System Control

1. Introduction

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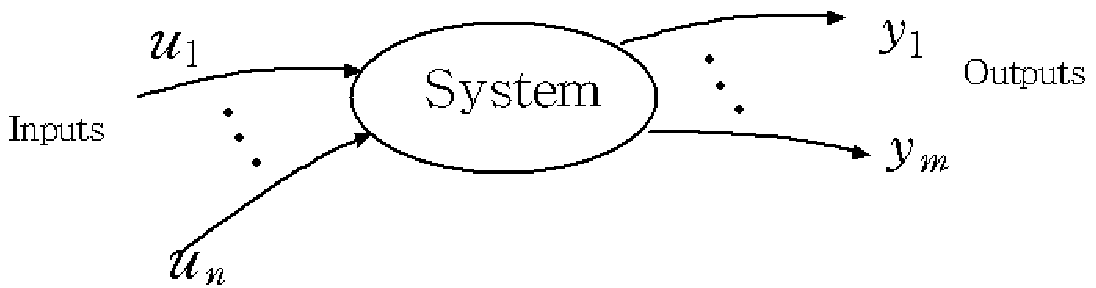
System / Control / Design

- **System**

- **A combination of components acting together to perform a certain objective**



- **Control**

- **Applying inputs to the system to correct or limit deviation of the output values from desired values**

