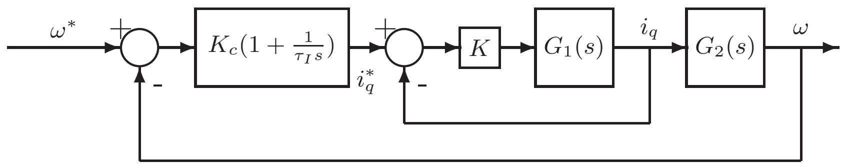
# Tutorial Five

**0.1.** An electro-mechanical system is controlled by a cascade PI controller as illustrated in Figure 0.1, where

$$G_1(s) = \frac{1}{s+1}; \quad G_2(s) = \frac{0.1}{s+0.1}$$

Choose the inner-loop controller gain $K$ such that the inner-loop system has a closed-loop pole at $-6$ and design the outer-loop PI controller by finding its proportional gain $K_c$ and integral time constant $\tau_I$. All desired closed-loop poles for the outer-loop system are chosen to be $-\lambda$ ($\lambda > 0$).




**0.2.** Continue from Prob 0.1. Because of the neglected dynamics from the inner-loop control system, there is a range of $\lambda$ for the closed-loop stability. Use Routh-Hurwitz stability criterion to determine the range of $\lambda$ for the stability of the closed-loop system.

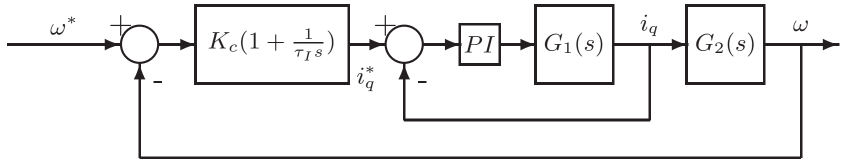
**0.3.** Continue from Prob 0.1. Suppose that there is a step input disturbance with amplitude 2. Find the transfer function between the input disturbance and the output (primary variable), and show that the disturbance will be rejected without steady-state errors if correct $\lambda$ is selected.

**0.4.** A cascade control system is shown in Figure 0.1, where

$$G_1(s) = \frac{-s+10}{(s+10)(s+3)}; G_2(s) = \frac{0.1}{s(s+2)}$$

- Find the proportional controller $K$ such that the inner-loop control system has a pair of identical real poles.
- Design a PID controller for the outer-loop system with all closed-loop poles positioned at $-1$.
- Use Nyquist stability criterion to check if the cascade control system is stable.

**0.5.** In many applications, we would like to have a PI controller for the inner-loop control system as well as for the outer-loop control system as shown in Figure 0.5. Design the cascade control systems for the following cases.




1. The system transfer functions are

$$G_1(s) = \frac{1}{(s+1)}; G_2(s) = \frac{0.1}{s+0.1}.$$

   The closed-loop poles for the inner-loop system are all positioned at $-6$; and for the outer-loop system are all positioned at $-0.6$. Find the transfer function between the input disturbance and the output (primary variable).

2. The system transfer functions are

$$G_1(s) = \frac{-5}{(s+30)(s+2)}; G_2(s) = \frac{0.1}{s(s+4)}.$$

   The closed-loop poles for the inner-loop system are all positioned at $-3$; and for the outer-loop system are all positioned at $-0.6$. Find the transfer function between the input disturbance and the output (primary variable).