Sluttprøve
Fag A3494 Prosessregulering
Thursday January 9th 2007
kl. 9.00-12.00

Sluttprøven består av: 3 oppgaver.
Oppgaven teller 70 % av sluttkarakteren.
Det er 3 sider i delprøven.
Tillatte hjelpemidler: ark og skrivesaker

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Task 1 (20%): Frequency analysis

Given a feedback system as illustrated in Figure 1.

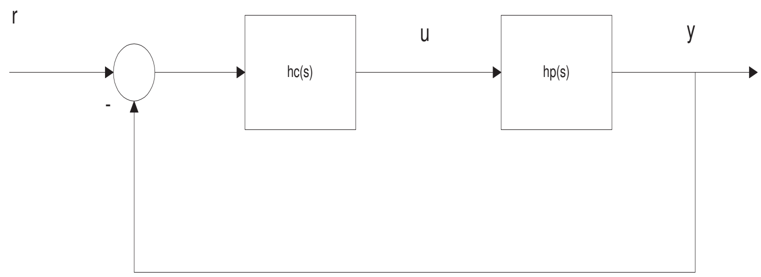

Figure 1: Standard feedback control system.

a) Write down an expression for the loop transfer function, $h_0(s)$.

b) Consider an PID controller on cascade form, $h_c(s)$, and a process, $h_p(s)$, given by

$$h_c(s) = K_p \frac{1 + T_i s}{T_i s}(1 + T_d s), \quad h_p(s) = k \frac{e^{-\tau s}}{(1 + T_1 s)(1 + T_2 s)}, \tag{1}$$

where $T_1 > T_2 > 0$. Chose the integral time T_i, and the derivative time, T_d, such that the loop transfer function can be written as follows

$$h_0(s) = k_0 \frac{e^{-\tau s}}{s}. \tag{2}$$

Write also down the expression for k_0.

c)

- Write the frequency response of the loop transfer function in (2) on polar form, i.e., such that

$$h_0(j\omega) = |h_0(j\omega)| e^{j \angle h_0(j\omega)}. \tag{3}$$

- What is the size $|h_0(j\omega)|$ denoted?
- What is the size $\angle h_0(j\omega)$ denoted?

d) Find the phase crossover frequency, ω_{180}, for the system.

e) Find a proportional gain, K_p, such that the closed loop system have a Gain Margin, $GM = 2$.

f)

- What is the definition of, and how can the gain crossover frequency, ω_c, be computed?
- What is the gain crossover frequency, ω_c, for the above feedback control system?

g)

- What is the definition of, and how can the phase margin, PM, be computed?
- What is the phase margin, PM, for the above feedback control system?

h) Consider now a PI controller, $h_c(s)$, and a process, $h_p(s)$, given by

$$h_c(s) = K_p \frac{1 + T_i s}{T_i s}, \quad h_p(s) = k \frac{1 - \tau s}{(1 + T_1 s)(1 + T_2 s)(1 + T_3 s)}. \tag{4}$$

where $T_1 > T_2 > T_3$.

- Chose the integral time, T_i, such that the loop transfer function, $h_0(s)$, can be written as follows

$$h_0(s) = k_0 \frac{1 - \tau s}{s(1 + T_2 s)(1 + T_3 s)}. \tag{5}$$

  Write also down the expression for k_0.

- Write down the frequency response on polar form of the loop transfer function in Equation (5).

Task 2 (10%): PID regulator

Given a PID controller in the Laplace plane

$$h_c(s) = K_p \frac{1 + T_i s}{T_i s} + K_p T_d s, \tag{6}$$

such that the control is generated by

$$u(s) = h_c(s) e(s) \tag{7}$$

where $e(s) = r - y(s)$ is the control error. We are assuming a constant reference signal, r, in this task.

a) Write down a continuous state space model for the PID controller in Equations (6) and (7).

b) Find a discrete time state space model for the PID controller in Step 2a) above. Use the explicit Euler method for discretization.

c) Write the discrete time PID controller in Step 2b) above on so called incremental (deviation) form, i.e. in such a way that the control is generated by the formula

$$u_k = u_{k-1} + g_0 e_k + g_1 e_{k-1} + g_2(y_k - 2y_{k-1} + y_{k-2}). \tag{8}$$

You should also write down the expressions for the parameters g_0, g_1 and g_2.

d) Show that the solution of the continuous state space model for the PID controller in Step 2a) above (over the time interval from t_0 to t) can be written as

$$u(t) = K_p e + z(t_0) + \frac{K_p}{T_i}\int_{t_0}^{t} e(\tau)d\tau + K_p T_d \dot{e} \tag{9}$$

where $z(t_0)$ is the initial state for the state equation in the PID controller found in Step 2a).

Task 3 (5%): Various questions

a) What is a Smith predictor? When is it suitable to use a Smith predictor? Sketch a block diagram of a system controlled by a Smith predictor.

b) What is meant by RGA analysis? Write down a formula for computing the RGA matrix. What can the RGA matrix be used for?