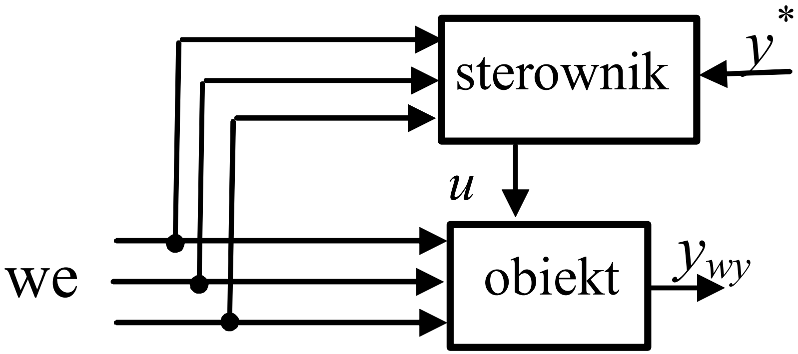
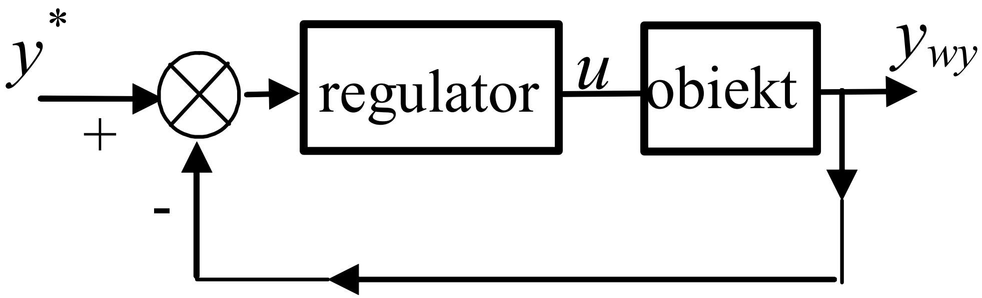
Podstawowe typy układów sterowania

Sterowanie w

układzie otwartym	układzie zamkniętym (regulacja)





