RBE 2004

ระบบอัตโนมัติ (Automatic System)

สาขาวิศวกรรมหุ่นยนต์

คณะวิศวกรรมศาสตร์และเทคโนโลยีอุตสาหกรรม

มหาวิทยาลัยราชภัฏสวนสุนันทา

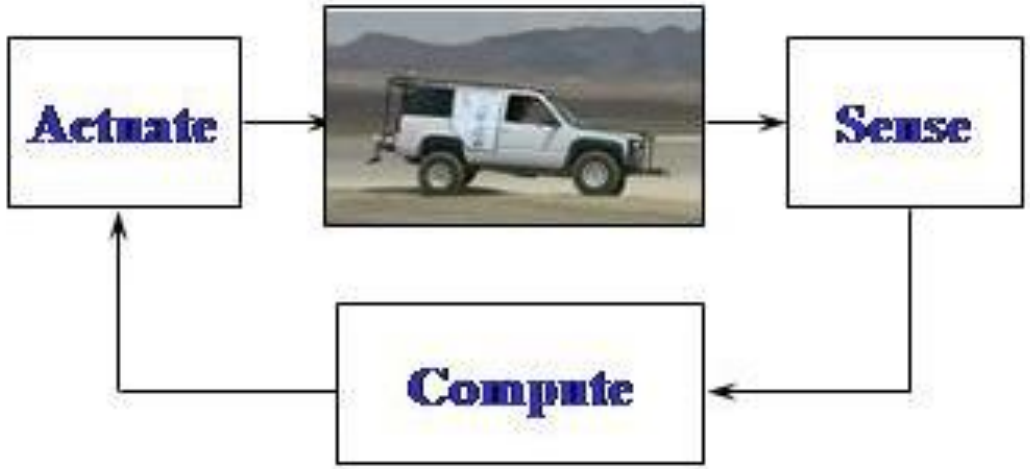
หนังสือและตำราอ้างอิง

- ศ. ดร.วิบูล แสงวีระพันธุ์ศิริ, การควบคุมระบบพลศาสตร์, โรงพิมพ์แห่งจุฬาลงกรณ์มหาวิทยาลัย
- ผศ. ดร.ปรัชญา เปรมปราณีรัชต์, พลศาสตร์ของระบบและการควบคุม, สำนักพิมพ์ มหาวิทยาลัยธรรมศาสตร์, 2562
- Richard C. DORF and Robert H. BISHOP, Modern Control Systems, Ninth Edition, Prentice Hall,2001
- Katsushiko OCATA, Modern Control Engineering, Fifth Edition, Pearson, 2020

CH 1 Introduction to Control System

Objective

- Introduction
- History of Automatic Control
- Control Engineering Practice
- Example of Modern Control System in Robotics
- Engineering Design
- Control System Design
- Design Example



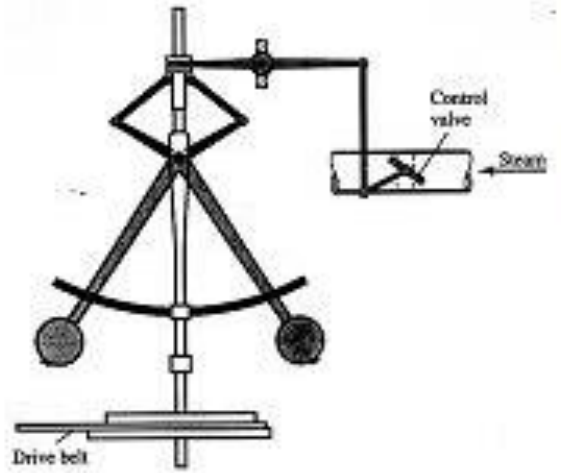
Control =

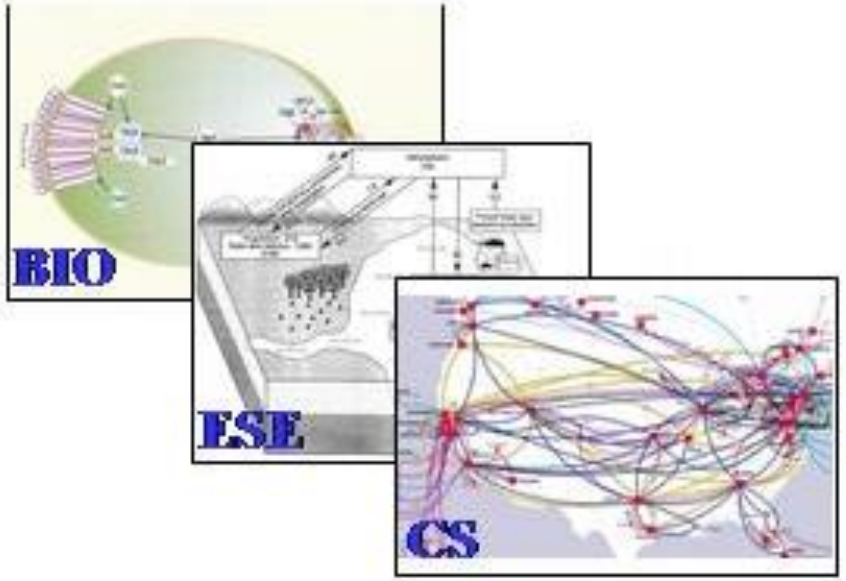
Sensing + Computation + Actuation

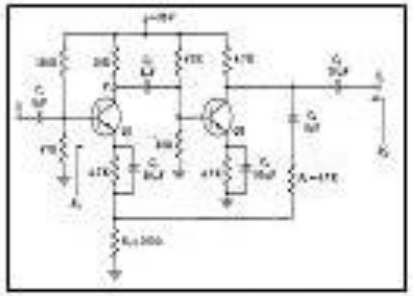
Feedback Principles

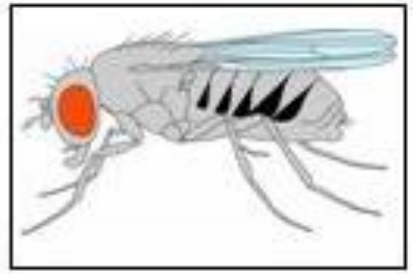
- Robustness to Uncertainty
- Design of Dynamics

Many examples of feedback and control in natural & engineered systems:

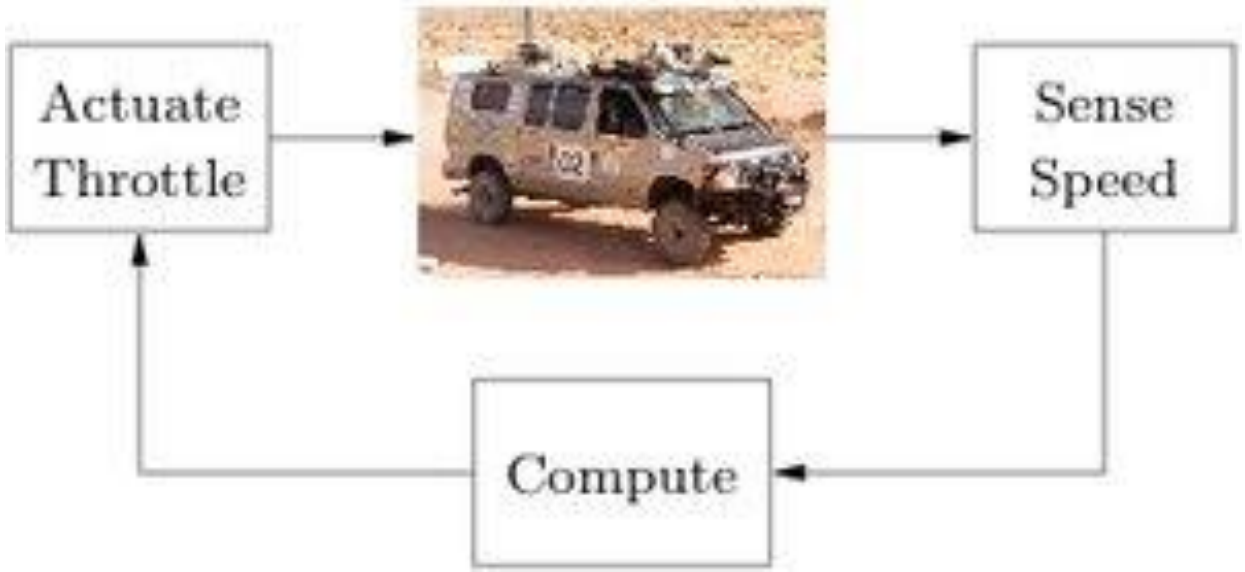




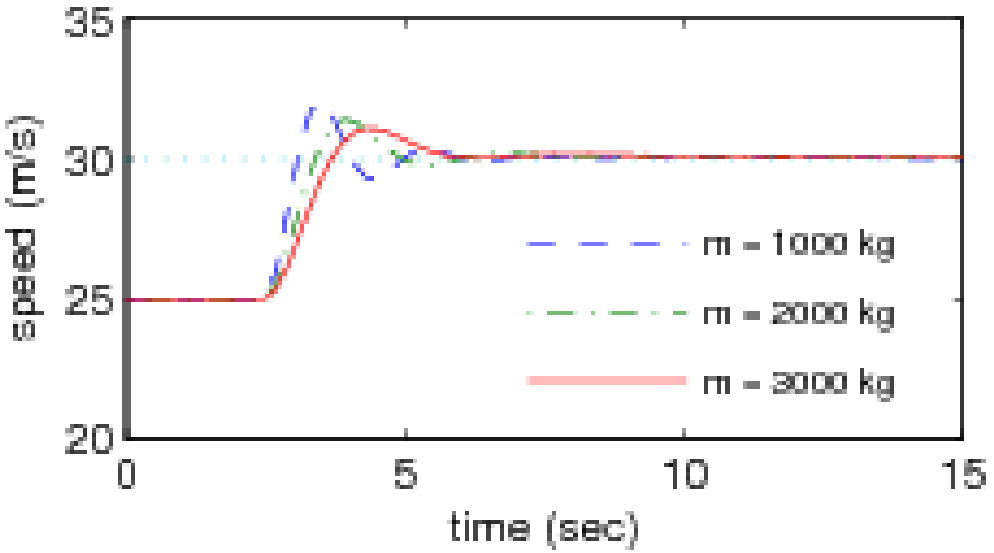




Introduction to automatic system (Control System Design)



