AUTOMATIC CONTROL

Computer, Electronic and Communications Engineering

Laboratory practice n. 4

Objectives: Feedback control systems simulation, steady state design, loop shaping design.

Problem 1: simulation of feedback systems, performance analysis

Consider the active queue management (AQM) system introduced in AC-Lab03 for a router working under TCP/IP represented by the standard feedback structure shown in Figure 1 below.

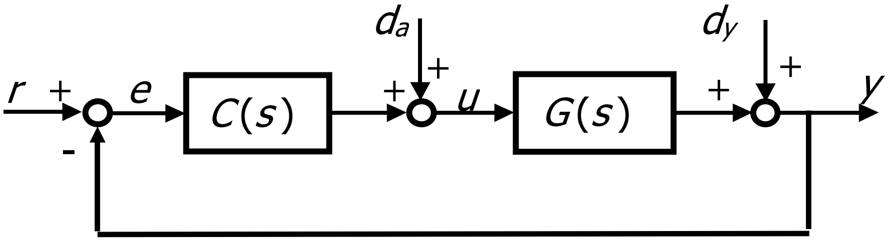


Figure 1

The packet information flow in the router is described by the transfer function:

$$G(s)=\frac{q(s)}{p(s)}=\frac{\dfrac{c^2}{2N}e^{-sR}}{\left(s+\dfrac{2N}{R^2c}\right)\left(s+\dfrac{1}{R}\right)}$$

where:

- q = queue length (packets)
- p = probability of packet mark/drop
- c = link capacity (packets/s)
- N = load factor (number of TCP sessions)
- R = round trip time (s)

The parameter values are the following:

- c = 3750 packets/s
- N = 60
- R = 0.246 s

Build a suitable Simulink scheme to simulate the control structure reported in Figure 1. Then, simulate the given AQM system using the nominal parameter values for $G(s)$ and in the presence of the (RED) controller:

$$C(s)=\frac{1.86\cdot 10^{-4}}{1+\dfrac{s}{0.005}}$$

In particular, evaluate the transient performance in terms of maximum overshoot, 10-90% rise time and settling time 1%, and the steady state tracking error when the reference signal is a step function with amplitude 1.

Repeat the same point assuming:

$$C(s) = \frac{9.64 \cdot 10^{-6}\left(1 + \frac{s}{0.53}\right)}{s}$$

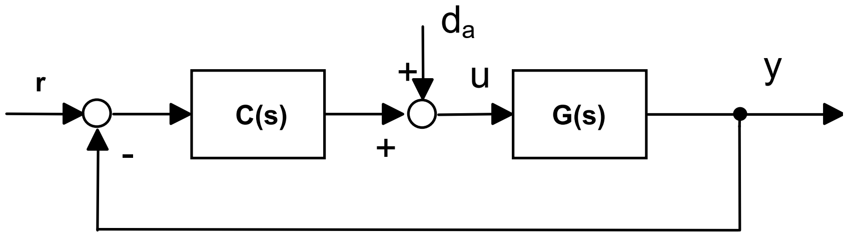
(Answer:

$$\hat{s} = 0, t_r' \approx 34.56\,s, t_{s,1\%} \approx 62.54\,s, \left|e_r^\infty\right| = 0.09$$
$$\hat{s} = 0, t_r' \approx 2.99\,s, t_{s,1\%} \approx 6.49\,s, \left|e_r^\infty\right| = 0$$

)

Problem 2: Steady state design

Consider the feedback control system below.



where:

$$G(s) = \frac{10}{s(s+5)(s+10)},\ d_a(t) = \delta_a \varepsilon(t),\ |\delta_a| \le 0.3$$

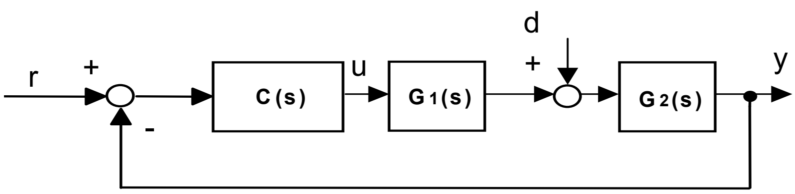
Design a steady state controller $C_{SS}(s)$ such that:

- $| e^{\infty}_{r} | \le 1$ in the presence of a linear ramp reference signal with unitary amplitude
- $| y^{\infty}_{da} | \le 0.1$;

(Result: $C_{SS}(s) = 5$)

Problem 3: steady state design

Consider the feedback control system below:



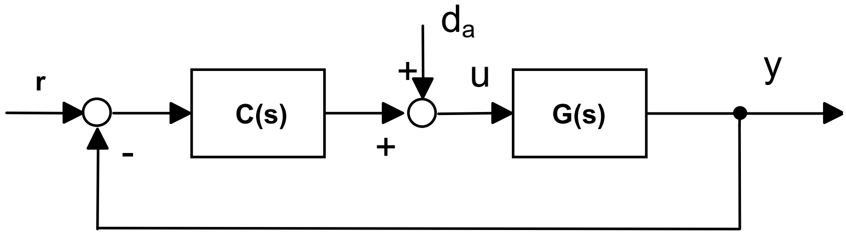
where: $G_1(s) = \frac{2.5}{s(1+0.4s)}$, $G_2(s) = -\frac{1.33}{(1+0.0133s)}$, design a steady state controller $C_{SS}(s)$ such that

- $\left| y^{\infty}_{d} \right| = 0$ in the presence of a constant disturbance $d(t)$
- $\left| e^{\infty}_{r} \right| \le 0.015$ for $r(t) = t\varepsilon(t)$.

