21/03/2019
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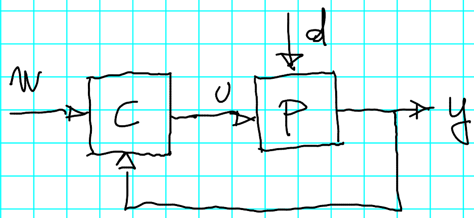
- DISTURBANCE COMPENSATION

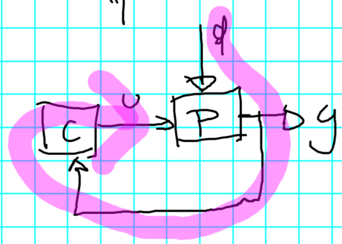
The case:



when d acts, feedack takes too long to recover y to w
PLUS cannot make feedback faster, typically for stability reasons

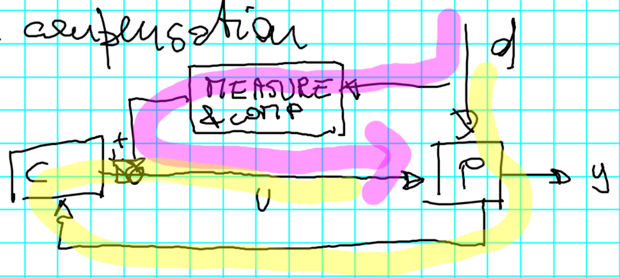
Solution: use a measurement of d to have u react "immediately"

w/o compensation



u reacts to d only through the dynamics of P and C $\Rightarrow$ takes time & evidence of the effect of d on y

with compensation

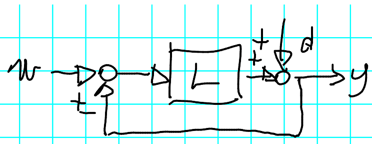


FAST reaction, as soon as d is sensed

NOTE there is no feedback here to fight uncertainty, reaction is prompt but in general not exact (but does immediately most of the job)

... and then, in the long run, feedback moves in to cancel the disturbance "exactly"

Remember



$$\frac{Y}{D} = \frac{1}{1+L}$$

low-freq part of d
killed by feedback

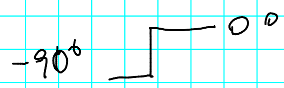
But also remember that a stability constraint (e.g., phase margin $\geq \overline{\varphi_m}$) implies a response speed limit (given the structure of the controller)

$$\left.\begin{array}{c} P(s) \\ \text{structure of } C \text{ (e.g., PID)} \\ \text{minimum desired } \varphi_m \end{array}\right\} \Rightarrow \text{max achievable cutoff frequency}$$

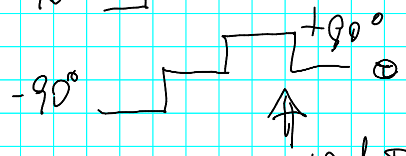
Let us see by example (positive gains for simplicity)

1) $\angle C(j\omega)$ cannot exceed 90° times the number of zeroes in C minus the number of poles in the origin

