

## **Two Degree of Freedom PID controller**

### 1. Scope

Examine properties of the Two Degree of Freedom PID controller.

### 2. Structure of 2DOF PID controller

The 2DOF PID controller combine feedforward path to classic PID control loop. The structure is presented in Fig. 1.

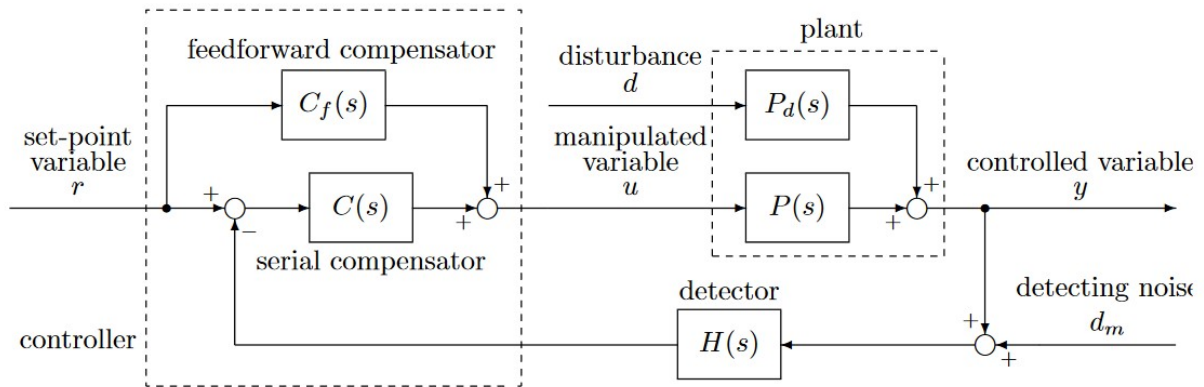


Fig. 1. 2DOF PID controller [1]

The transfer functions for reference and disturbance signal is given by:

$$G_{yr2}(s) = \frac{P(s)\{C(s) + C_f(s)\}}{1 + P(s)C(s)H(s)}$$

$$G_{yd2}(s) = \frac{P_d(s)}{1 + P(s)C(s)H(s)}$$

The steady state error to the unit step disturbance become 0 if following conditions are fulfilled:

$$\lim_{s \rightarrow 0} C(s) = \infty, \quad \lim_{s \rightarrow 0} \frac{C_f(s)}{C(s)} = 0,$$

$$\lim_{s \rightarrow 0} H(s) = 1,$$

$$\lim_{s \rightarrow 0} P(s) \neq 0, \quad \lim_{s \rightarrow 0} \left| \frac{P_d(s)}{P(s)} \right| < \infty.$$

Condition could be satisfied e.g. by following controllers:

$$C(s) = K_P \left\{ 1 + \frac{1}{T_I s} + T_D D(s) \right\},$$

$$C_f(s) = -K_P \{ \alpha + \beta T_D D(s) \},$$

where:

$K_P$  - proportional gain,  $T_I$  - integral time constant,  $T_D$  - derivative time constant,  $D$  - real derivative component,  $\alpha, \beta$  - additional 2 DOF controller parameters.

$$D(s) = \frac{s}{1 + \tau s}, \tau = 10^{-4}$$

For simplification following assumption are assumed:  $H(s) = 1$ ,  $d_m = 0$ ,  $P_d(s) = P(s)$ .

### 3. Simulation of 2 DOF PID controller

1. According to Fig. 1, Fig. 2 and following equation build diagram in Simulink with plant defined as  $P(s) = \frac{1}{1+s} e^{-0.2s}$ .
2. Disconnect feedforward compensator  $C_f(s)$ . In this way you obtain classic PID control loop.
3. Set parameters in  $C(s)$ :  $K_P=3.6$ ,  $T_I=0.4$ ,  $T_D=0.084$ . Check step response for reference and disturbance signal. Plot result on the figure.
4. Set parameters in  $C(s)$ :  $K_P=4.75$ ,  $T_I=1.35$ ,  $T_D=0.094$ . Check step response for reference and disturbance signal. Plot result on the figure.
5. Comment results. Is it possible to achieve high disturbance rejection ratio and fast response for reference signal in classic PID control loop? During 15min try to find "optimal" (in your opinion) parameters to meet both requirements (disturbance rejection and fast reference response). Plot results on the graph and comment.
6. Reconnect feedforward compensator  $C_f(s)$  to build 2 DOF PID controller.
7. Set parameters in  $C(s)$ :  $K_P=3.6$ ,  $T_I=0.4$ ,  $T_D=0.084$ . Set parameters in  $C_f(s)$ :  $\alpha=0.6$ ,  $\beta=0.63$ . Check step response for reference and disturbance signal. Plot result on the figure.
8. Compare results with classic PID control loop. Comment differences.
9. Ask teacher to assign plant object for you and repeat point 2 to 8 for the new plant. Don't use set of parameters  $K_P=3.6$ ,  $T_I=0.4$ ,  $T_D=0.084$  and  $K_P=4.75$ ,  $T_I=1.35$ ,  $T_D=0.094$ . For the new plant you have to find classic PID controller parameters similar to the former exercise "PID controller".

