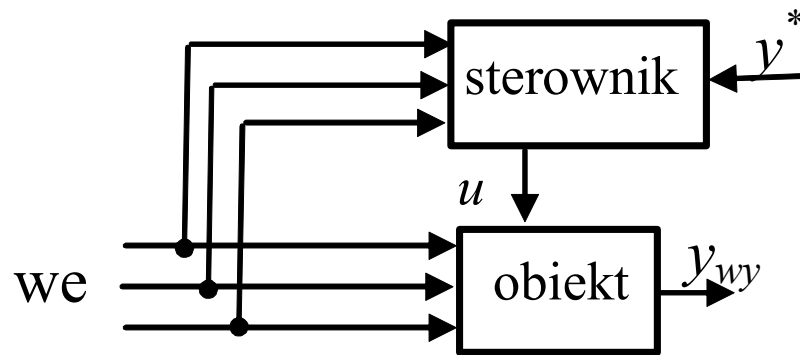


Podstawowe typy układów sterowania

Sterowanie w

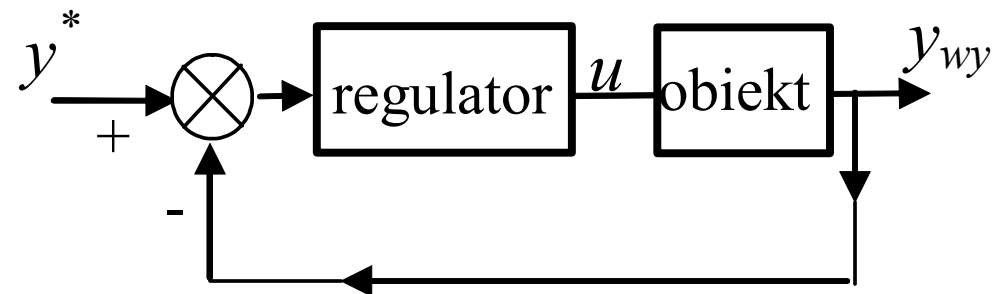
układzie otwartym

układzie zamkniętym
(regulacja)



- znany „przepis” na sterowanie
- stabilne
- niedokładne

Feedforward Control



- sterowanie jest wypracowywane
- stabilne/niestabilne
- dokładne

Feedback Control

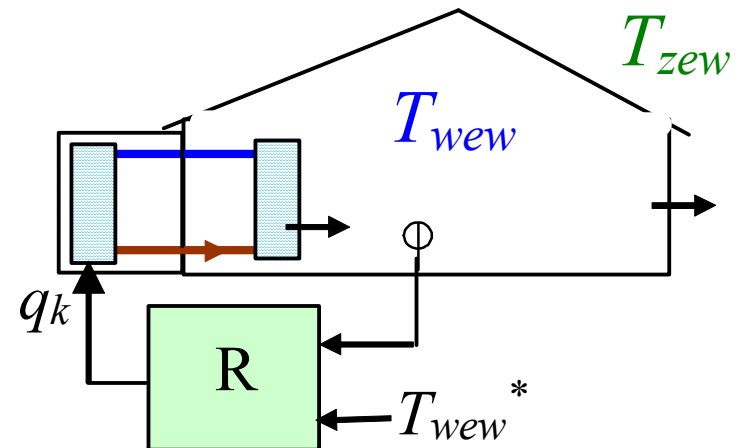
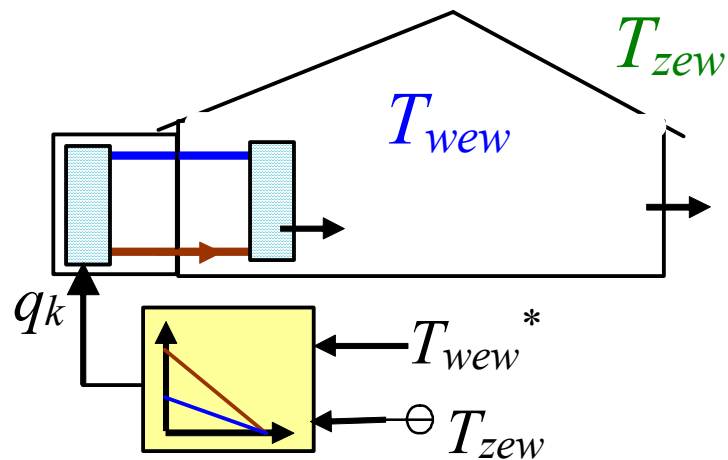
Process Control

