LUNDS UNIVERSITET

Institutionen för
REGLERTEKNIK

Automatic Control, Basic Course, FRT 010

Exam January 10, 2017, 8–13

Points and grades

All solutions must be well motivated. The whole exam gives 25 points. The number of points are presented after each problem. Preliminary grades:

Betyg 3: 12 points
4: 17 pointsq
5: 22 points

Aids

Mathematical collections of formulae (e.g. TEFYMA), collections of formulae in automatic control, and calculators that are not programmed in advance.

Results

The results are presented through LADOK. Time and place for exam presentation will be announced on the course web page.

1. A system is given by the following differential equation

$$\ddot{y} + 3\dot{y} + y = \dot{u} + u.$$

a. Determine the transfer function of the system. (1 p)

b. Write the system on state-space form. (1 p)

2. A nonlinear system is given by

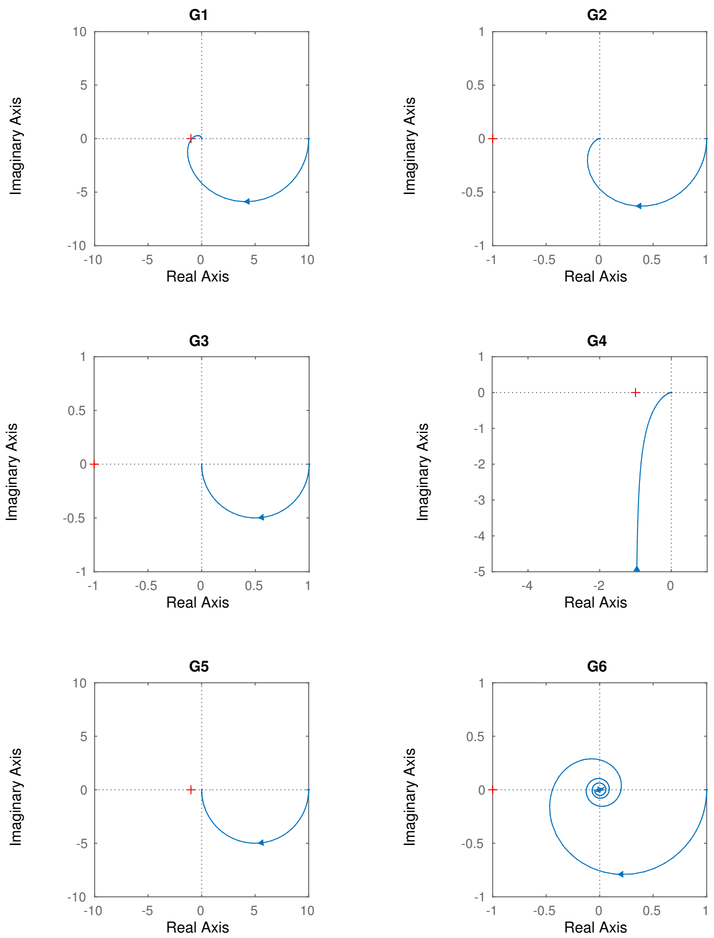
$$\begin{aligned}\dot{x}_1 &= -(x_2 + 1)x_1 \\ \dot{x}_2 &= -x_2 + u \\ y &= x_1\end{aligned}$$

a. Verify that $x_1 = 0$, $x_2 = 0$, $u = 0$ is a staionary point. (1 p)

