11 – Industrial controllers

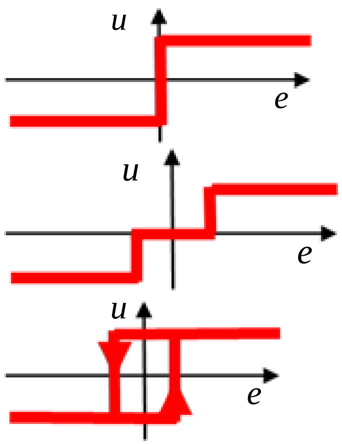
Martin Hromcik

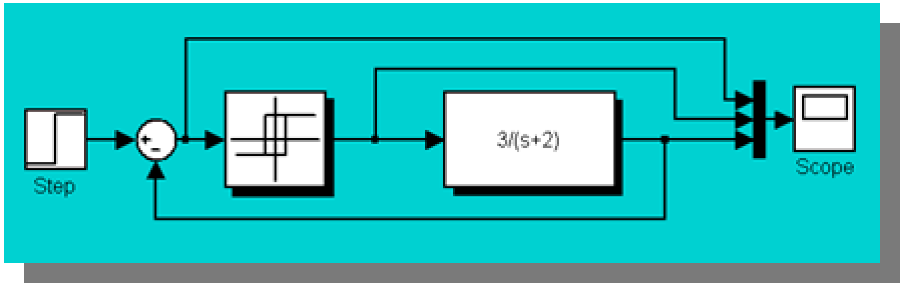
Automatic control

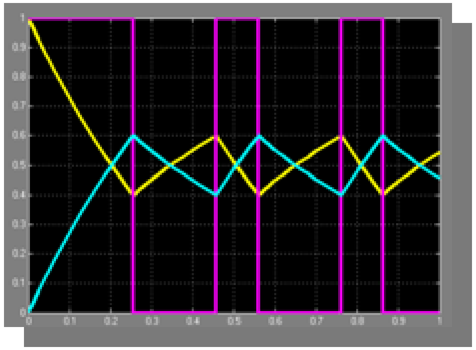
22-III-12

Impulse controllers

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







PID controllers

P I D

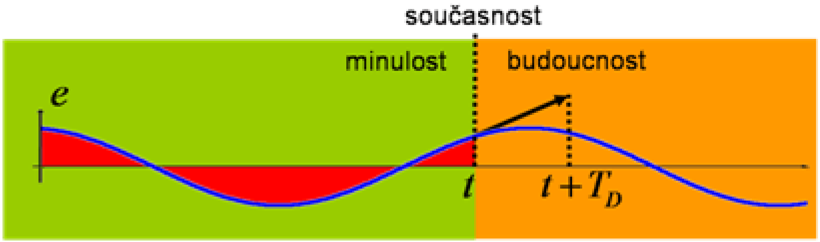
$$u(t) = k_P e(t) + k_I \int_{t_0}^{t} e(\tau) d\tau + k_D \dot{e}(t)$$