Podstawowe typy układów sterowania - przykład

Sterowanie w

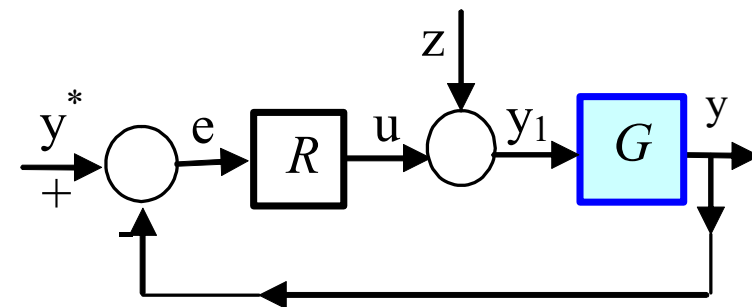
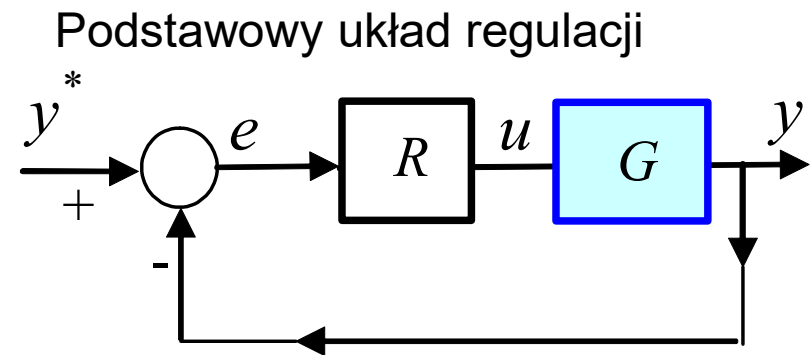
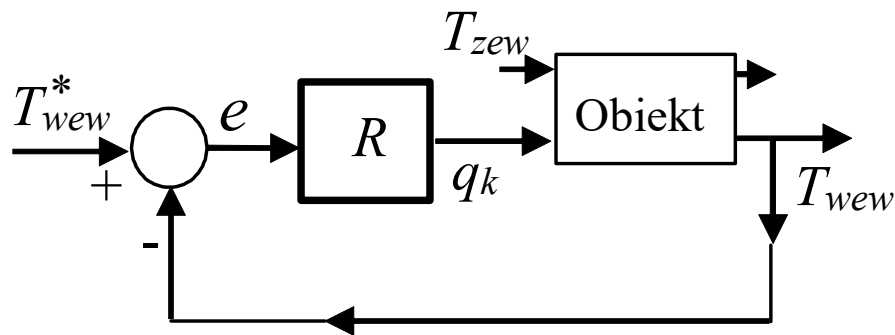
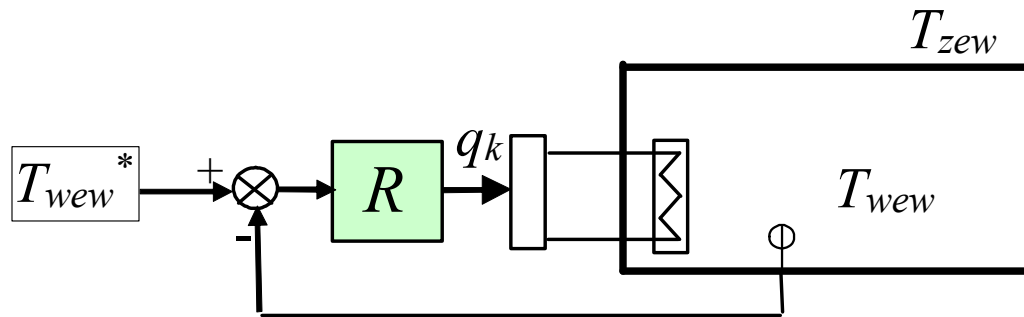
układzie otwartym

układzie zamkniętym
(regulacja)