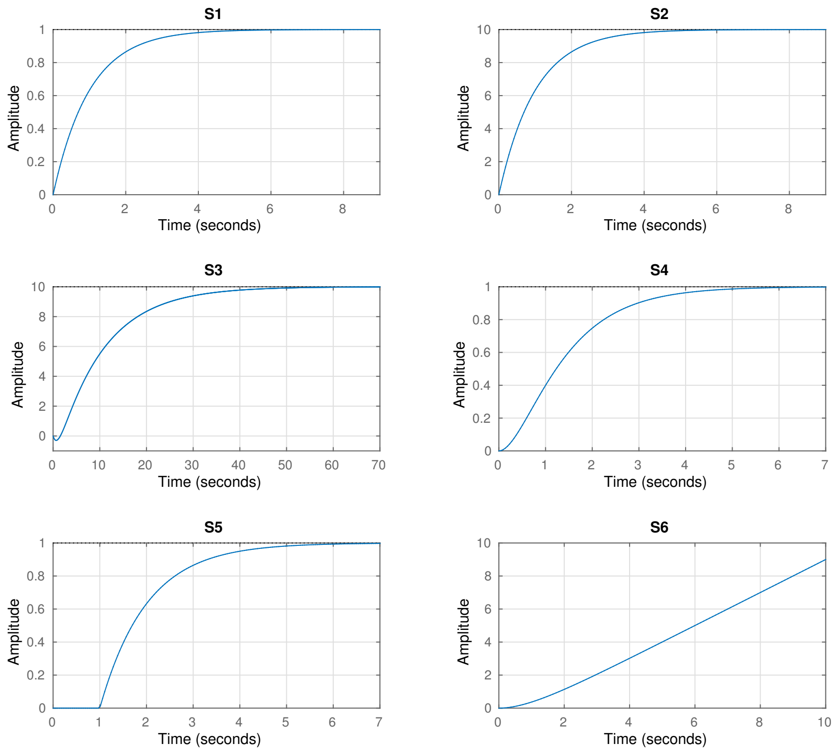
b. Linearize the system around the stationary point $x_1 = 0$, $x_2 = 0$, $u = 0$. (1 p)

c. Is the system stable around the stationary point? (1 p)

3. Figure 1 and 2 show Nyquist plots and step responses, respectively, for six different systems. Pair the Nyquist plots with the corresponding step responses. Don't forget to motivate your answers. (3 p)



Figur 1 Nyquist plots in Problem 3



Figur 2 Step responses in Problem 3

4. Determine whether the statements **a-f** are true or false, and motivate why. Points are only given for correctly motivated answers. (3 p)

a. A lag compensator can be used to reduce stationary errors.

b. A Kalman filter can always be used to estimate all states in a system.

c. A first order system without delay has infinite gain margin.

d. If the integral time T_i of a PID controller is reduced, the low-frequency gain of the controller is increased.

e. When a process is controlled by a P controller, there will always be a stationary error after step changes of the setpoint.

f. When the magnutude of the measurement noise is high, the gain K of the Kalman filter should be chosen large, i.e. the observer should be designed to be fast.

5. Calle is to design a controller for the following system

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} 1 & 2 \\ 0 & 3 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u$$

a. Is the system controllable? (1 p)

b. Design a state feedback on the form $u = -Lx$ so that the closed-loop system gets a double pole in -2. (2 p)

c. The goal of the control is to place the poles, there is no requirement on the process output. Therefore, Calle can decide which state to measure. Help Calle to make the right choice of state to measure, and motivate why. (1 p)

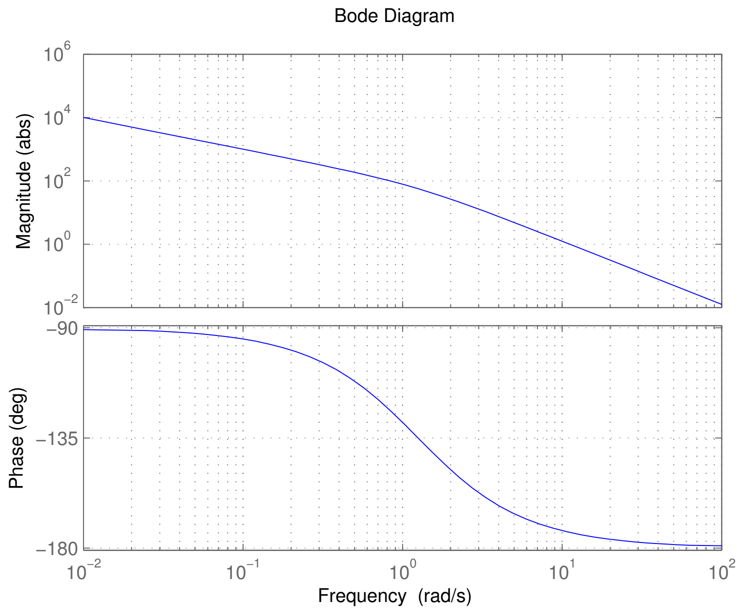
d. Design a Kalman filter with poles that are twice as fast at the poles of the closed-loop system. (2 p)

