TKP4140 Process Control

Department of Chemical Engineering NTNU

Autumn 2019 - Midterm Exam

11. October 2019

Student number: ______________________________

- Write your student number on **every** page in the indicated space.
- Write your answers on the enclosed pages.
- Use the last page for details if you have too little space.
- Do not separate the enclosed pages.
- Time: **90** minutes

Problem 1: System analysis (16 points)

(a) Calculate the poles and zeros for $g_1(s)$ and $g_2(s)$.

i. $g_1(s) = 3 - \frac{1}{5s+1}$

ii. $g_2(s) = 3 - \frac{4}{5s+1}$

(b) Sketch the step responses for $g_1(s)$ and $g_2(s)$ for a unit step ($u(t) = 1$) given at time $t = 2$ in Fig. 1

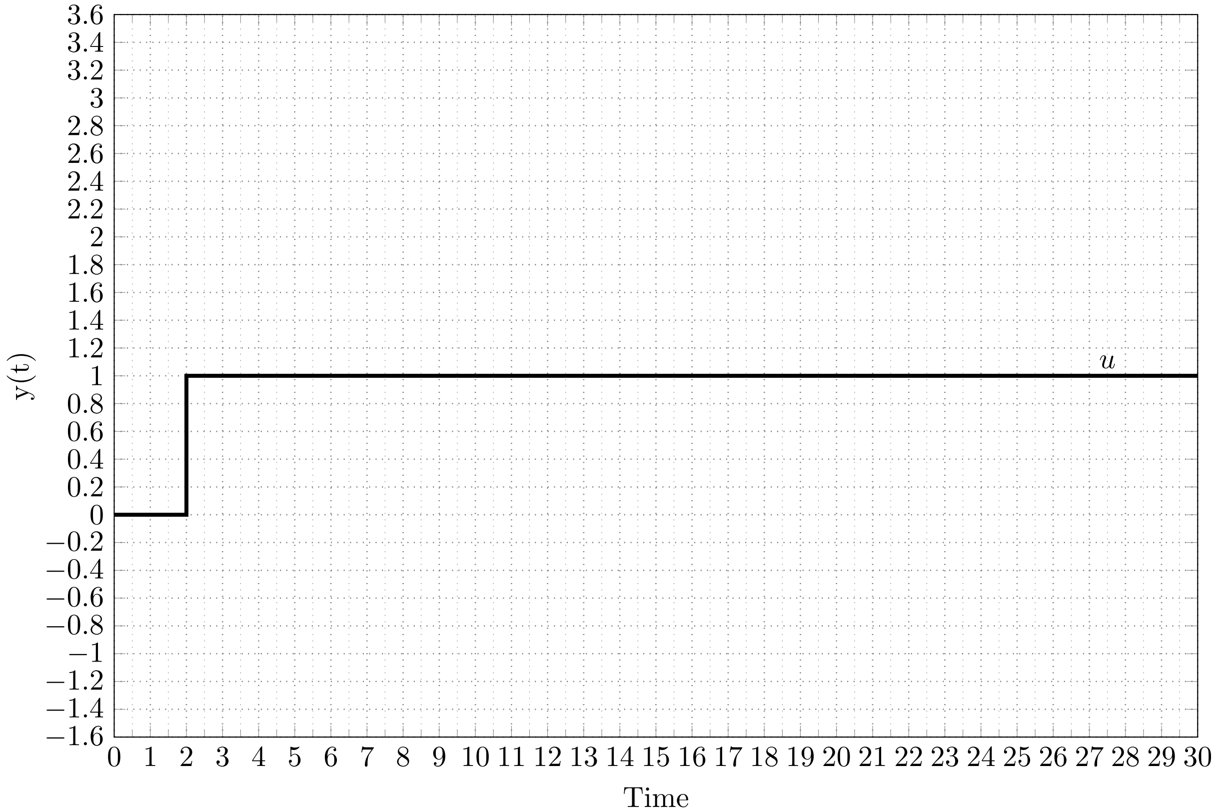


Figure 1: Step responses for $g_1(s)$ and $g_2(s)$

Problem 2: Transfer function responses (16 points)

Given the transfer functions

$$g_1 = k_1$$
$$g_2 = k_2 e^{-\theta s}$$
$$g_3 = \frac{k_3}{\tau_3 s + 1}$$
$$g_4 = \frac{T_4 s + 1}{\tau_4 s + 1}$$

And given the responses for a unit step ($u(t) = 1$) given at time $t = 2$ shown in Fig. 2

