Automatic Control, Basic Course

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Lecture 1 - Content

- Presentation: Control Department and Myself
- Course Overview
- Introduction to Automatic Control
- The PID controller
- Laboration 1

Dept. of Automatic Control at Lund University

- Founded in 1965 by Karl Johan Åström
- Approx. 50 persons
- M-building floors 1,2,5

Bo Bernhardsson

Academia

- LTH - E81, MSc 1986
- PhD in Automatic Control, Lund University, 1992.
- Post-doc at Univ. of Minnesota 1992-93
- Associate Professor etc, Lund University, 1993-1999
- Professor 1999-2001, on leave 2001-2010

Industry

- Senior Researcher/Specialist, Ericsson, Lund 2001-05
- Expert, Ericsson 2005-2010 (80/20 split with LU)
- Expert area: “Mobile System Design and Optimization”
- 15 granted patents in the area of mobile communications
- 10^9 control loops

Goal of the Course

The aim of the course is to give knowledge about the **basic principles of feedback control**.

The course will give insight into what can be achieved with control—the possibilities and limitations.

The course focuses on **linear continuous-time systems**.

Course Program

15 Lectures

15 Exercises

3 Mandatory Laborations, sign up for lab1 asap

Literature

Exam

Like More Control Theory?

Follow the parallel course

Control Theory 3hp

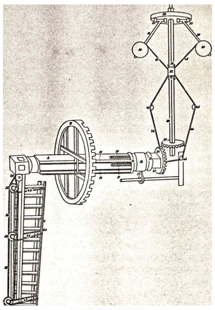
First Lecture: Thursday 20/1 at 8.15-10, M:D

Introduction to Control

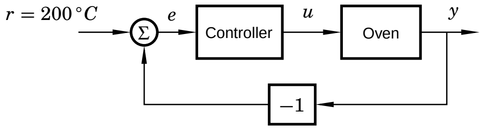
Switch to other presentation

The PID Controller

- The oldest controller type
- The most widely used
  - Pulp & paper industry 86%
  - Steel industry 93%
  - Oil refineries 93%




Example: Oven

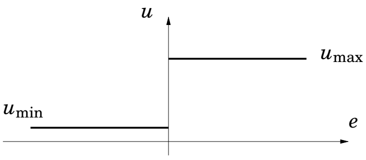


- y – actual temperature
- r – desired temperature
- e – control error
- u – heating element power $(0 \le u \le 1)$

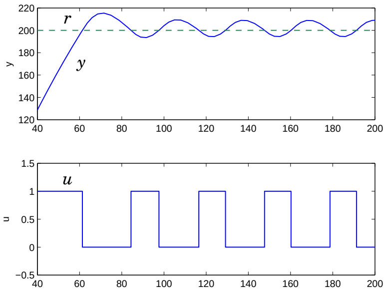
On/Off Control

Control error: $e = r - y$

$$u = \begin{cases} u_{\min}, & e < 0 \\ u_{\max}, & e > 0 \end{cases}$$

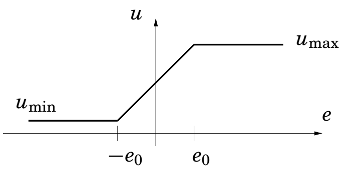


On/Off Control – Oven Example



- Oscillations

Proportional Control

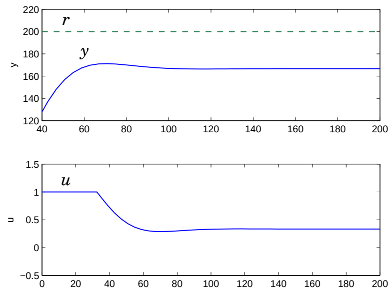


$$u = \begin{cases} u_{\max}, & e > e_0 \\ u_0 + Ke & \\ u_{\min}, & e < -e_0 \end{cases}$$

K – proportional gain

u_0 – bias term (often 0)

P Control – Oven Example



- Stationary error

(What is the value of K in the simulation above, $u_0 = 0$?)