- *znany „przepis" na sterowanie*
- *stabilne*
- *niedokładne*

- *sterowanie jest wypracowywane*
- *stabilne/niestabilne*
- *dokładne*

Feedforward Control

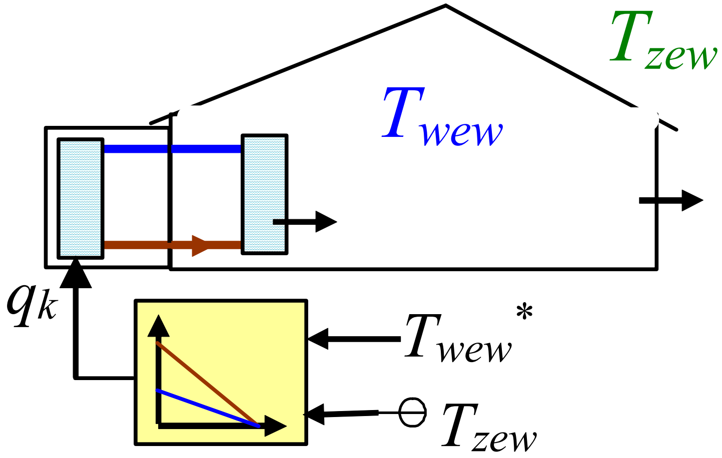
Feedback Control

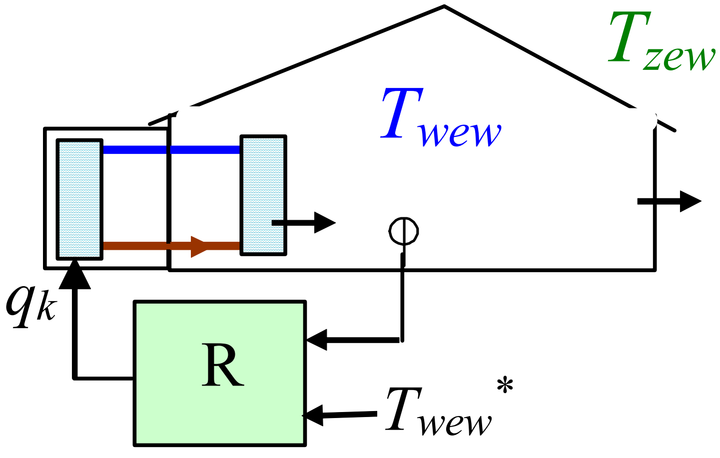
Process Control

Podstawowe typy układów sterowania - przykład

Sterowanie w

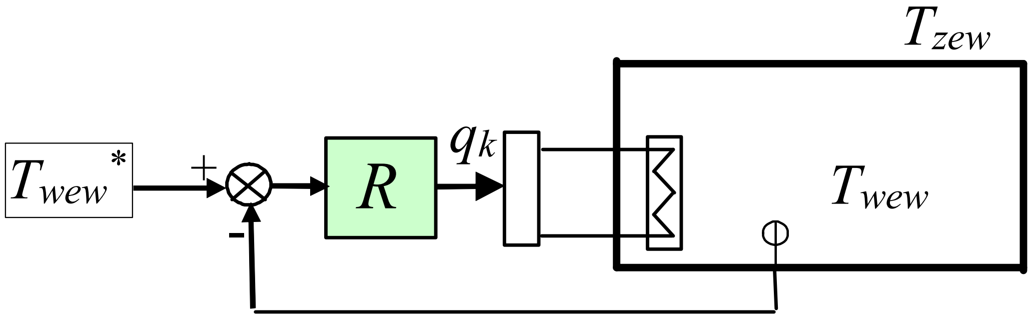
układzie otwartym	układzie zamkniętym (regulacja)

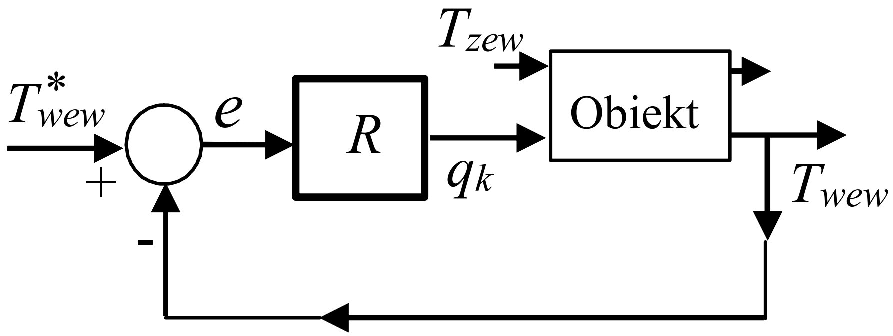




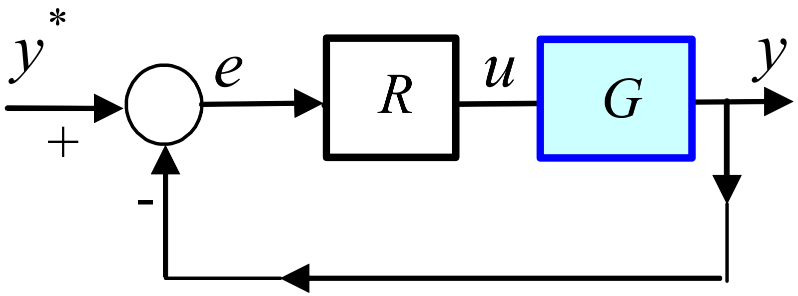
Podstawowy układ regulacji

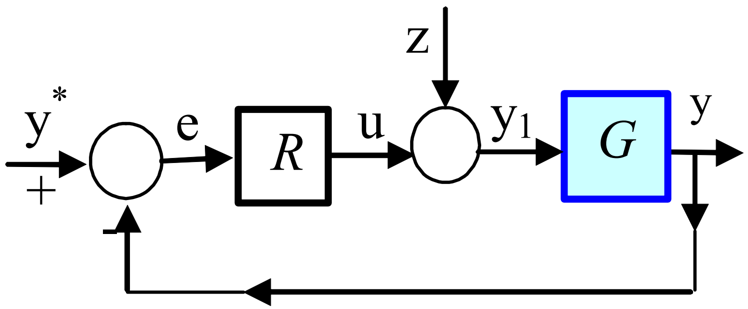
PV = T_{wew}, CV = q_k, R – regulator (Matlab: controler, compensator)