e.g. PI



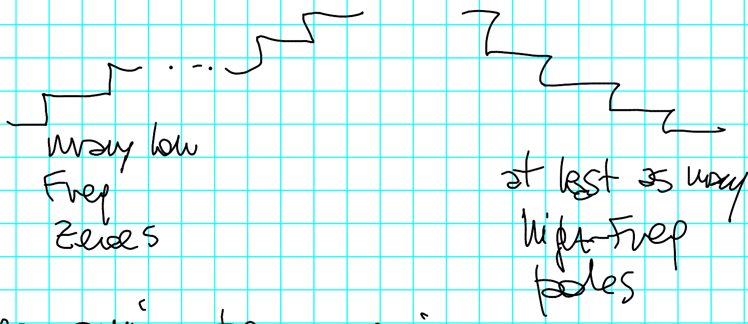
PID



real PID, 2nd pole

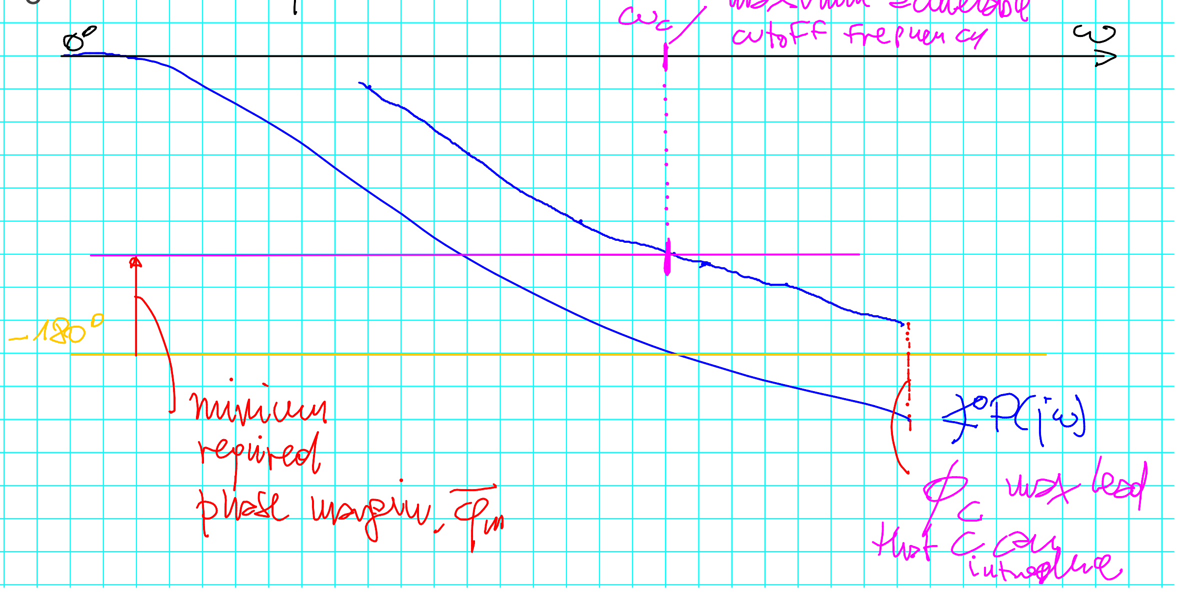
Let us set $\phi_c = \max_{\omega} \measuredangle C(j\omega)$

NOTICE: there is a limit here as well, because to get a very high ϕ_c you need



BAD idea owing to numeric ill-conditioning

Back to topic



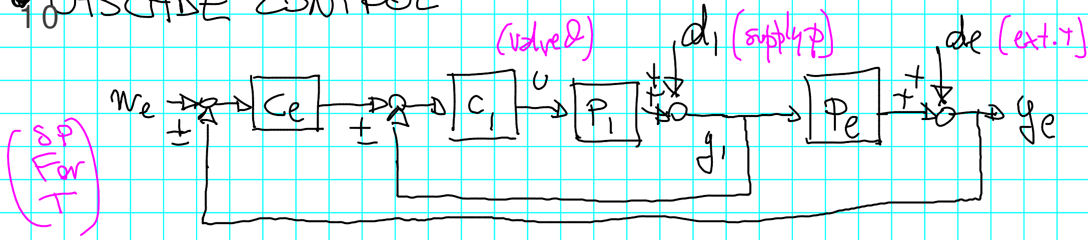
9 If I want a larger ω_c, then not even the maximum phase lead that C can give is enough to have the phase reach $\varphi_m - 180°$

of the loop frequency response

Hence if a disturbance has significant frequency components near or above the max ω_c that the loop can give, and the effects of such a disturbance are unacceptable, then you need compensation.

CASCADE CONTROL

example



REMARK #1: if there is no d_1, then cascade is useless (see the slides)

The use: you control something through another system (e.g. valve acts on flow to ultimately control temperature)

AND either the "internal" ($\vartheta \to$ Flow) relationship is uncertain, or there are disturbances on it

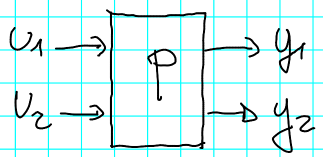
AND you can measure something about this internal relationship (Flow) to close a loop

setup $\Rightarrow$ slides

Another case: want to make two different actuators look equal

$\square$

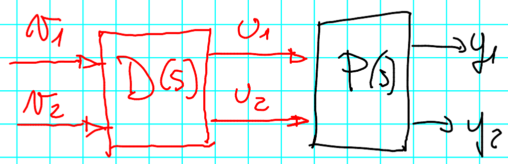
DECOUPLING (2 by 2 case)



$$\begin{bmatrix}Y_1(s)\\ Y_2(s)\end{bmatrix} = \underbrace{\begin{bmatrix}p_{11}(s) & p_{12}(s)\\ p_{21}(s) & p_{22}(s)\end{bmatrix}}_{P(s)\ \text{trasfer MATRIX}} \begin{bmatrix}U_1(s)\\ U_2(s)\end{bmatrix}$$