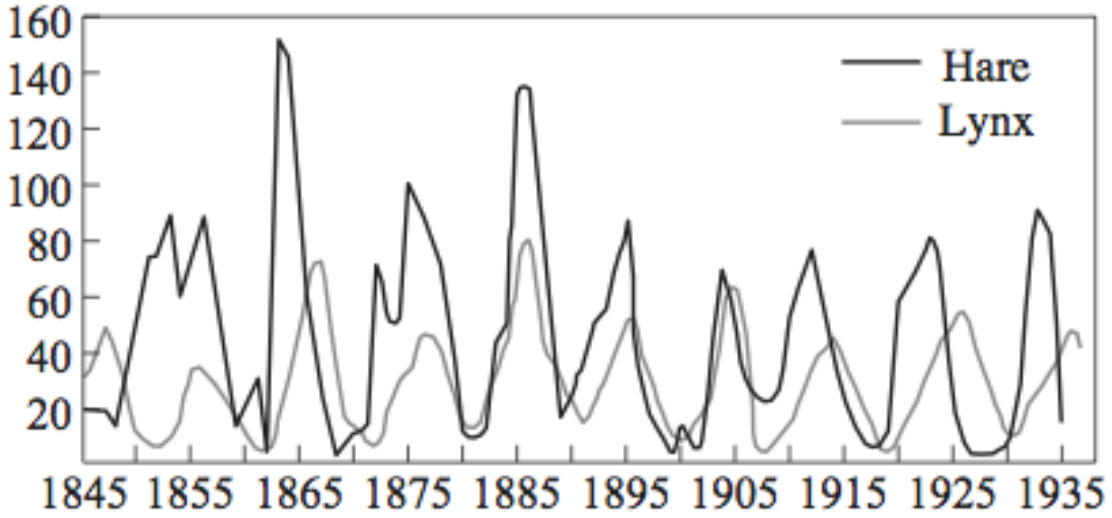
$$m\frac{dv}{dt} = F - F_d.$$



Cruise control

https://www.youtube.com/watch?v=zqc4hLAmnxM

Introduction to automatic system (Control System Design)



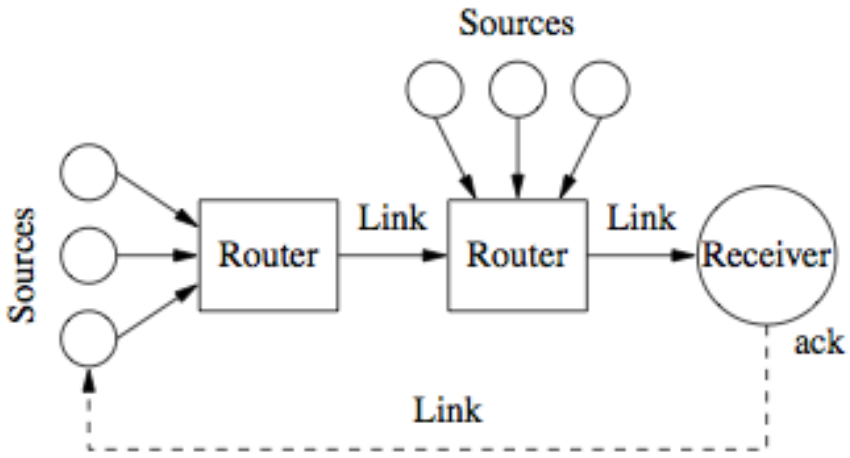
$$\frac{dH}{dt} = rH\left(1 - \frac{H}{k}\right) - \frac{aHL}{c+H}, \qquad H \geq 0,$$

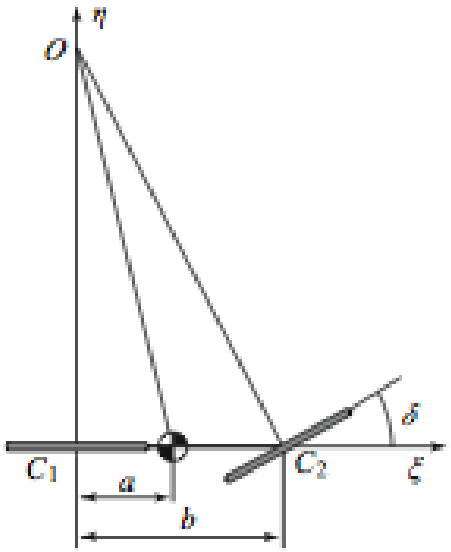
$$\frac{dL}{dt} = b\frac{aHL}{c+H} - dL, \qquad L \geq 0.$$

Prey predator model

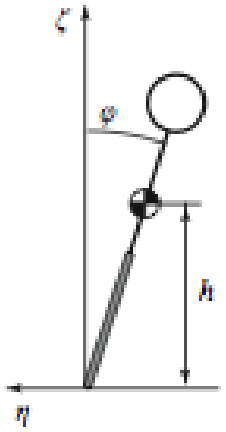
Introduction to automatic system (Control System Design)

Computer networking Congestion Control

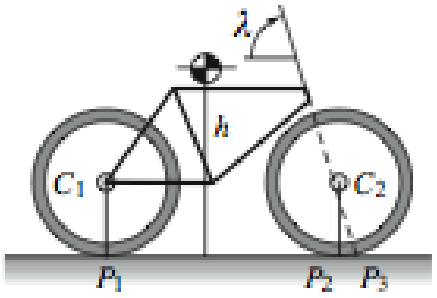




(a) top view



(b) rear view



(c) side view

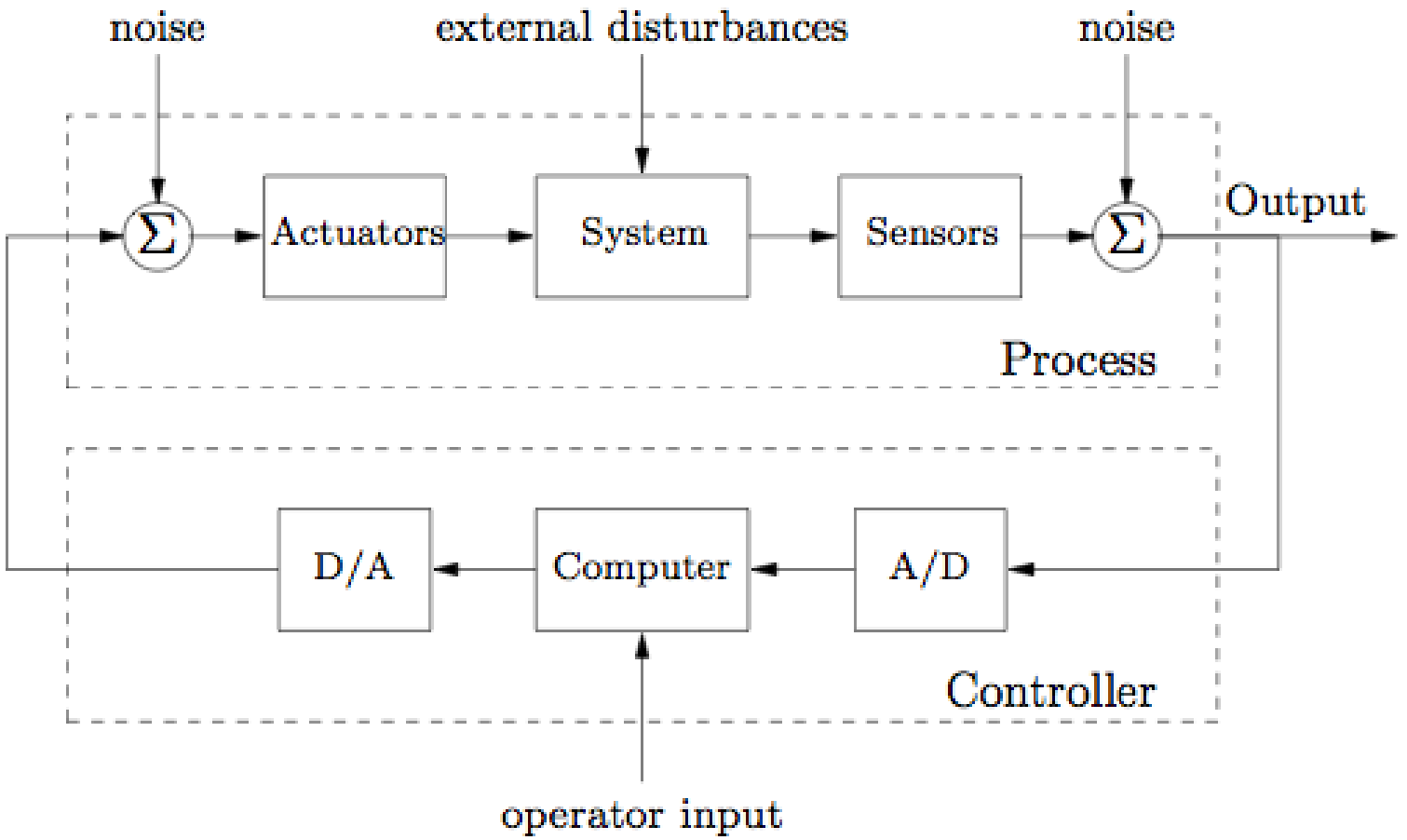
$$J\frac{d^2\phi}{dt^2} - \frac{Dv_0}{b}\frac{d\delta}{dt} = mgh\sin\phi + \frac{mv_0^2 h}{b}\delta,$$

$$M\begin{bmatrix}\ddot{\phi}\\ \ddot{\delta}\end{bmatrix} + Cv_0\begin{bmatrix}\dot{\phi}\\ \dot{\delta}\end{bmatrix} + (K_0 + K_2 v_0^2)\begin{bmatrix}\phi\\ \delta\end{bmatrix} = \begin{bmatrix}0\\ T\end{bmatrix},$$