Control systems
Engineering systems

System / Control / Design

- System

- Control

System control

Control systems

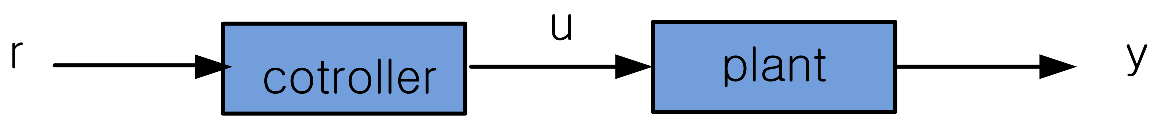
Engineering systems

Control system examples

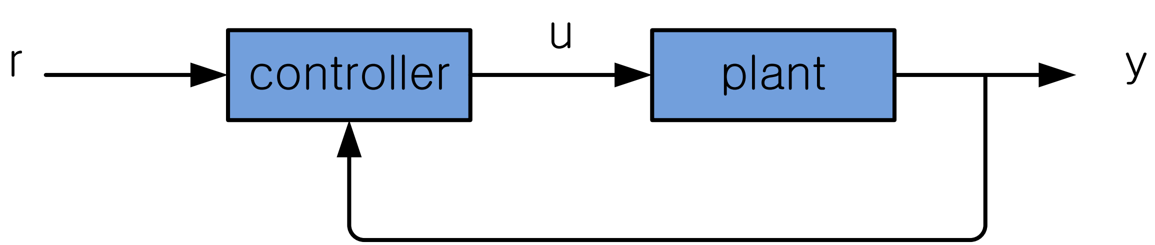
Open / Closed loop control

- **OPEN loop control**

$$u = f(r)$$

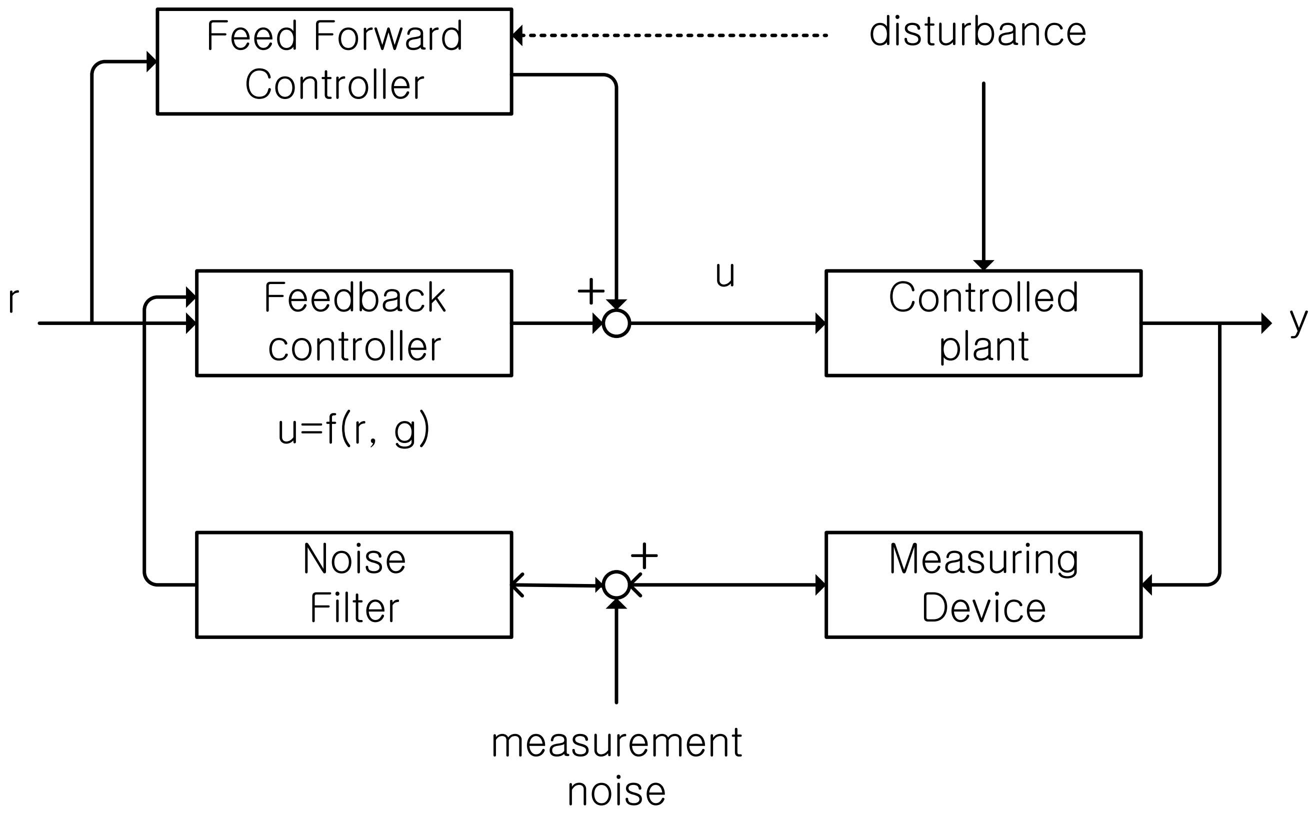


- **CLOSED loop control (Feedback control)**



$$u = f(r, y)$$

Block Diagram of Typical control system



System / Control / Design

- **Design (System Design)**

- **The process of finding a system that accomplishes a given task**
- **Trial and error : Not unique**

- **Controller Design : control algorithm**

$$u(t) = f\left(r, y, u(\tau), t\right) \qquad \tau < t$$

- **Control System Design**

- **Design controller and decide what kind of sensors/actuators are used for the control for a given plant**
- **Design whole control system, i.e. plant and controller, selection of sensor and actuators to satisfy given performance specifications**