Stationary Error with P Control

Assume the controller works within the proportional band $(-e_0 < e < e_0)$. Then

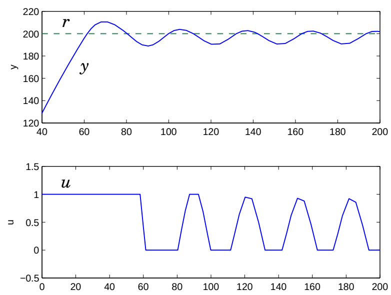
$$e = \frac{u - u_0}{K}$$

Two ways to reduce the stationary control error:

- Make K larger
- Adjust u_0

P Control – Oven Example

Increased gain K:



- Smaller stationary error
- Larger oscillations

Proportional–Integral Control

Add automatic adjustment of the bias term ("automatic reset")

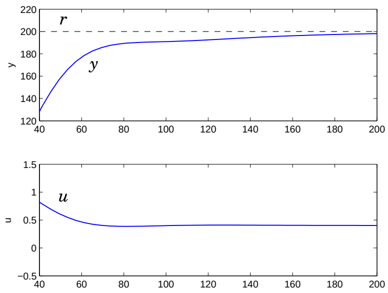
Keep adjusting the control signal as long as there is an error

PI-controller:

$$\begin{aligned} u(t) &= Ke(t) + K_i \int_0^t e(s)ds \\ &= K\left(e(t) + \frac{1}{T_i}\int_0^t e(s)ds\right) \end{aligned}$$

T_i – integral time

PI Control – Oven Example



- No stationary error

The Amazing Property of Integral Action

Consider a PI-controller:

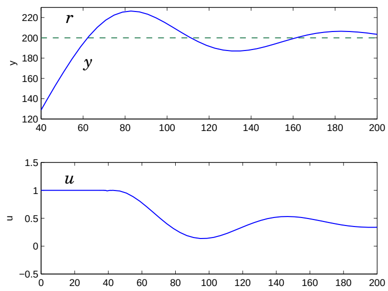
$$u(t) = Ke(t) + K_i \int_0^t e(s)ds$$

Assume that there is an equilibrium with constant $e(t) = e_0$ and $u(t) = u_0$. Then we must have $e_0 = 0$!

Can you explain this?

PI Control

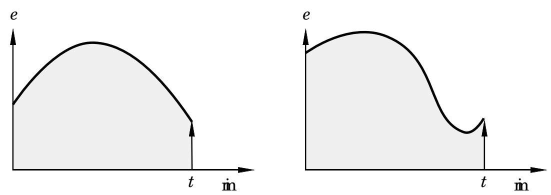
Smaller integral time T_i (i.e. larger integral action):



- Larger oscillations

Limitations of PI Control

A PI controller gives the same control signal in these two cases:

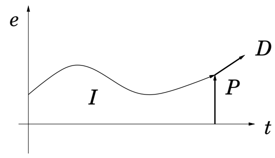


Problematic for processes with inertia, e.g.

- temperature
- position

PID Control

Add prediction of the control error

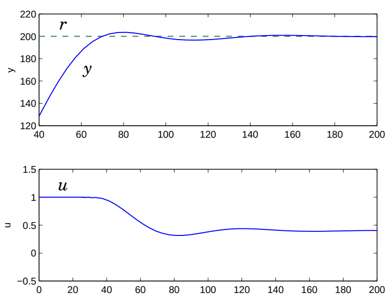


PID-controller:

$$u(t) = K\left(e(t) + \frac{1}{T_i}\int_0^t e(s)ds + T_d\frac{de(t)}{dt}\right)$$

T_d – derivative time

PID Control – Oven Example



- Reduced oscillations

Laboratory Exercise 1

Control of the water level in the upper or lower tank

- Open-loop and closed-loop control
- Manual and automatic control
- Empirical tuning of P, PI and PID controllers

Laboratorions - Lab 1

The manuals for Labs 2 and 3 contain **preparatory assignments** that must be solved before the laboratory exercise.

At the start of Lab 2, a **quiz** with two review questions will also be given. You must give correct answers to both questions in order to proceed with the laboratory exercise.

Signup for Lab 1 at home page now.

No written lab reports.

What You Should Do Now

- Sign up for Lab1 asap !
- Read course program and get all material
- Read math repetition material if needed
- Read first lecture in [TH]