Course of
"Automatic Control Systems"
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Problems

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Problem 1.a

✧ *Compute the analytic expression of the step response of the following LTI systems:*

- $G_1(s) = \frac{s+10}{s^2+6s+5}$; $G_2(s) = \frac{s+20}{s^2+s+1}$; $G_3(s) = \frac{-3(s-2)}{(s^2+4s+3)}$;
- $G_4(s) = \frac{s+14}{s^2+10s+30}$; $G_5(s) = \frac{s+24}{s^2+3s+45}$; $G_6(s) = \frac{s+15}{s^2+9s+20}$.

✧ *Plot the step response for the different LTI systems*

Problem 1.b

- ***Compute the transfer function of the following LTI system:***

$$\dot{x} = \begin{pmatrix} 0 & 1 \\ \boldsymbol{a} & -1 \end{pmatrix} x + \begin{pmatrix} 0 \\ 1 \end{pmatrix} u \,,$$

$$y = \begin{pmatrix} 1 & 0 \end{pmatrix} x$$

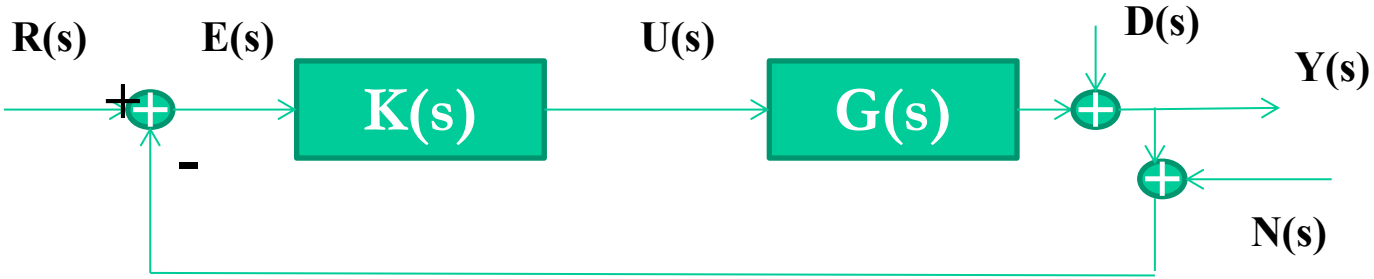
- ***Discuss the stability by varying*** $a \in (-\infty, +\infty)$.
- ***Plot the step response for the LTI system with a = -4.***

Problem 1.c

✧ *Study the frequency response of the following LTI systems by drawing the asymptotic Bode diagrams:*

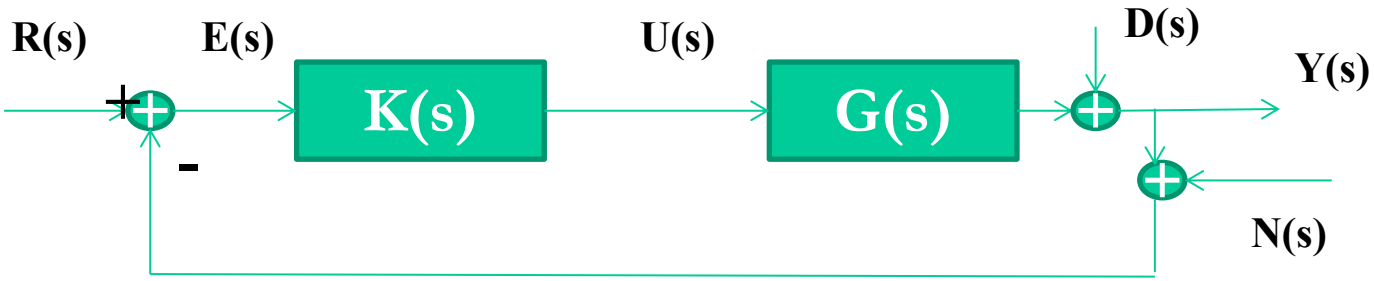
- $G_1(s) = \frac{s}{s^2+6s+5}$
- $G_2(s) = \frac{s}{s^2+s+1}$
- $G_3(s) = \frac{20(s+0.1)}{(s^2+21s+20)}$
- $G_4(s) = \frac{10(s+3)}{(s+1/3)(s+9)}$
- $G_5(s) = \frac{10(s+3)}{s(s+1/3)(s+9)}$