6. The transfer function of a system is given by

$$G(s) = \frac{10(s+1)}{s(s/10+1)}.$$

Plot the asymptotes for $|G(i\omega)|$. Use the form on the last page and submit it together with your solutions. (2 p)

7. The Bode plot of a loop transfer function is shown in Figure 3.



Figur 3 Bode plot for Problem 7

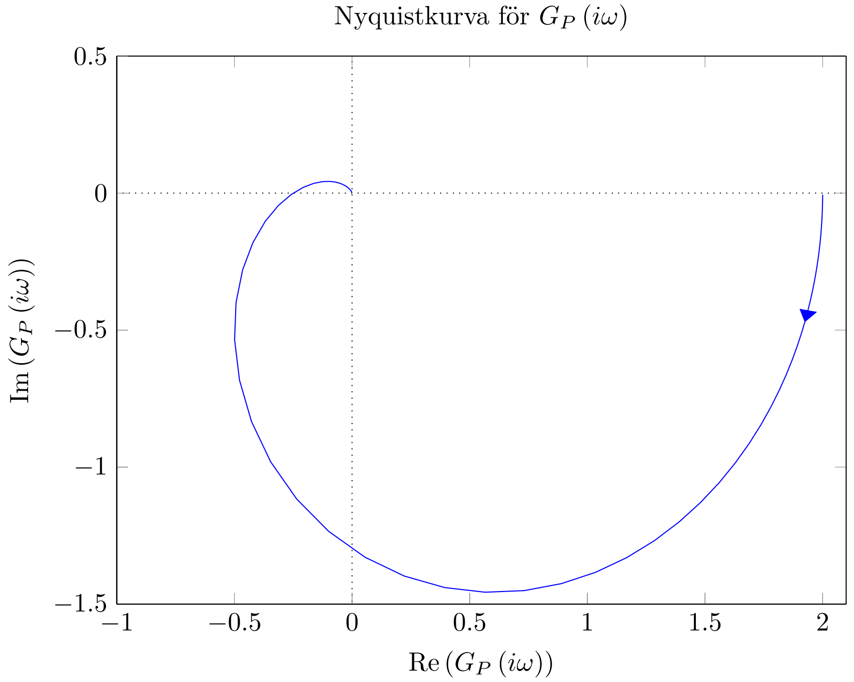
a. Is the closed-loop system stable? (1 p)

b. For the closed-loop system, a reference change in form of a ramp gives a stationary error. Design a compensator that reduces this error a factor of 10. (2 p)

8. A process transfer function $G_P(s)$ is given on the form

$$G_P(s) = \frac{K_P}{\left(1 + \frac{s}{10}\right)^n}$$

The Nyquist plot of G_P is shown in Figure 4.

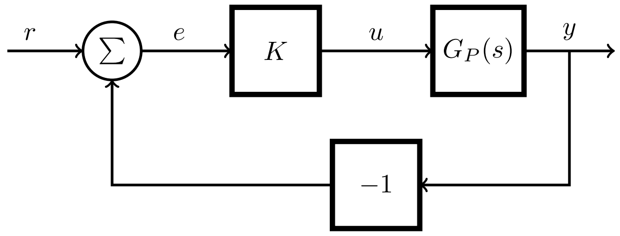


Figur 4 Nyquist plot of process G_P in Problem 8.

a. Determine the static gain K_P of the process and the order n. (1 p)

b. Determine the gain margin A_m. (0.5 p)

c. Process $G_P(s)$ is controlled by a proportional controller with gain $K > 0$, according to Figure 5. Determine the least possible stationary error $e(\infty)$ that can be obtained when r is a unit step. (1.5 p)



Figur 5 The closed-loop system in Problem 8c.

Form for the Bode plot in Problem 6

Remove this page from the exam and submit it togher with your solutions.