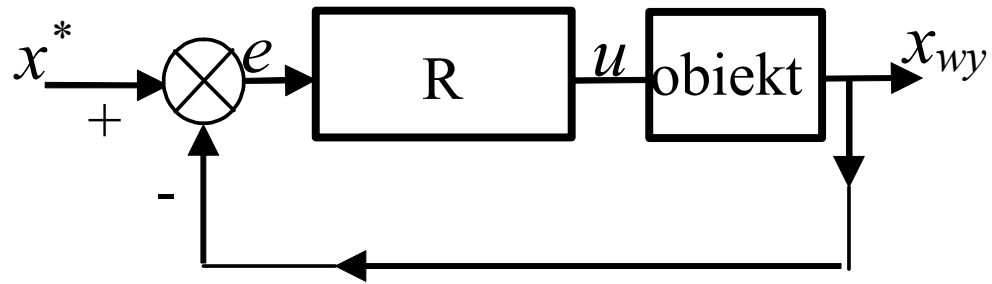
Podstawowy układ regulacji

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

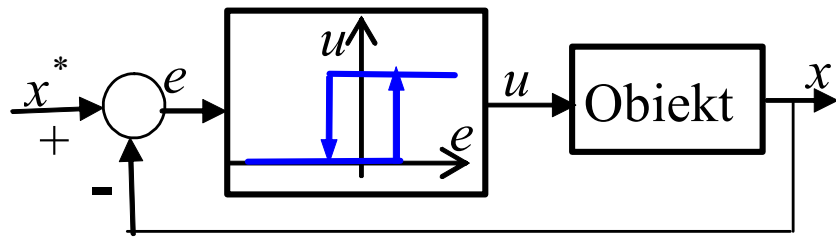


y – zmienna procesowa (PV – Process Variable)
 y^* – wartość zadana (SP – Set-Point)
 e – uchyb regulacji (control error)
 u – zmienna sterująca (CV – Control Variable)
 z – zakłócenia

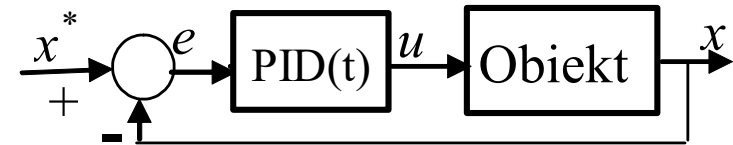
Typy regulatorów



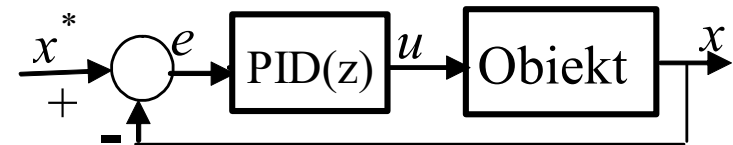
- regulatory przekaźnikowe (binarne)



- regulatory ciągłe



- regulatory dyskretne

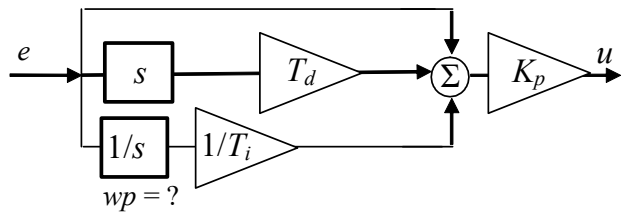
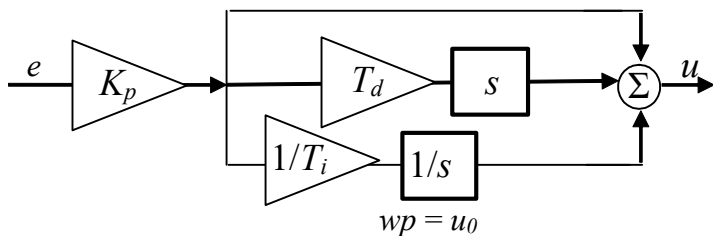


Regulator ciągły: Struktura PID i sposób realizacji

PID-ISA (Ideal Standard Algorithm)

