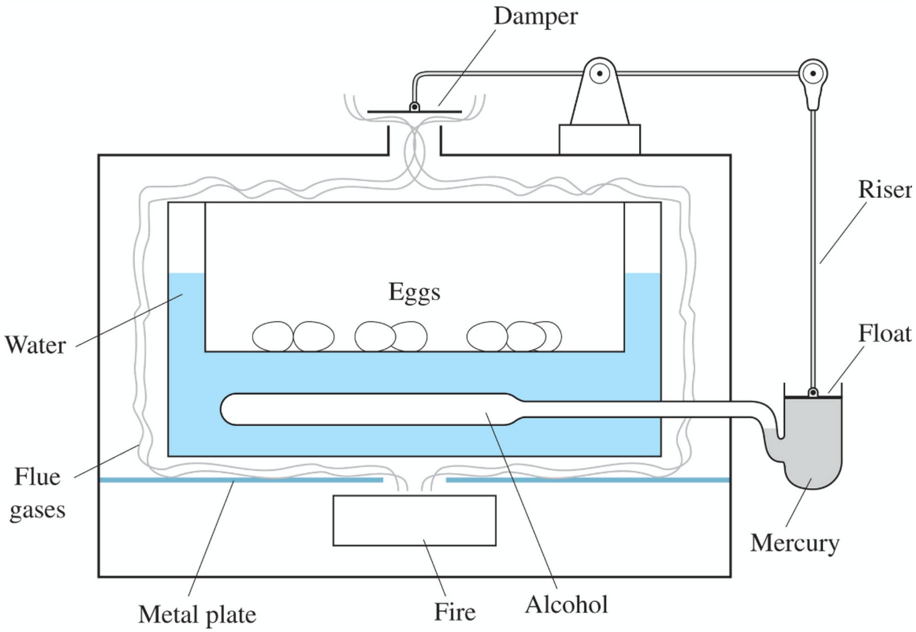
1. Stability: the system must be stable at all times, instability may have two causes,
    - in the first place, the system being controlled may be unstable (segway)
    - a second cause of instability may be the addition of feedback.
2. Tracking: the system output must track the command reference signal as closely as possible.
3. Disturbance rejection: the system output must be as insensitive as possible to disturbance inputs
4. Robustness: the aforementioned goals must be met even if the model used in the design is not completely accurate or if the dynamics of the physical system change over time.

4 A Brief History

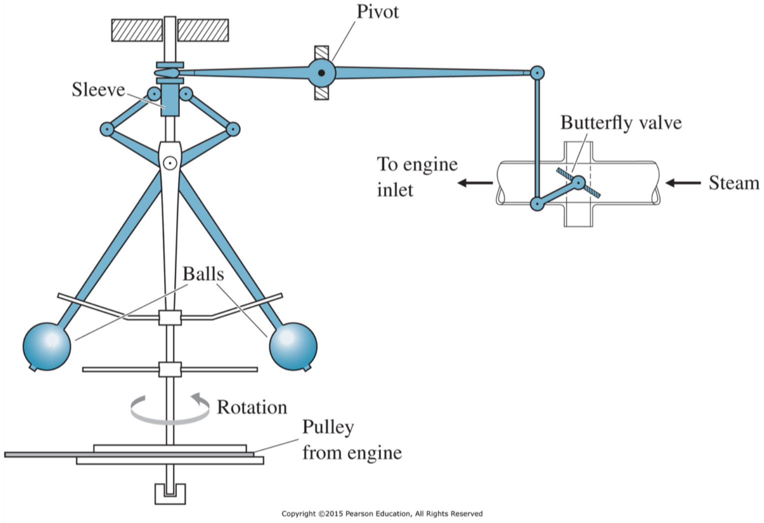
1. Float valve: early historical control of liquid level and flow [Fig. 1.7]



2. Drebbel's incubator (1620) [Fig. 1.8]



3. Fly-ball governor [Fig. 1.11]



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4. Airy (1840) : instability in a feedback control system
5. Maxwell (1868) : linearization of the control system
6. Routh (1877) : stability criterion on linear system
7. Lyapunov (1892) : stability criterion on nonlinear system
8. Nyquist (1932) : stability from graphical plot of the loop frequency response
9. Callender (1936) : PID control
10. Bode (1945) : bode plot and feedback amplifier
11. James (1947) : servomechanism
12. Evans (1947) : root locus
13. 1950s several authors: Bellman, Kalman, Pontryagin