Control system – perform specific task

Performance specifications

Transient response requirements

– speed of response, relative stability

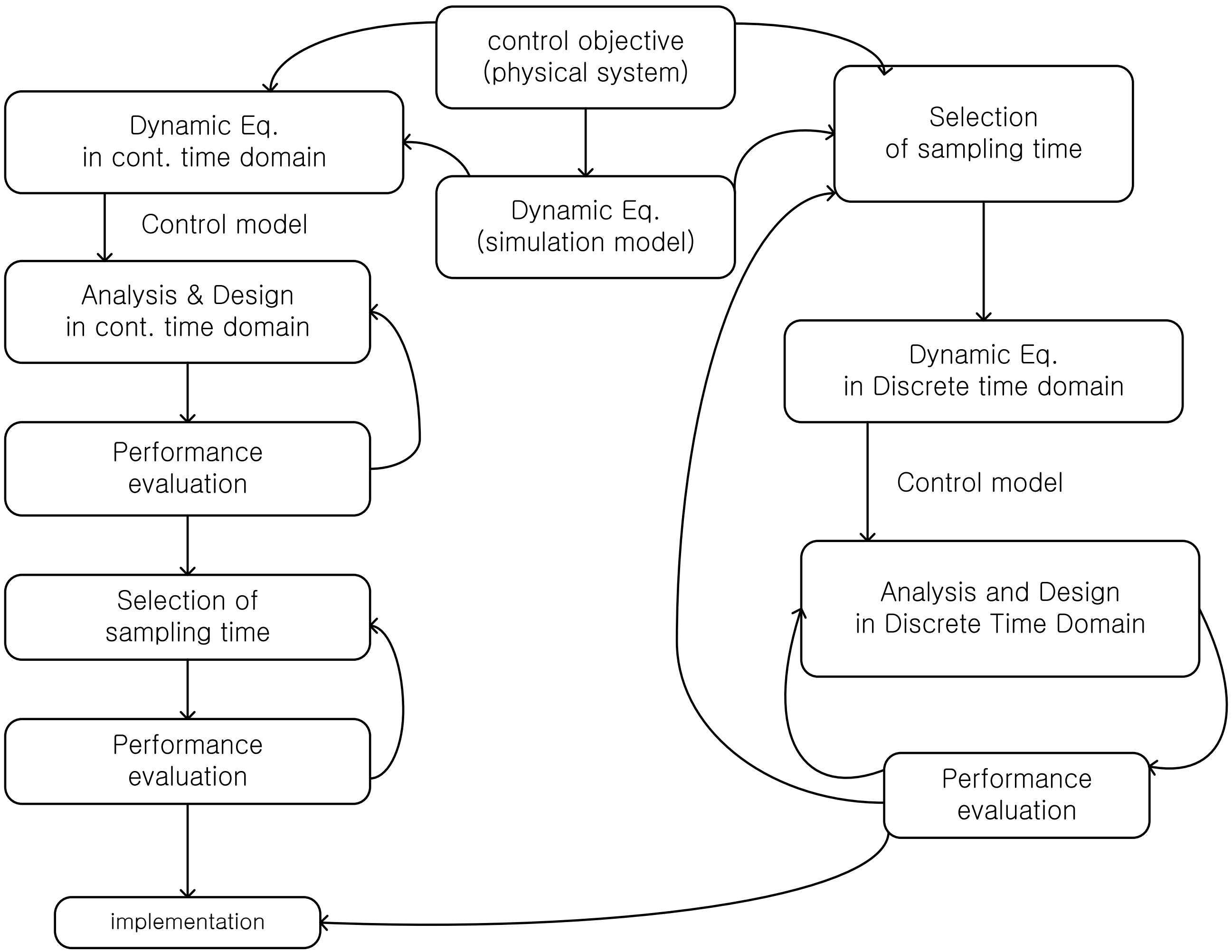
Steady state requirements - accuracy

Frequency response terms

The Process of Designing a Control System

1. **Study** – Study the system to be controlled and decide what types of sensors and actuators
2. **Modeling** – Model the resulting system
3. **Simplify** – Simplify the system if necessary so that it is tractable
4. **Analyze** – Analyze the resulting model; determine its properties
5. **Performance Specifications** – Decide on performance specifications
6. **Type of Controller** – Decide on the type of controller to be used
7. **Design a Controller** – Design a controller to meet the specs, if possible; if not, modify the specs or generalize the type of controller sought
8. **Simulations** – Simulate the resulting controlled system, on a computer or in a pilot plant
9. **Evaluation** – Repeat from step 1 if necessary
10. **Hardware Implementation**
11. **Tuning** – Tune the controller on-line if necessary

Design Approach



The Process of Designing a Control System

- **Control Engineers' Role**

- **Not simply "wrapping a little feedback" around an already fixed physical system**
- **Assisting in the choice and configuration of hardware by taking " a system-wide view of performance"**

- **Key Issues in Control Systems**

  ① Stability

  ② Performance

  - **command tracking**
  - **disturbance rejection**

  ③ Robustness

  - **model uncertainty**
  - **time varying characteristics**
  - **sensor noise**

