LUNDS UNIVERSITET

Institutionen för
REGLERTEKNIK

Automatic Control, Basic Course FRTF05

Exam October 29, 2018, 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 points
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.

Good luck!

1. Consider the system described by

$$G(s) = \frac{5}{s+4} - \frac{1}{s+1}.$$

a. Determine the poles, zeros, and the static gain of the system. (1 p)

b. Is the system stable? Is it asymptotically stable? (1 p)

c. Give an expression for the impulse response of the system in the time domain. (1 p)

2. A system is described by the following nonlinear differential equation

$$\ddot{y} + \sin \dot{y} + \cos \dot{y} + y^2 = u$$

a. Introduce the states $x_1 = y$ and $x_2 = \dot{y}$ and write the system in state-space form. (1 p)

b. Determine all the stationary points. (1 p)

c. Linearize the system around the/those points that you found in b. (1.5 p)

3. Given the step responses A-E on the next page, identify which transfer function $G_1 - G_9$ that corresponds to each step response. The answers must be clearly motivated. (2.5 p)

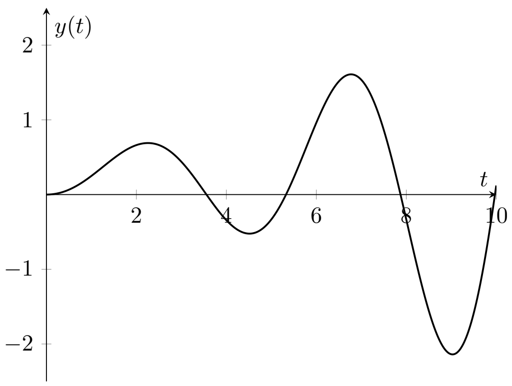
$$G_1(s) = \frac{1}{s+1} \qquad G_2(s) = \frac{4}{s^2+3s+4}$$

$$G_3(s) = \frac{4-s}{s^2+3s+4} \qquad G_4(s) = \frac{0.25}{s^2+0.5s+1}$$

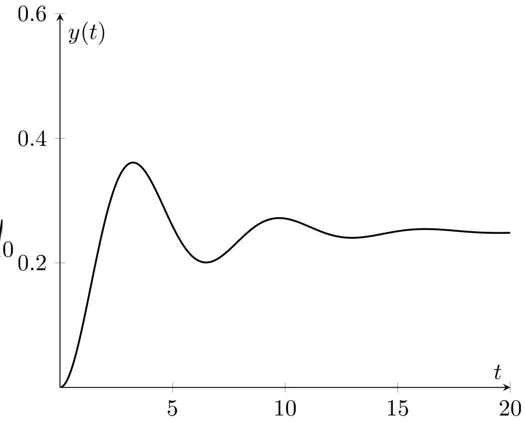
$$G_5(s) = \frac{10}{s+10} \qquad G_6(s) = \frac{0.5}{s^2-0.5s+2}$$

$$G_7(s) = \frac{4+s}{s^2+3s+8} \qquad G_8(s) = \frac{1}{s^2+3s+4}$$

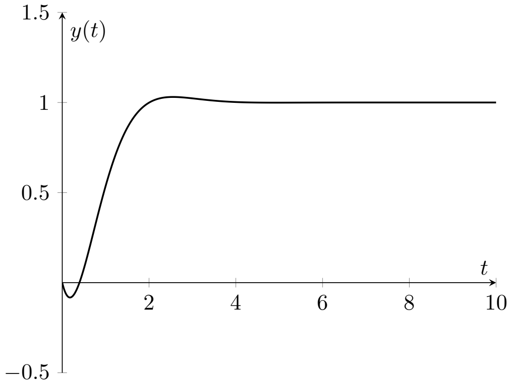
$$G_9(s) = \frac{0.01}{s^2+0.15s+0.01}$$