Introduction to Control System Design

Process to be controlled

Exercise (Human Balance System)



Introduction to Control System Design

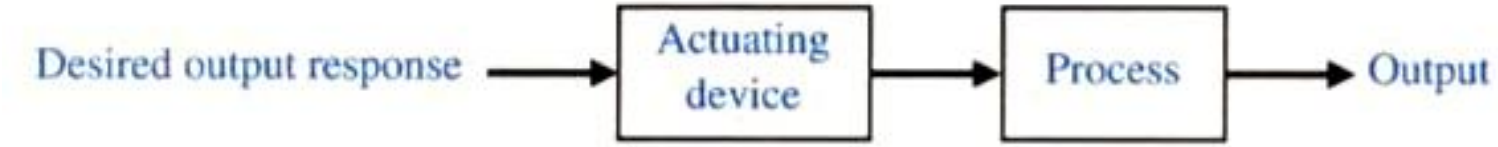
Mathematical Model of Systems

Relationship between input and output

Test inputs

Control System Designs

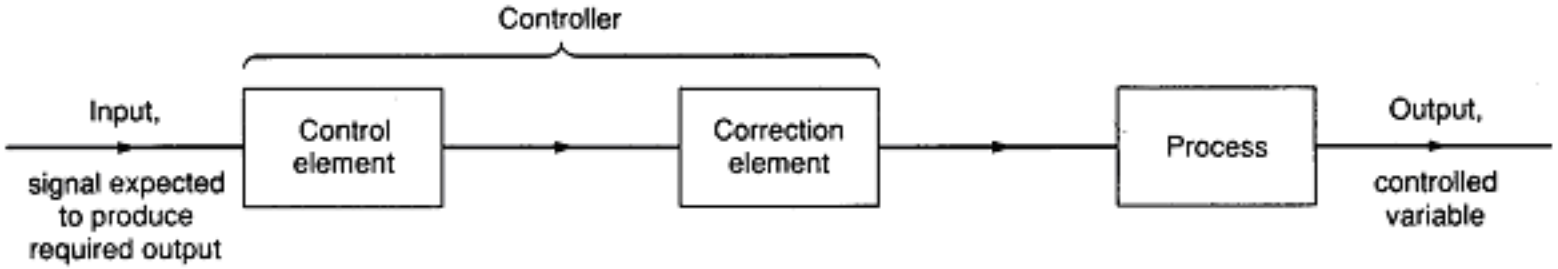
Open-loop Control



Actuating device / actuator

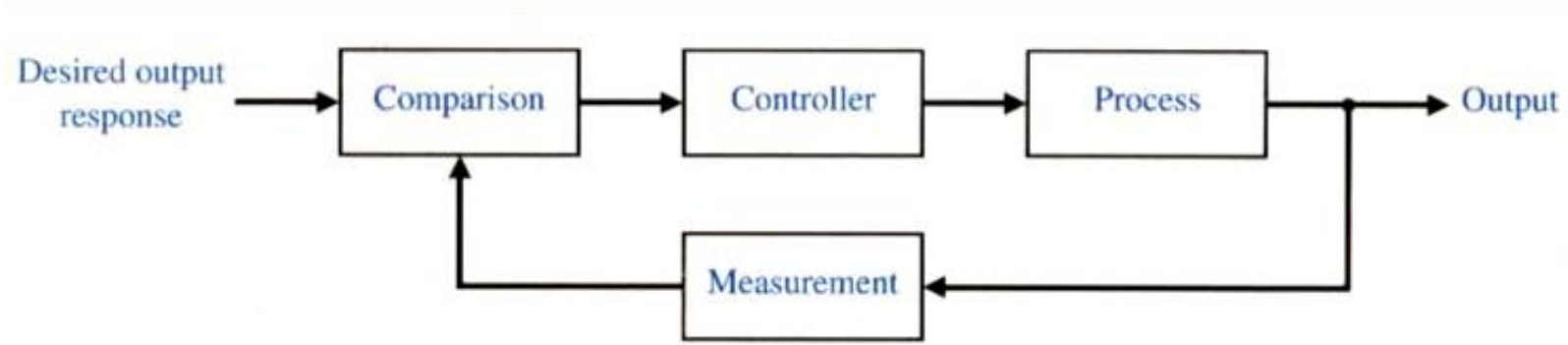
Control System

Open-loop Control



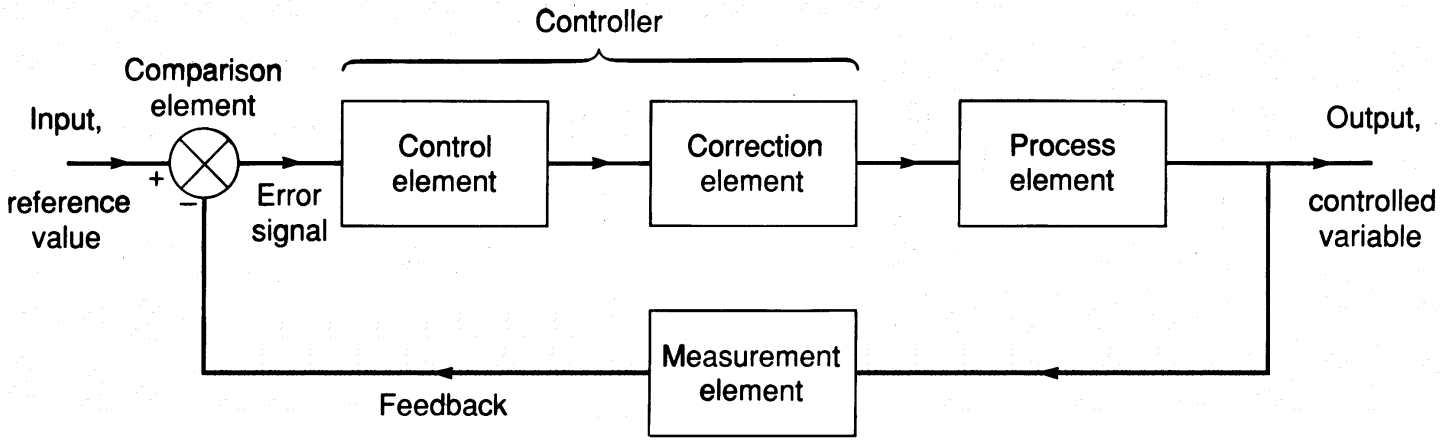
Control System

Closed-loop Control or Feedback Control



Control System

Closed-loop Control (Feedback Control)



Closed-loop Control

Comparison Element

Control Element

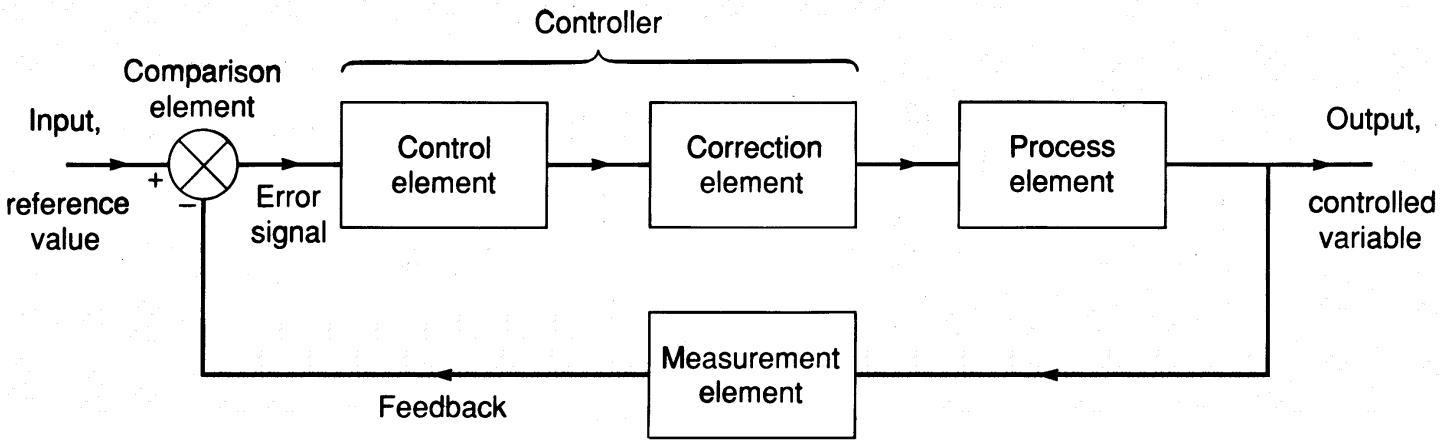
Correction Element

Process Element

Measure Element

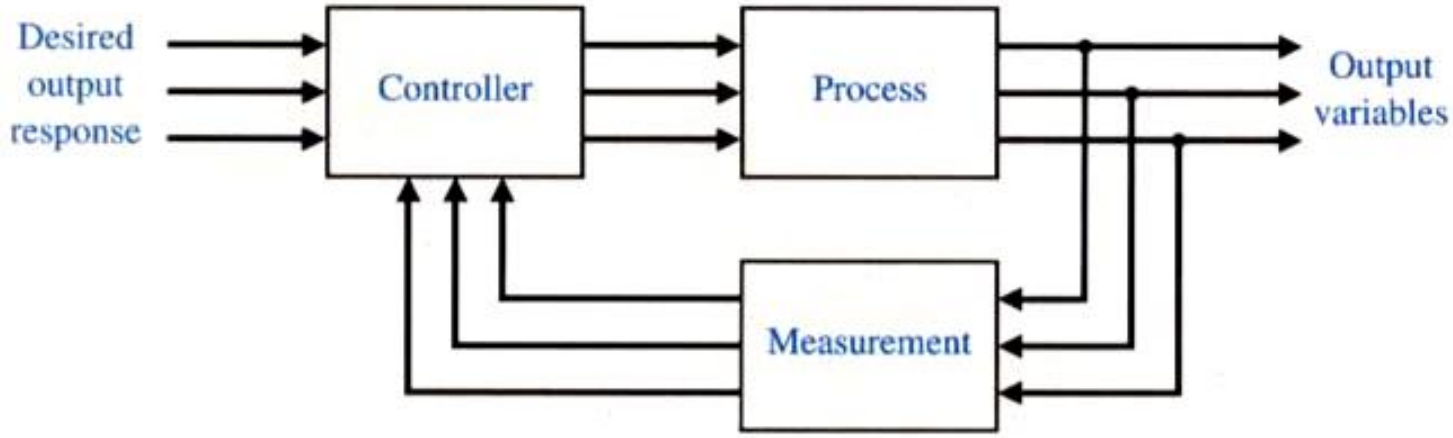
Control System

SISO (Single Input Single Output)



