

## ***Control system with feedback loop***

### **1. Scope**

Examine dynamic and static properties of the system with closed loop feedback.

Parameters of the systems are individual tuned for each Student. Determine individual parameters of the system depend on your name and student ID (e.g. *Jan Nowak*, ID 50789)

k=length of the first name (3)

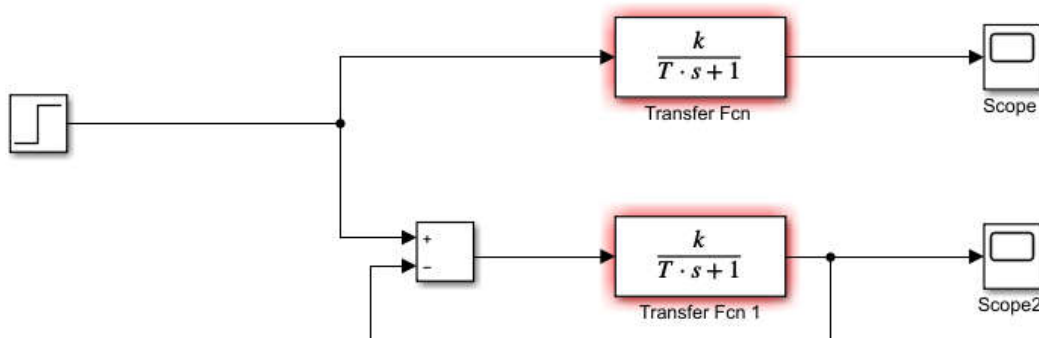
T=length of the last name (5)

a=fifth digit of the ID (9)

b= fourth digit of the ID (8)

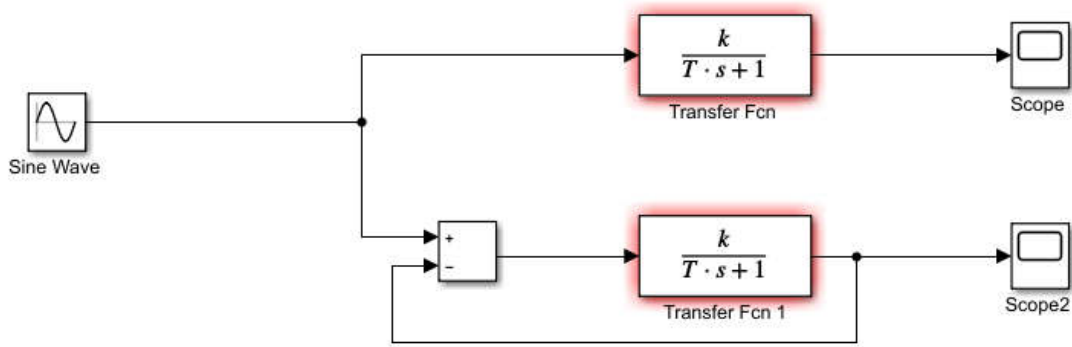
### **2. Feedback loop**

- a) System described by first order transfer inertia  $G(s) = \frac{k}{Ts + 1}$  is closed with unity, negative close loop. Prepare a simulation in Simulink for both (open and closed) systems – check step response. Draw the time plots for both systems.



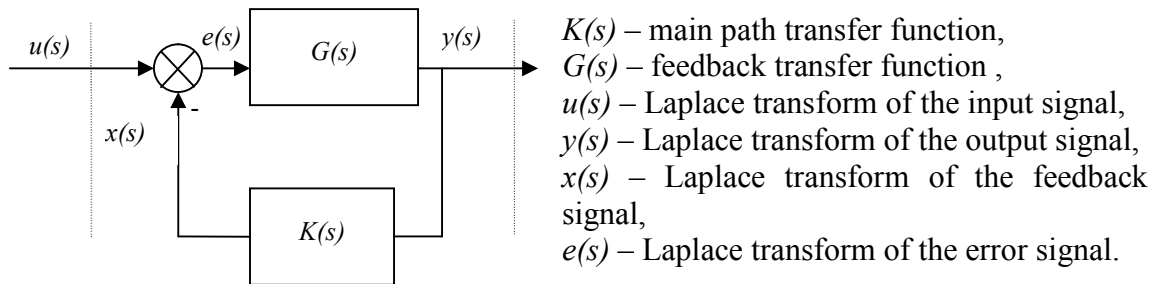
Determine the equivalent gain and time constant from the Scope2.

- b) Use harmonic input signal (instead of step) with amplitude 3. Input the signal into closed and open system. In the table note the amplitude of the output signal for both systems. Change the signal frequency 0.1 Hz to 100 Hz with increasing step e.g. 0.1Hz, 0.2 Hz, 0.4 Hz ....



Plot results in a linear scale. Find static gain ( $k$ ) the -3dB bandwidth ( $\omega_{3db}$ ). Find the BH for both system.  $BH = k * \omega_{3db}$  for both system.

### 3. Closed loop transfer function



$$W(s) = \frac{y(s)}{u(s)} = \frac{y(s)}{x(s) + e(s)} = \frac{1}{\frac{x(s)}{y(s)} + \frac{e(s)}{y(s)}} = \frac{1}{K(s) + \frac{1}{G(s)}} = \frac{G(s)}{1 + K(s)G(s)}$$

$$W(s) = \frac{G(s)}{1 + K(s)G(s)}$$

Equation is valid for  $s = j\omega$  and  $\omega = 0$ ,

$$w = \frac{g}{1 + k \cdot g}$$

where  $w$ ,  $k$ ,  $g$  states for static gain of the connected systems.

