Automatic Control - Laboratory 1
Closed-loop systems
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Exercise 1

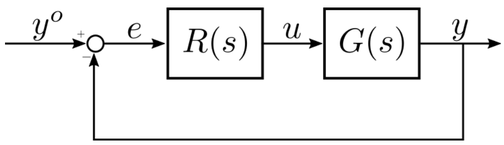
Consider a negative feedback closed-loop system with loop transfer function

$$L(s) = \frac{100}{(1+s)^2 (1+0.01s)}$$

1. Using Bode stability criterion verify that the closed-loop system is asymptotically stable.
2. Simulate the unitary step response of the closed-loop system and of its first/second order approximation obtained considering crossover frequency and phase margin. Compare the results.

Exercise 2

Consider the following block diagram

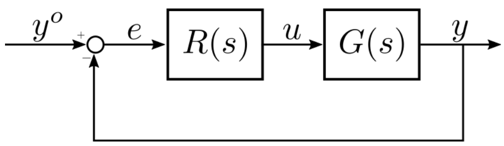


where $G(s) = 10\dfrac{1-2s}{1+10s}$.

1. Design a controller $R'(s)$ so that:
   - steady-state error is equal to zero when $y^o(t) = \text{sca}(t)$;
   - phase margin φ_m is greater or equal to 40°;
   - crossover frequency is (approximately) $0.2\,rad/s$.
2. Simulate the unitary step response of the closed-loop system and compare the result with the control system requirements specification.
3. Design another controller $R''(s)$ that fulfils the requirements specification in 1 and maximises the crossover frequency.
4. Analyse the stability robustness of the closed-loop system obtained considering $R'(s)$ and $R''(s)$ (hint: assume that the gain of the plant $G(s)$ can change of 35% with respect to its nominal value).

Exercise 3

Consider the following block diagram



where $G(s) = \dfrac{10}{s(1+10s)}$ and the regulator can be chosen among the following transfer functions

$$R'(s) = 0.03\frac{1+10s}{1+s/3} \qquad R''(s) = 0.03\frac{1+10s}{1+0.1s} \qquad R'''(s) = 0.03\frac{1+10s}{1+s}$$

1. Compare the magnitude Bode diagram of the loop transfer functions obtained using each of the previous controllers.

2. Compare the magnitude Bode diagram of the control sensitivity functions obtained using each of the previous controllers.

3. Simulate the closed-loop system response to the reference signal $y^o(t) = 5\sin(0.1t) + \sin(3t)$ considering each of the previous controllers and compare the time history of the control variables.

Control System Toolbox - Useful functions

`sist = tf(num,den)`	Define a transfer function given numerator and denominator coefficients
`[num,den]=tfdata(sist,'v')`	Get numerator and denominator coefficients from transfer function object
`sist = zpk(z,p,k)`	Define a transfer function given zero/pole vectors and gain
`[z,p,k]=zpkdata(sist,'v')`	Get zero/pole vectors and gain from transfer function object
`pzmap(sist)`	Plot the pole/zero map in the complex plane
`[y,t]=lsim(sist,u,tu)`	Compute the zero-state response given input u, defined on time vector tu
`[y,t]=step(sist)`	Compute the unitary step response
`[y,t]=impulse(sist)`	Compute the unitary impulse response
`bode(sist)`	Plot Bode diagrams of the loop transfer function frequency response
`nyquist(sist)`	Plot Nyquist diagram of the loop transfer function frequency response
`margin(sist)`	Plot Bode diagrams of the loop transfer function frequency response showing crossover frequency, phase margin and gain margin
`F=feedback(sist1,sist2)`	Compute the closed-loop system transfer function of the negative feedback between sist1, in the feedforward path, and sist2, in the feedback path