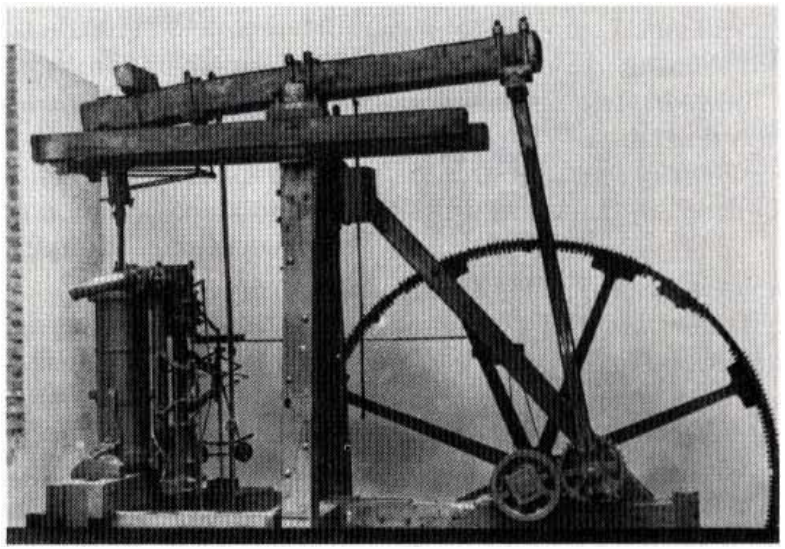
Control System

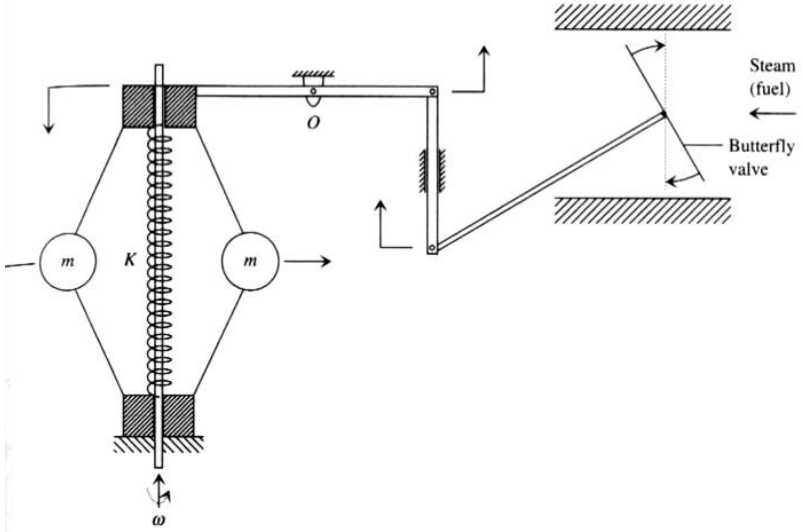
Multivariable Control System



History of Control System

1728 – Jame Watt



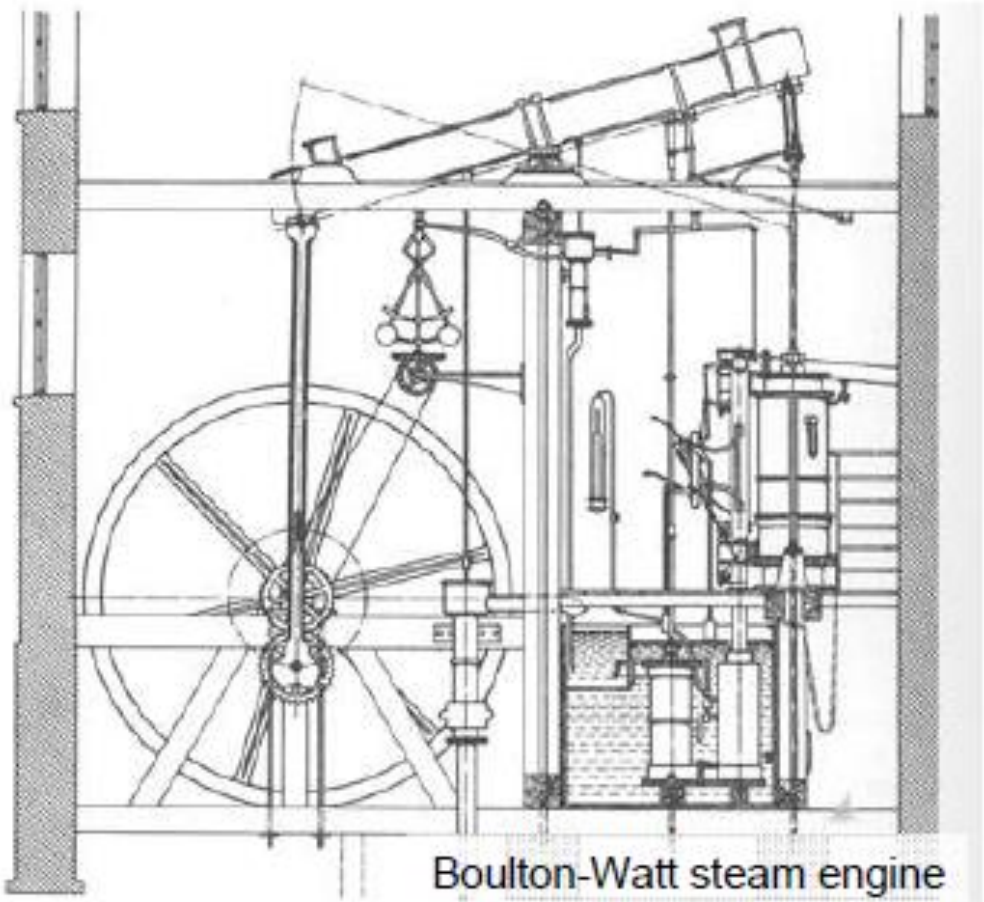


Flyball governor

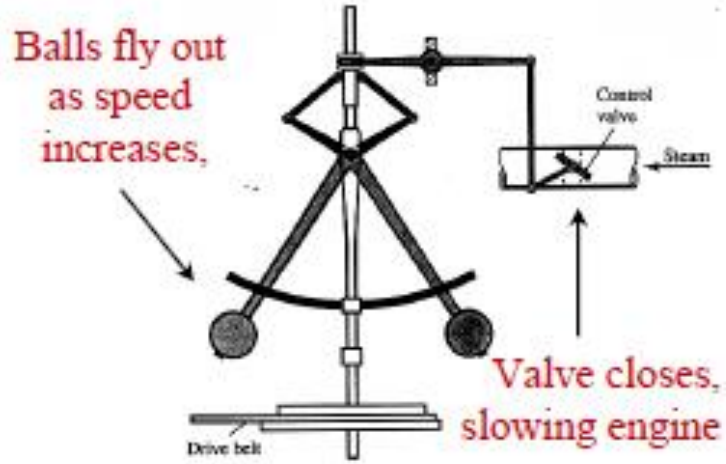
https://www.youtube.com/watch?v=Nr9UtEhyvfk

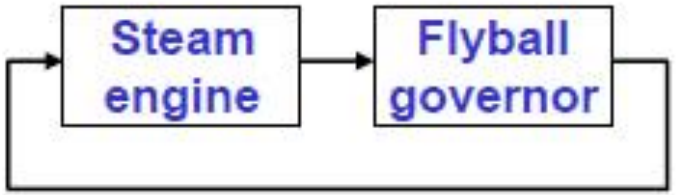
"Flyball" Governor (1788)

- Regulate speed of steam engine
- Reduce effects of variations in load (disturbance rejection)
- Major advance of industrial revolution



Boulton-Watt steam engine





History of Control System

1769 – Jame Watt

1868 – James Clark Mexwell

1877 – Routh's Stability Criterion

1890 - Liapunov M.A.