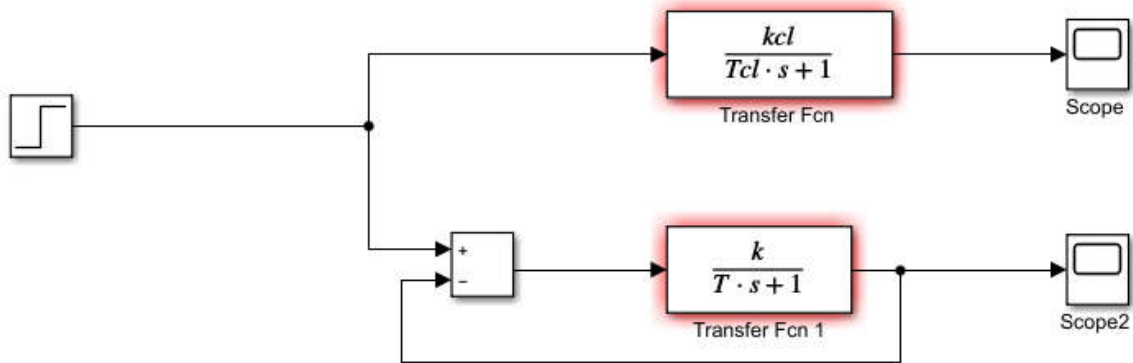
According to  $G_{cl}(s) = \frac{K(s)}{1 + K(s)G(s)}$  calculate the equivalent gain  $k_{cl}$  and time constant  $T_{cl}$  of the closed system.

Simplify equation in order to achieve first order inertia system in the form:

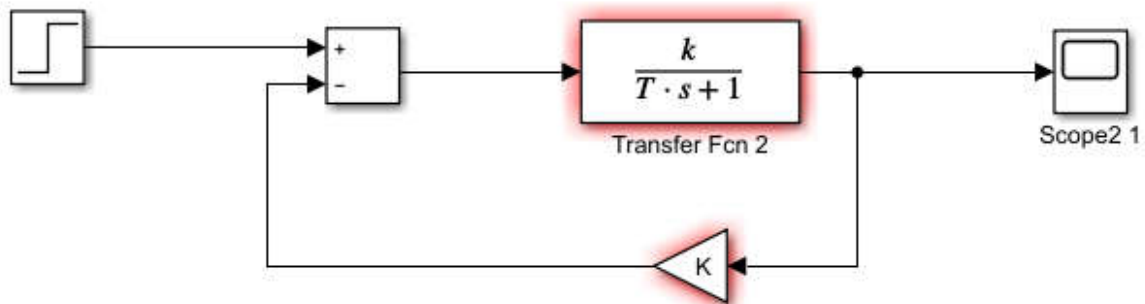
$$G_{cl}(s) = \frac{k_{cl}}{T_{cl}s + 1}$$

Compare results with those from point 2a.

Build simulation in order to check step response to of the system with closed feedback path and  $G_{cl}(s)$  .



#### 4. Frequency characteristic of the closed loop system for negative and positive feedback.



$$G(s) = \frac{k}{Ts + 1}, G = tf([k], [T \ 1]); \dots$$

Define transfer function for different value of K.

$$G_{cl}(s) = \frac{G(s)}{1 + K G(s)}$$

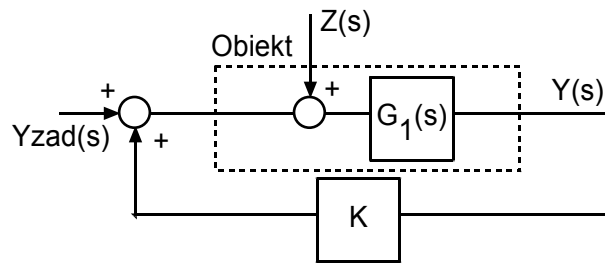
Plot the bode characteristic for each system. In this plot find the value of gain (in absolute unit)  $G$  for 0 rad/s and bandwidth  $H$  (for 3dB). Check product  $BH$  for each value of  $K$ . (for bode plot type `ltiview('bode', Gcl)`).

- $K=0$
- $K=5$ ,
- $K=-1$ ,
- $K=-0.5$ .

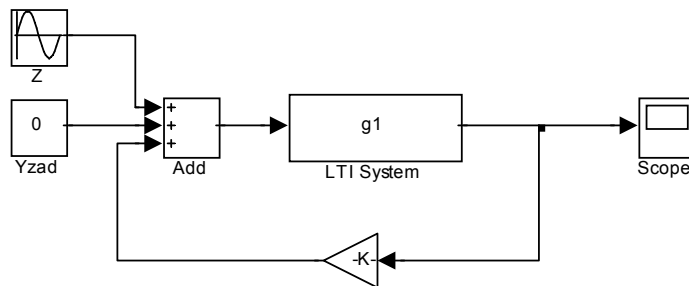
Summarise what happen to the bandwidth and gain in examined systems?

#### 5. Disturbance rejection

Prepare model in Simulink:



Disturbance  $Z(s)$  is harmonic signal with amplitude 1 and different values of frequency, object  $G_1(s) = \frac{1}{0.1s+1}$ , reference signal  $Y_{zad}=0$ , (use *LTI System* from *Control System Toolbox* for  $G_1$ ):



Check the amplitude of the output signal oscillation for different value of  $K = -100, -10, -1, +.5, +3$  and for disturbance frequency 1, 10, 100 rad/s. Note how the feedback gain influences on the disturbance observed in the output signal.