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

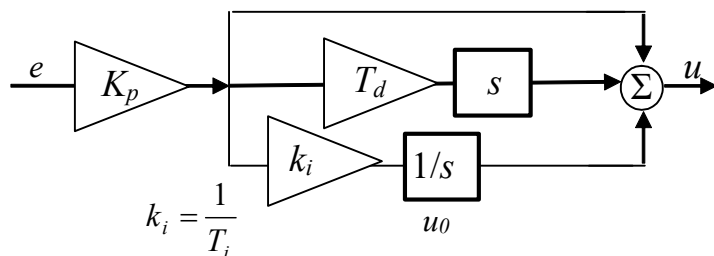
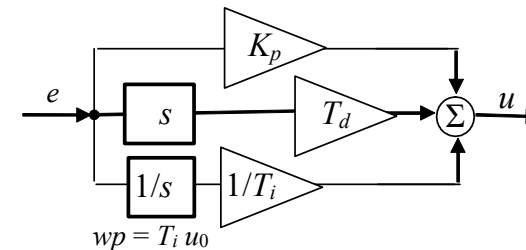
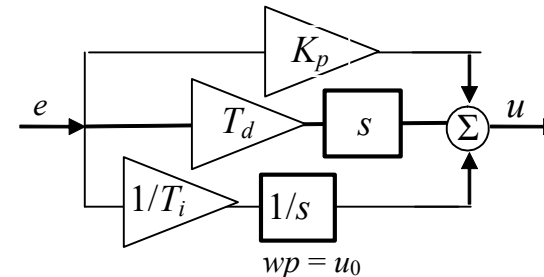
$$R = K_p \left(1 + \frac{1}{T_i s} + T_d s \right)$$



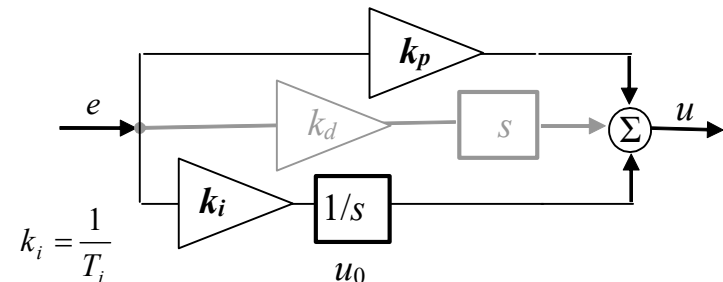
PID-IND (INDEpendent algorithm)

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

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



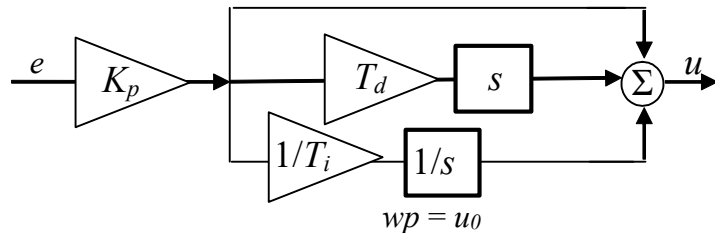
Realizacja PID (wybór)



Regulator ciągły: Struktura PID w teorii

PID-ISA (Ideal Standard Algorithm)

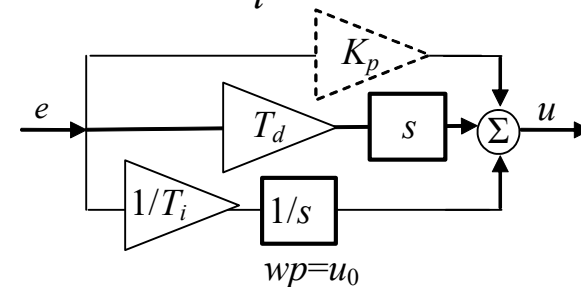
$$R = K_p \left(1 + \frac{1}{T_i s} + T_d s \right)$$



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

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):

