LUNDS UNIVERSITET

Institutionen för
REGLERTEKNIK

Automatic Control, Basic Course FRT 010

Exam October 24, 2016, 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

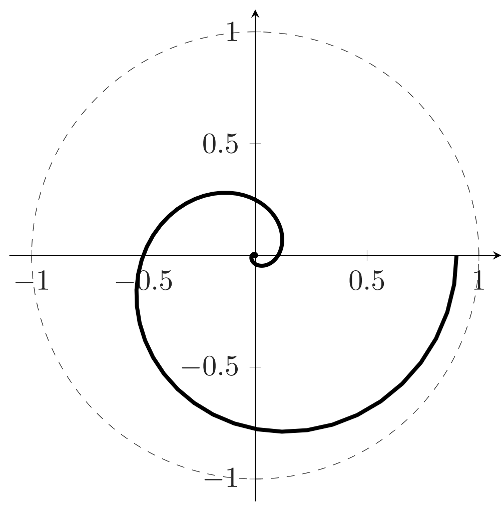
Aids

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!



Figur 1 Nyquist plot for the loop transfer function in Problem 2

1. A system is modelled by the following linear differential equation

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

a. Determine the poles and the zeros of the system. Is the system unstable, stable, or asymptotically stable? (1.5 p)

b. Give an expression for the impulse response of the system. Make a drawing of the impulse response. (1.5 p)

2. Figure 1 shows the Nyquist plot of a loop transfer function. Determine if the following statements are true or false. Don't forget to motivate!

a. There is an integrator in the loop.

b. There is a derivator in the loop.

c. The closed-loop system will be stable even if time delays are added to the loop.

d. We will introduce a P controller in the loop. The closed-loop system will be stable independent of the controller gain. (2 p)

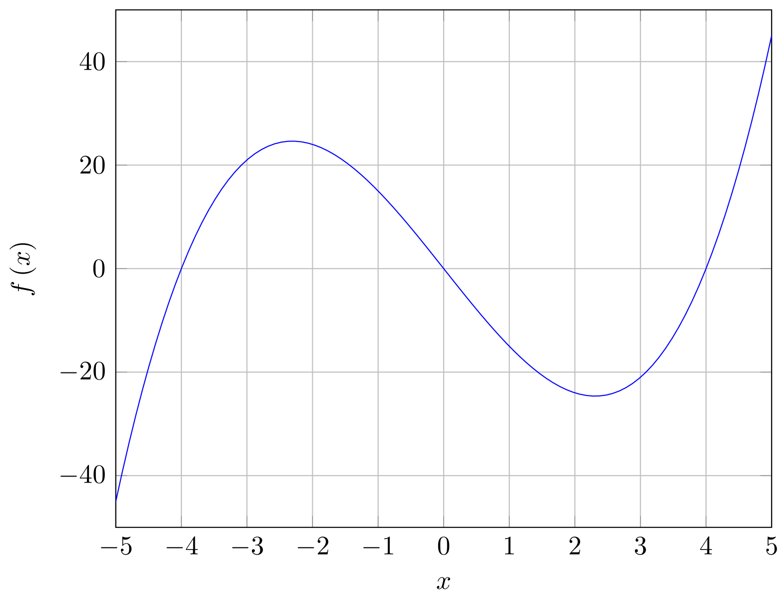
3. A nonlinear system is given by the following state-space equations