IDEA:

set



& determine $D(s)$ in such a way that the overall system be diagonal

13 In other words, setting $y = \begin{bmatrix} y_1 \\ y_2 \end{bmatrix}$ $u = \begin{bmatrix} u_1 \\ u_2 \end{bmatrix}$, $v = \begin{bmatrix} v_1 \\ v_2 \end{bmatrix}$

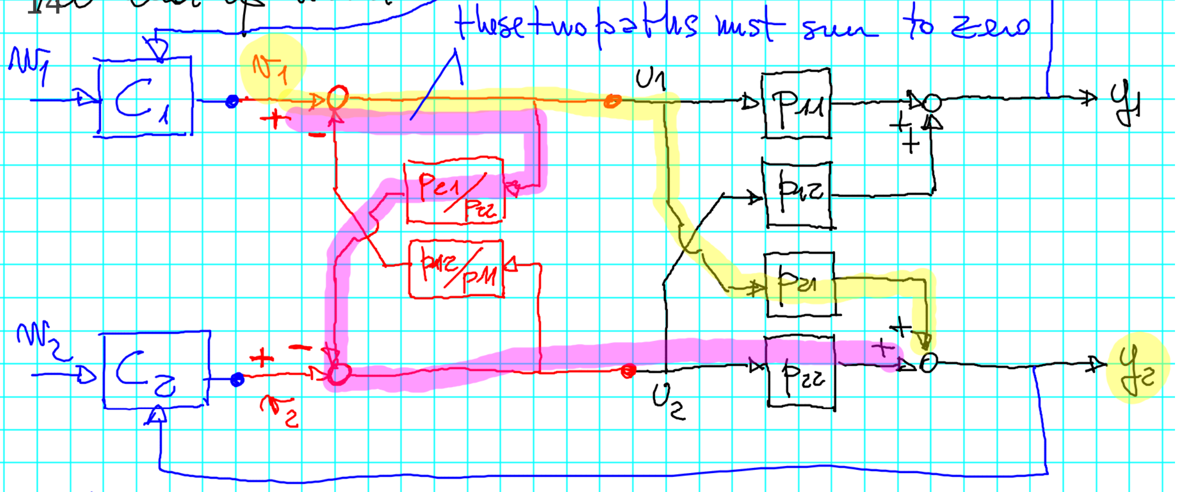
we have

$$y = P u = P D v$$

and we want

$$P(s) D(s) = \begin{bmatrix} p_{11}(s) & 0 \\ 0 & p_{22}(s) \end{bmatrix}$$

we end up with



then design C_1 to only control P_{11} (C_2 for P_{22})

There are two problems

1) Feasibility

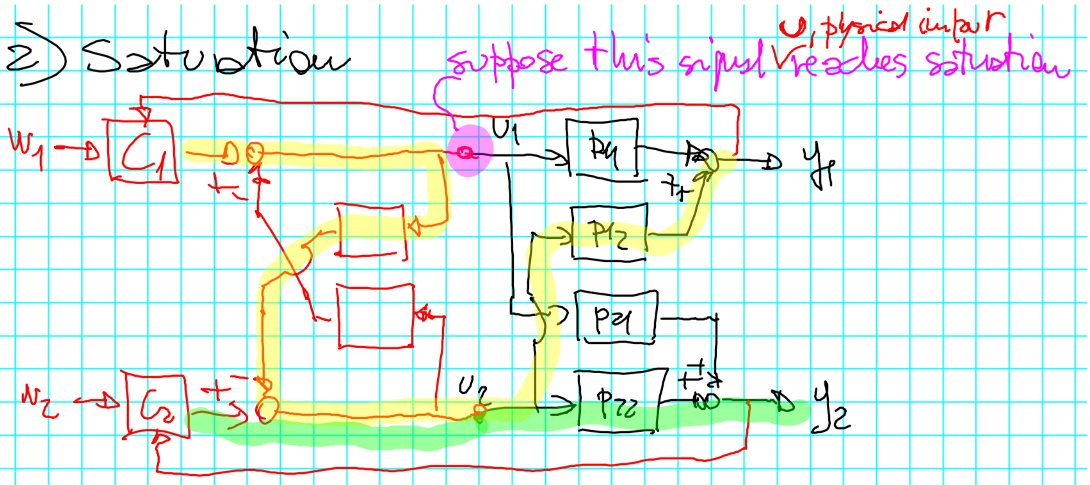
$\frac{P_{21}}{P_{22}}$ may have more zeroes than poles

Find Bode slope pos

Solution

DECIDE A MAX FREQUENCY FOR DECOUPLING TO BE EFFECTIVE

2) Saturation



C1 still wants to control y_1. Is there a path to do that?

!! YES ⇒ two controllers competing for the one available control input u_2 ⇒ BOTH loops lost