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

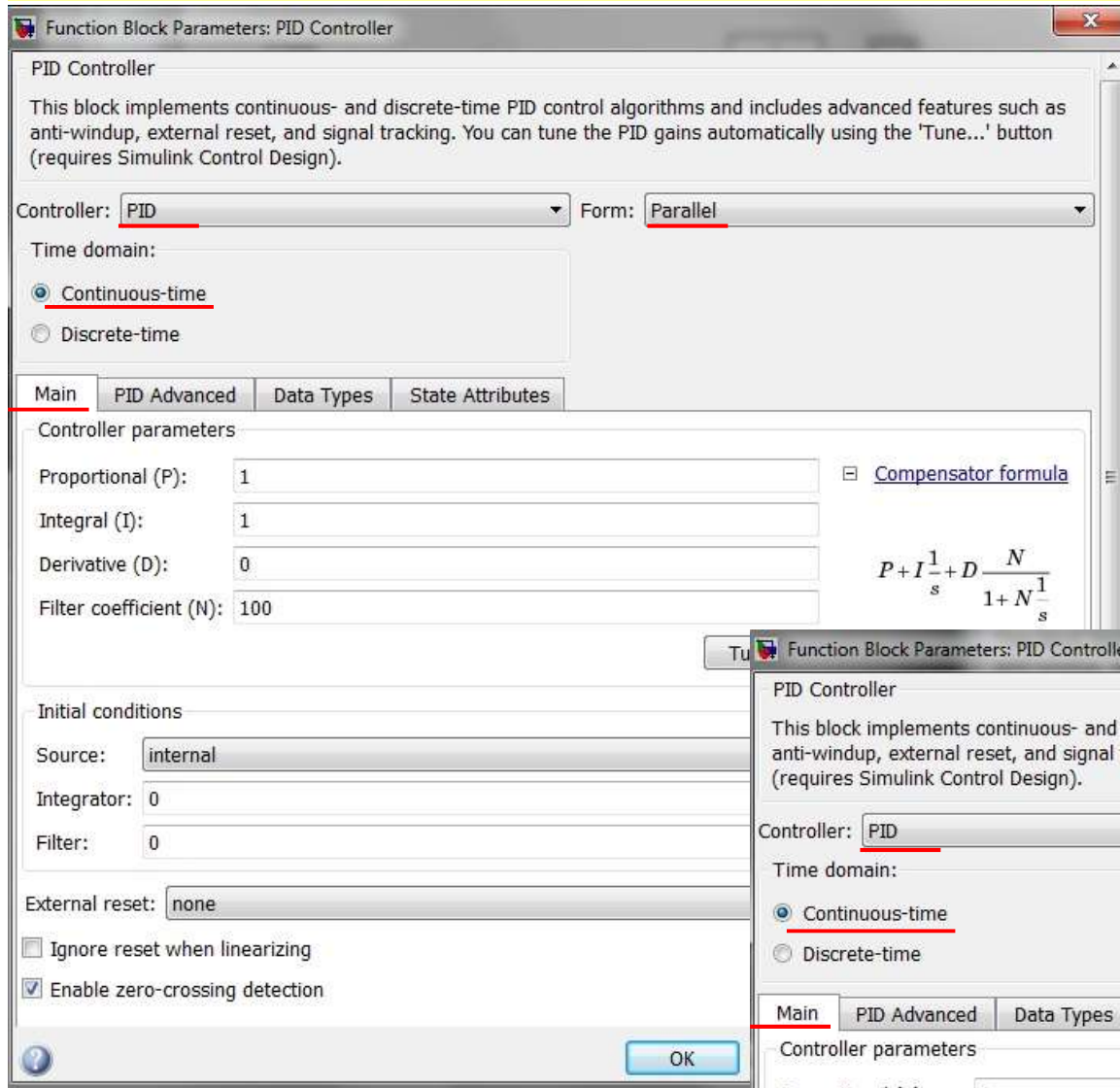
PI:
$$K_p \frac{T_i s + 1}{T_i s} = K_p \left(1 + \frac{1}{T_i s} \right)$$

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 -> Continuous -> PID Controller



Function Block Parameters: PID Controller

PID Controller

This block implements continuous- and discrete-time PID control algorithms and includes advanced features such as anti-windup, external reset, and signal tracking. You can tune the PID gains automatically using the 'Tune...' button (requires Simulink Control Design).

Controller: PID Form: Parallel

Time domain:

Continuous-time

Discrete-time

Main PID Advanced Data Types State Attributes

Controller parameters

Proportional (P): 1 [Compensator formula](#)