$$\dot{x} = f(x)$$
$$y = 2x^2 + x$$

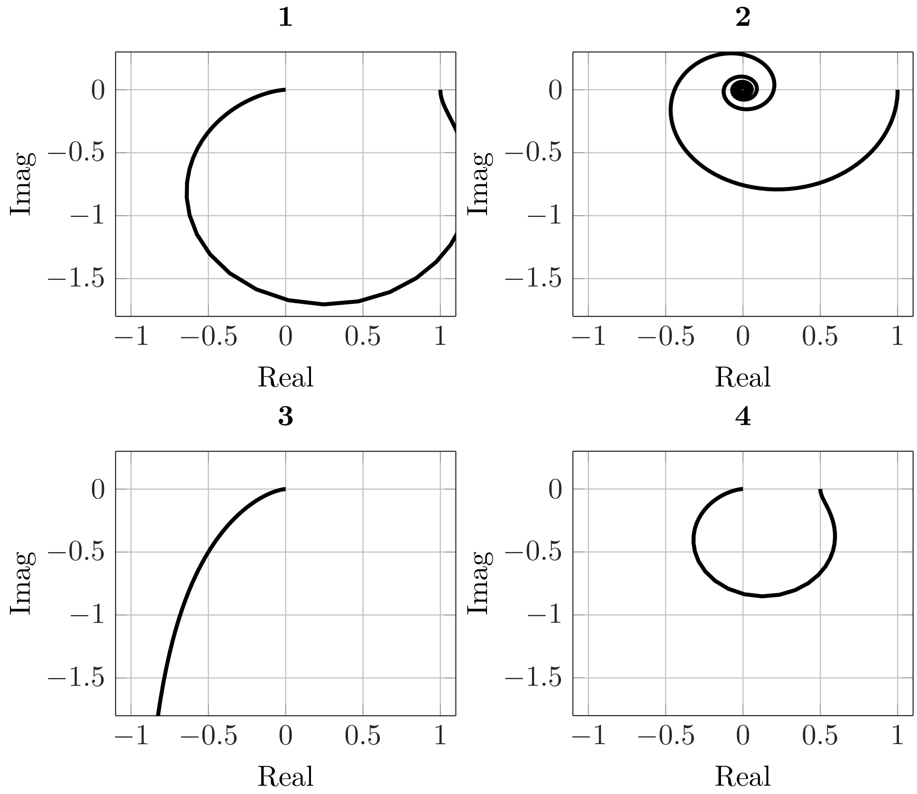
where $f(x)$ is given in Figure 2.

a. Determine all stationary points in the interval $x \in$ [-5, 5]. (0.5 p)

b. Linearize the system at the point that gives an asymptotically stable system. (1.5 p)

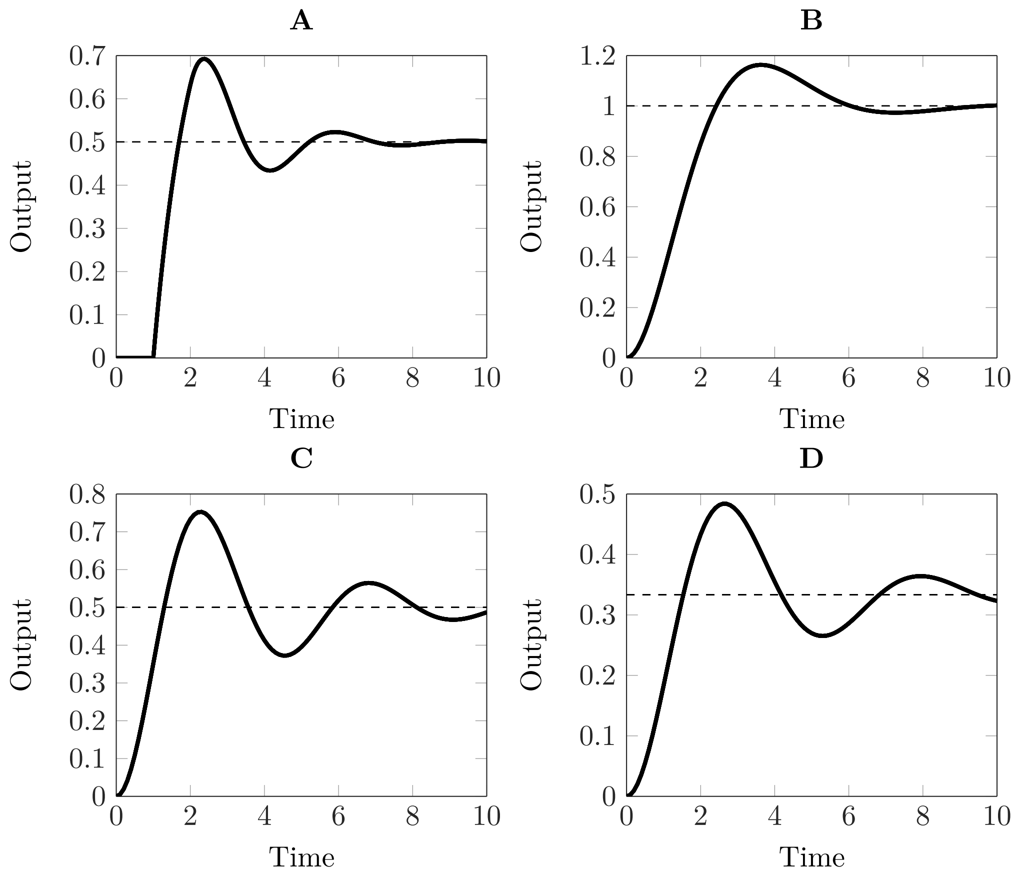


Figur 2 The function $f(x)$ in Problem 3.