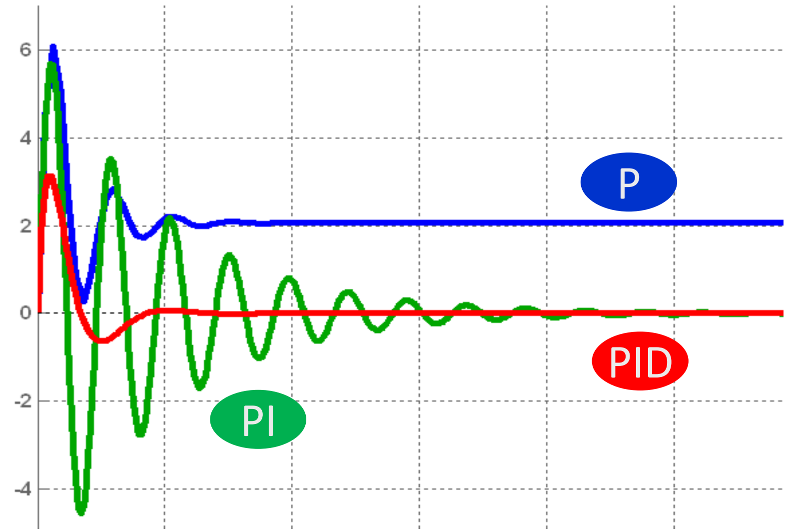
P I D

$$\frac{U(s)}{E(s)} = D_C(s) = k_P + \frac{k_I}{s} + k_D s$$

$$D_C(s) = k_P \left[1 + \frac{1}{T_I s} + T_D s \right]$$

P I D





"Industrial" PID's

$$u(s) = k_P\left[1 + \frac{1}{T_I s} + T_D s\right]e(s)$$

- additional parameters on top of the basic formula (defining various limiters, high freq. roll off, dead-zones, saturations, anti-windup measures etc.). For example:

$$u(s) = k\left[\left(b y_{sp}(s) - y(s)\right) + \frac{1}{T_I s}\left(y_{sp}(s) - y(s)\right) - \frac{T_D s}{1 + T_D s/N} y(s)\right]$$

setpoint weighting (reference and output separation; b=0...1)

- filtered derivative part (limited gain for high freqs)
- D attached to output only

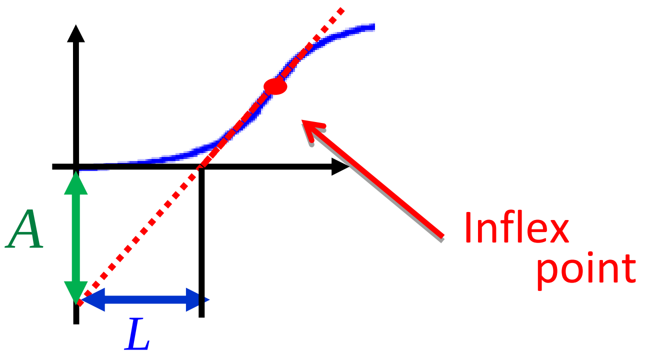
$$\approx N \in [3, 20]$$

- Alternative ("industry-common") formulation:

$$u(s) = k'_P\left(1 + \frac{1}{T'_I s}\right)\left(1 + T'_D s\right)e(s)$$

Ziegler-Nichols experimental PID tuning

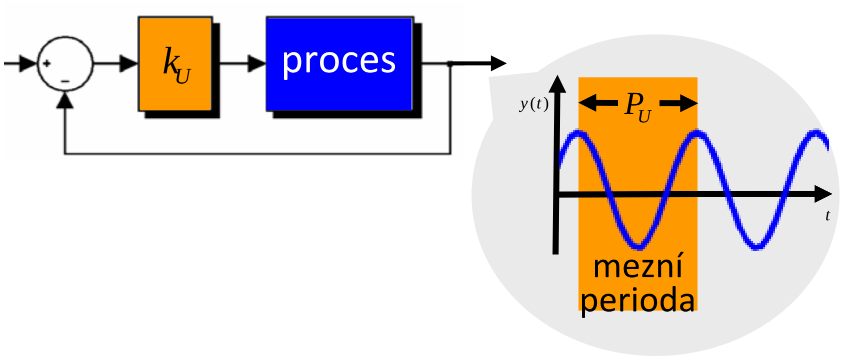
1st method …



P	$k_P = 1/A$
PI	$k_p = 0.9/A, T_I = 3L$
PID	$k_P = 1.2/A, T_I = 2L, T_D = 0.5L$

2nd method …

$\rightarrow k_U, P_U$



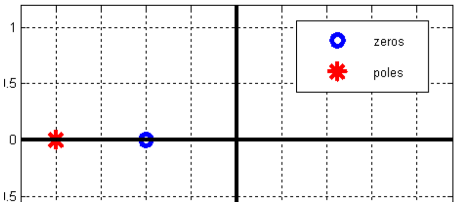
P	$k_P = 0.5k_U$
PI	$k_P = 0.45k_U, T_I = P_U/1.2$
PID	$k_P = 0.6k_U, T_I = P_U/2, T_D = P_U/8$

Lead/lag controllers

$$D_C(s) = k\,\frac{s+z}{s+p}$$

Lead controller (i.e. phase-lead)

~ PD $\qquad p > z \qquad -p < -z$



Lag controller (i.e. phase lag)

~ PI $\qquad p < z \qquad -p > -z$