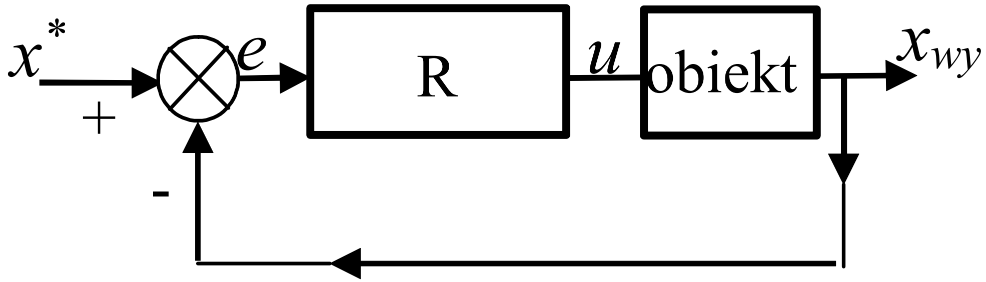
Podstawowy układ regulacji



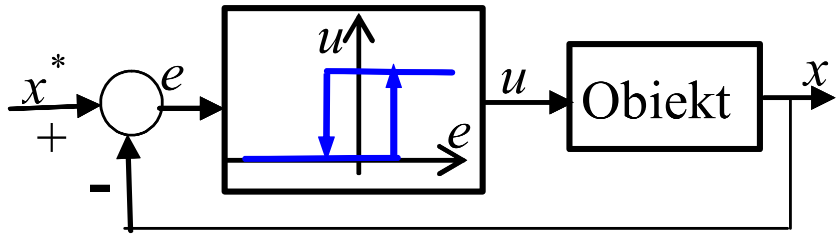


y – zmienna procesowa (PV – Process Variable)
y^* – wartość zadana (SP – Set-Point)
e – uchyb regulacji (control error)
u – zmienna sterująca (CV – Control Variable)
z – zakłócenia

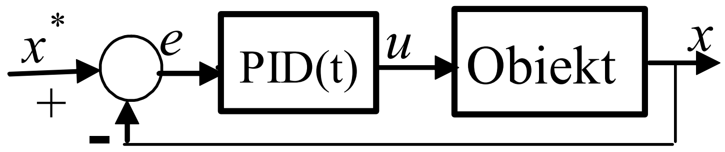
Typy regulatorów



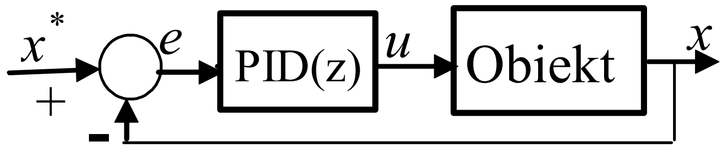
- regulatory przekaźnikowe (binarne)



- regulatory ciągłe



- regulatory dyskretne



Regulator ciągły: Struktura PID i sposób realizacji

PID-ISA (Ideal Standard Algorithm)

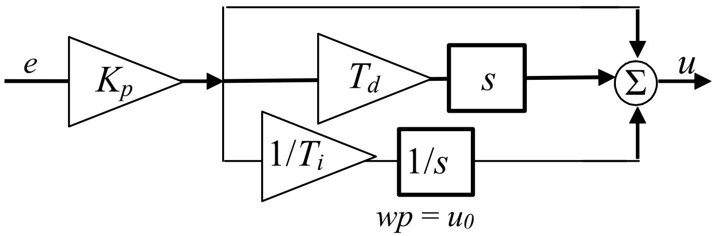
$$u(t) = K_p\left[e(t) + \frac{1}{T_i}\int_0^t e(\tau)d\tau + T_d\frac{de(t)}{dt}\right] + u_0$$

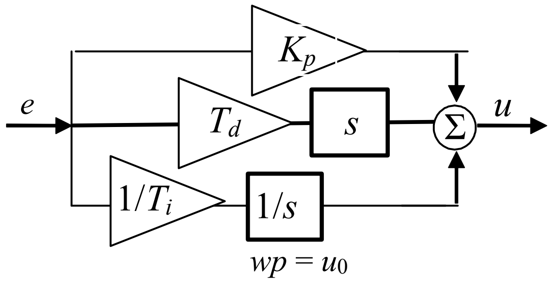
$$R = K_p\left(1 + \frac{1}{T_i s} + T_d s\right)$$

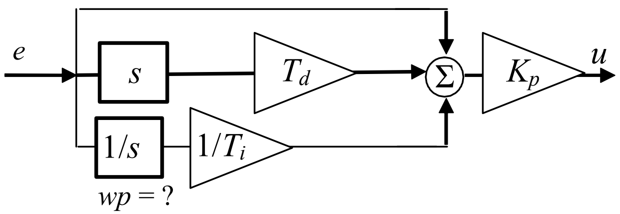
PID-IND (INDependent algorithm)

