Process control and automation (CHEM-C2140)
Exam

June 7, 2023

Q1) Describe the operation principle of the thermal camera (max 100 words) (2.5p).

Q2) What means feedforward control? (max 75 words) (1p)

Q3) In the context of the controller design, what means the derivative kick? Which types of controllers it may affect? (max 75 words) (1p)

Q4) Essay: Describe the structure of the distributed automation system: Basic functions, supportive functions. How has cloud computing, artificial intelligence and wireless systems changed the automation systems? (max 600 words) (5p)

Q5) Sketch by hand the ouput response $y(t)$ of the FOPDT model when the input variable $u(t)$ is that shown in Fig. 1. The FOPDT model has the process gain of $K_\mathrm{p} = 5$, time coefficient of $\tau_\mathrm{p} = 3$ s, and dead time of $\theta_\mathrm{p} = 4$ s. At $t = 0$ s, the output response is at a steady-state value of $y(0) = 10$. Make the sketch for the range of [0, 20] s.

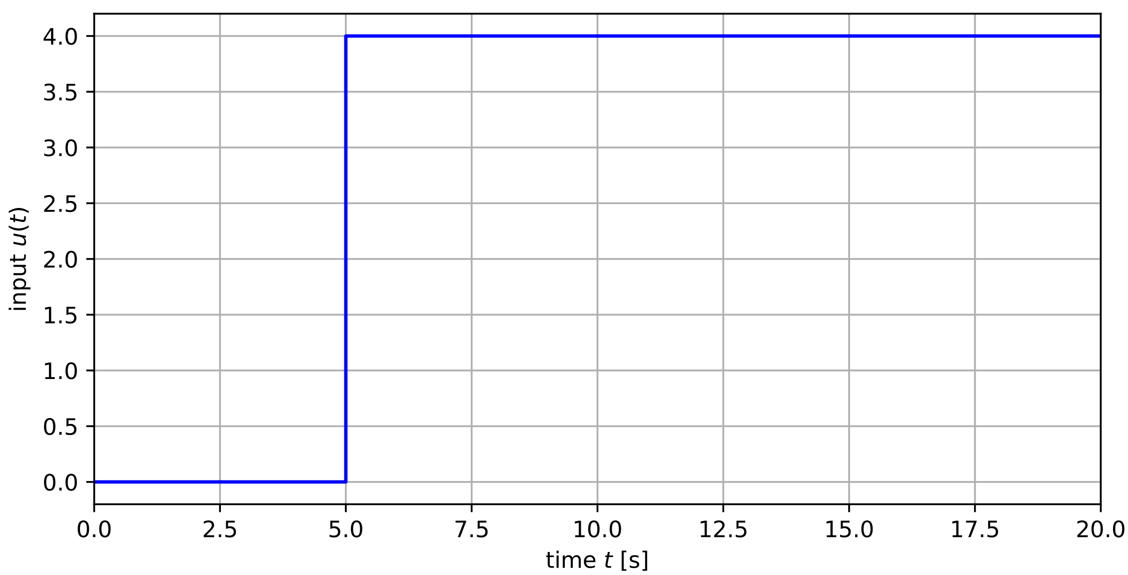

Figure 1: The input variable $u(t)$ during the time window $t \in [0, 20]$ s.

(3p)

Q6) The dynamic behaviour of the liquid level h in the conical mixing tank is shown in Figure 2.

Develop the model for the conical mixing tank.

Follow the steps of the systematic model development. State all assumptions that are needed, and pay special attention to the classification of inputs.