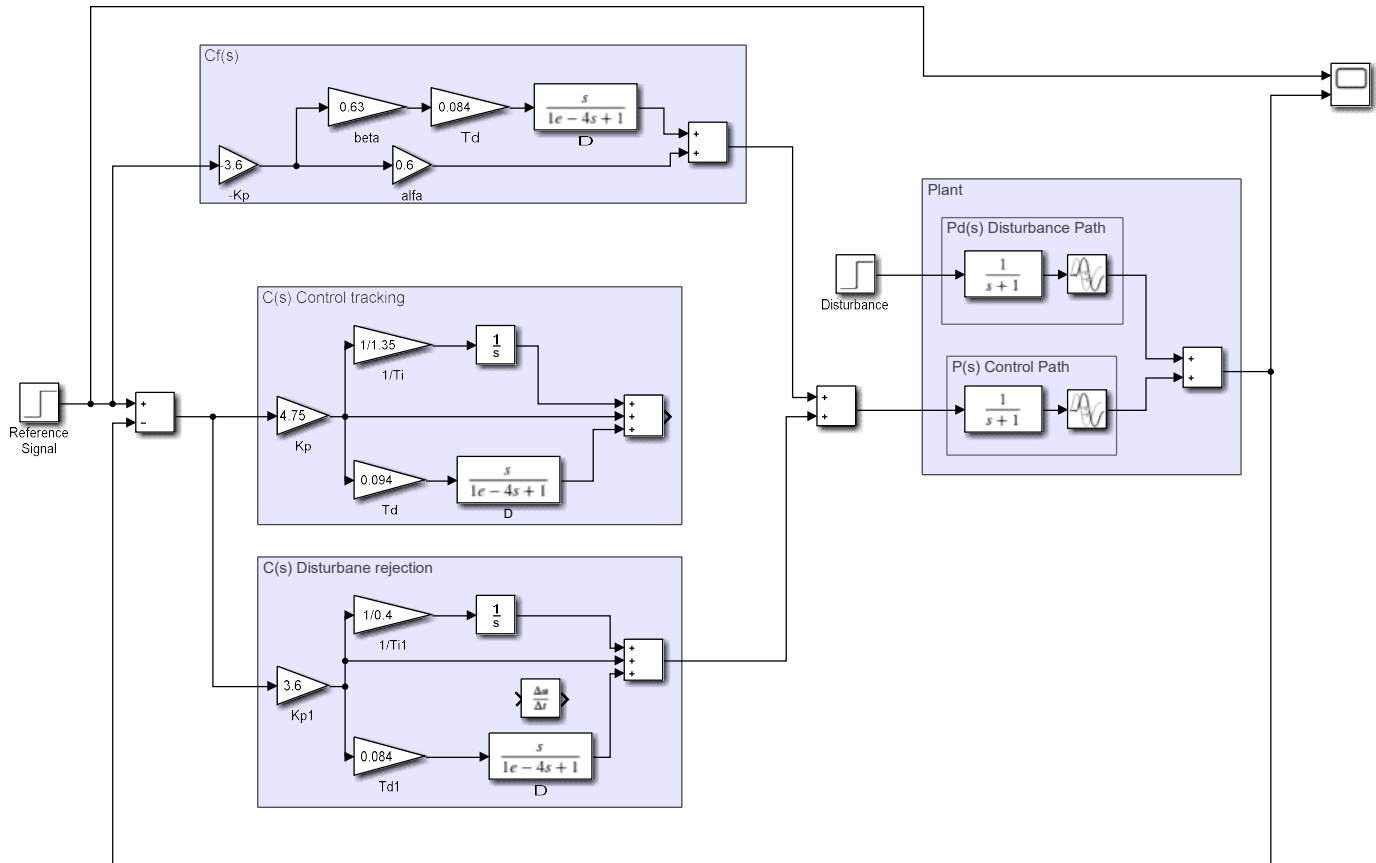


Fig. 2. Simulink model of 2DOF PID controller

[1] Mituhiko Araki and Hidefumi Taguchi: Two-Degree-of-Freedom PID Controllers. International Journal of Control, Automation, and Systems Vol. 1, No. 4, December 2003