1932 – H.Nyquist

1934 – H.W.Bode

1947 – Nichols chart

1948 – W.R.Evans

1954 – George Devol

History of Control System

1956 – 1969 Optimal control, Dynamic program, Optimization system, Fuzzy logic

1970 – 1979 State space model, Adaptive control

1980 – 1989 Robustness control, AI

1990 – 1999 Robot development and application

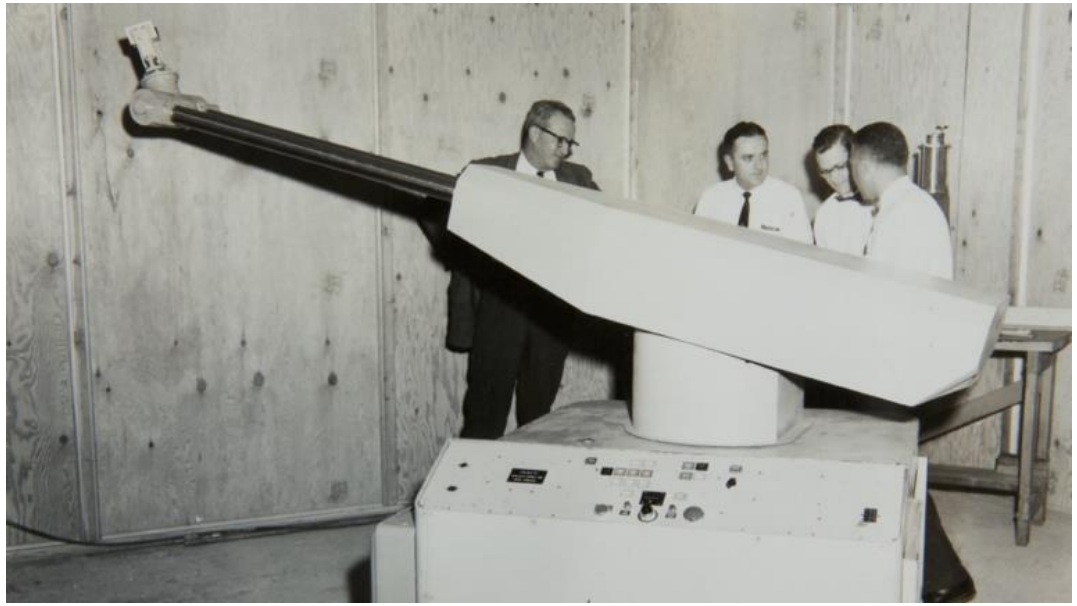
Control Engineering Practice

Analysis

- Stability
- Dynamic Response and Performance Indices
  - ☒ Speed ☒ Accuracy ☒Tolerance

Design

Example of Modern Control System in Robotics

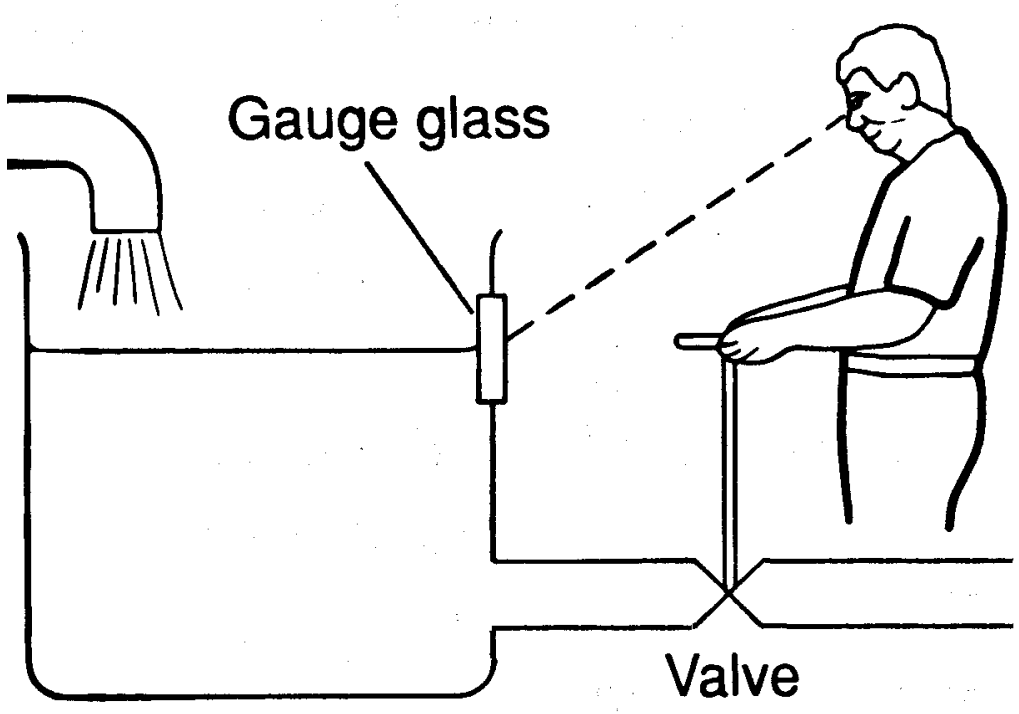


https://www.fanuc.eu/uk/en/robots

https://robotsdoneright.com/Articles/history-of-abb-robots.html

1940s-1950s: The Birth of Modern Robotics

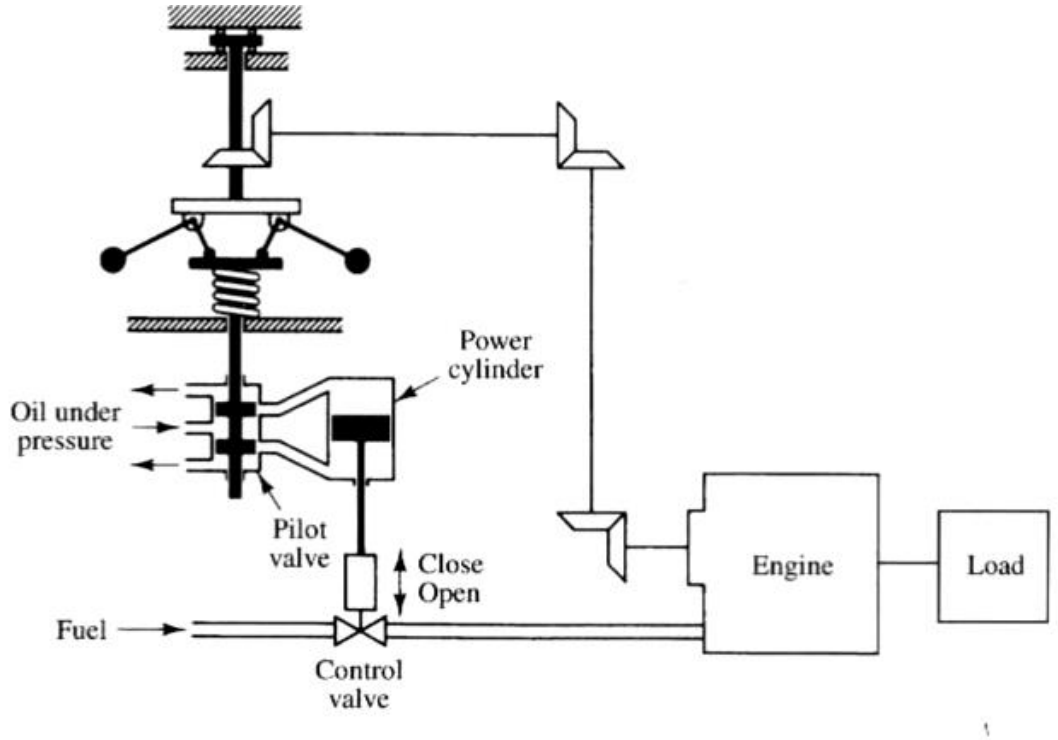
Examples of control systems



ระบบควบคุมการเปิดน้ำเข้าสู่ถังแบบปิด

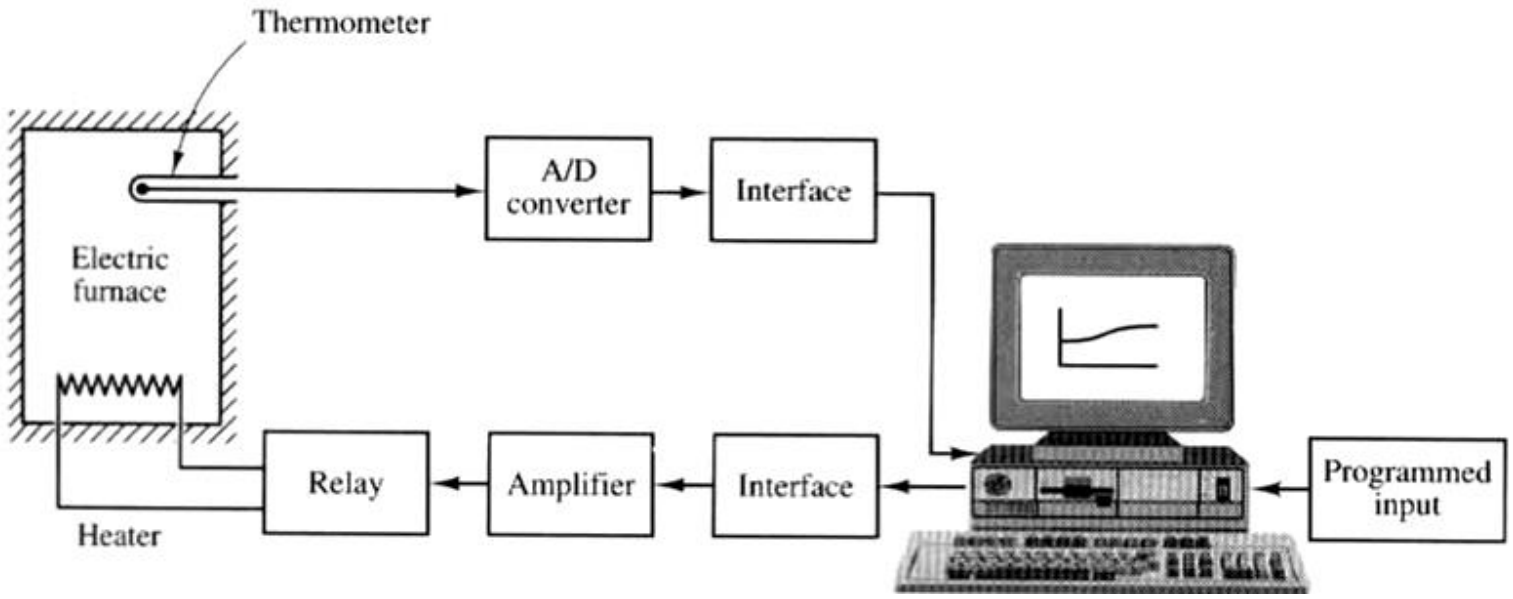
Controlled variable	ระดับน้ำในถังเก็บ
Reference valve	ระดับน้ำที่ต้องการในถัง ซึ่งอาจจะกำหนดด้วยขีดบนถังเก็บ
Comparison element	ผู้ควบคุม
Error signal	ความแตกต่างระหว่างระดับน้ำในถัง กับระดับน้ำที่ต้องการ
Control element	ผู้ควบคุม
Correction element	วาล์วน้ำ
Process	ปริมาณน้ำในถัง
Measuring device	ตาของผู้ควบคุมที่ใช้การมองระดับน้ำ

