LUND INSTITUTE
OF TECHNOLOGY
Lund University

Department of
AUTOMATIC CONTROL

Tentamen i Systemteknik/Processreglering

2014-05-27

Poängberäkning och betygsättning

Lösningar och svar till alla uppgifter skall vara klart motiverade. Tentamen omfattar 7 uppgifter om totalt 20 poäng (Systemteknik) eller 8 uppgifter om totalt 25 poäng (Processreglering). Poängberäkningen finns markerad vid varje uppgift. Preliminära betygsgränser:

Systemteknik:		Processreglering:	
Grade 3:	10 poäng	Betyg 3:	12 poäng
4:	14 poäng	4:	17 poäng
5:	17 poäng	5:	21 poäng

Tillåtna hjälpmedel

Matematiska tabeller (TEFYMA eller motsvarande), formelsamling i reglerteknik samt icke förprogrammerade räknare.

Tentamensresultat

1. A system is described by the following differential equation:

$$\ddot{y}(t) + 3\dot{y}(t) + 5y(t) + 2\dot{u}(t) = 8u(t)$$

a. Is the system asymptotically stable? (1.5 p)

b. What is the order of the system? (0.5 p)

c. Is the system linear or nonlinear? Motivate your answer. (0.5 p)

2. A process has the following transfer function:

$$G_p(s) = \frac{8s - 3}{s^2 + 4s - 1}$$

a. Determine the poles and zeros of the process. Is the process stable? (1 p)

b. Determine a differential equation that describes the relation between the input $u(t)$ and the output $y(t)$. (0.5 p)

3. Consider the nonlinear dynamical system

$$\begin{aligned}
\dot{x}_1 &= x_1 x_2 - x_2^2 u \\
\dot{x}_2 &= -(x_1 - 2)^2 + \sqrt{x_1}\sqrt{x_2}.
\end{aligned}$$

a. Find all stationary points of the system corresponding to $u^0 = 1$. (1.5 p)

b. Linearize the system around the stationary point that has the largest value of x_2^0. (2.5 p)

c. Find the poles of the linearized system and comment upon its stability properties. (1 p)

4. The Bode diagram of a system $G(s)$ is shown in Figure 4. Determine the output $y(t)$ if the input is given by
$u(t) = 3\sin(3t), \; -\infty < t < \infty.$ (2 p)

5. A fellow engineer at the company where you are employed has put in weeks of hard work and dedication in order to come up with a controller that controls a valve in a power plant. The valve controls the inflow of cooling water in the plant, and it is crucial that it works. You know that both the valve and the controller are asymptotically stable in open-loop. The fellow engineer walks into your office and shows you the Nyquist plot for the open-loop system depicted in Figure 2. The fellow engineer tells you that focus in the design process has been to ensure good amplitude and phase margin.

a. Is the open-loop system—that is, the series connection of the controller and the valve—asymptotically stable? Is the system stable in closed loop? Do not forget to motivate your answer. (1 p)

b. What are the amplitude and phase margins? (1 p)

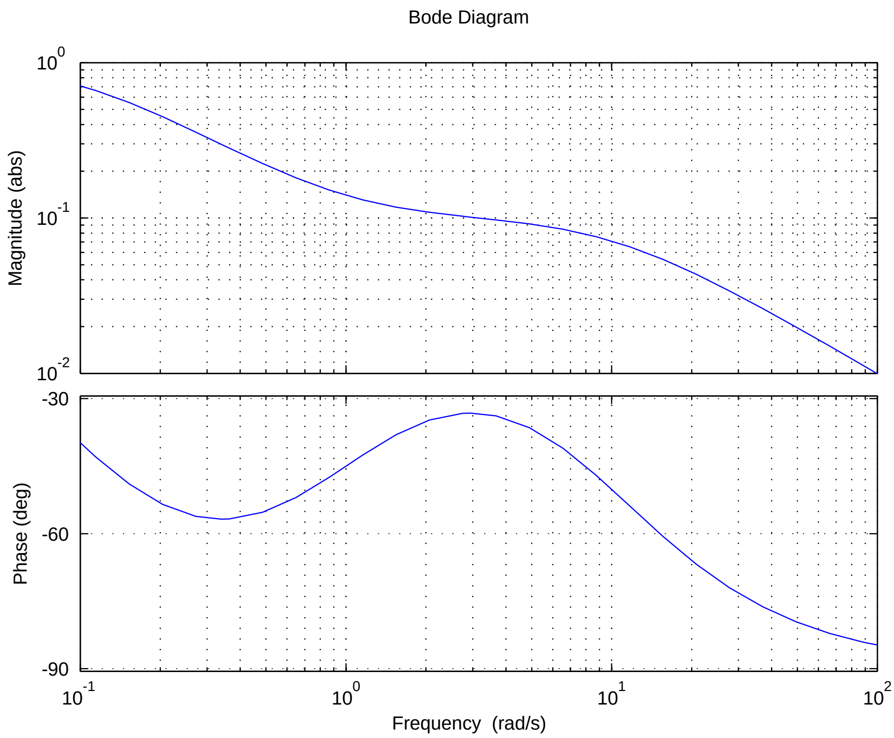

Figure 1 Bode diagram for problem 4.