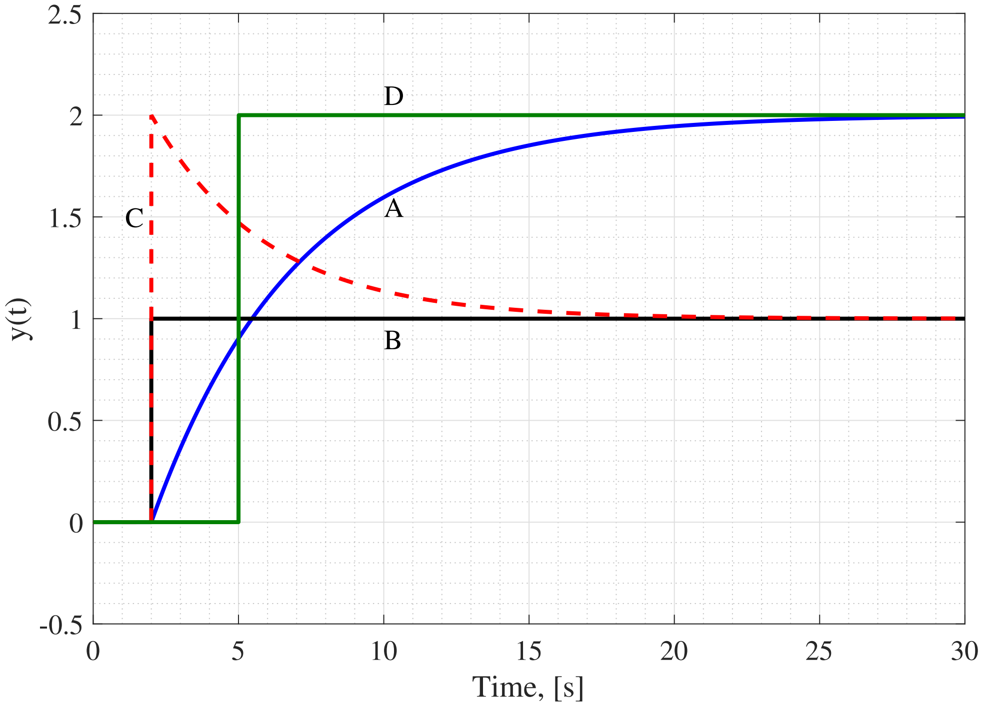


Figure 2: Step responses

(a) Match function g_1, g_2, g_3, g_4 with functions A, B, C, D.

A = B = C = D =

(b) Find the missing parameters for g_1, g_2, g_3, g_4. Comment your choice.

$g_1 =$ $g_2 =$ $g_3 =$ $g_4 =$

Problem 3: Block Diagrams (16 points)

Given the block diagram from Fig. 3

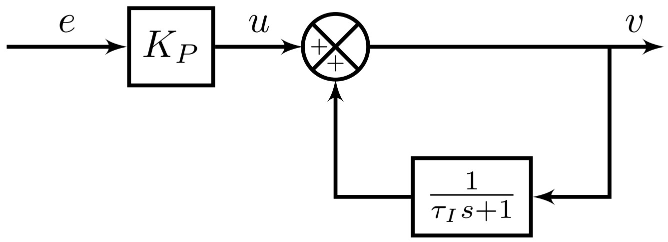


Figure 3: Block diagram

(a) Find the closed loop transfer function $K(s)$ from e to v. (Note that this is positive feedback.)

(b) What can you say about $K(s)$?

Problem 4: Controller design (16 points)

(a) What is the transfer function for a PI-controller?

C(s) =

(b) Design a SIMC-controller for

$$g(s) = k\frac{-\theta s + 1}{\tau s + 1}$$

(c) What SIMC-controller do you get for $g(s)$ if $\tau = 0$?

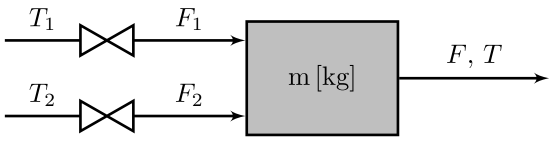
Problem 5: Modelling and linearization. (36 points)

Consider the mixing process shown in Fig. 4, where stream F_1 with temperature T_1 is mixed with stream F_2 with temperature T_2 to produce stream $F\,[\mathrm{kg\,s^{-1}}]$ with temperature $T\,[^\circ\mathrm{C}]$. We assume constant mass m, $c_p \approx c_V$ (liquid) and constant and equal c_p.

The nominal operating conditions are:

$F_1^* = 0.5\,\mathrm{kg\,s^{-1}}$ $\quad F_2^* = 1.5\,\mathrm{kg\,s^{-1}}$ $\quad T_1^* = 80\,^\circ\mathrm{C}$ $\quad T_2^* = 20\,^\circ\mathrm{C}$ $\quad m = 1\,\mathrm{kg}$

The control objective is to keep the outlet flow at setpoint ($F = F^{sp}$) and the outlet temperature at setpoint $T = T^{sp}$.



Variables

- **CVs** = (F, T)
- **MVs** = (F_1, F_2)
- **DVs** = (T_1, T_2)

Figure 4: Mixing process (shower)

(a) Derive the mass balance (note that m is constant).

(b) Derive the energy balance in temperature form ($\frac{dT}{dt} = ...$).

(c) Find the steady-state values for F and T.

(d) Introduce deviation variables and linearize the two balances.

(e) Let

$$F(s) = g_{11}(s)F_1(s) + g_{12}(s)F_2(s)$$
$$T(s) = g_{21}(s)F_1(s) + g_{22}(s)F_2(s) + g_{d1}(s)T_1(s) + g_{d2}(s)T_2(s)$$

What are g_{11}, g_{12}, g_{21}, g_{22}, g_{d1} and g_{d2}?

(f) Suggest a control structure based on single loop controllers, that is suggest where to place (TC) and (FC) in Fig. 4. Comment on why you made this choice.

Extra space

Please indicate clearly to which problem the solution belongs.