Examples of control systems



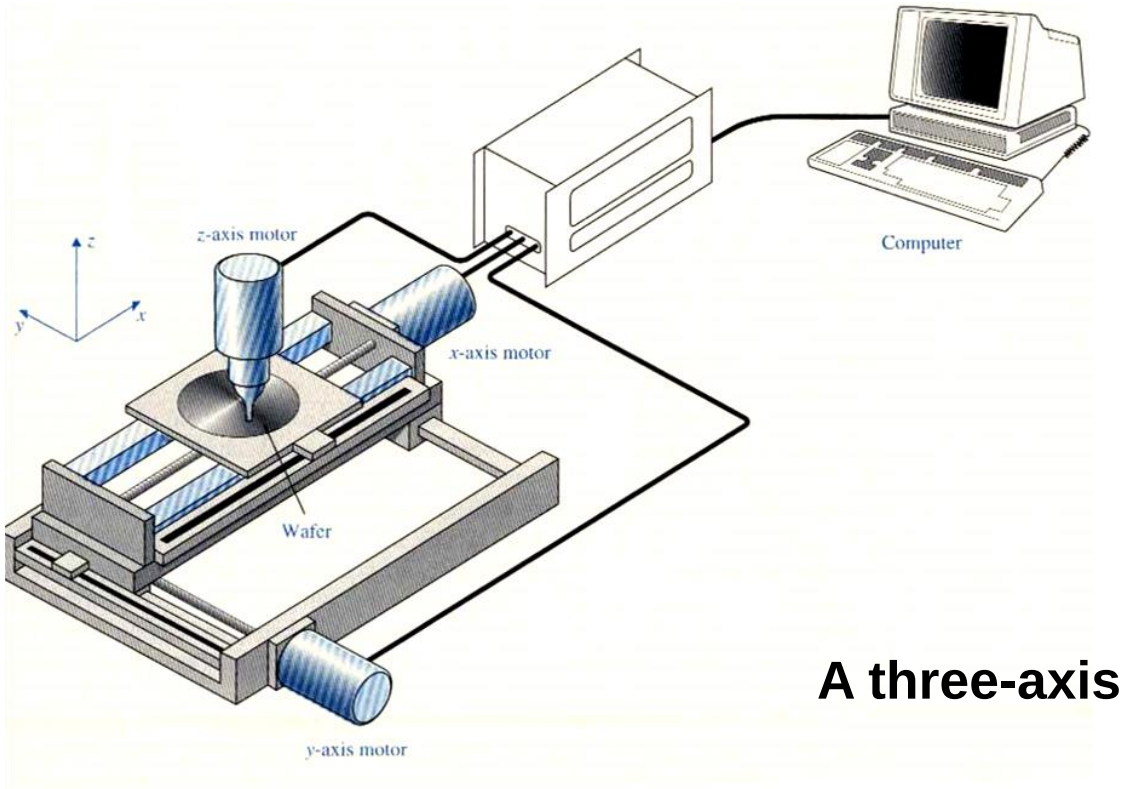
Speed Control System

Examples of control systems



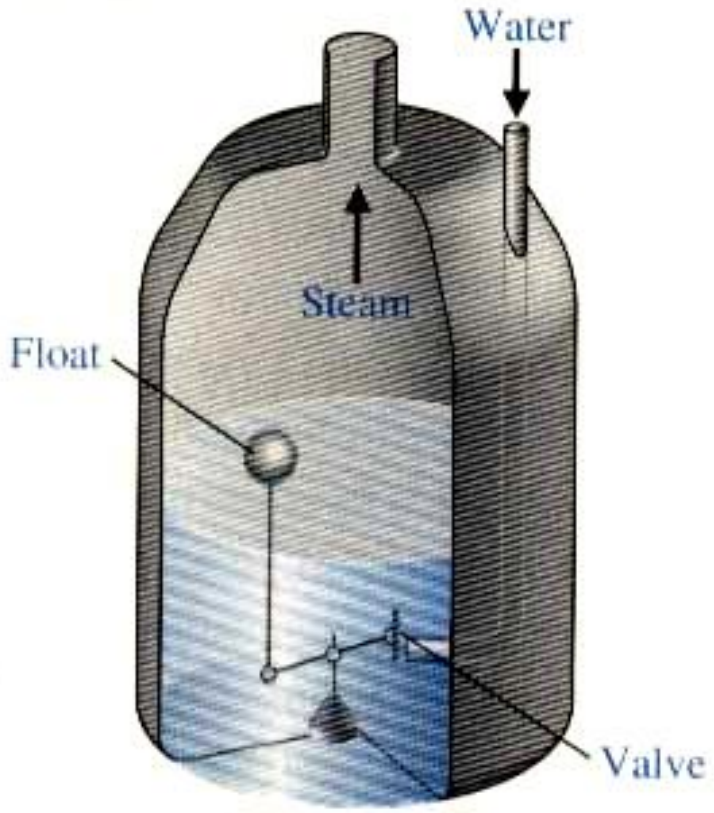
Temperature control system

Examples of control systems



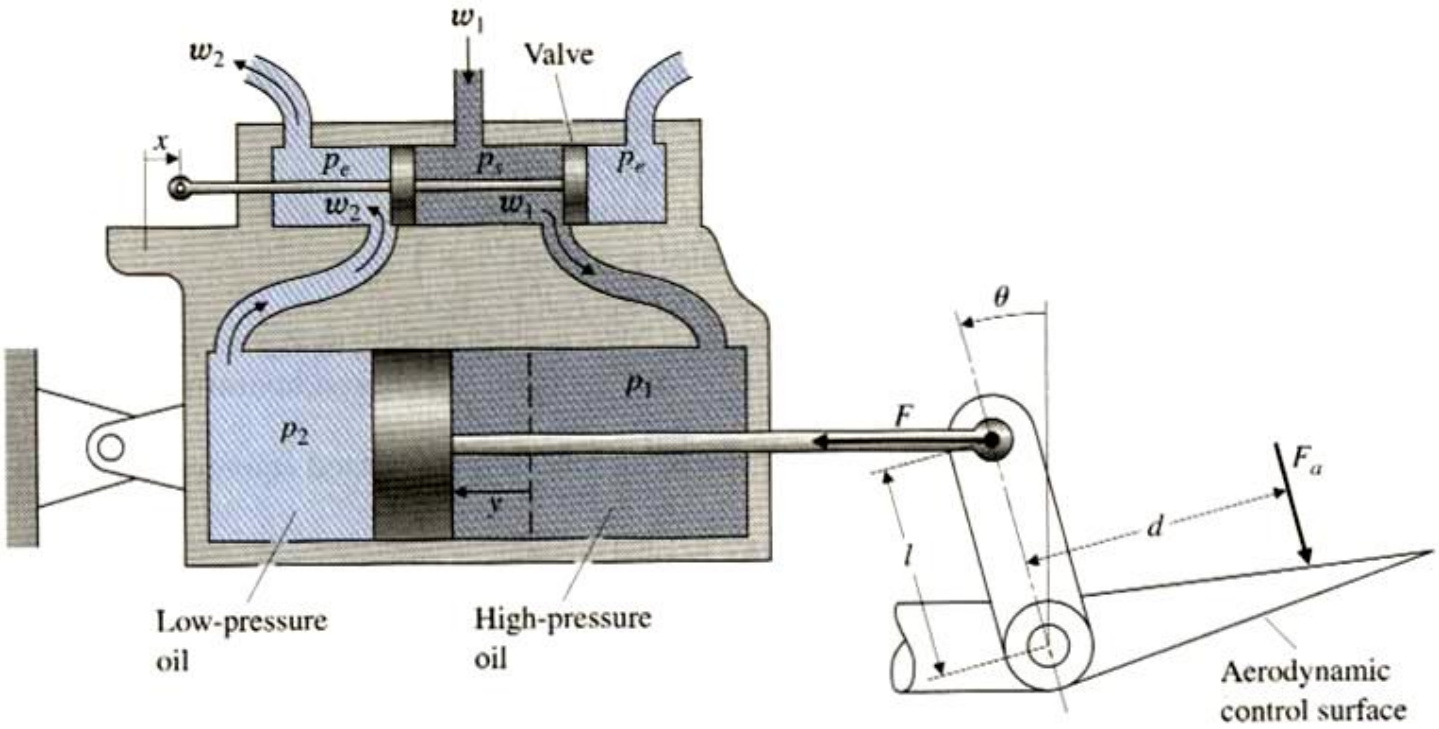
A three-axis control system

Examples of control systems



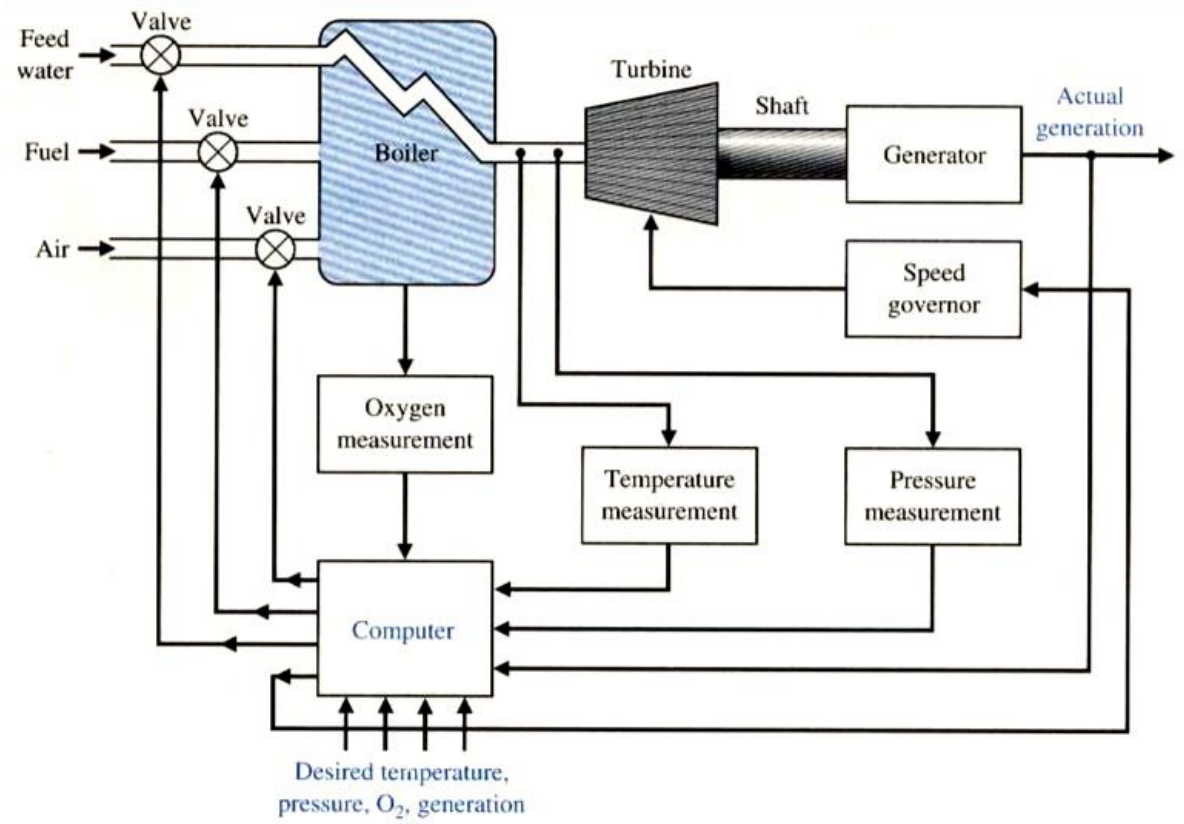
Water-level float regulator

Examples of control systems



Hydraulic actuator with valve

Examples of control systems

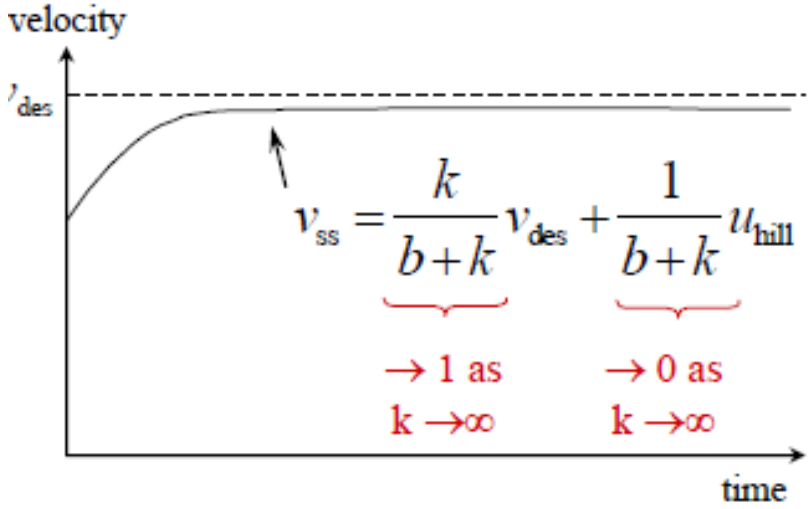


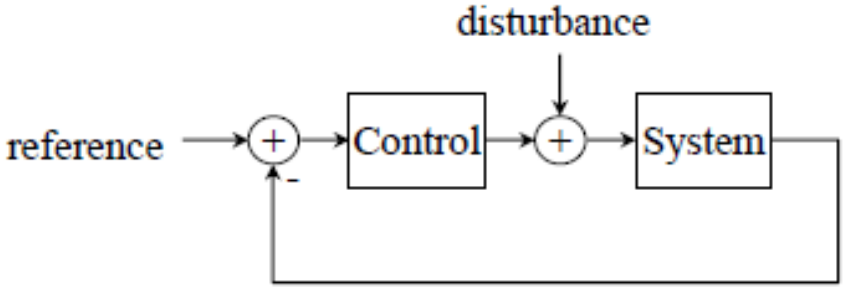
Coordinated control system for a boiler-generator

Engineering Design

Design is the process of conceiving or inventing the forms, parts and details of a system to achieve a specific purpose

