Master of science-level in Mechanical Engineering
Academic Year 2019-2020, Second Semester

Automatic Control (05LSLQD, 05LSLNE)

Vito Cerone

Homework n. 7

Main learning objectives

Upon successful completion of this homework, students will

1. Be able to discuss the sign of the generalized steady-state gain K_c for which the control system is stabilizable with dynamical networks (phase-lead and/or phase-lag).
2. Be able to design a controller $G_c(s)$ with a PI network.

Problem 1

Consider the feedback control system below.

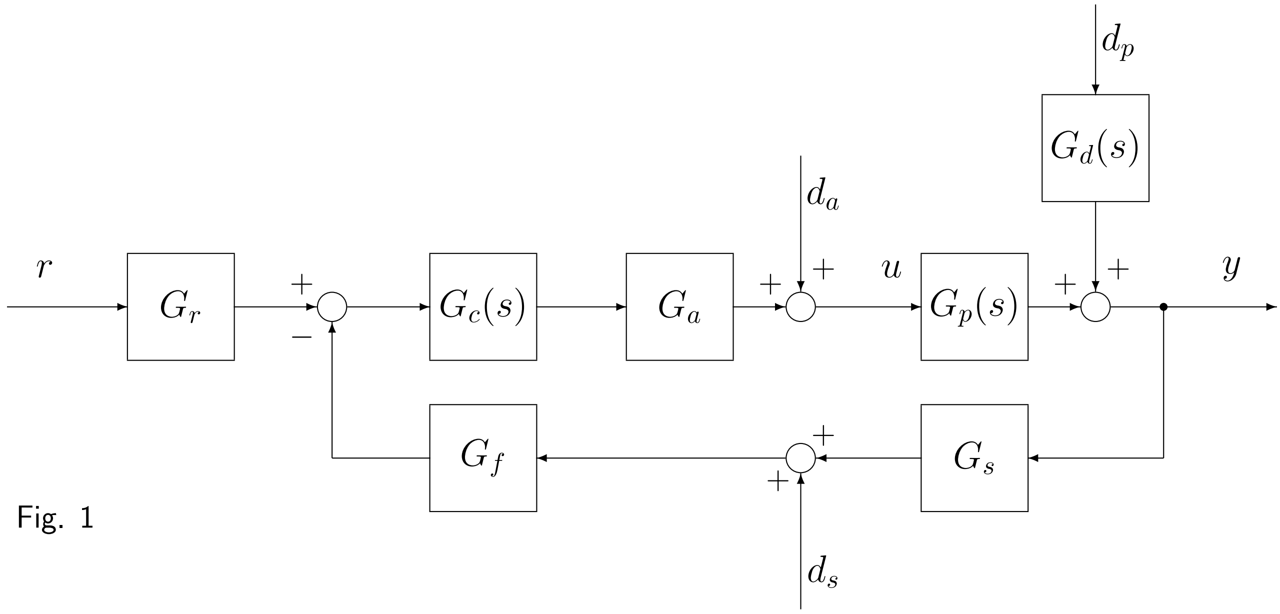

Fig. 1

For problem $P1$ to problem $P8$ (see previous homeworks), students are asked to:

(a) Discuss the sign of the generalized steady-state gain K_c for which the control system is stabilizable with dynamical networks (phase-lead and/or phase-lag).

(b) Design a feedback controller G_f and a cascade controller G_c with a PI network (if possible), trying to meet all required specifications, through loop-shaping design techniques.

(c) Check, through time simulation of the feedback control system, that all required specifications are met.

(d) Provide accurate graphical and numerical documentation of time domain performance of the designed feedback control system, even if requirements are not satisfied.