y(t)
t
2
1
−1
−2
2
4
6
8
10

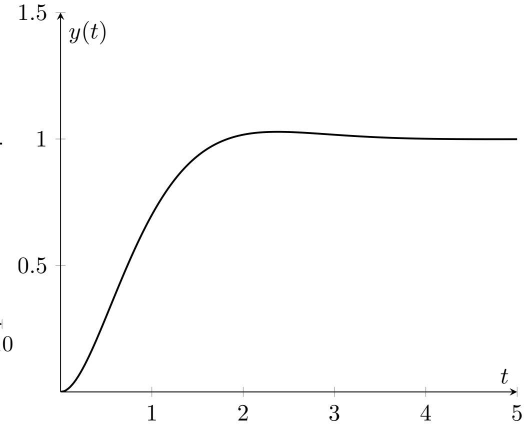
A


0.6
y(t)
0.4
0.2
t
5
10
15
20

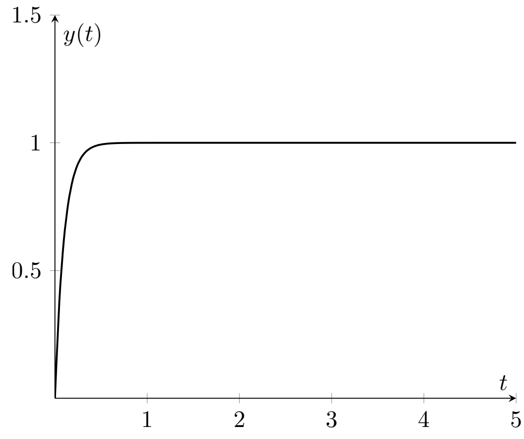
B


1.5
y(t)
1
0.5
−0.5
t
2
4
6
8
10

C


1.5
y(t)
1
0.5
t
1
2
3
4
5

D


1.5
y(t)
1
0.5
t
1
2
3
4
5

E

4. An inverted pendulum can be described by the following system

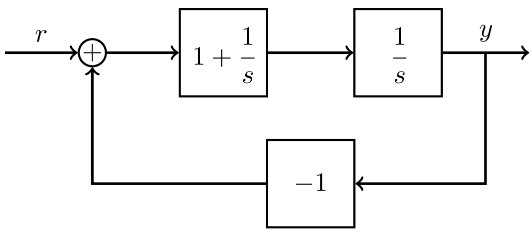
$$\dot{x} = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} x + \begin{pmatrix} 0 \\ -1 \end{pmatrix} u$$
$$y = \begin{pmatrix} 1 & 0 \end{pmatrix} x$$

a. Determine a state feedback so that the closed-loop poles are given by $s^2 + 2\zeta\omega s + \omega^2$. (2 p)

b. Since we can't measure all the states we have to introduce a Kalman filter to estimate the states. Determine a Kalman filter where the poles of the filter are placed so that the Kalman filter is two times faster than the state feedback. (2 p)

c. Draw a block diagram of the closed-loop system, with the state feedback and the Kalman filter included. (1 p)

5. Consider the system in Figure 3.



Figur 3: The system in Problem 5.

a. Determine the loop transfer function. (0.5 p)

b. Sketch the Nyquist plot and mark the gain margin A_m and the phase margin φ_m if they exist. (1 p)

c. Determine the gain margin A_m, phase margin φ_m, and delay margin L_m (1.5 p)

6. At the local bookstore, the books that are used in the courses are printed every study period. Since the number of students has increased, the books have to be printed faster.

Suppose that the machine that prints the books has the dynamics

$$G_p(s) = \frac{s + 10}{3s(s+1)(s+2)^2}.$$

A control engineer, that use to order the books for the department, suggests that a compensator that makes the system 50 % faster without reducing the phase margin is introduced. Help him designing the compensator that fulfils these requirements. (3 p)

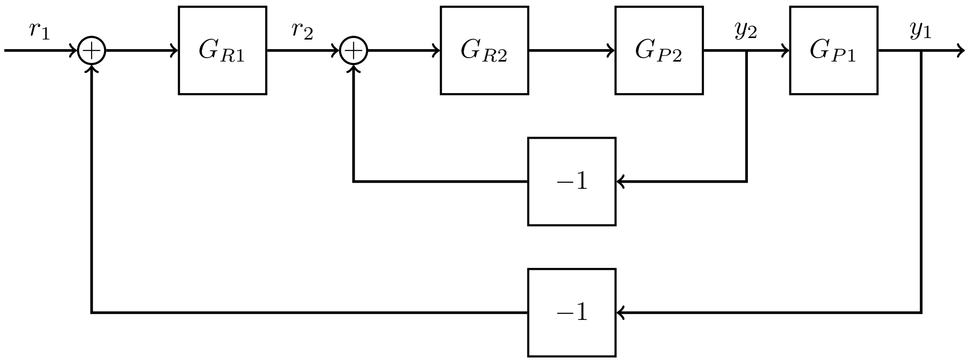
7. In lab 1 it was mentioned that the control signal is not controlling the pump directly, but that a local feedback from a flow meater was used. Today, we will design this local feedback controller. The control structure is given in Figure 4.

If we assume that we have the same dynamics as in the lab, process transfer function G_{p1} becomes

$$G_{p1} = \frac{K}{s+a}.$$

Assume that $K = 1$ and $a = 0.1$ in this case. We also assume that the pump can be modelled as

$$G_{p2} = \frac{1}{s(s+5)}.$$



Figur 4: Cascade control for Problem 7.

a. Design a P controller for the pump (G_{r2}) so that the komplex conjugated poles of the inner closed-loop system are placed at a distance 30 times longer from the origin than the pole of the tank model. (2 p)

b. With this controller, what relative damping do we get? What is the static gain? (1 p)

c. If the outer loop is designed so that it is significantly slower than the inner loop, the inner loop can be approximated with its static gain only. Design a PI controller for the tank (G_{r1}) and place the poles so that they are placed 10 times closer to the origin compared to the poles of the inner loop. Approximate the inner loop with its static gain. (2 p)