28/03/2019
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Generalities
Modelling principles
OOM / BOM

Control needs & typical structures/schemes

Now

Models of components for electric & thermal energy systems

⇓

problems & solutions

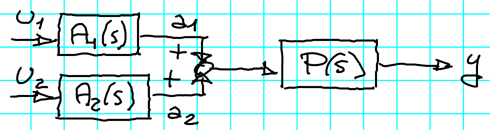
⇓

case studies

Dist compensation
Cascade control
Decoupling
IMC

Es 1

Given a process with two actuators to be used in conjunction

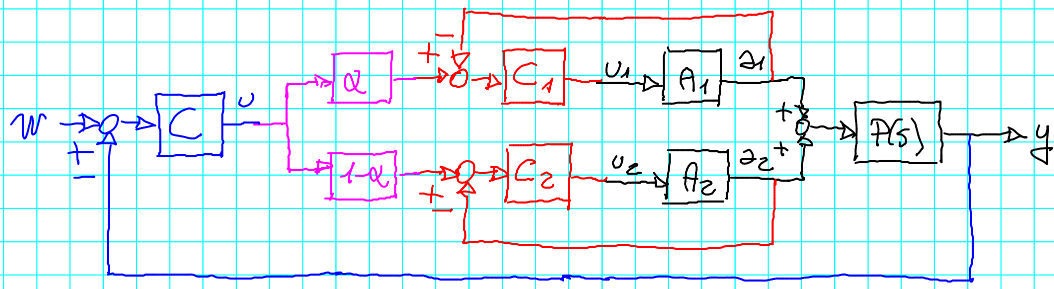


$$A_1(s) = \frac{100}{1+5s}, \quad A_2(s) = \frac{500}{1+30s}, \quad P(s) = \frac{1}{1+200s}$$

1) Draw a scheme with one controller for y, two inner cascade loops (one per actuator) assuming that the output of the external controller is distributed to the inner loops for A_1 and A_2 multiplied respectively by α and $1-\alpha$

2) Tune the three controllers so that the outer loop settling time be 10 minutes and the inner/outer loop frequency separation be 1 decade.

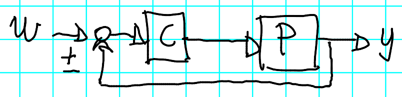
1) Scheme:



2.4) I start with the outer loop, assuming that

$$\frac{C_1 A_1}{1+C_1 A_1} = \frac{C_2 A_2}{1+C_2 A_2} = 1$$

hence the scheme is



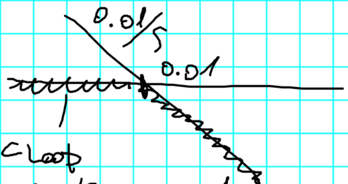
I want settling in 600 s

$\Rightarrow$ dominant closed-loop TC $\frac{600}{5} = 120\,s$

$\Rightarrow$ critical / crossover / cutoff } frequency $\frac{1}{120} \sim 0{,}01\ r/s$

Hence I want

$$CP \sim \frac{0.01}{s} \qquad \frac{\omega_c}{s}$$



$$\Rightarrow C = \frac{0.01}{s} \underbrace{\frac{1+200s}{1}}_{1/P} = 0.01 \frac{1+200s}{s}$$

PI ✓

CLoop

$$\frac{0.01/s}{1+0.01/s} = \frac{1}{1+100s} = \frac{1}{1+s/\omega_c}$$

Cutoff freq for external loop 0.01 r/s

1 decade separation

$\Rightarrow$ cutoff freq for both internal loops 0.1 r/s

(10 times faster)

Hence I need $\quad A_1 C_1 = A_2 C_2 = \frac{0.1}{s}$

$$C_1 = \frac{0.1}{s} \, \frac{1+5s}{100} \quad \ldots$$

$$C_2 = \frac{0.1}{s} \, \frac{1+30s}{500} \quad \ldots$$

both PIs

$\square$

IVT

if $V(s) = \mathcal{L}[v(t)]$

then $v(0)$ or $\lim_{t\to 0^+} v(t) = \lim_{s\to\infty} sV(s)$

FVT

if $V(s) = \mathcal{L}[v(t)]$

AND $\lim_{t\to\infty} v(t)$ EXISTS

then $\lim_{t\to\infty} v(t) = \lim_{s\to 0} sV(s)$

Ex 8

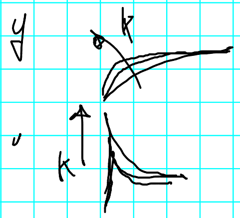
$$C(s) = k\,\frac{1+s}{s} \qquad P(s) = \frac{1}{1+s}$$

$$\frac{u}{w} = \frac{C}{1+CP} = k\,\frac{1+s}{s}\,\frac{1}{1+\frac{1}{s}k}$$

$$= k\,\frac{1+s}{\cancel{s}}\,\frac{\cancel{s}}{s+k} = \frac{1+s}{1+s/k}$$

w = step : initial u ?

$$y(0^+) = \lim_{s\to\infty} \underbrace{\cancel{s}}_{\text{IVT}} \cdot \underbrace{\frac{1}{\cancel{s}}}_{\mathcal{L} \text{ of input}} \frac{1+s}{1+s/k} = k$$