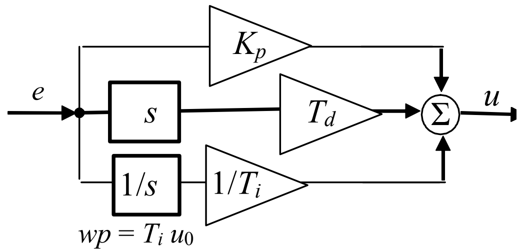
$$u(t) = K_p e(t) + \frac{1}{T_i}\int_0^t e(\tau)d\tau + T_d\frac{de(t)}{dt} + u_0$$

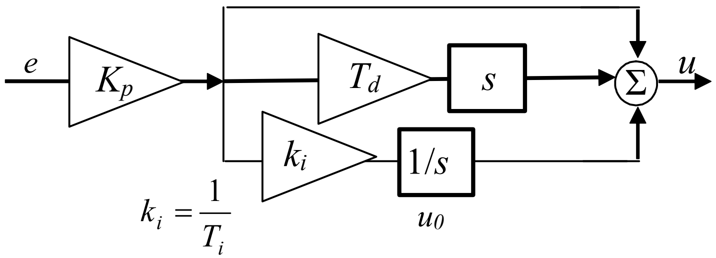
$$R = K_p + \frac{1}{T_i s} + T_d s$$



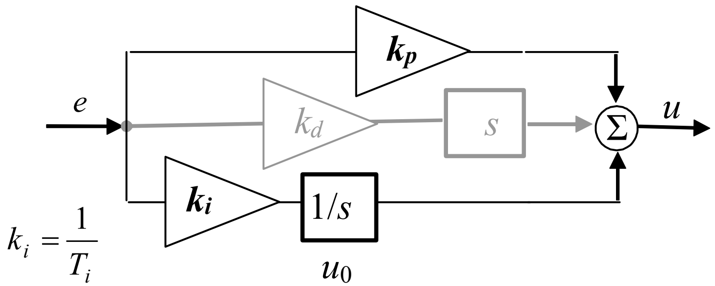








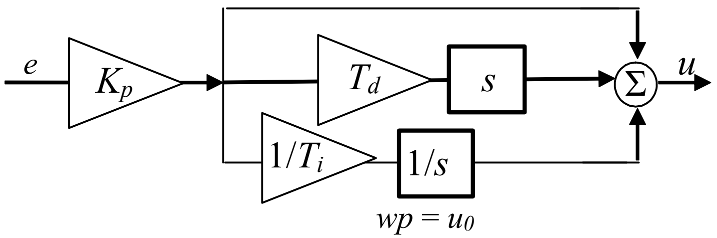
Realizacja PID (wybór)



Regulator ciągły: Struktura PID w teorii

PID-ISA (Ideal Standard Algorithm)

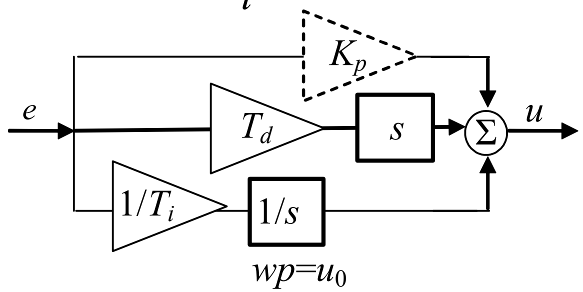
$$R = K_p\left(1 + \frac{1}{T_i s} + T_d s\right)$$



$$R = K_p + \frac{K_p}{T_i s} + K_p T_d s$$

PID-IND (INDependent algorithm)

$$R = K_p + \frac{1}{T_i s} + T_d s$$



$$R = k_p + \frac{k_i}{s} + k_d s$$

$$k_p = K_p, k_i = K_p / T_i, k_d = K_p T_d$$

$$R = k_p + \frac{1}{t_i s} + t_d s$$

$$k_p = K_p, t_i = T_i / K_p, t_d = K_p T_d$$

PID-kaskadowy (interacting)

PID kaskadowy (interacting):

$$K_p \frac{T_i s + 1}{T_i s}(T_d s + 1) = K_p\left(1 + \frac{1}{T_i s}\right)(T_d s + 1)$$