c. It is known that both the gain of the valve and the time-delay in the system varies. Would you recommend that the proposed controller is used to control the valve? Do not forget to motivate your answer. (1 p)

6. You are given a physical process with transfer function

$$G_p(s) = \frac{3}{s+2}$$

a. Design a PI regulator for the process so that both poles of the closed-loop system are located in -2. (2 p)

b. When the controller has an integrator part, there is a risk of integrator windup. Explain shortly what integrator windup means and suggest a solution of the problem. (1 p)

7. An unstable chemical heating process has the transfer function

$$P(s) = \frac{2}{s-1}. \tag{1}$$

Three engineers have agreed that the process should be controlled with the controller

$$C(s) = K\frac{4s+1}{sT_f+1} \tag{2}$$

but they cannot agree on how to choose the gain, K, and the filter time-constant, T_f. Engineer A claims that the closed-loop system is asymptotically stable as long

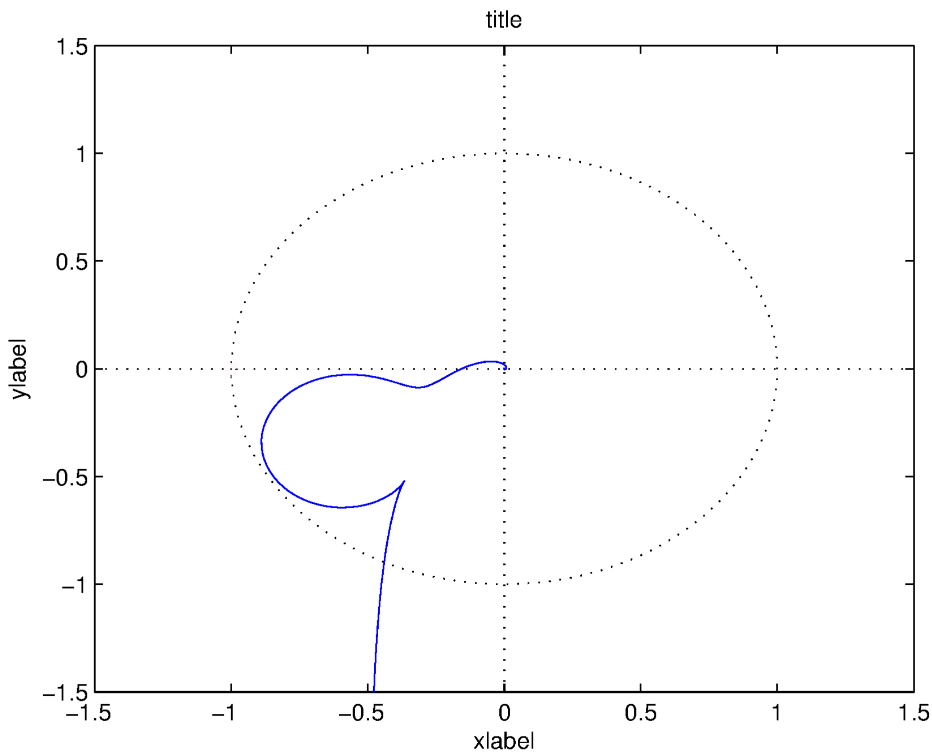

Figure 2 Nyquist plot for the open-loop system in problem 5.

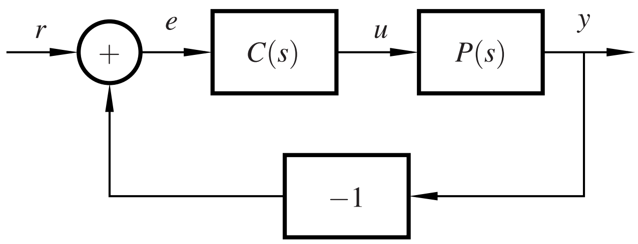

Figure 3 Block diagram for problem 7

as both parameters are positive. Engineer B claims that, since the process is open-loop unstable, K should be negative. Engineer C claims that the filter time-constant should be positive and that K must be large to ensure that the closed loop system is asymptotically stable. The controller structure can be seen in Figure 3.

a. For which values of K and T_f are both the closed-loop system and the controller asymptotically stable? Which of the three engineers made a correct claim? (2 p)

b. A unit step is applied to the reference. What is the smallest value of K that ensures that the steady-state error is within 0.05 from the reference? (1 p)

8. Only for Process Control:

Consider the following state-space model:

$$\dot{x} = \begin{pmatrix} -1 & -1 \\ -1 & -3 \end{pmatrix} x + \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} u$$
$$y = \begin{pmatrix} 2 & 0 \\ 0 & 2 \end{pmatrix} x$$

a. Determine the corresponding transfer function matrix $G(s)$. (1 p)

b. How should two single-loop controllers be connected to this process? (2 p)

9. Only for Process Control:

A metal workshop has, due to a decreasing demand for gasoline tanks, started to produce lighters instead. The lighters consist of two parts, the fuel unit and the fire unit. The two units are produced separately in production lines. In order to facilitate the high-level control the company uses a JGrafchart program to coordinate the two production lines.