(Result: $C_{SS}(s) = -21$)

<u>Problem 4</u> <u>: loop shaping design of feedback control systems</u>

Consider the feedback control system below



where:

$$G(s) = \frac{10}{s(s+5)(s+10)},\ d_a(t) = \delta_a \varepsilon(t),\ |\delta_a| \le 0.3$$

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

1. $|e^{\infty}_{r}| \le 1$ in the presence of a linear ramp reference signal with unitary slope
2. $|y^{\infty}_{da}| \le 0.1$;
3. $\hat{S} \le 5\%$;
4. $t_{s,2\%} \le 2$ s.

Evaluate through time domain simulation

- requirements satisfaction;
- the maximum magnitude of the input signal *u*(*t*) in the presence of a step reference signal with amplitude 0.1;
- the maximum magnitude of the output signal *y*(*t*) in the presence of both a step reference signal with amplitude 0.1 and the disturbance d_a

After the design evaluate

- the resonant peak T_p (in dB) of the complementary sensitivity function as well as its bandwidth ω_B;
- the resonant peak S_p (in dB) of the sensitivity function as well as its bandwidth ω_{BS}.

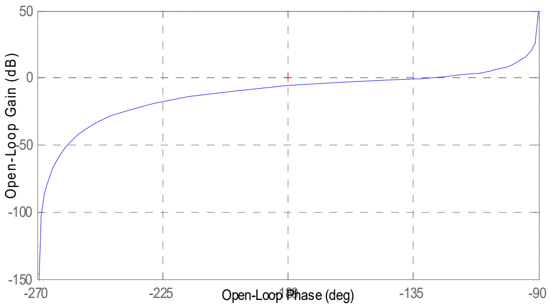
Write the expression of the final controller in the dc-gain form.

Conceptual problem

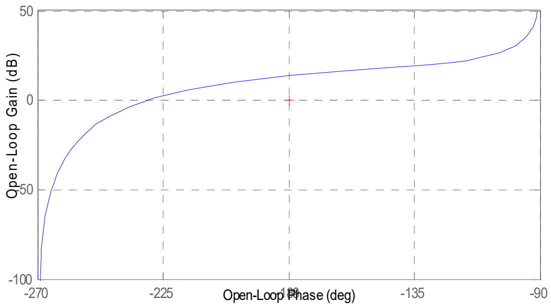
Problem 5: steady state analysis

Consider the following Nichols plots of four different loop functions L(s) of a unitary negative feedback, cascade compensation control system configuration

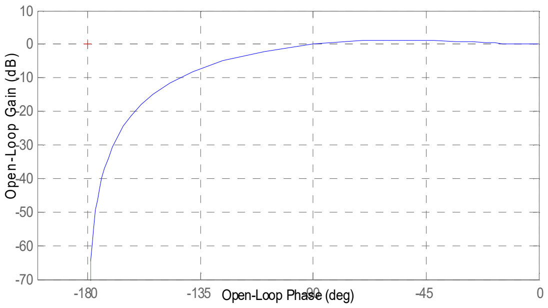
1



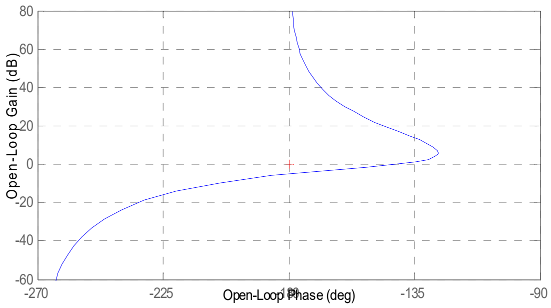
2



3



4



Suppose that, for each L(s), $K_g=\lim_{s\to 0} s^g L(s) > 0$, then, based on the Nichols plot only determine which of the four

1. corresponds to a closed loop stable system
2. guarantees a finite value of $|e_r^\infty|$ in the presence of a constant reference signal
3. guarantees $|e_r^\infty| = 0$ in the presence of a constant reference signal
4. guarantees a finite value of $|e_r^\infty|$ in the presence of a linear ramp reference signal
5. guarantees $|e_r^\infty| = 0$ in the presence of a linear ramp reference signal
6. surely guarantees $|y_{d_a}^\infty| = 0$ in the presence of a constant actuator disturbance signal $d_a(t)$

(Answer:

1. → 1,3,4 2. → 1,3,4 3. → 1,4 4. → 1,4 5. → 4 6. → none)