AUTOMATIC CONTROL

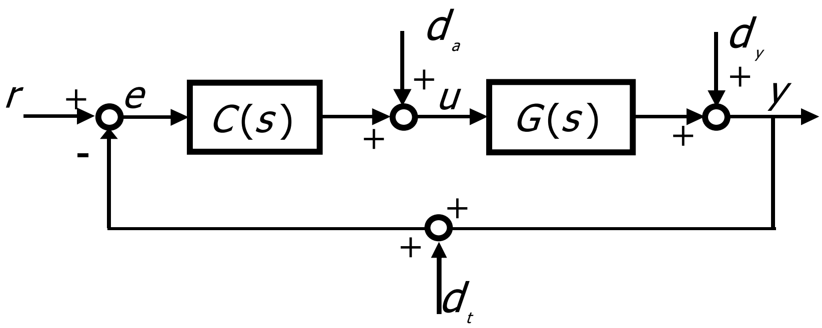
Computer, Electronic and Telecommunications Engineering

Laboratory practice n. 5

Objectives: loop shaping design of feedback control systems

Problem 1

Consider the feedback control system reported below.



where:

$$G(s) = \frac{2e^{-0.066s}}{(0.21s+1)(4s+1)},\ d_a(t) = \delta_a \varepsilon(t),\ |\delta_a| \le 0.01$$

Design a cascade controller C(s) in order to meet the following requirements:

1. $|e_r^{\infty}| = 0,\ r(t) = \varepsilon(t)$
2. $|y_{da}^{\infty}| \le 0.001$;
3. $\hat{S} \le 10\%$
4. $t_{s,2\%} \le 10$ s

After the design evaluate, through simulation, the maximum steady state amplitude of the tracking error signal *e*(*t*) in the presence of an output disturbance such that $d_y(t) = 0.1 \sin(0.05t)$.

Write the expression of the controller transfer function in the dc-gain form.

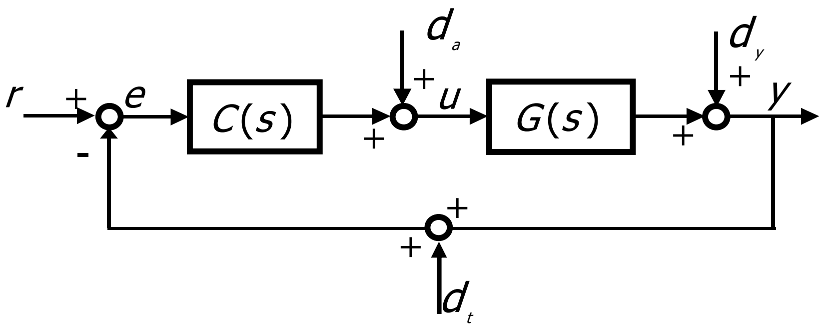
Problem 2

Repeat Problem 1. replacing requirement n. 1 with the following.

$|e_r^{\infty}| \le 1,\ r(t) = t\varepsilon(t)$

Problem 3

Consider the feedback control system reported below.



where

$$G(s) = \frac{6}{(1+s)(1+s/20)} \qquad d_t(t) = \delta_t \sin(\omega_t t), |\delta_t| \le 0.2, \; \omega_t \ge 100 \text{rad/s}$$

Design the cascade controller C(s) in order to meet the following requirements.

1. $|e_r^\infty| = 0$ in the presence of constant reference signals
2. $|y_{dt}^\infty| \le 1.5 \cdot 10^{-3}$
3. $\hat{S} \le 12\%$
4. $t_r \le 0.5$ s
5. $\max_t |u(t)| \le 1.4$ when $r(t) = 2\varepsilon(t)$

After the design, evaluate the maximum amplitude u_{MAX} of the control input variable $u(t)$ in the presence of both $r(t) = 2\varepsilon(t)$ and $d_t(t) = 0.2\sin(100t)$.

Steady state requirements analysis and design (4 points, quit the exercise evaluation in the presence of either a “destabilizing” steady state controller or the wrong type of the control system)

Report here all the steps needed to analyze the steady state requirements including

- How you handle steady state errors in the presence of both polynomial and sinusoidal signals
- The steady state design procedure (i.e. system type, choice of K_c)
- The K_c sign discussion (with detailed motivations obtained using the nyquist diagram)

Report the expression of the steady state controller in the form $C_{SS}(s)=\frac{K_c}{s^h}, K_c=\ldots, h=\ldots$

$C_{SS}(s)$ =

Transient and other requirements analysis (2 points)

Describe here how you analyzed the transient requirements in order to get the data useful for the design ($\omega_{c,des}$, T_p, S_p, …), including considerations on the input saturation constraints (if present)

Design procedure description (5 points)

Please resume and deeply motivate all the design steps performed to obtain the final controller

Describe here the design procedure including all the choices you did in order to get the final controller (in order to better describe the procedure, include also qualitative but conceptually correct sketches of the obtained Nichols plots). Please **avoid the inclusion of any Matlab code**. All the design steps must be adequately motivated.
The evaluation of this part includes:

- Completeness of the reported discussion and documentation in support of the made design choices, e.g. why controller parameters have been chosen in a given way
- Choice of the controller form, e.g. too complicated as the case of not necessary networks

Report the expression of the final controller in the **dc-gain form**

(e.g. $C(s) = K_c \dfrac{1+s/\omega_d}{1+s/(m_d\omega_d)}, K_c = \ldots, \omega_d = \ldots, m_d = \ldots$ **this only an example!!**)

(**If the expression of C(s) is missing quit the exercise evaluation -1 point if provided in the wrong form**)

C(s) =

Performance evaluation (5 points)

Use simulation in order to evaluate the achieved performance (5 points)

(0,5 each correct evaluation, 0 if the evaluation is wrong or missing

0,5 if the requirement has been satisfied (within 5%),

0 for each unsatisfied requirement with an error > 5%

-0,5 for each unsatisfied requirement with an error > 15%

-1 for each unsatisfied requirement with an error > 30%)

Report below the exact (i.e. not approximate) values obtained in simulation.

- $|e_r^\infty| =$
- $|y_{d_t}^\infty| =$
- $\hat{S} =$
- $t_r =$
- $\max_t |u(t)| =$ in the presence of $r(t) = 2\varepsilon(t)$

Final evaluation after design

(1 if the evaluation and the employed procedure are correct (within 10%), 0 if it is wrong or missing)

$u_{MAX} =$

Report here details on the procedure performed to compute / evaluate the requested quantity.

Save results `>> save Results_AC_s123456 G C` **(-3 if not done)**