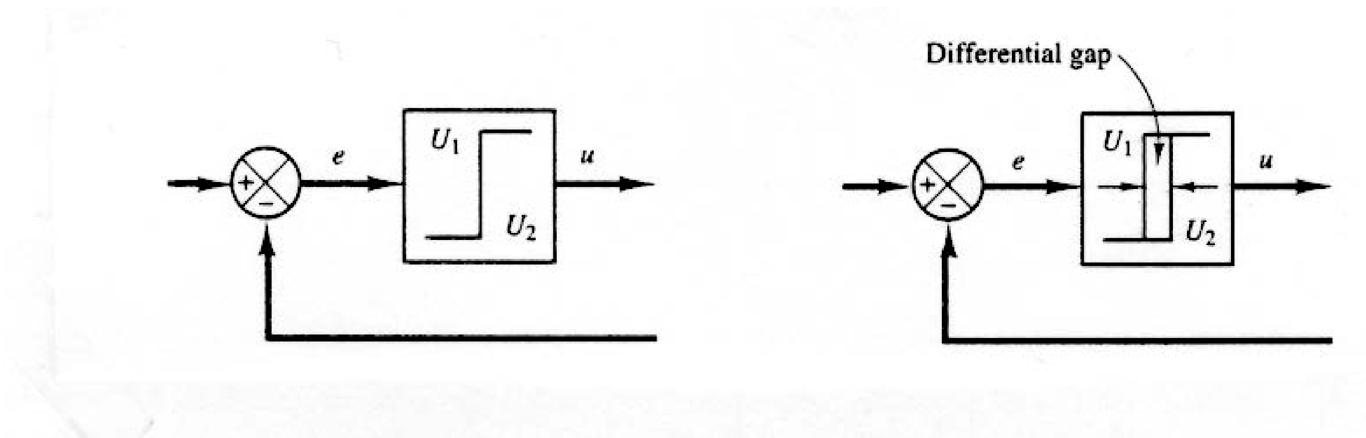
- **Control System Design**

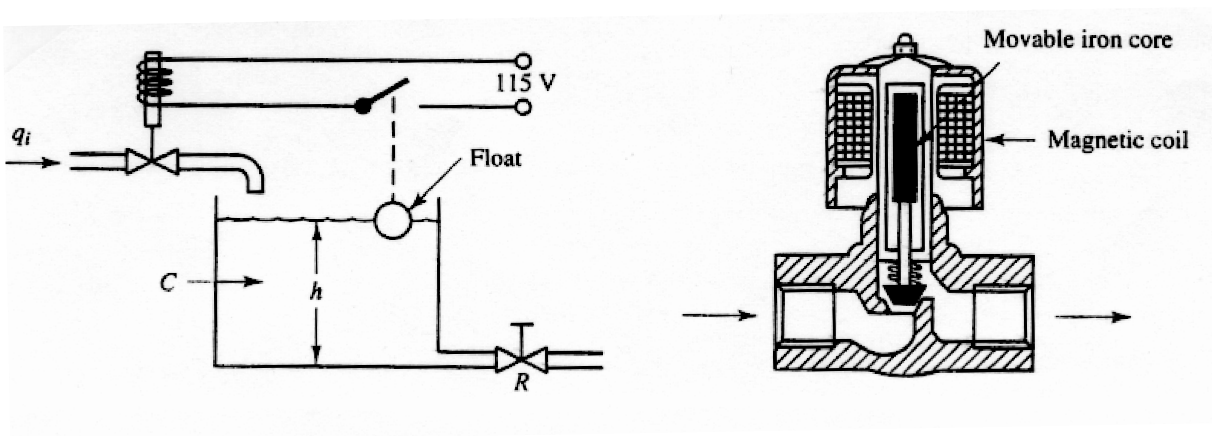
  - "trade off" between Performance and Robustness

End

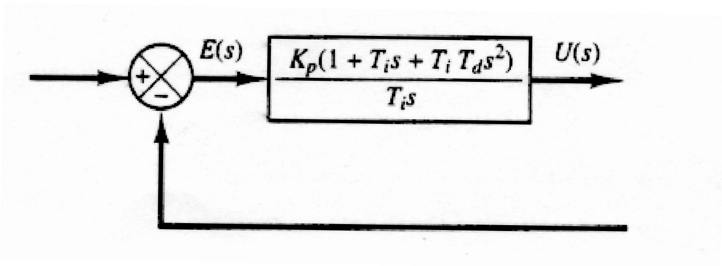
Vehicle System

On – Off Control (Liquid level control system)

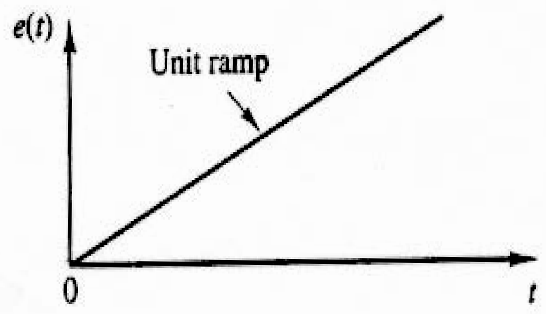




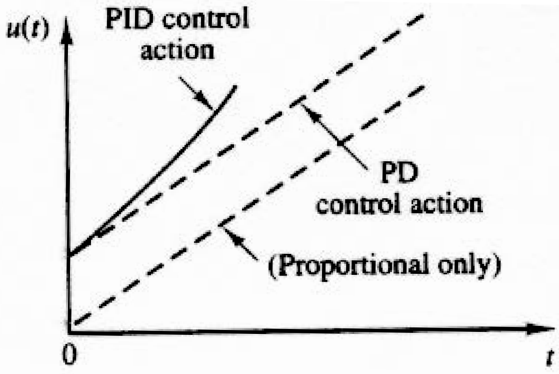
PID Control



E(s)
$\frac{K_p(1 + T_i s + T_i T_d s^2)}{T_i s}$
U(s)