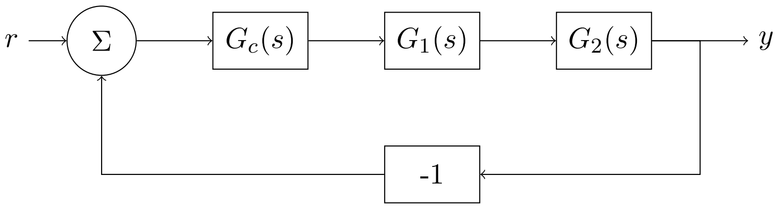


Figur 3 Nyquist plots of four loop transfer functions.

4. Figure 3 shows Nyquist plots of four loop transfer functions $G_0(s)$. Figure 4 shows responses to unit steps, together with their stationary values, from the corresponding closed-loop systems, i.e. from $\frac{G_0(s)}{1+G_0(s)}$. Combine the Nyquist plots 1–4 with the step responses A-D, and don't forget to motivate the answers! (2 p)



Figur 4 Unit step responses and stationary values of four closed-loop systems.



Figur 5 The control loop in Problem 5

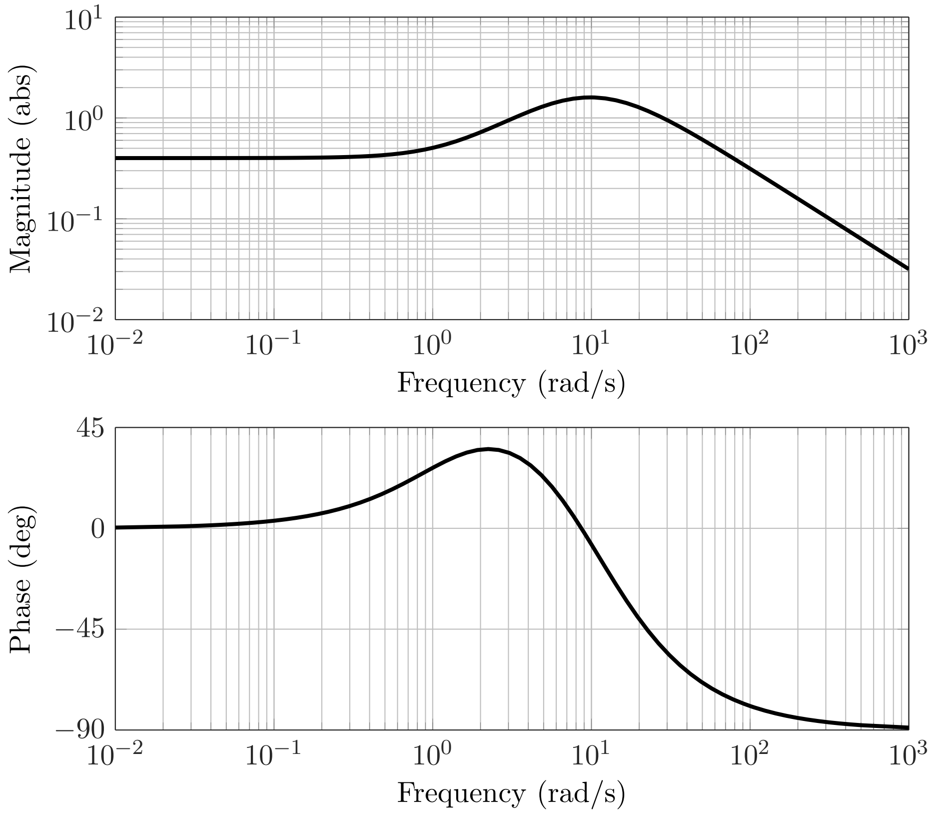
5. We are going to design the control loop shown in Figure 5. The process is given by the two transfer functions

$$G_1(s) = \frac{1}{s+7} \quad \text{och} \quad G_2(s) = \frac{3}{s-a}.$$

coupled in series. We are to design controller $G_c(s)$.

a. Suppose that $a = 3$. Let $G_c(s)$ be a PD controller and determine it's parameters so that the closed-loop system gets two poles in -8. (2 p)

b. The value of a in $G_2(s)$ is unsure. For which values of a will the closed-loop system, with the controller designed in **a**, remain asymptotically stable? (2 p)