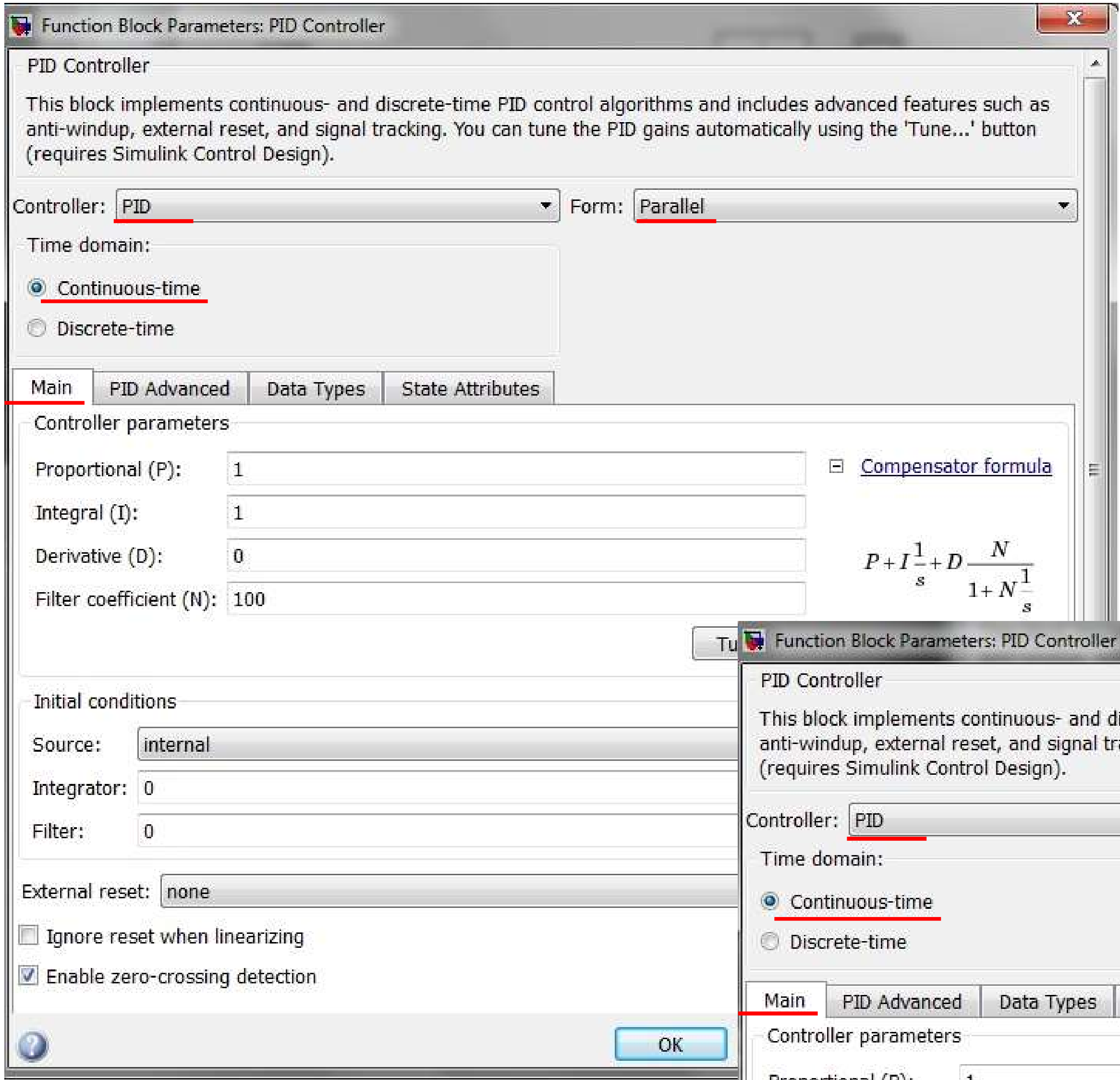
PI: $$K_p \frac{T_i s + 1}{T_i s} = K_p\left(1 + \frac{1}{T_i s}\right)$$

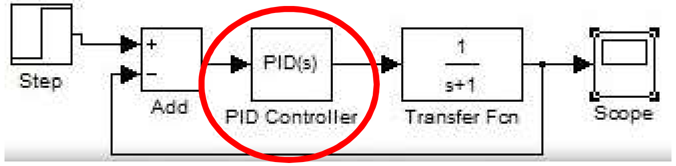
PID ISA (non-interacting):