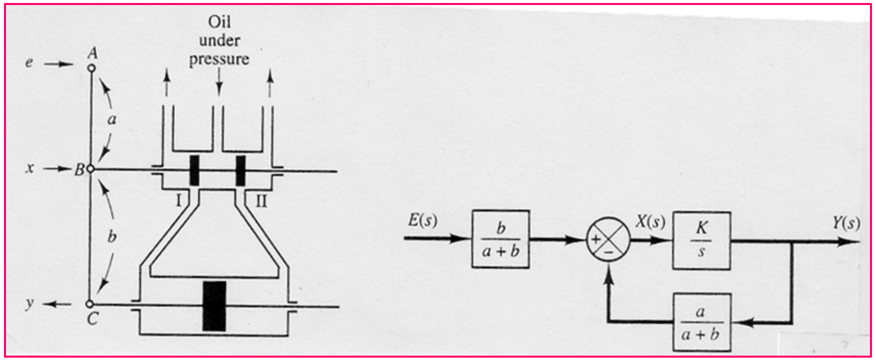


e(t)
Unit ramp
0
t



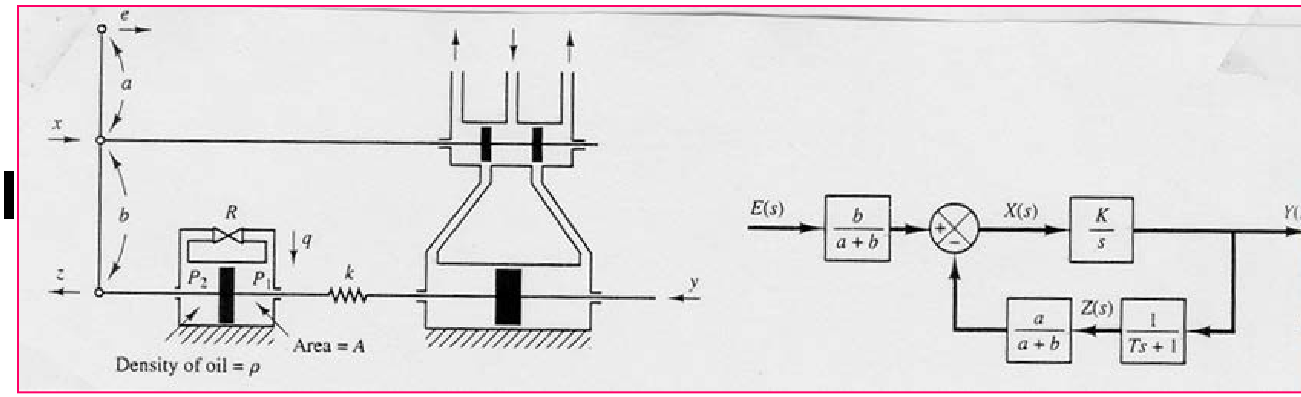
u(t)
PID control
action
PD
control action
(Proportional only)
0
t