It is supposed to work in the following way:

- When the operator presses the start-button the production of 10 batches should start.
- Every batch consists of 25 fuel units and 50 fire units.
- The production of fuel and fire units should execute in parallel since the time for producing the specified units might differ.
- When 10 batches are produced the system should return to the initial state and wait for the operator to press start again.
- The digital input `Start` is true when the operator presses the start button.
- Fuel and fire units are produced when the digital outputs `ProduceFuel` and `ProduceFire` are true.
- The analog inputs `FuelUnitsDone` and `FireUnitsDone` count the number of units produced since the respective production line last started to produce units. You can assume that the inputs only take integer values.
- The integer `Bacthes` should count how many batches that has been produced since the operator pressed the start button.

The best engineer in the workshop has put a lot of time and effort into the program but it still does not work the way it is supposed to. The engineer has made sure that the inputs and outputs works the way they should. However, the engineer has made four mistakes in the implementation of procedure. Find and correct his mistakes without making structural changes to the program, that is, you are not allowed to add or remove blocks or transitions or make changes in how the blocks and transitions are connected. (2 p)

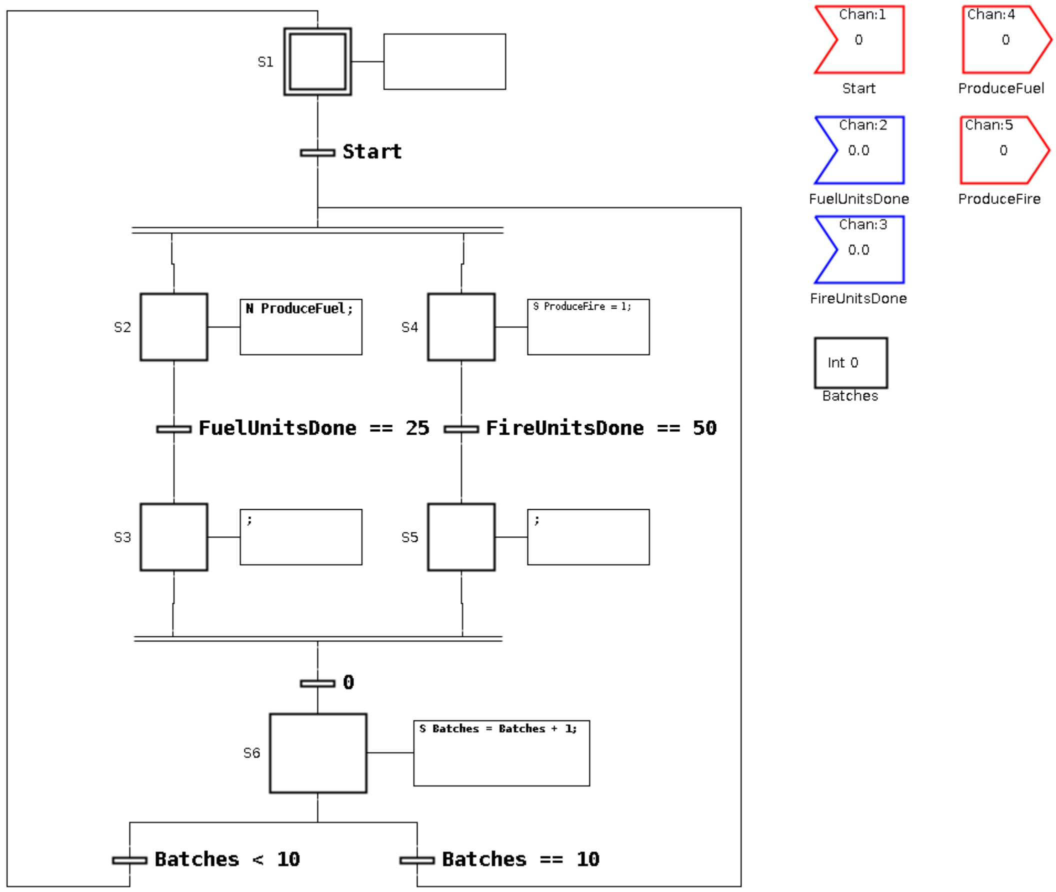

Figure 4 JGrafchart structure for problem 9.