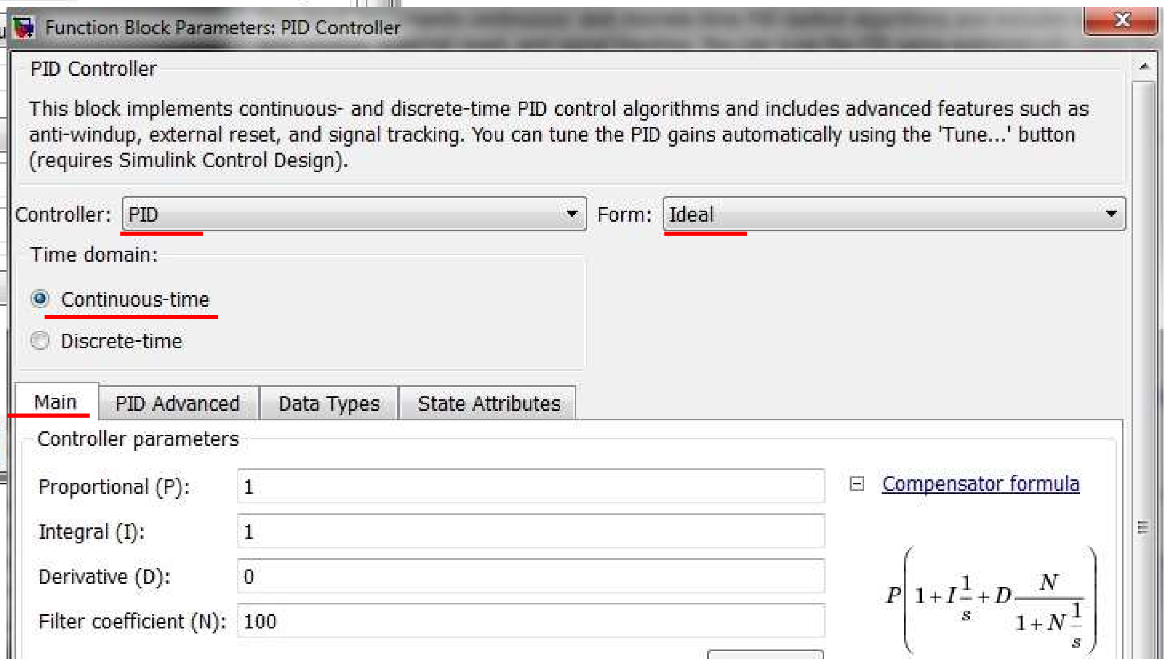
$$K_p\left(1 + \frac{1}{T_i s} + T_d s\right)$$

PI: $$K_p\left(1 + \frac{1}{T_i s}\right)$$

Simulink -> Continous -> PID Controller



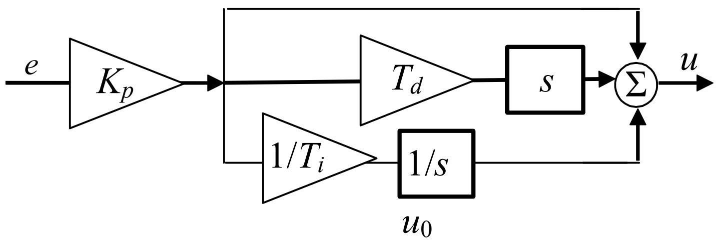




Regulator ciągły: Struktura PID i sposób realizacji

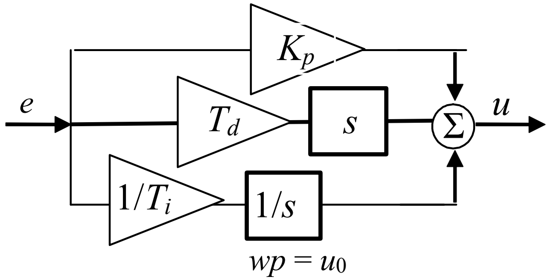
PID-ISA (Ideal Standard Algorithm)

$$R = K_p\left(1 + \frac{1}{T_i s} + T_d s\right)$$



PID-IND (INDependent algorithm)