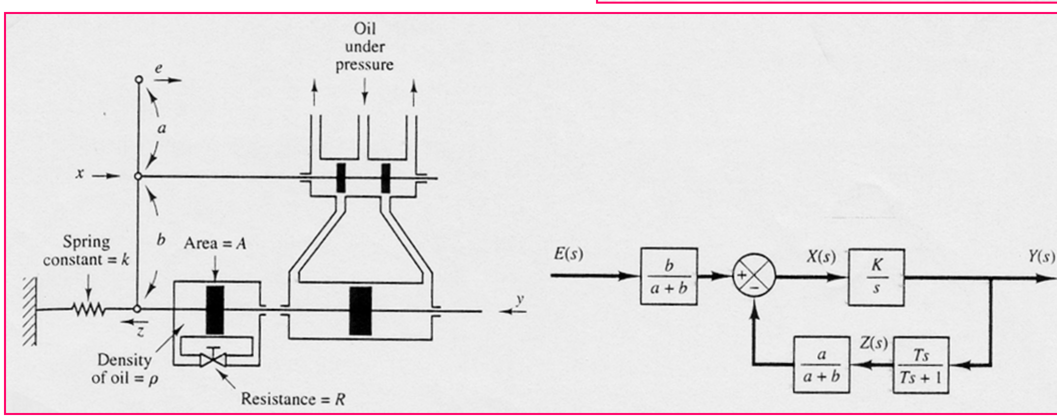
Hydraulic Controller



P -control

PD -control





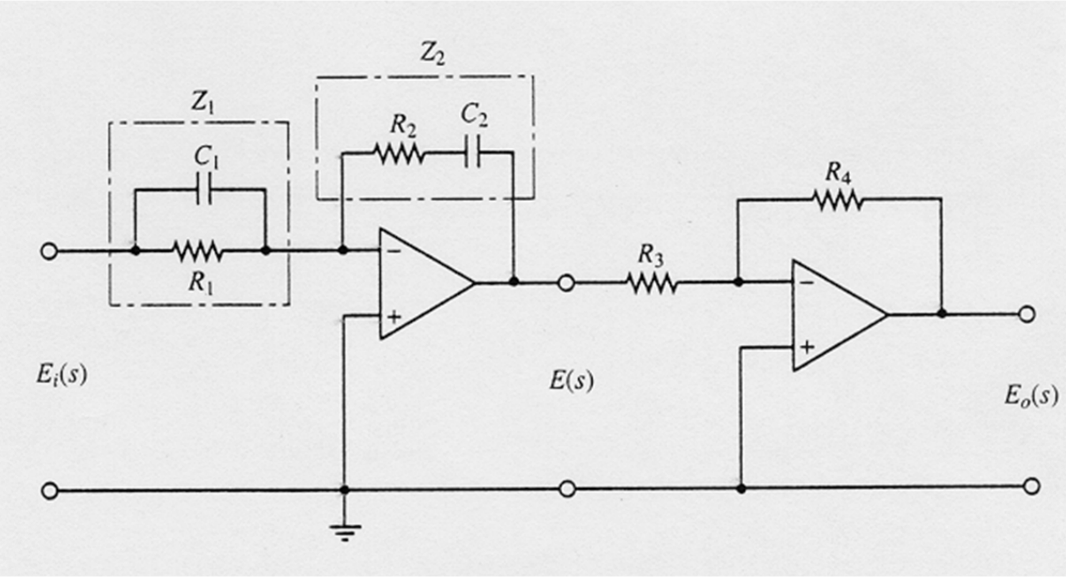
PI -control

Electronic Controller

$$\frac{E_o(s)}{E_i(s)} = \frac{E_o(s)}{E(s)}\frac{E(s)}{E_i(s)} = \frac{R_4R_2}{R_3R_1}\frac{(R_1C_1s+1)(R_2C_2s+1)}{R_2C_2s}$$