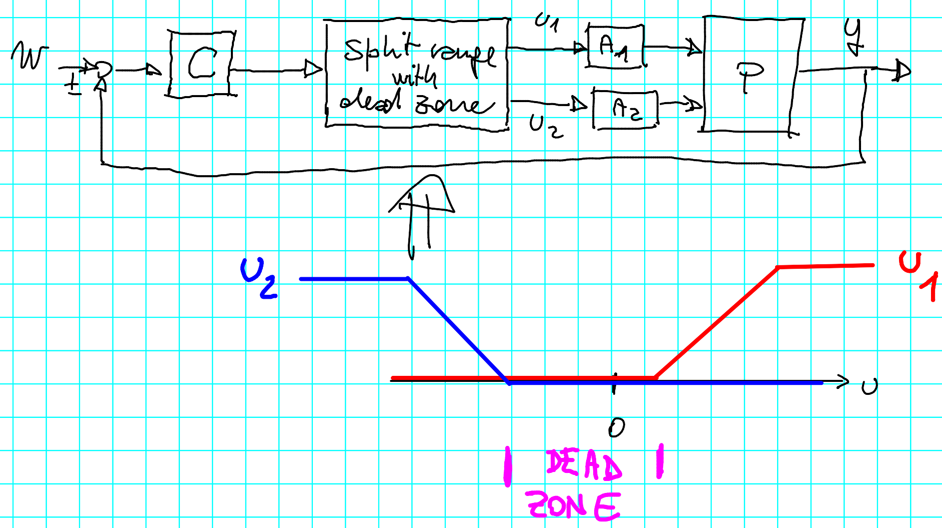


$\square$

- TYPICAL NEED: keep a variable between two bounds, and if it floats in between the two, do nothing.

  We assume two actuators & explain through an air conditioning example, hence we talk about "heater" & "cooler"

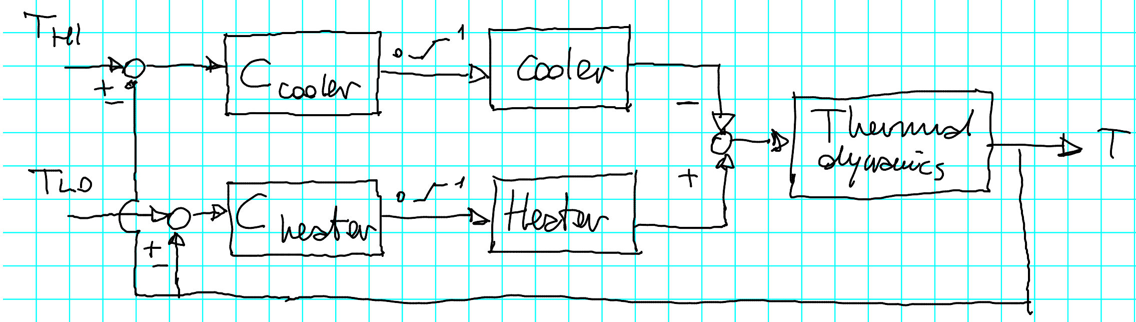
Naïve solution



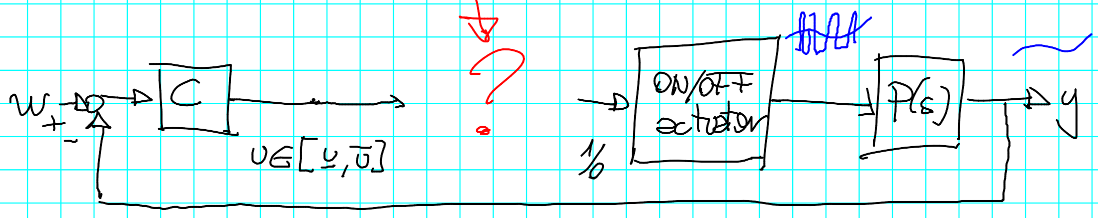
Suppose however you want $y_{LO} \le y \le y_{HI}$

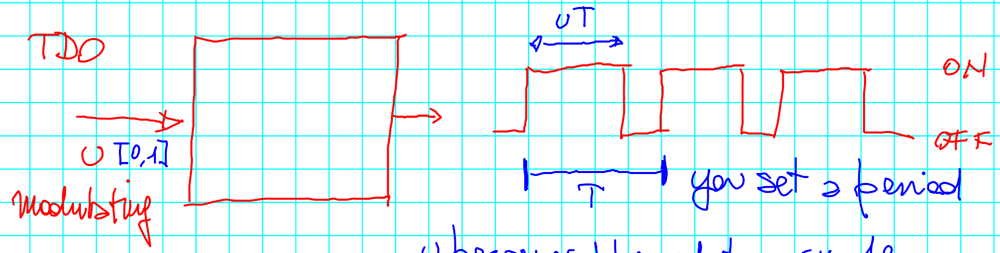
How to set the boundaries of the dead zone?

Clever solution (heat + cool)



TIME DIVISION OUTPUT actuation





you set a period

u becomes the duty-cycle