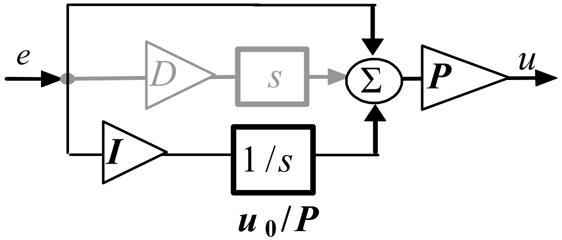
$$R = K_p + \frac{1}{T_i s} + T_d s$$

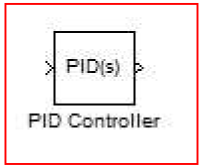


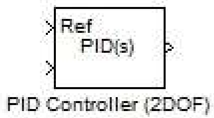
Simulink

PID Ideal

$$C = P\left(1 + I\frac{1}{s} + Ds\right)$$

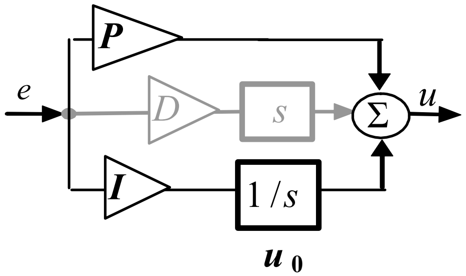






PID Paralell

$$C = P + I\frac{1}{s} + Ds$$

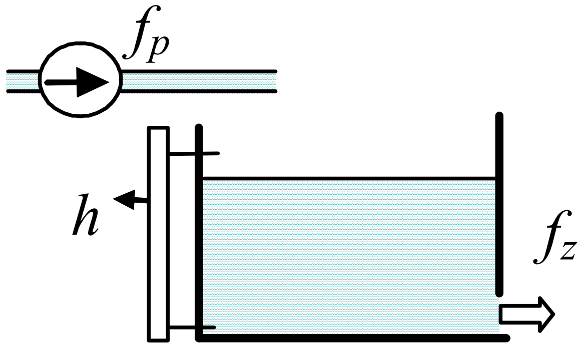


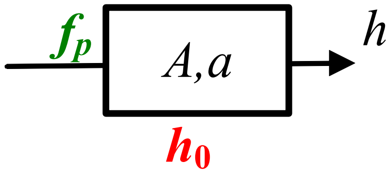
$$C = P\left(1 + I\frac{1}{s} + D\frac{N}{1 + N\frac{1}{s}}\right)$$

$$D\frac{N}{1 + N\frac{1}{s}} = D\frac{N}{\frac{s+N}{s}} = D\frac{sN}{s+N} = Ds\frac{1}{\frac{1}{N}s + 1}$$