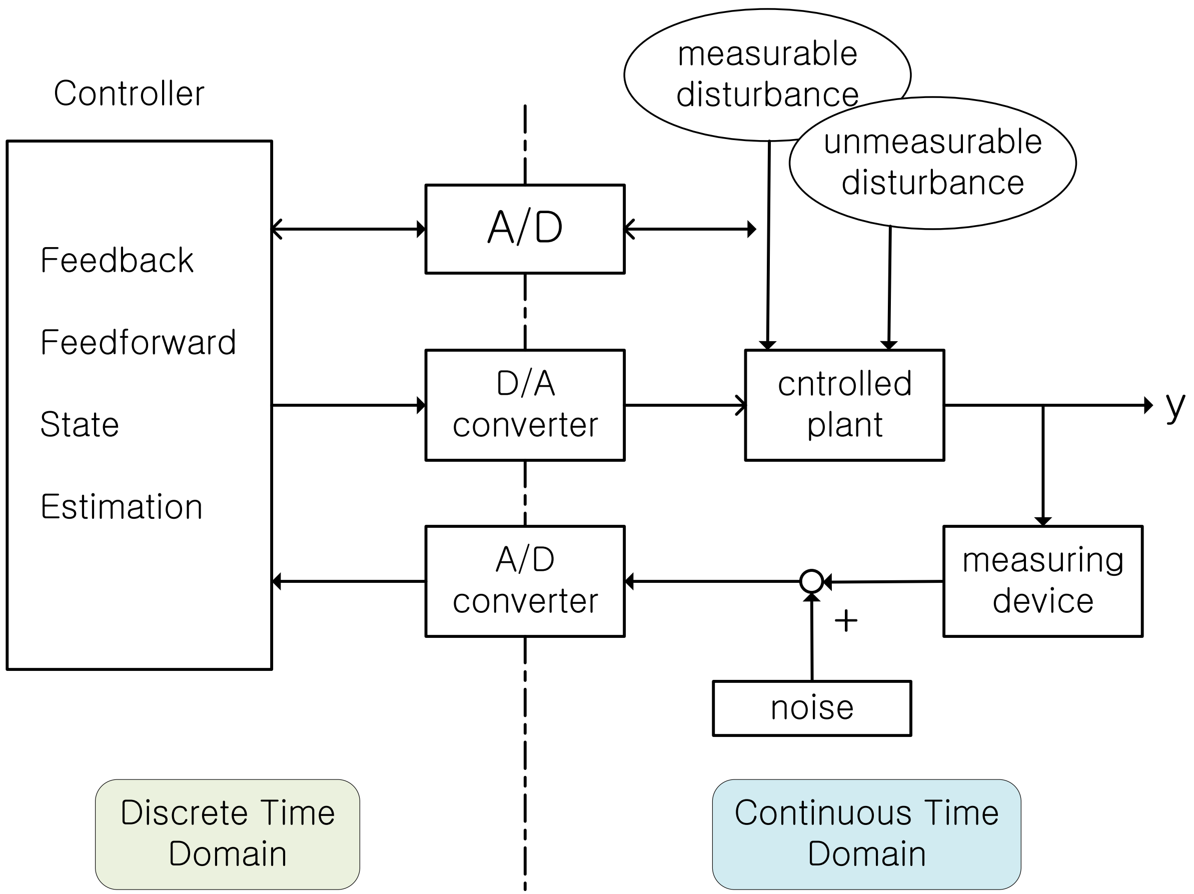
$$= \frac{R_4R_2}{R_3R_1}\left(\frac{R_1C_1+R_2C_2}{R_2C_2s} + \frac{1}{R_2C_2s} + R_1C_1s\right)$$

$$= \frac{R_4(R_1C_1+R_2C_2)}{R_3R_1C_2}\left(1 + \frac{1}{(R_1C_1+R_2C_2)s} + \frac{R_1C_1R_2C_2}{R_1C_1+R_2C_2}s\right)$$