Integral (I): 1

Derivative (D): 0

Filter coefficient (N): 100

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

Initial conditions

Source: internal

Integrator: 0

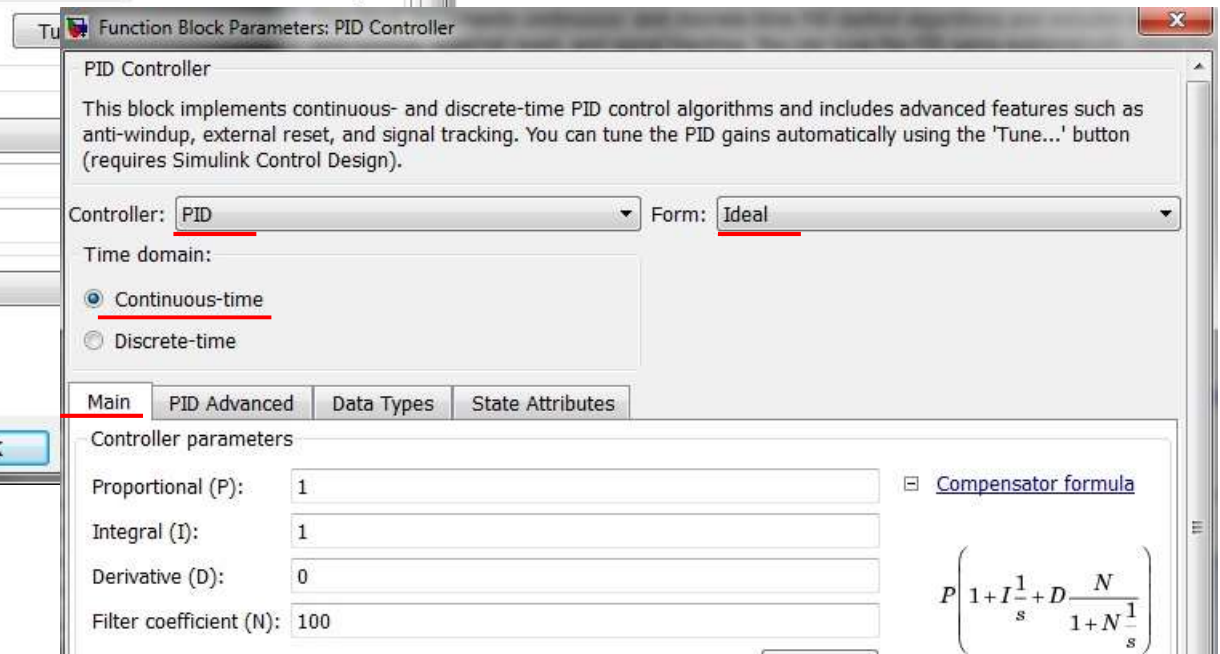
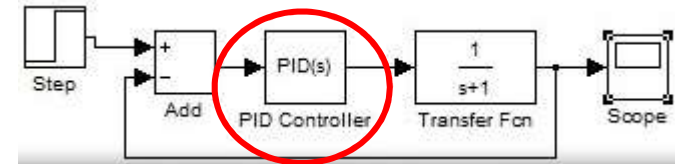
Filter: 0

External reset: none

Ignore reset when linearizing

Enable zero-crossing detection

OK



Function Block Parameters: PID Controller

PID Controller

This block implements continuous- and discrete-time PID control algorithms and includes advanced features such as anti-windup, external reset, and signal tracking. You can tune the PID gains automatically using the 'Tune...' button (requires Simulink Control Design).

Controller: PID Form: Ideal

Time domain:

Continuous-time

Discrete-time

Main PID Advanced Data Types State Attributes

Controller parameters

Proportional (P): 1 [Compensator formula](#)

Integral (I): 1

Derivative (D): 0

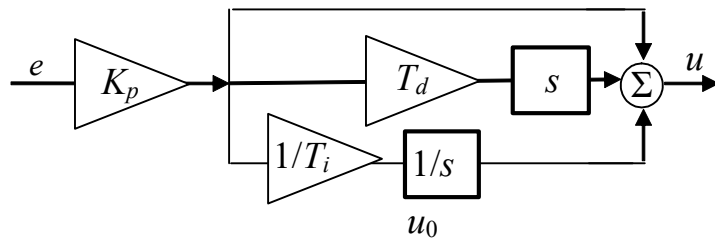
Filter coefficient (N): 100

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

Regulator ciągły: Struktura PID i sposób realizacji

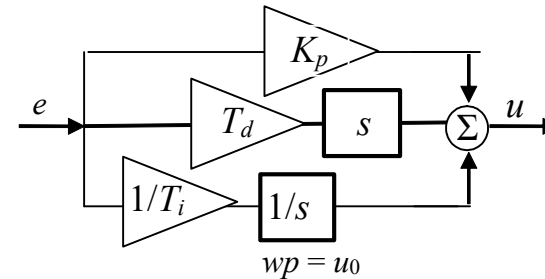
PID-ISA (Ideal Standard Algorithm)

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



PID-IND (INDependent algorithm)