Problema 2

Consider the following list of transfer functions and the feedback control system shown in Fig. 1. Assume that $G_r = 1$, $G_s = 1$, $G_f = 1$, $G_a = 1$, $G_c = K_c$ and G_p is taken from the list below. Discuss the sign of the generalized steady-state gain K_c for which the control system is stabilizable with dynamical networks (phase-lead and/or phase-lag).

$$H(s) = \frac{1}{s(s+2)(s+4)} \tag{1}$$

$$H(s) = \frac{-0.1(1-2s)}{s(s+0.2)(1+s)} \tag{2}$$

$$H(s) = \frac{1}{s^2(s+3)} \tag{3}$$

$$H(s) = \frac{2(1+0.5s)}{(1+s)(1-s)^2} \tag{4}$$

$$H(s) = \frac{s^2+1}{(s-2)(s+2)(s+4)} \tag{5}$$

$$H(s) = \frac{0.125(1+s^2)}{s(1+0.25s)(1+0.5s)} \tag{6}$$

$$Hs) = \frac{s-2}{(s+2)(s^2+1)} \tag{7}$$

$$H(s) = \frac{0.25}{s(1-0.5s)^2} \tag{8}$$

$$H(s) = \frac{1}{(s^2+1)(s+2)} \tag{9}$$

$$H(s) = \frac{-(1-s)}{s(1+s^2)} \tag{10}$$

$$H(s) = \frac{s+1}{(s+2)(s^2+4s+5)} \tag{11}$$

$$H(s) = \frac{(s+3)(s^2+2s+2)}{s(s-1)(s+2)(s+4)} \tag{12}$$

$$H(s) = \frac{1}{2s^3} \tag{13}$$

$$H(s) = \frac{s^3+4s^2+7s+6}{s^4+5s^3+10s^2+11s+3} \tag{14}$$

$$H(s) = \frac{(s^2-1)}{s^3+s^2+s-3} \tag{15}$$

Problema 3 Consider the feedback control system shown in Fig. 1.

Given

$$G_p(s) = \frac{1.8}{s^2 + 2.6s + 1.2}$$

$G_s = 0.5$;
$G_a = 0.1$;
$G_r = 1$;
$G_d(s) = 1$;
$d_a(t) = D_{a0}t$; $\mid D_{a0} \mid \leq 1.5 \cdot 10^{-3}$;
$d_p(t) = D_{p0}t$; $\mid D_{p0} \mid \leq 8.0 \cdot 10^{-3}$;
$d_s(t) = a_s \sin(\omega_s t)$, $\mid a_s \mid \leq 10^{-3}$, $\omega_s \geq 20$ rad s^{-1}.

Specifications
(S1) Steady-state gain of the feedback control system: $K_d = 4$.
(S2) Steady-state output error when the reference is a ramp $r(t) = 0.25t$: $\mid e_r^\infty \mid < 12 \cdot 10^{-1}$.
(S3) Steady-state output error in the presence of d_a: $\mid e_{d_a}^\infty \mid < 1.6 \cdot 10^{-3}$.
(S4) Steady-state output error in the presence of d_p: $\mid e_{d_p}^\infty \mid < 1.0 \cdot 10^{-2}$.
(S5) Steady-state output error in the presence of d_s: $\mid e_{d_s}^\infty < 0.2 \cdot 10^{-4}$.
(S6) Rise time: $t_r < 4$ s.
(S7) Settling time: $t_{s,\,5\%} < 8$ s.
(S8) Step response overshoot: $\hat{s} < 15\%$.

Design

(a) Translate steady-state and transient specifications.

(b) Discuss the sign of the generalized steady-state gain K_c which allows one to stabilize the control system with dynamical networks (phase-lead and/or phase-lag).

(c) Design a feedback controller G_f and a cascade controller G_c with a PI network (if possible), trying to meet all required specifications, through loop-shaping design techniques.

(d) Check, through time simulation of the feedback control system, that all required specifications are really met.

(e) Provide accurate graphical and numerical documentation of time domain performance of the designed feedback control system, even if requirements are not satisfied.

(f) In the presence of a unit step reference $r(t)$ only:

- Check, through simulation, the maximum value of $u(t)$. Can you spot the time when the maximum occurs?
- Draw the time plot of $u(t)$.

(g) In the presence of the disturbance $d_s(t)$ only:

- Evaluate the steady-state amplitude of $u(t)$.
- Check, through simulation, the amplitude of $u(t)$ which was found at the previous point.
- Draw the time plot of $u(t)$.