Microprocessor Based Control Systems

- **Digital Control System**

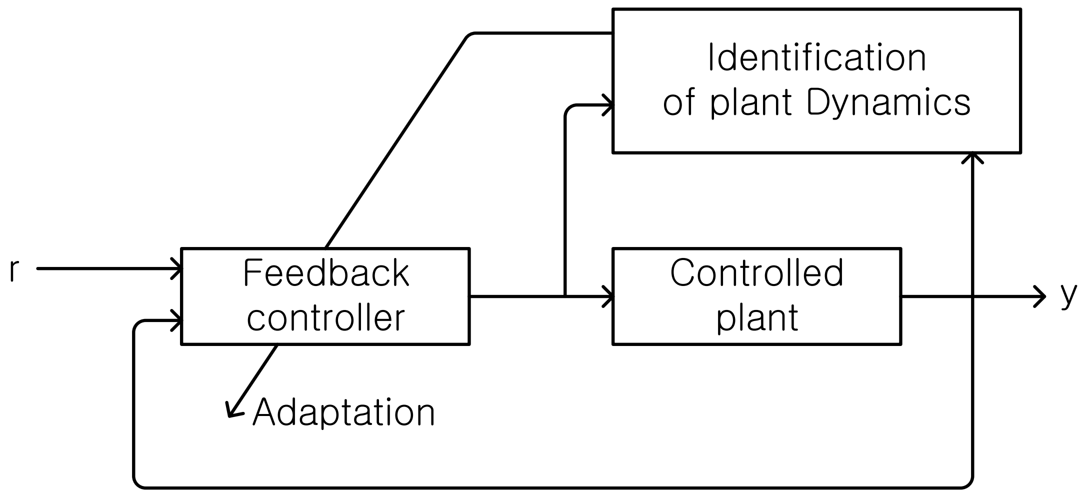


Role of Computers in Control

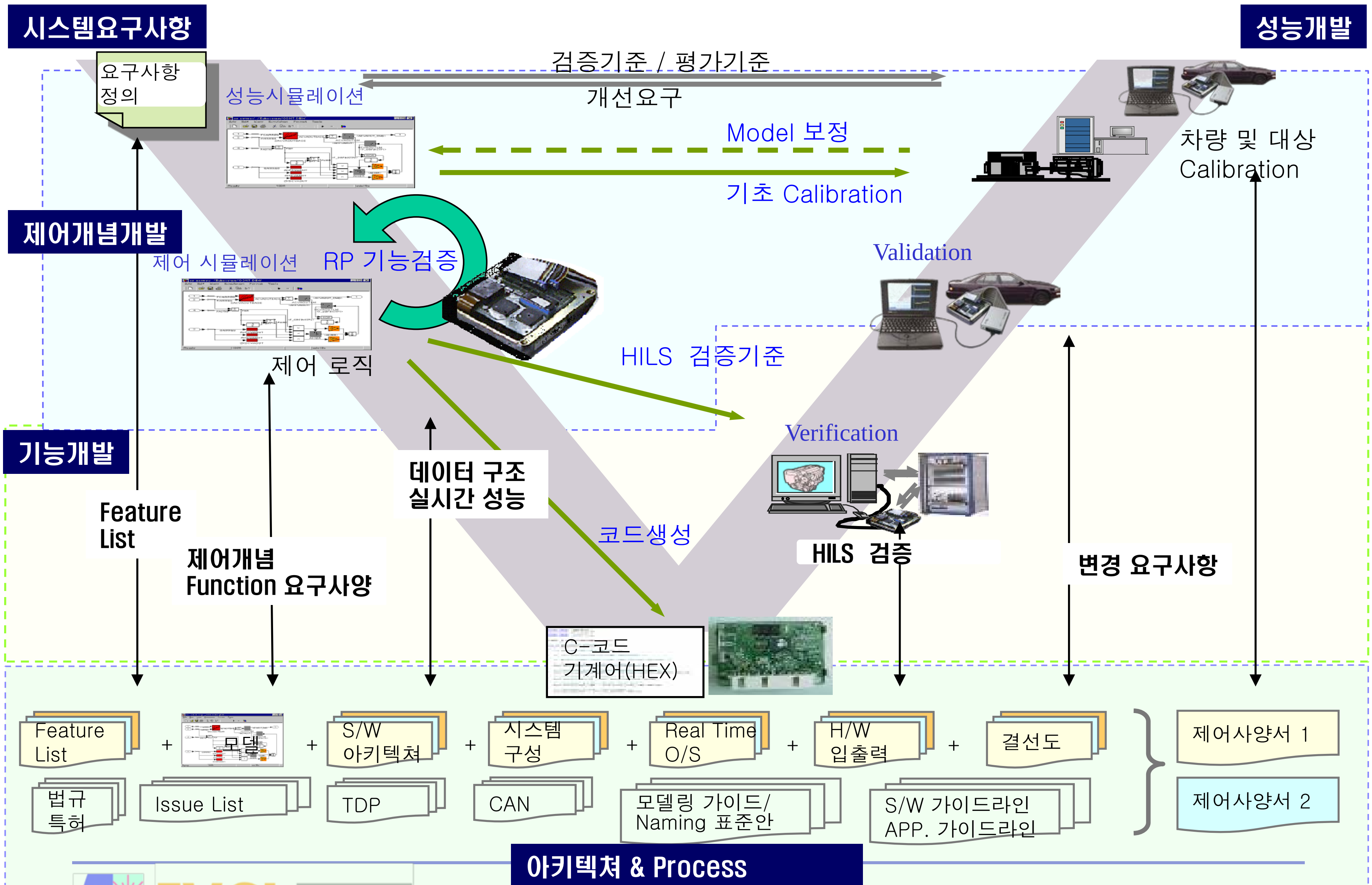
~ 1950's analog circuits

Mid 1950's	- control engineer, possibility of introducing digital computers to on-line control of physical systems	
1960's	- digital computers ; luxury device - criterion : a number of analog loops – digital computer - IC (Integrated Circuits)	
1970's	- MSI (Medium Scale Integration) - VLSI (Very Large Scale Integration) ➔ size and cost reduction of computers ➔ the use of computer in control problem reality	
1980's	- μ-processor : low cost / high performance ➔ advanced control algorithm in practice	
~1990's	- Optimal control - Learning control - Intelligent control	- Adaptive control - Robust control (Fuzzy logic, Neural Net etc.)
Applications :	Engineering Systems, Biological Systems, Biomedical Economic / Socioeconomic Systems etc...	

Adaptive Control



Intelligent Vehicle Control Systems Development



IVCL Intelligent Vehicle Control Laboratory

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Intelligent Vehicle Control Systems for Active Safety and Driver Assistance

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