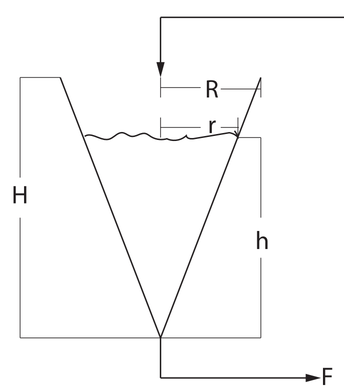

Figure 2: The conical mixing tank process

(8p)

Q7) The process is described by the following differential equation

$$\frac{dy(t)}{dt} - 3y(t) = u(t), y(0) = 0$$

a) Form the total transfer function of the process ($G(s) = Y(s)/U(s)$) (0.5 p).

b) Determine the unit step response of the process $y(t)$ and illustrate it in the time domain. (0.5p).

c) The process is controlled by a P regulator whose gain is K_p. Form the total transfer function of the feedback system ($G_{tot}(s) = Y_{tot}(s)/R(s)$) (1 p).

d) With what gain values can the system be stabilized? (2 p.).

e) Determine the unit step response of the feedback system $y_{tot}(t)$ in the time domain when the gain of the P controller is $K_p = 5$. Illustrate the response (1 p).

Q8) a) In your own words, how fast should the signal sampling frequency be to digitize an analog signal? Is there exceptions? (2 p.)

b) The characteristic equation for a certain closed loop digital control system is give as:

$$P(z) = z^2 - z + 2 = 0$$

Determine whether this system is stable or not. Use Appendix 1 as a help. (3 p.)

1 Appendix 1

z-transform notation of closed-loop transfer function notation:

$$y(z) = \frac{g_f(z)g_c(z)}{1 + g_l(z)g_c(z)} y_d(z)$$

Characteristic equation:

$$1 + g_l(z)g_c(z) = 0$$

Jury stability test

1 Write the characteristic equation in the "forward" form:

$$P(z) = a_0 z^n + a_1 z^{n-1} + ... + a_{n-2} z^2 + a_{n-1} z + a_n = 0$$

2 Carry out the first part of the Jury test:

Determine:

$$P(1) = \quad \textstyle\sum_{i=0}^{n} a_i P(-1) = \quad \displaystyle\sum_{i=0}^{n} (-1)^{n-i} a_i$$

and then test if

1. $|a_n| < a_0$
2. $P(1) > 0$
3. $P(-1) > 0$, for n even, or $P(-1) < 0$, for n odd

If any of these conditions are not satisfied, then we can immediately conclude that $P(z)$ has roots outside the unit circle, and it is not necessary to prozeed further. The system is unstable.

3 Generate the Jury table

The Jury Table

Row 1	a_n	a_{n-1}	a_{n-2}	a_{n-3}	...	a_2	a_1	a_0
Row 2	a_0	a_1	a_2	a_3	...	a_{n-2}	a_{n-1}	a_n
Row 3	b_{n-1}	b_{n-2}	b_{n-3}	a_{n-4}	...	b_1	b_0	
Row 4	b_0	b_1	b_2	b_3	...	b_{n-2}	b_{n-1}	
Row 3	c_{n-2}	c_{n-3}	c_{n-4}	c_{n-5}	...	c_0		
Row 4	c_0	c_1	c_2	c_3	...	c_{n-2}		
Row 2n-5	p_3	p_2	p_1	p_0				
Row 2n-4	p_0	p_1	p_2	p_3				
Row 2n-3	q_2	q_1	q_0					
Row 2n-2	q_0	q_1	q_2					

$$b_k = \begin{vmatrix} a_n & a_{n-1-k} \\ a_0 & a_{k+1} \end{vmatrix}; k = 0, 1, 2, ..., n-1$$

$$c_k = \begin{vmatrix} b_{n-1} & b_{n-2-k} \\ b_0 & b_{k+1} \end{vmatrix}; k = 0, 1, 2, ..., n-2$$

$$q_k = \begin{vmatrix} p_3 & p_{2-k} \\ p_0 & p_{k+1} \end{vmatrix}; k = 0, 1, 2$$

4 Determine stability from the elements of the first column:

The necessary condition for stability is that all three tests above are sarisfied.

Then for stability it is further necessary that the following conditions in the first column be satisfied:

$$\begin{aligned} |b_{n-1}| &> |b_0| \\ |c_{n-2}| &> |c_0| \\ &\vdots \\ |q_2| &> |q_0| \end{aligned}$$