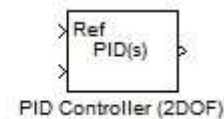
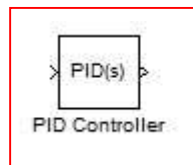
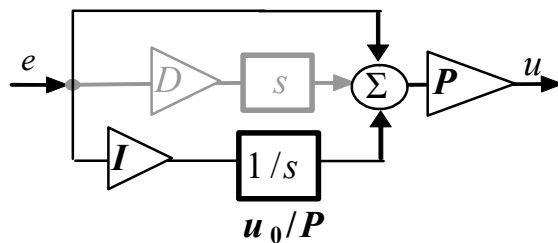
$$R = K_p + \frac{1}{T_i s} + T_d s$$



Simulink

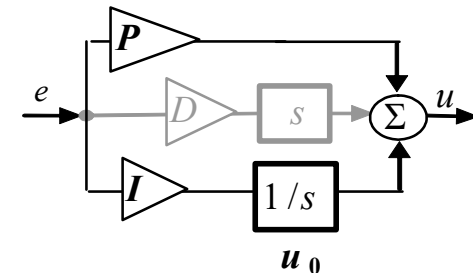
PID Ideal

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



PID Paralell

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

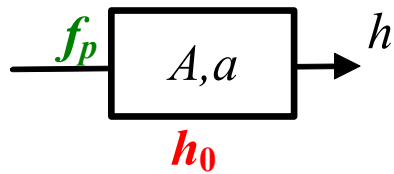
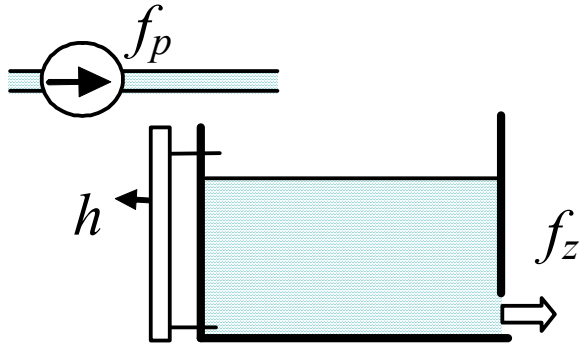


$$C = P \left(1 + I \frac{1}{s} + D \frac{N}{1 + N \frac{1}{s}} \right)$$

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

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

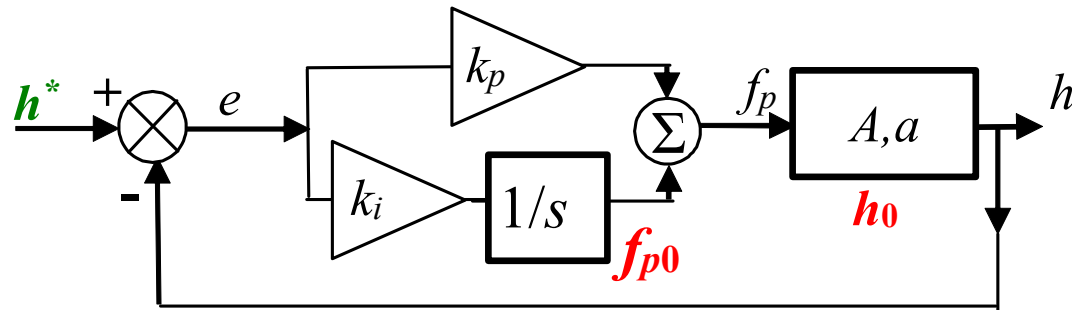
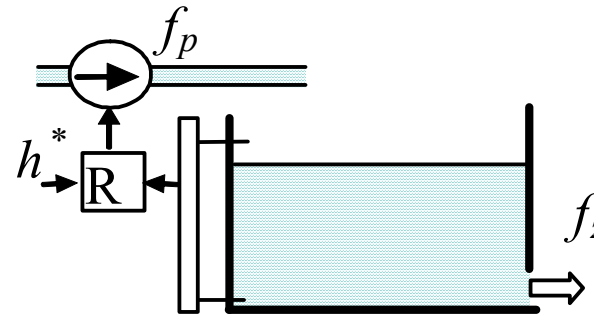
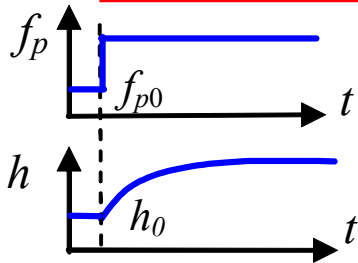
Układ regulacji ciągłej PID – wartości początkowe