$$C = P + I\frac{1}{s} + D\frac{N}{1 + N\frac{1}{s}}$$

Układ regulacji ciągłej PID – wartości początkowe

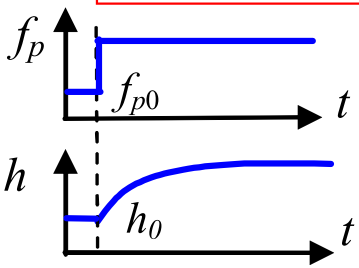


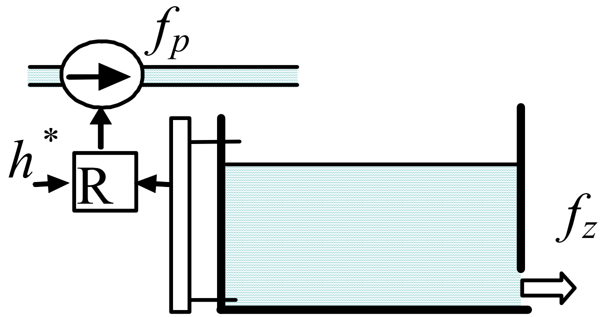


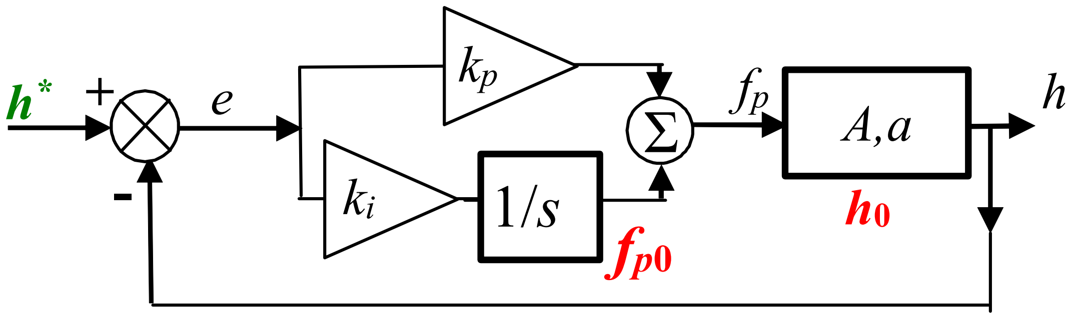
$$A\dot{h}(t) = f_p(t) - ah(t)$$

$$0 = f_{p0} - ah_0$$

$$h_0 = f_{p0} / a$$





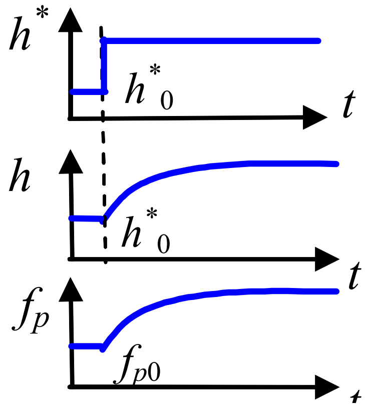


$$\begin{cases} A\dot{h}(t) = f_p(t) - ah(t) \\ f_p(t) = k_p e(t) + k_i \int e(t) \end{cases}$$

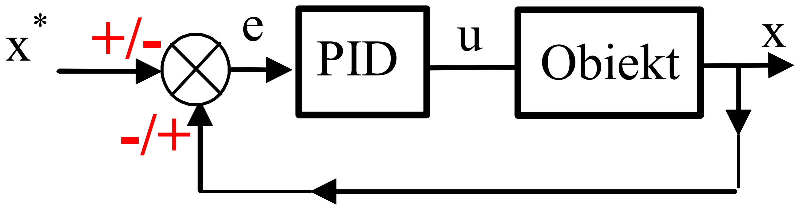
$$e = 0 \rightarrow h_0 = h_0^*$$

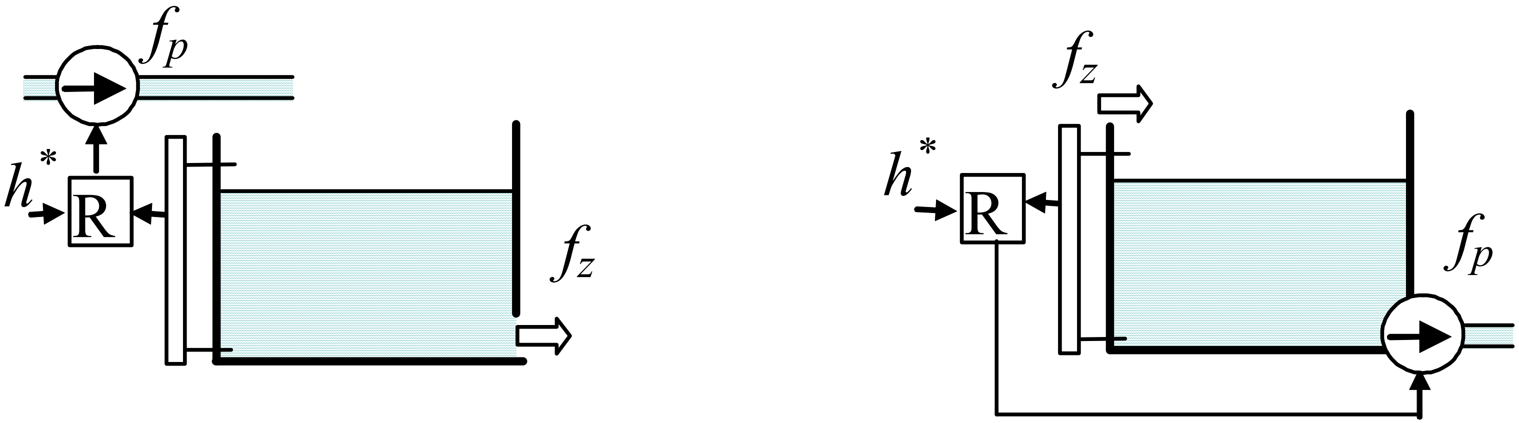
$$0 = f_{p0} - ah_0^*$$

$$f_{p0} = ah_0^*$$



Układ regulacji ciągłej PID - znak





$h^* > h$ (poziom za niski)

zwiększ f_p — *zmniejsz* f_p

$e=h^*-h$ — sterowanie $K_p e + \frac{1}{T_i}\int e$ — $e=h-h^*$

Układ regulacji ciągłej PID – przykłady

Jakie znaki w węźle sumacyjnym? Jakie warunki początkowe w regulatorze?