$$m\dot{v} = -bv + f_{\text{engine}} + f_{\text{hill}}$$
$$f_{\text{engine}} = k(v_{\text{desired}} - v)$$





Stability/performance

- Steady state velocity approaches desired velocity as $k \to \infty$
- Smooth response; no overshoot or oscillations

Disturbance rejection

- Effect of disturbances (eg, hills) approaches zero as $k \to \infty$

Robustness

- Results don't depend on the specific values of *b*, *m* or *k*, for *k* sufficiently large

Major Challenge in Engineering Design

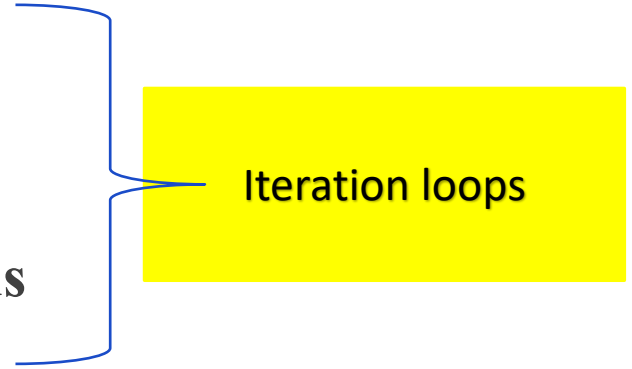
- **Specification**

How to appropriately obtain

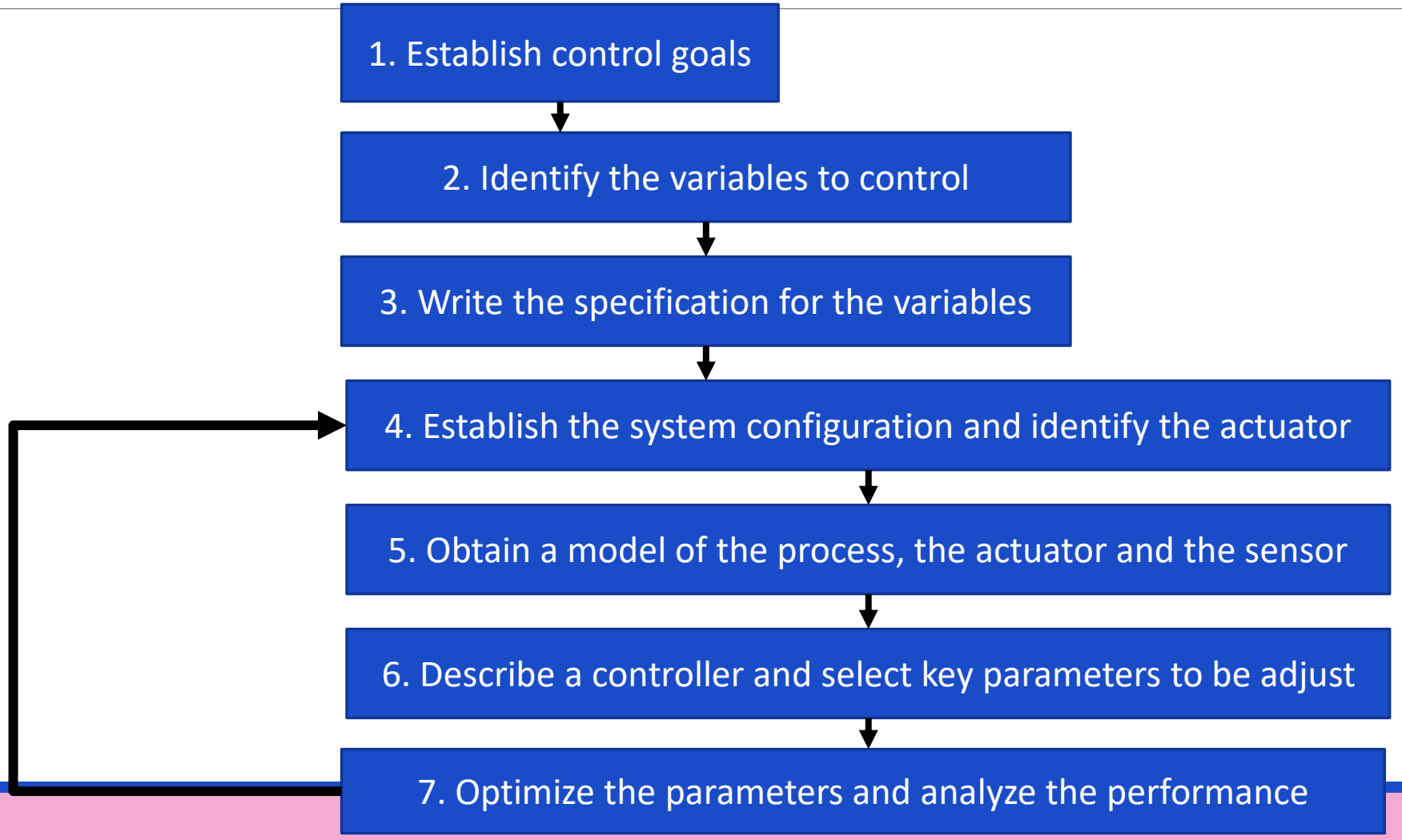
1. **Complexity of Design**
2. **Trade-Off**
3. **Design Gabs**
4. **Risk**