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

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

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



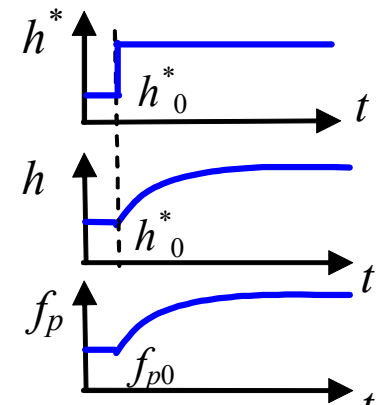
$$\begin{cases} A\dot{h}(t) = f_p(t) - ah(t) \end{cases}$$

$$\begin{cases} f_p(t) = k_p e(t) + k_i \int e(t) \end{cases}$$

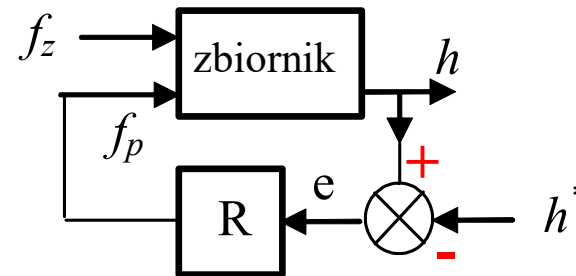
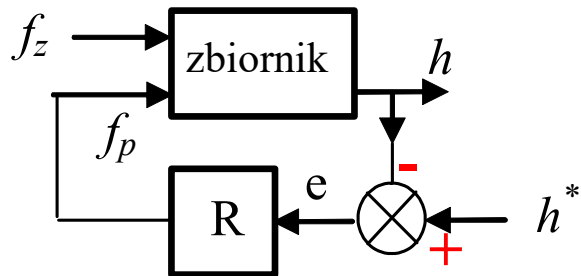
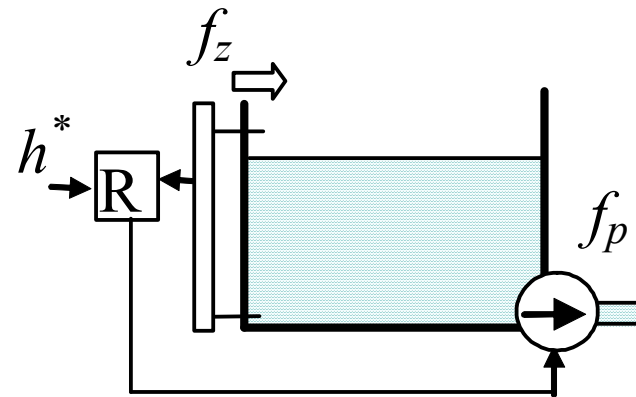
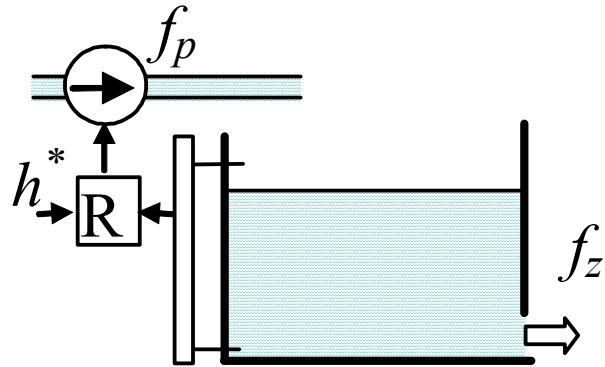
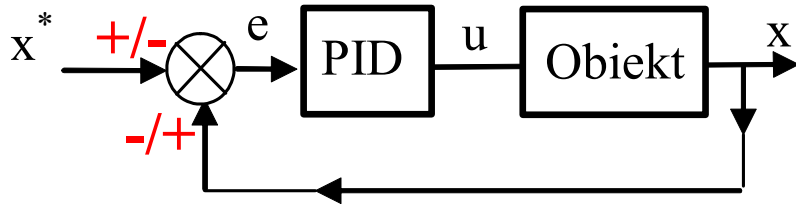
$$e = 0 \rightarrow h_0 = h_0^*$$

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

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



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?

