# Control Engineering II - Project

## Assignment 4

The transfer function of the process from the closed loop system shown in Fig. 1 is given as

$$H_f(s) = \frac{K_f}{s(T_f s + 1)}$$

**Requirement**: Compute a controller $H_r(s)$ that ensures a phase margin of the open loop process of $\gamma_k = 60^o$.

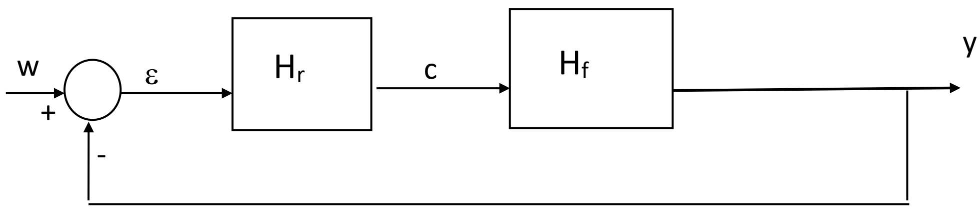


**Fig. 1** Closed loop system

**Handout**: A short documentation containing the obtained controller, the closed loop system performance and the Bode diagram showing that the phase condition is met.

**Theoretical background:**

Some brief tuning steps of the PD controller: $H_c(s) = k_p \frac{1+\tau_d s}{1+\beta\tau_d s}$, $\beta \in (0.1, 0.125)$

1. $\angle H_{ol}(j\omega_c) = -180° + \gamma_k$
2. $choose \angle H_c(j\omega_c)$ maximum

   $$\angle H_c(j\omega_c) = atan\frac{1-\beta}{2\sqrt{\beta}}$$

   $$\omega_c = \frac{1}{\tau_d\sqrt{\beta}}$$

$$|H_c(j\omega_c)| = \frac{k_p}{\sqrt{\beta}}$$

3. select $\beta \in (0.1, 0.125)$ => $\angle H_c(j\omega_c)$ = ?
4. $\angle H_{ol}(j\omega_c) = \angle\left(H_p(j\omega_c)H_c(j\omega_c)\right) = \angle H_p(j\omega_c) + \angle H_c(j\omega_c)$

   $\angle H_p(j\omega_c) = -180° - \angle H_c(j\omega_c) + \gamma_k$ => $\omega_c$= ? (read it from Bode)
5. $\tau_d = \frac{1}{\omega_c\sqrt{\beta}}$
6. $|H_{ol}(j\omega_c)| = |H_c(j\omega_c)| \cdot |H_p(j\omega_c)| = 1$

   $\frac{k_p}{\sqrt{\beta}} \cdot |H_p(j\omega_c)| = 1$ (read $|H_p(j\omega_c)|$ from Bode)

   $$k_p = \frac{\sqrt{\beta}}{|H_p(j\omega_c)|}$$

Some brief tuning steps of the PI controller: $H_c = k_p\left(1 + \frac{1}{T_i s}\right)$

1. $\angle H_{ol}(j\omega_c) = -180° + \gamma_k$
2. assume that $\angle H_c(j\omega_c) = -15°$

   $|H_{ol}(j\omega_c)| \cong k_p$ and $T_i = \frac{4}{\omega_c}$
3. $\angle H_p(j\omega_c) = -180° + 15° + \gamma_k = -165° + \gamma_k$
4. $\omega_c = ?$
5. $T_i = \frac{4}{\omega_c}$
6. $|H_{ol}(j\omega_c)| = |H_c(j\omega_c)| \cdot |H_p(j\omega_c)| = 1$
7. $k_p = \frac{1}{|H_p(j\omega_c)|}$