Effective Engineering Design

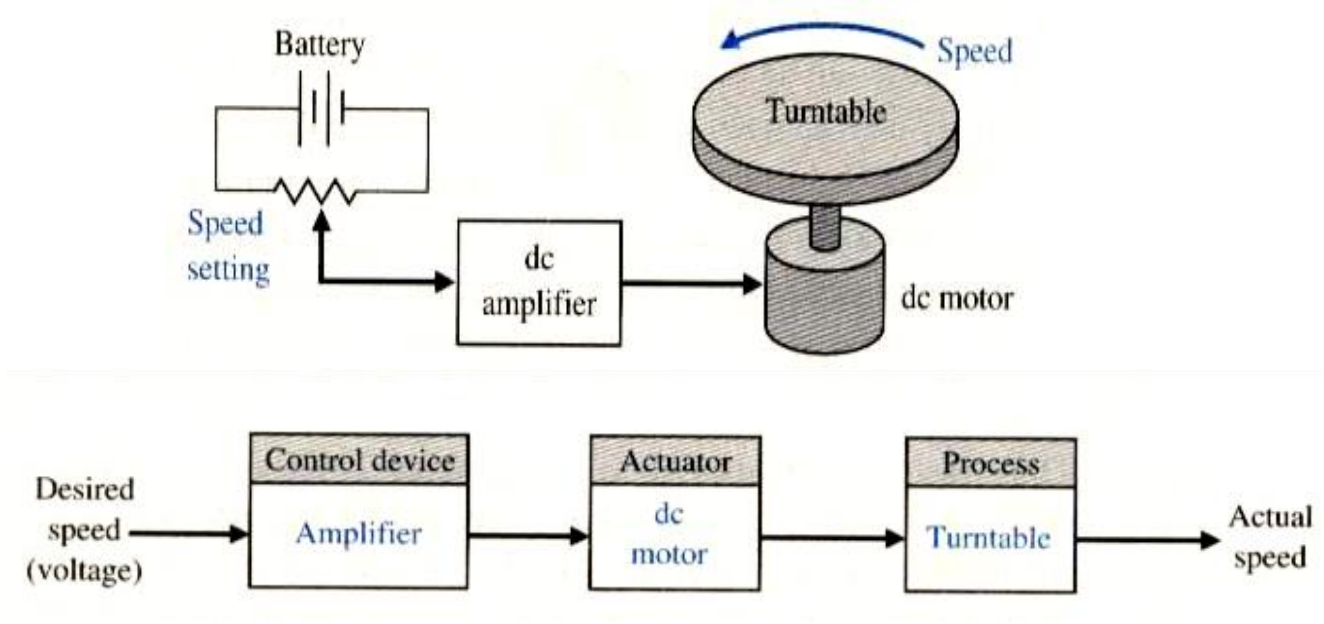
1. Analysis and
    1. Identification of key parameters
    2. Generation of the system configurations
    3. Evaluation of how well the configuration meets the needs
2. Optimize the parameters



CONTROL SYSTEM DESIGN PROCESS

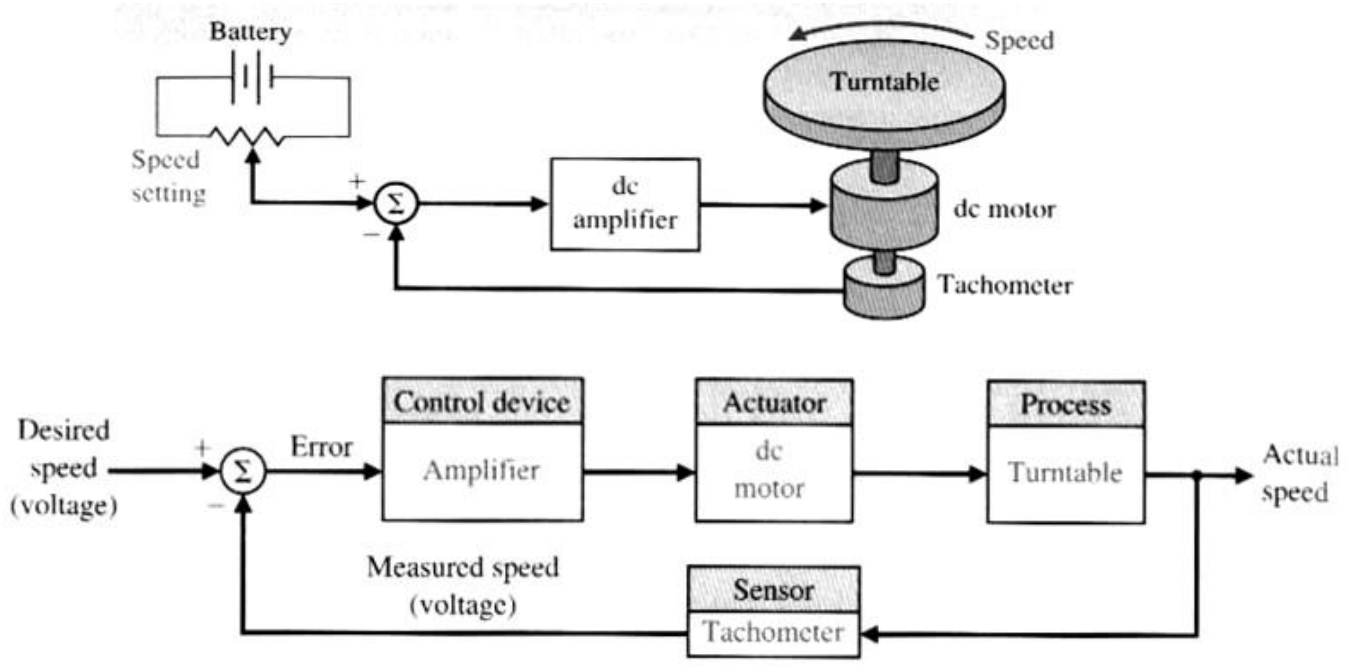


Design Examples of control systems "Turntable Speed Control"



Turntable speed control (Open-loop control)

Design Examples of control systems "Turntable Speed Control"



Turntable speed control (Closed-loop control)

Sequential Design Example "Disk Drive Read System"

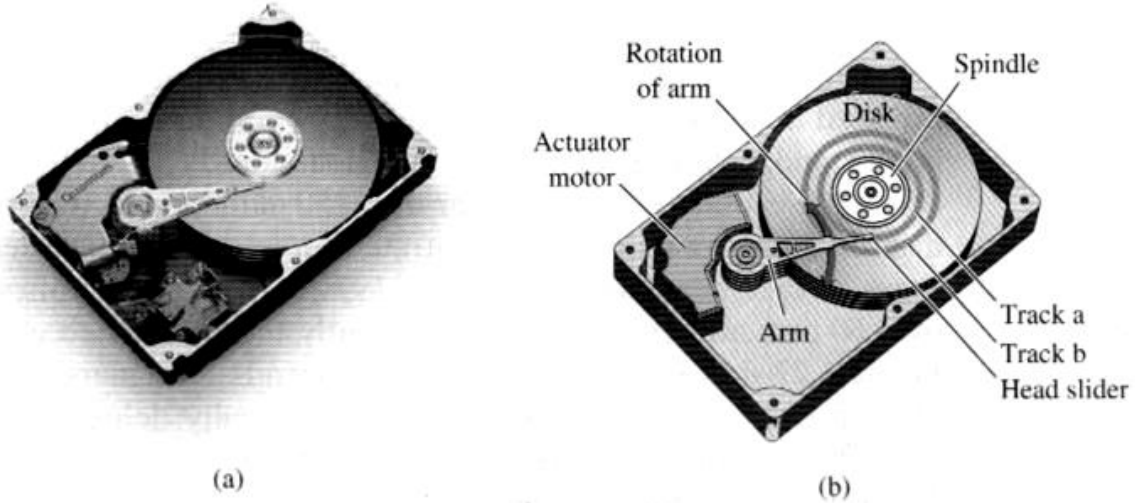


FIGURE 1.28
(a) A disk drive © 1999 Quantum Corporation. All rights reserved. (b) Diagram of a disk drive.

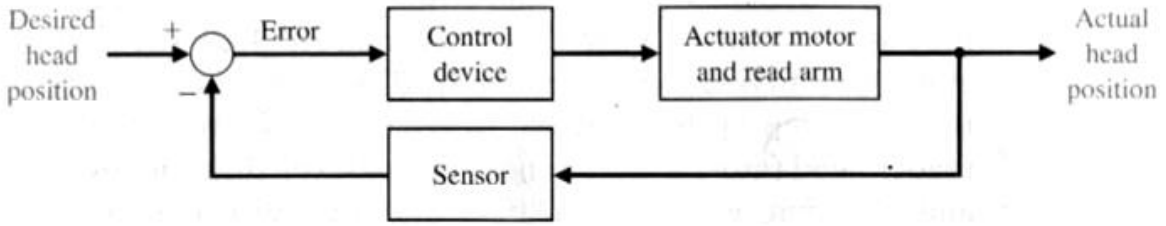


FIGURE 1.29
Closed-loop control system for disk drive.

ADVANTAGES OF CONTROL SYSTEMS

ADVANTAGES OF CONTROL SYSTEMS

ADVANTAGES OF CONTROL SYSTEMS