Figur 6 Bode plot for the process in Problem 6

6. An asymptotically stable process has the Bode plot shown in Figure 6.

a. The structure of the process transfer function is

$$G(s) = K\frac{sT_z + 1}{(sT_p + 1)^n}.$$

Determine K and n. (2 p)

b. The process is fed by the input signal $u(t) = 1 + \sin(t)$. When the transients have died out, what will the process output be? (2 p)

7. A system is given in state-space form by

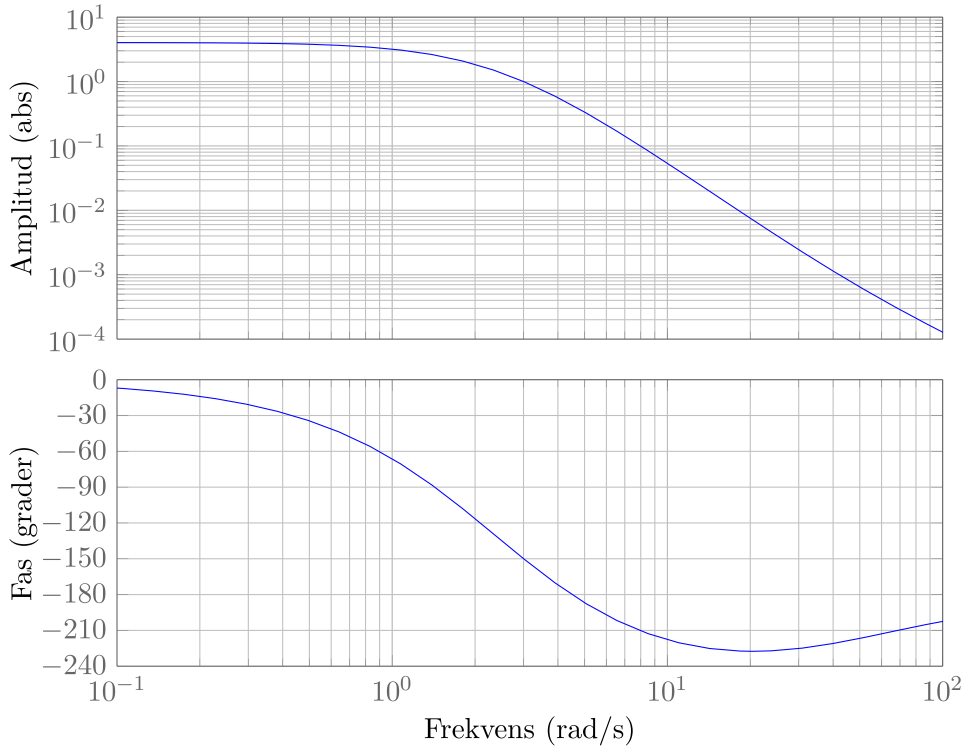
$$\dot{x} = \begin{bmatrix} -1 & 0 \\ 0 & -1 \end{bmatrix} x + \begin{bmatrix} 3 \\ 1 \end{bmatrix} u$$
$$y = \begin{bmatrix} 1 & 0 \end{bmatrix} x$$

a. Determine the poles of the system. (0.5 p)

b. Show that the system is not controllable. (1 p)

c. Design a state feedback $u = -Lx$ that places the poles in -1 and -3. (1.5 p)

d. Show that only one of the poles can be moved from its original position using state feedback. (1 p)



Figur 7 Bode plot of the open-loop system G_0 in Problem 8.

8. A controller has been designed for a process so that the loop transfer function G_0 is obtained. Figure 7 shows the Bode plot for the loop transfer function. Initial lab tests showed that the closed-loop system had desired properties. However, when the control is done over a network with delays up to 0.35 s, the closed-loop system becomes unstable.

a. Confirm, by suitable checks of the Bode plot and calculations, that adding a delay of 0.35 s to G_0 gives an unstable closed-loop system. (1 p)

b. Design a suitable compensator that retains the speed of the system and that guarantees stability when the process is controlled over the network. (2 p)

c. Suppose that you try to solve the problem using an Otto-Smith controller instead. Simulations with a constant delay of 0.35 s gives a closed-loop system with good properties. When the controller later is applied to the real network, you notice that the performance has deteriorated. Give two possible explanations for this! (1 p)