Problem 2 - Controller design



- *Stability*
- *Robust stability*
- *Steady-state performances*
- *Transient performances*

Problem 2 – Example 1



$$G(s) = \frac{1}{s^2+s+1}$$

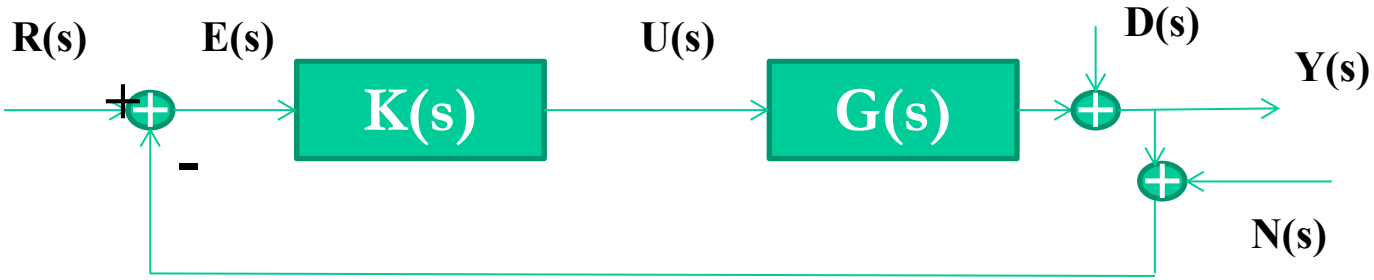
Design K(s) in order to achieve the following requirements:

- $e_{\infty r} \leq 10\%$ for a reference signal $r(t) = r_0 1(t)$ with $r_0 = 1$
- Overshoot $s \leq 30\%$
- Settling time $t_{s5\%} \leq 1s$

For the devised controller, evaluate the frequency range of the reference signal that the control systems is capable of tracking with an $e_{\infty,r} < 0.1$

See *problem_2_ex1.m* file included in *Matlab and Simulink code* folder for the solution

Problem 2 – Example 2



$$G(s) = \frac{1}{s^2+s+1}$$

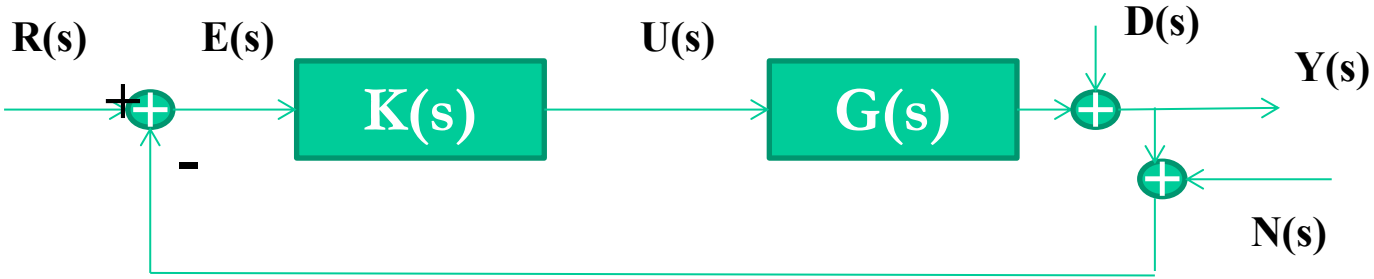
Design K(s) in order to achieve the following requirements:

- $e_\infty = 0$ for a disturbance signal $d(t) = d_0 1(t - t_0)$
- Overshoot $s \leq 30\%$
- Settling time $t_{s5\%} \leq 2s$

For the devised controller, evaluate the effect of multifrequency noise *n*(*t*) in the range [50 100] rad/s on the system output *y*(*t*).

See *problem_2_ex2.m* file included in *Matlab and Simulink code* folder for the solution.

Problem 2 – Example 3



$$G(s) = \frac{4}{(s+4)(s+2)}$$

1. Devise a controller $K(s)$ with the aim to satisfy the following requirements:
   - $e_{\infty,r} < 10\%$ for a reference signal $r(t) = r_0 1(t)$ with $r_0 = 1$.
   - overshoot $s \leq 30\%$.
2. Compute the gain and phase margins of the open loop function for $K(s)$ devised at *1)*.
3. Evaluate the frequency range of the reference signal that the control systems is capable of tracking with an $e_{\infty,r} < 0.1$.
4. Plot the resulting step response of the closed loop system.